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- Environmental Science and Technology
- Natural Resources Management
- Disaster and Sustainability
- Environmental Education and Health
- Environmental Management Tools

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Environmental Performance and Optimization Approaches of Aluminum and Beech Wood Window Frames

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Abstract

Environmental Performance and optimization approaches are methods for performance assessment and efficiency for the natural viewpoints and potential effects related with a product, by aggregating a stock of important material data sources and natural releases such as Life Cycle Assessment (LCA) technique and DesignBuilder Software. In this research, the LCA of the aluminum and the beech wood, as two usually utilized materials components in Egypt for the window outlines, is conducted with applied optimization model. Window outlines manufactured of the two unique materials have been surveyed considering their creation, energy utilization and ecological effects. The impact of aluminum and beech wood materials on environmental change for the windows, are 81.7 mPt and -52.5 mPt (milliPoint) respectively for a reference window (1.2m×1.2m). Non-renewable energy source utilization, potential commitments to the green architecture impact and amounts of waste have a tendency to be minor for the wood items contrasted with aluminum items. Whereas their impact in use for the comfort are vise versa.

Keywords: green building; LCA; optimization; SimaPro; DesignBuilder; aluminum window frame; beach wood window frame

1. Introduction

The concept of green building is to enhance the natural performance in all parts of structures. As structures are included various materials and sub-assemblies, tools have been created to better educate naturally ideal choices [1]. Windows assume a noteworthy part in structures, accounting for 10-25% [2] of a building's uncovered surface and are accessible in an extensive variety of plans and selection of different frame materials. The vital part of windows is their ecological effect – energy utilization, natural resource depletion and other burdens related with their make [3], where the environmental impact is measured by milliPoint in which 1 mPt is corresponds to one thousandth of a total annual environmental burden caused by an average European [4].

The most suitable materials and components for any application relies on upon the thought of a scope of specialized and financial elements including, usefulness, toughness and cost. An undeniably critical element for material selection, in our current reality where practical improvement awareness is expanding, is the related natural performance of material for the applications from the perspective of assembling and item performance [5]. Among the valuable tools that accessible to assess natural execution, life cycle appraisal (LCA) gives an all-encompassing way to deal with assess ecological execution by considering the potential effects from all phases of fabricate, item utilize and end-of-life stage. This is alluded to as the cradle-to-grave process [6].

Salazar J. [1] applied LCA on three window sorts regularly accessible in America: polymers such as Polyvinyl Chloride (PVC), fiberglass, and wood secured by aluminum cladding. The PVC window life cycle utilized the most non-sustainable power source and brought on the most harm. This is likely due to the window's shorter administration life, 18 years versus 25 years for the fiberglass and also the aluminum cladding wood. The utilization of cladding materials other than aluminum additionally kept the transfer of aluminum into metropolitan landfills which decreased the sea-going Eco harmfulness of the wood window life cycle [7].

Asif M. et al [3] kept an eye on the life cycle examination of the materials used for window edges that made of aluminum, PVC, also a timber window as a reference window (1.2m×1.2m). They presumed that the aluminum outlines make the most astounding weight nature in light of the unsafe contaminations released and the high-energy consumption during production. Richter K. et al [8] addressed similar materials evaluated by Asif, but also include steel, stainless steel and nonferrous window frames. Considering the entire life cycle, including the remuneration of warmth misfortunes; heating framework, mass-based allotment of co-generation procedures is applied all through the wood processing chain; reusing material is demonstrated with the cut-off technique. Kreissig J. et al [9] analyzed some of window frames such as aluminum, wood, wood-aluminum and PVC; due to different system boundaries. They made an immediate correlation of these window sorts. This blend permits the assessment of natural impacts of the entire development handle including its warm properties. The last is essential because the pay of warmth misfortunes is a noteworthy benefactor to the ecological profiles of the windows, Werner F. [10].

Jungmeier G. [11] made an application for the LCA for ranger service wood, biofuel and wooden items. The consequences of the stock evaluation for this version of the solid-state wood window that are greenhouse gases and fermentation potential. The highly negative a worldwide temperature alteration capability of the wood outlines comes about for the most part from the inexhaustible CO_2 that is encapsulated onto the wood buildups that are delivered amid the window creation. The wood residues [12] were dealt with as waste, so all upstream mediations including the CO_2 up-take were not designated to them, albeit 90% of the last window edge is burned in the disposal procedure. Elizabeth M. et al [13] chosen a fundamental single-sheet window as a gauge to think about two essential twofold sheet windows and four energy effective windows in a solitary family home. Seventeen cities form the United State country were explored to represent 17 atmosphere areas. While suspecting the impacts of retrofitting a significant number of homes, it was found that the Metro Atlanta reduce CO_2 radiations by about a half million metric huge amounts of CO_2 in a year by changing to any of the energy profitable window decisions.

The primary focus of this research is to settle on a choice about which is better material for the window edges to be utilized as a piece of green working as indicated by what is the one of them impacts thermal in the inside space that referenced to natural effect, human wellbeing and environmental change examination comes about [14]. In this manner, a near investigation consider utilizing LCA and optimization for window outline and materials of 1.2m*1.2m was performed using SimaPro programming ver. 8.0.4.30, where the optimized technique is adopted to select the frame type that used in the windows to maximize the thermal comfort and LCA by using the DesignBuilder package ver. 5. The paper additionally gives a basic audit of a few sorts for the material performance of the windows analyzed.

2. Materials and methods

The sensible relationship of the 4 parts of the LCA as exhibited in the ISO (14040) "Standards and Framework" of LCA is appeared in Fig. 1 [15]. As in ISO 14041, a technique for framework limit setting and designation are plot without framework extension for the two outlines of windows that are ordinarily accessible in Egypt. The average transportation distance is assumed 200 km for the two materials to get their effects on green architecture design in tkm (ton kilometer), also the distance for recycling is assumed as 10 km. The maintenance, and the estimations of service life are utilized in the life cycle inventory paradigm. The framework for this research is presented in Fig. 2. This paper evaluates the differences between the frames of the two materials for the aluminum (Jumbo sector 2mm) and the beech wood using the simulation tool SimaPro and DesignBuilder. The reference window is (1.2m×1.2m), so the aluminum window weigh is 4.0992 kg and the volume of wood window is 12000 cm^3. The two materials properties are as follows:

A. Aluminum

The Aluminum window is made of hollow expelled profiles, so it is durable, light, and conductive for highly heat. Assume the Aluminum window is a slide and it has one glaze. The aluminum is produced from abundantly available ore, bauxite [16]. The aluminum stages from extraction till end of life is known as cradle to gate, Fig. 3, where the flow diagram of aluminum window assembly is described in Fig. 4. The production of a primary aluminum requires a lot of energy (225MJ/kg) [17], where it produces a large amount of ecologically dangerous pollutants as dust, Carbon Dioxide and Acidic Sulphur Dioxide. The aluminum recycle requires nearly 7% of the energy which required for produced the primary aluminum from ore [18], where to melt a 1 kg of aluminum, the average energy required is 13 kWh [19].

B. Beech wood

The wood is a sustainable material that can be utilized for wood items and the generation of energy [20]. It is a traditional window frame type, for its availability, easer to process and it considered the lowest thermal conductivity in all the framing types [21]. The wood window is a slide and it has one glaze. The wooden material affected with moisture, so it has to be painted and maintained every period of few years [3]. The life cycle stages of the beech wood window as shown in Fig. 5. The wood products LCA consists of 3 main phases: production, use, and end of life [19]. The phase of production is the largest input and it has 3 basic parts of modelling; these basic parts as follows:

1. The data of cutting a tree and sawing it in planks using sawmill will be utilized from the database in SimaPro eco-invent.
2. Assuming 40% from beech wood shed burned, and the existing 60% is sent to landfill [22].
3. Electricity used in the sawmill will be added.
4. The beech wood window pathway of flow is shown in Fig. 6.

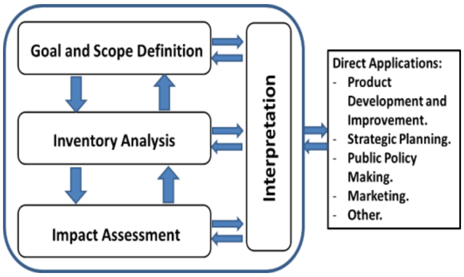

Figure 1. LCA Framework (ISO 14040).

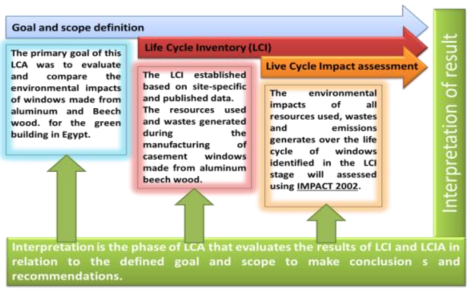

Figure 2. LCA framework for aluminum and beech wood windows.

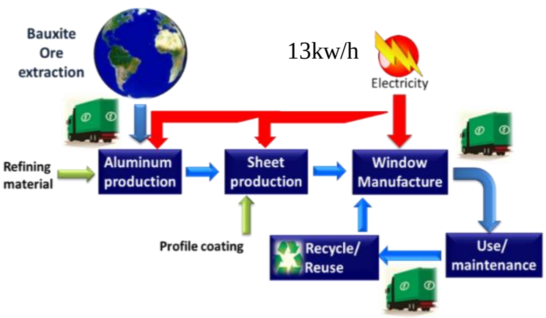

Figure 3. Aluminum window life.

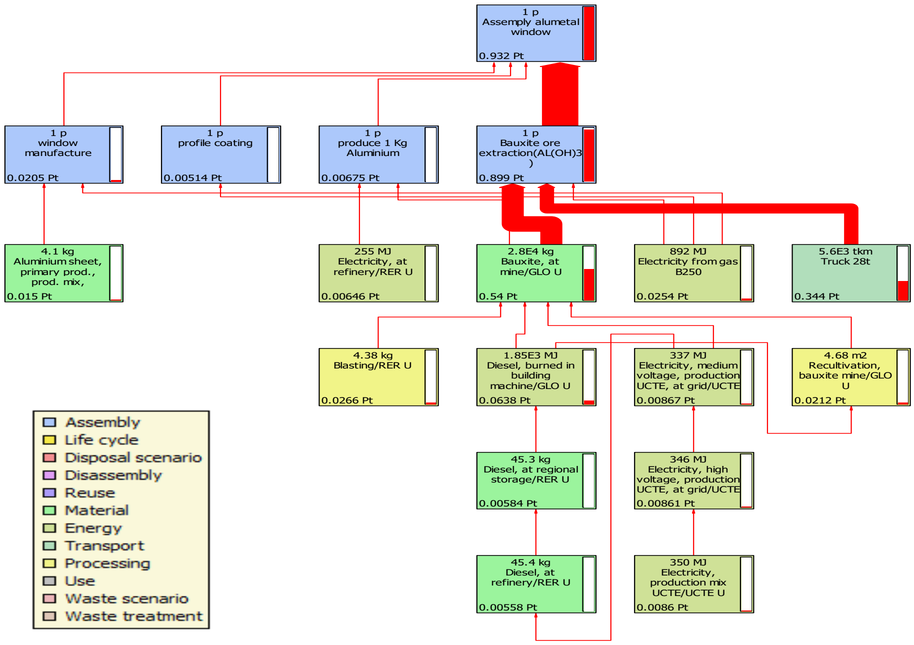

Figure 4. The assembly aluminum window flowchart.

The standard data required for the approach of beech wood window is depending on the goal and scope of the study, that as follows: (if sawmill co-products are only utilized for energy) [20, 23, 24].

-LCA particle boards: particle board (1 m^3) + electricity (y kWh) + heat (z kWh).

-LCA wooden products: wooden product (1) + electricity (y kWh) + heat (z kWh).

-LCA bioenergy for heat and electricity: electricity (y kWh) + heat (z kWh).

-LCA sawmill: wood board (1 m^3) + electricity (y kWh) + heat (z kWh).

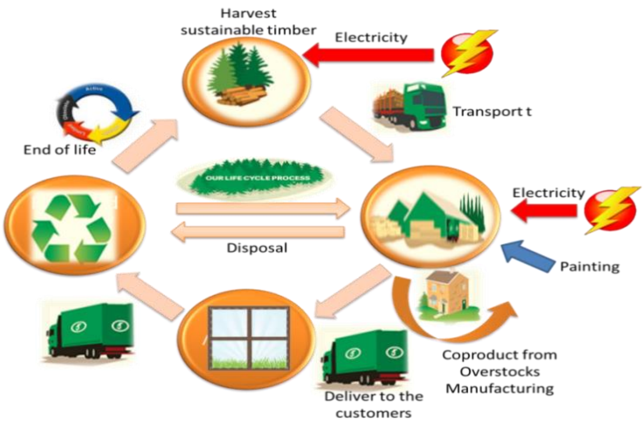

Figure 5. Life cycle stages of a beech wood window.

2.1 Goal and Scope

The research primary objectives are to assess and compare the effects of the production of window frames by using LCA tool and DesignBuilder software. That aim to illustrate the impacts of the two materials on the green building design. The functional unit is defined by the following points:

- Materials: Aluminum and beech wood window.
- Size: 1.2m x 1.2m.
- Style: casement.
- Frame profile: standard frame profile for Egypt manufacturer.
- Length of service: 75 years.
- Maintenance: sealed unit replacement.
- Operable: operable.

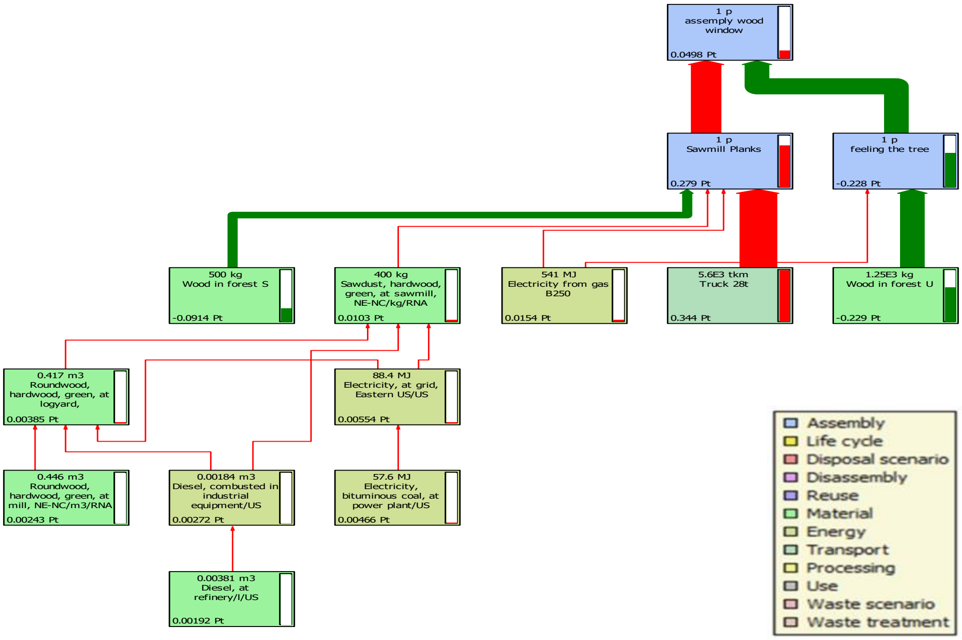

Figure 6. The assembly beech wood window flowchart.

2.2 Life Cycle Inventory

The two materials inventories are assembled into effect classifications and scaled considering IMPACT 2002+ methodology v2.12 portrayal and damage factors [25]. The streams of assets utilized and outflows in the item framework are computed for each procedure, this is known as the life-cycle-inventory (LCI) [26]. The environment impacts are calculated based on the LCI for the products, their factors, and their flows in the environmental degradation, which are specified as the characterization factors. The LCI input data for the materials of aluminum and beech wood is presented in Table 1.

2.3 Life Cycle Impact Assessment

Life Cycle Assessment is a quantitative procedure for assessing the resources utilization and related ecological burdens of an item from "cradle to grave", and emissions that recognized in the lCI. All the resources as health and ecological consequences are grouped into impact categories to calculate the impact indicators as specifies in the ISO 14042 (2000) [27]. LCA is accomplished by scaling inventory values with their relative impacts of greenhouse gas emissions and CO2 equivalents. The categories of emission equivalence are referred to midpoint impact categories, while the further modeling calculate their effects on human health, ecological quality, and resources utilization. The life cycle effects are reported directly and normalized for relative scale, or weighted based on estimation of the valuation functions [28].

2.3.1 Midpoint results

The classification of midpoint results is presented in equivalence to a substance which connected with that effect [29]. Whereas, the midpoint values give a little knowledge into the impacts of the item framework past the relative intra-category impacts towards the three zones of protection: human health, natural resources, natural environment (the three distinguished by ISO) [22]. When multiply the midpoint results by the characterization factors that related to the midpoint class to a damage impact, the significance towards the total effects on human wellbeing, natural quality, and the world's capacity limit might be known [1]. In the following, the units that calculate the damage effects for the midpoint categories are described:

- Human Health: Disability Adjusted Life Years (DALY) is defined as the decrease in expectancy of life and the healthy years cause disability. The aluminum DALY was 0.36 (Point) Pt, and the wood DALY is 0.14 Pt; therefore, the aluminum has a bad impact on the human health.

- Ecosystem Quality: is the degradation in species of populations over a given area and the period time that related to ecosystem damage. Beech wood has a better effect on ecosystems than the aluminum.

- Carrying Capacity — Resource Use (MJ): The increasing of energy values that expected in the future that required to recover the resource use. The manufacturing of wood uses that resources in a better manner than the manufacturing of aluminum.

- Carrying Capacity — Global Warming (kg CO2): The global warming is affected by the manufacturing of aluminum and/or wood. Wood has a lesser impact on warming than aluminum. The graphical results for cradle to grave midpoint impact for the aluminum and beech wood frames are presented in Fig. 7.

2.3.2 Damage results

The life cycle effects for the two window types are classified into different stages. The significant stages of life incorporate the extraction of resources and fabrication for the completed item, as utilization, maintenance, and treatment to end of life. Figure 8 shows the damage impact of the two types of windows, where the effect of damage on human health in case of wood is 43% and in case of aluminum is 100%. The aluminum impact of damage is decreased to 75% in case of ecosystem, where for the wood frame type increased to 100%; these changes interpreted the damage impact for the due to the cutting of trees which convert the CO_2 to O_2 that affected on the ecosystem. The impact of beech wood on climate change is less than in case of aluminum, where the consumption of wood is higher than in case of aluminum.

2.3.3 Cradle to gate findings

The cradle to gate results showed that, first, the energy used by wood is little which gives a less acidification/nitrification. Secondly, the emissions of greenhouse gas in wood is less than the aluminum materials. The aluminum frame total impacts are greater between these materials.

2.4 LCA Optimization

LCA, as a tool for evaluating ecological performance, can likewise be actualized with a specific end goal to help leaders pick the best options for incorporated of other goals as the limiting the inconvenience in the working as far as natural effects [30-32]. Keeping in mind the end goal to abstain from making assumptions, DesignBuilder bundle show coordinated to LCA may permit us to recognize an ideal situation of these goals from the ecological perspective, among each one of those hypothetically accessible. Table 2, shows the designBuilder Pareto optimization points for the objectives of discomfort and LCA (simple) as the main objectives in case of using the two materials for design window frame type. Fig. 9 shows the optimization pareto points in case of the two window frame types.

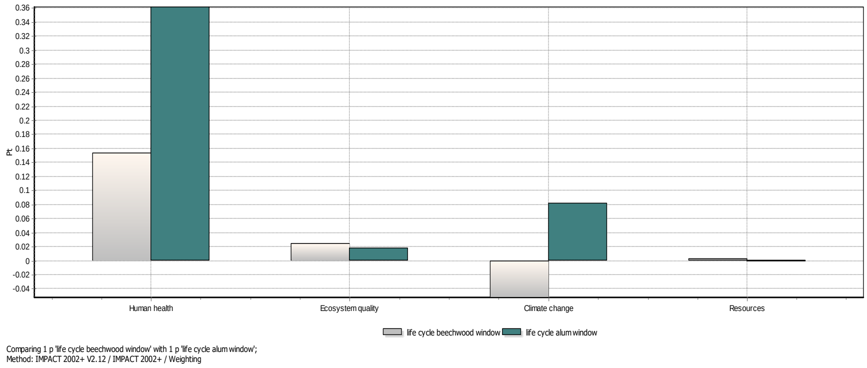

Figure 7. The Cradle to grave Midpoint Impacts for the aluminum and the beech wood.

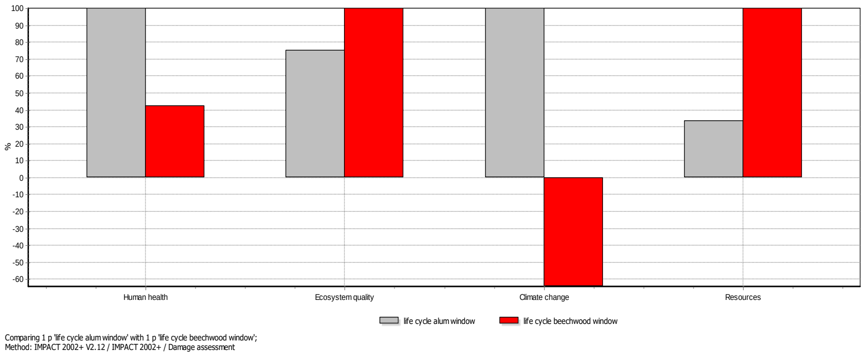

Figure 8. The mid-point damage categories for life stages of beech wood and aluminum.

Table 1. Input data for aluminum and beech wood.

	Input	Amount	Ref.
Aluminum			
Bauxite ore extraction	-Bauxite, at mine/GLO U	28 ton	[3]
	-Electricity from gas B250	140 kWh	[16]
	-Truck 28t	5600 tkm	Assumed
Produce 1 kg aluminum	-Process water, ion exchange, production mix, at plant, from surface water RER S	9500 kg	
	-NaOH ETH U	0.215 kg	
	-Lime I	0.086 ton	
	-Bauxite, at mine/GLO U	4.750 kg	[3]
	-Carbon monoxide, CO, at plant/RER U	0.400 kg	
	-Aluminum fluoride, at plant/RER U	0.018 kg	
	-Cryolite, at plant/RER U	0.007 kg	
	-Electricity, at refinery/RER U	255 Mj	[16]
Produce 1 kg aluminum from aluminum scrap	-Aluminum scrap, post-consumer, prepared for melting {RoW}| treatment of aluminum scrap, post-consumer, by collecting, sorting, cleaning, pressing | Alloc Rec, U	1.180 kg	[3]
	-Electricity from gas B250	15.75 Mj	[16]
Profile coating	-Coating powder, at plant/RER S	0.06148g	[2]
	-Electricity from gas B250	50 kWh	[16]
Window manufacture	-Aluminum sheet, primary prod., prod. mix, aluminum semi-finished sheet product RER S	4.0992 kg	[2]
	-Transport, single unit truck, diesel powered/US	0.040992 kgkm	Assumed
	-Electricity from gas B250	53.2896 kWh	[16]
Beech wood			
feeling the tree	-Wood in forest U	1.25 ton	[29]
	- Chain sawing I	3 min	
	-Electricity from gas B250	0.386116 kWh	
Sawmill Planks	-Wood in forest S	500 kg	[29]
	-Saw dust, hardwood, green, at sawmill, NE-NC/kg/RNA	400 kg	
	-Pine log with bark, reforested managed forest, production mix entry to saw mill, 44% water content DE S	100 kg	
	-Electricity from gas B250	150 kWh	
	-Truck 28t	5600 tkm	Assumed
shed for product window	-Wood board ETH S	6.12 kg	[29]
	-Steel low alloy ETH U	2 kg	
	-Transport, single unit truck, diesel powered/tkm/RNA	0.0612 tkm	Assumed
	-Automotive painting, electro coating, per m2/RNA	0.02400615 m2	[24]

Table 2. LCA (Max.) and Discomfort (Min.) data optimization in case of using aluminum and beech wood frame type.

Iteration	Design Variables			Objectives	
	Glazing type	**WWR%**	**Window frame type**	**Discomfort (all clo) (hr)**	**LCA (Simple)(kg)**
108	Sgl LoE (e2=.2) Clr 6mm	30	Aluminium window frame (no break)	3569.229279	11105.57493
225	Sgl Elec Ref Colored 6mm	95	Aluminium window frame (no break)	3529.163994	11103.12912

3. Results and Discussion

In this paper, we used two purposes for windows in the light of life cycle assessments; the first purpose is the comparing of window frame materials to decide their contribution to their impacts. The second one is the windows performance according to the selection of material, maintenance, service and durability. The aluminum window needs a low maintenance in comparing to the beech wood window.

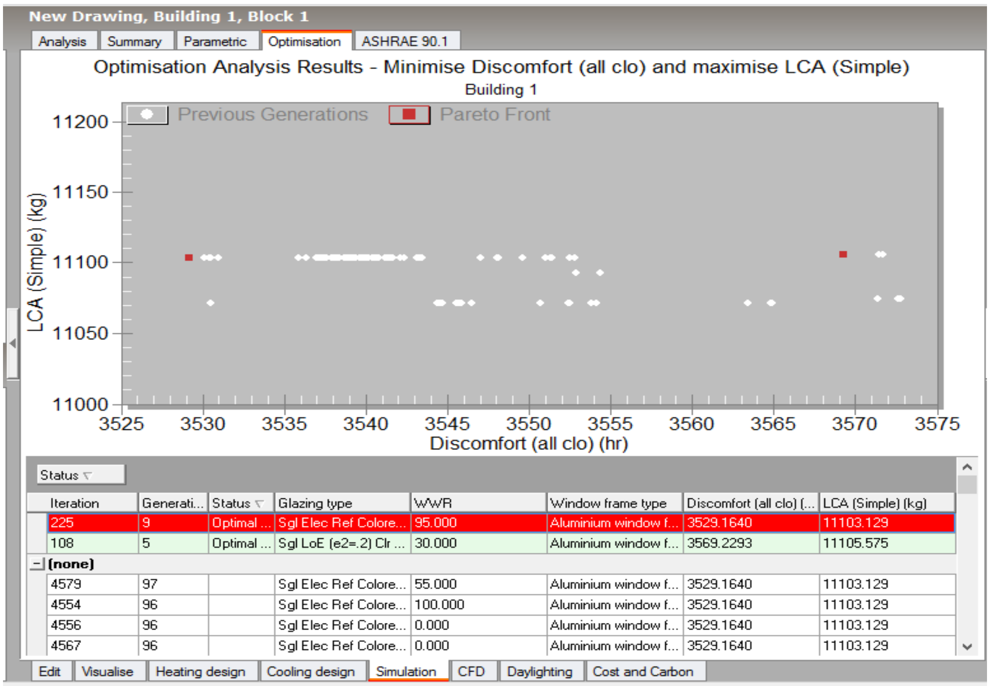

Figure 9. The characterization factor for the two materials.

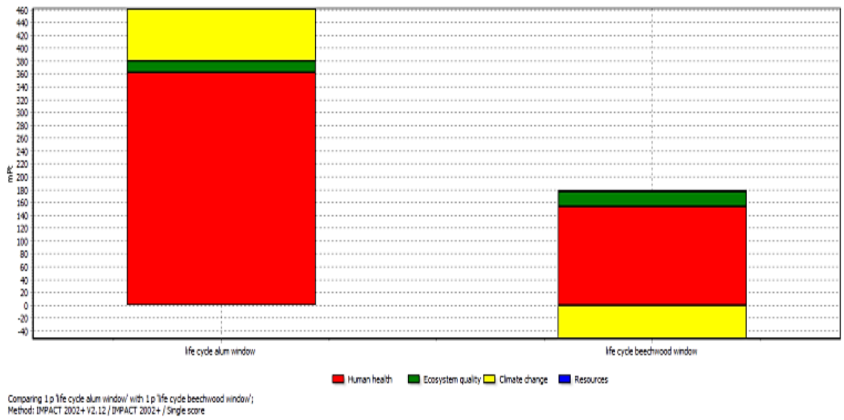

Figure 10. The single score for the two frame materials.

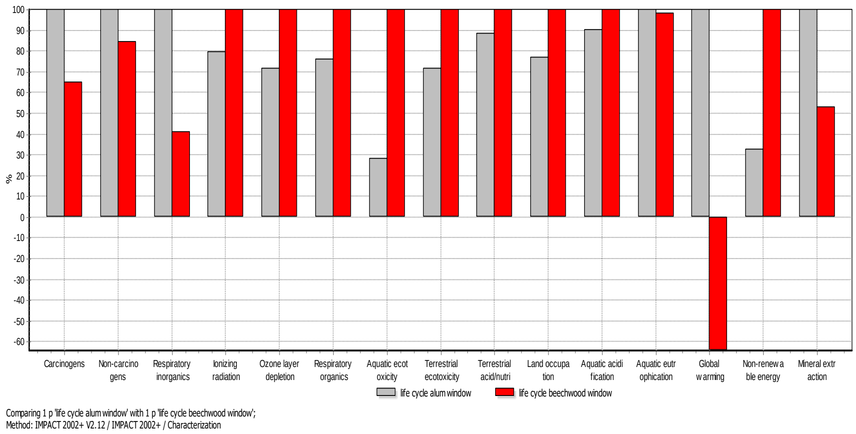

Figure 11. The two frame materials characterization.

The impact of windows from the two types (aluminum and wood) on human health, climate change, ecosystem, and the ecological resources as single score results are showed in Fig. 10. The aluminum frames negatively affect the human health with extensive points, but in case of wood frames is much lower. In case of climate change, the wood has the positive impact, where the aluminum has the negative effect. The impacts of aluminum and wood frame as shown in Fig. 11, where the difference between all scores are floated from 29% up to 90% as the allocation factor, but the global warming has a lesser effect in case of wood window. In table 2, it will be find that the aluminum has the best impact for comfort on the long run time, where it has the maximum impact on LCA (simple) to achieve the maximum hours of comfort, because the aluminum is easily maintainable than that in case of wood window.

4. Conclusion

In this research, the differences between the two materials that are used in window manufacturing are depicted to present the greener choice in the building design. In the case of climate change the wood frame has a lesser impact than aluminum frame. Here to, removal for the effects of some remaining uncertainties in LCA (climate impact assessment practice, allocation, and system boundaries) of wood products will be invaluable. The participation between the agencies and the sector of forest product to develop the datasets in LCI will support the wood in green building design. In this research, a benchmarking of the building component alternatives that can be used to evaluate environmental performance in terms of air quality index, energy utilization, global warming, water quality, forest structure/health, waste is conducted. The results indicated that in the case of climate change wood window frames as a wood product has less impact on environment, but on the other hand the aluminum frames has a good impact after used or installed in the sites on the long run time.

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Coconut Shell Activated Carbon with βeta-Silicon Carbide Reinforced Polymer Composites: An Alternative Dielectric Material for Microwave Absorber

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Abstract

The effect of adding natural based activated carbon, namely coconut shell activated carbon (CSAC) on the structural and dielectric properties of beta-silicon carbide (β-SiC) reinforced polymer composites were investigated. This work aims to assess the potential of using CSAC as conductive filler in the β-SiC based dielectric material used for microwave absorber. Material characterization of the CSAC in term of elemental composition, particle morphology and structural analysis have been performed by using carbon, hydrogen, nitrogen, sulfur (CHNS) elemental analyzer, scanning electron microscope (SEM) and X-ray Diffractometer (XRD). Room temperature open-ended coaxial line method was performed to determine the dielectric properties over broad band frequency of 200 MHz - 20 GHz by using Agilent 85070E Dielectric Probe Kit and Agilent E8362B PNA series network analyzer. The microwave conductivity of the composites was evaluated based on the measured dielectric properties. Experimental result shows that CSAC is highly carbonaceous material with 83.94% of carbon composition and presence of macroporous structure with particle porosity ranging from 446.6nm to 2.5μm was detected. The XRD pattern of coconut shell activated carbon revealed that presence of broad diffraction peaks are detected at 2Ө= 23.985° and 44.015°, which corresponded to amorphous structure. With the addition of CSAC, it was found that the dielectric properties of the β-SiC composites show improved dielectric properties (ε' and ε”) starting from 6.18 GHz to 20 GHz. Both real and imaginary parts of permittivity of the composites decrease with increasing frequency, which present the typical dielectric relaxation characteristic. The presence of CSAC increases the composite electrical conductivity at microwave frequency. This indicates that the natural activated carbon, CSAC could thus be used as conductive filler not only for their dielectric losses performance, but also for their cost effective production.

Keywords: coconut shell activated carbon; beta silicon carbide; dielectric properties

1. Introduction

Nowadays, various electronic equipment and systems become sophisticated with complex circuitry performing critical functions due to development in the advanced technology. These equipment or systems are susceptible to electromagnetic interference (EMI). EMI is defined as malfunctioning or degradation of performance of the system because of the fields produced by electromagnetic environment (Bakshi and Baksi, 2009). Dielectric based microwave absorbing material (MAM) has been widely used to reduce the unwanted EMI by attenuating the microwave energy through ohmic loss and is greatly influenced by the dielectric properties.

The dielectric properties are presented in term of complex permittivity (ε), as presented in equation (1).

$$\varepsilon = \varepsilon' + j\varepsilon'' \qquad (1)$$

where ε' is the real part of permittivity and ε'' is the imaginary part of the permittivity. ε' represent the dielectric constant, i.e. the ability of the MAM to store the microwave energy whereas ε'' represent the dielectric loss factor, i.e. the ability of the MAM to convert and dissipate the stored microwave energy to heat loss (Harmuth, 1983; Zhang et al., 2002; Chen et al., 2004; Singh et al., 2015). Materials like ceramic, conducting polymers and carbon are commonly used as dielectric based MAM (Kumar et al., 2014). Among aforementioned MAMs, the ceramic based materials, silicon carbide (SiC) is a typical MAM that is widely used due to its thermal stability, chemical stability and mechanical properties (Su et al., 2011; Yang et al., 2013). However, the absorption ability of SiC material is not satisfactory as a single absorber. Researchers have tried to combine the SiC with synthetic carbon materials such as the carbon black or carbon nanotubes to enhance the absorption ability in terms of dielectric properties. Carbon is used as the conductive filler due to its excellent electric conductivity (Saib et al., 2006; Liu et al., 2011; Zhu et al., 2011; Bi et al., 2014; Su et al., 2014; Wan et al., 2014).

In this paper, an attempt has been made to make use the natural activated carbon, i.e. coconut shell activated carbon (CSAC) as the conductive filler in the beta-silicon carbide (β-SiC) based dielectric material. Many composites combining the dielectric fillers with conducting polymer have been studied and it was reported that such composites leads to formation of multi-component composite possessing unique combination of electrical, dielectric properties useful for suppression of EMI (Saib et al., 2006; Liu et al., 2008; Liu et al., 2011; Wan et al., 2014;Hussain et al, 2015).This paper aims to report on the elemental and structural characterization, dielectric properties and electrical conductivity of the CSAC/β-SiC reinforced polymer composites. This paper is arranged in four sections. In section 2, the materials and methods in the composite preparation, the elemental and material structural characterization are described, and the experimental dielectric measurement over broadband frequency range of 200 MHz- 20 GHz are presented. The results are discussed in Section 3, which is followed by conclusion in Section 4.

2. Materials and Methods

2.1 Materials

The commercially available CSAC powders (mesh size 200; Tan Meng Keong Sdn Bhd., Malaysia) and β-SiC nanopowder (99+% pure, 45-65nm, cubic; US Research Nanomaterials, Inc.) was used as the raw materials. Bis-phenol A (Epocast 100) based epoxy resin and amine curing agent was used as the matrix of blending CSAC-SiC composites.

(a) Coconut shell activated carbon powder, mesh size - 200

(b) Beta silicon carbide (β-SiC) nano powder(99+%, 45-65 nm, cubic)

(c) Polymer matrix (Epocast 100 epoxy resin and amine curing agent)

Figure 1. Materials for composite preparation

2.2 Composite Preparation

The composites were prepared by homogeneously combine 50 wt% fillers (CSAC, β-SiC) in the 50 wt% polymer matrix based on the compositions shown in Table 1. The room temperature curing epoxy resin and the corresponding hardener were mixed in a ratio of 5:1 by weight as per recommendation. In order to insure good dispersion of the CSAC and SiC fillers with the matrix, IKA RW 20 Digital Stirrer at moderate revolution per minute (100-140 RPM) was used to blend the mixture. The uniformly stirred mixture was poured into a planar mold with the dimension of 40 mm x 40 mm and thickness of 5mm and cured at room temperature. The dimension of the fabricated composite must be greater that the size of the high temperature dielectric probe (20mm) used in measuring the dielectric properties in order to minimize the fringing field effect (Iqbal, 2014). The sample thickness is determined based on equation reported elsewhere (Yew et al., 2016)

Table 1. Composition ratio of CSAC/β-SiC

Composite	Weight Percentage (wt %)	
	CSAC	β-SiC
1	0	100
2	10	90
3	30	70
4	50	50

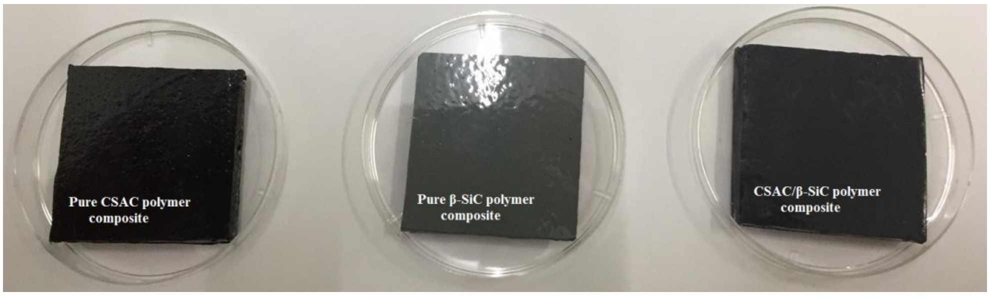


Figure 2. Fabricated composites.

2.3 Elemental Composition Determination

The carbon composition of CSAC was examined through elemental analysis by using Vario MICRO cube carbon, hydrogen, nitrogen and sulfur (CHNS) analyzer at temperature of 23 ± 3 ℃ and relative humidity 50 ± 5% of room temperature.

2.4 Material Structural Characterization

JEOL JSM-6360LA and ZEISS Supra55 scanning electron microscopes (SEM) was used to determine the morphology of CSAC particles. Since the CSAC is in the powder form, the specimens under test for the SEM analysis was prepared by lightly sprinkle and pressed the CSAC on the carbon conductive adhesive double sided tape that was mounted on the SEM stub. Since CSAC is a poor/non-conductive specimens, it tend to charge-up when scanned by the electron beam during the imaging process. In order to prevent charge-up as well as to ensure uniform conductivity, excessive CSAC powder on the carbon conductive adhesive double sided tape was removed by using a rubber hand blower. The CSAC specimens were coated with a thin layer of electrically conductive layer by using the BAL-TEC SCD

005 sputter coater machine. In this analysis, gold and platinum conductive materials were used to coat the CSAC specimens and the morphology of the CSAC specimens were viewed at magnification up to 5.0 KX with acceleration voltage of 15kV. All processes were illustrated in Figure 3.

In order to prepare the powder specimen of the fabricated composites for crystallographic structure analysis, the composites were pulverized up to 106 micro meters (µm) fined powder form by using the Rocklabs Bench Top Ring Mill. The type of the head for ring mill that was used is Zirconia. Refer to Fig. 4. In powder diffraction, it is important to have a sample with a smooth plane surface in order to obtain a specimen that is homogeneous and the crystallites are randomly distributed. The powder specimen of the composites was pressed into a sample holder to obtain a smooth flat surface. The crystallographic structure of the fillers and composites was examined by using Rigaku, Miniflex II Benchtop X-ray Diffractometer (XRD) with Cu Kα radiation (λ = 0.015418 nm). The diffraction patterns were recorded in the 2 theta (Θ) range of 10°-80°.

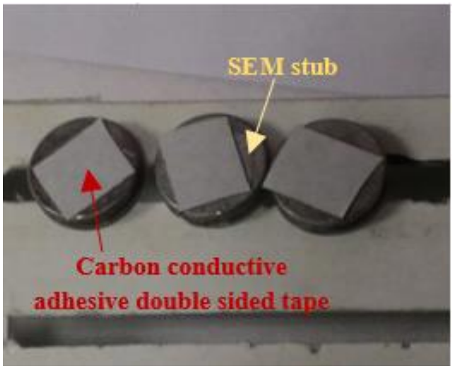
2.5 Dielectric Measurement

The dielectric properties of the fabricated composites were measured using open-ended coaxial line method over broad band frequency range (200 MHz-20 GHz) at room temperature. The measurement apparatus include Agilent 85070E Dielectric Probe Kit (high temperature dielectric probe and material measuring software) and Agilent E8362B PNA series network analyzer. Measurement is made by contacting the high temperature dielectric probe to the surface of the composite. It is important to make sure that composites were fabricated with flat and smooth surface to minimize the dielectric measurement inaccuracy that may be caused by the leakage of reflected signals through the air gaps. Similar measuring method had been reported elsewhere (Wee et al., 2011; Yew et al., 2016a; Yew et al., 2016b). Fig. 5 shows the apparatus and dielectric properties measurement on the fabricated composite.

3. Results and Discussion

3.1 Elemental Composition Determination

As shown in Table 1, the CHNS elemental composition analysis for CSAC has been listed. It was found that the carbon composition of CSAC is 83.940% (Siti Nurbazilah et al, 2016). This indicates that CSAC is a highly carbonaceous material that is potentially useful as the conductive filler in the microwave absorbing material. The microwave energy attenuation is the dominant EMI shielding mechanism in the porous form composite and the employment of the conductive filler with ideal electrical conductivity and large surface area has greatly influences the microwave energy attenuation within the composite (Song et al., 2014). The enhanced electrical conductivity within a composite facilitates the dissipation of the microwave energy into heat losses, and this is attributed by the loading of carbonaceous conductive filler. The effect of the larger surface area is further discussed in subsection 3.2.



(a) (b)

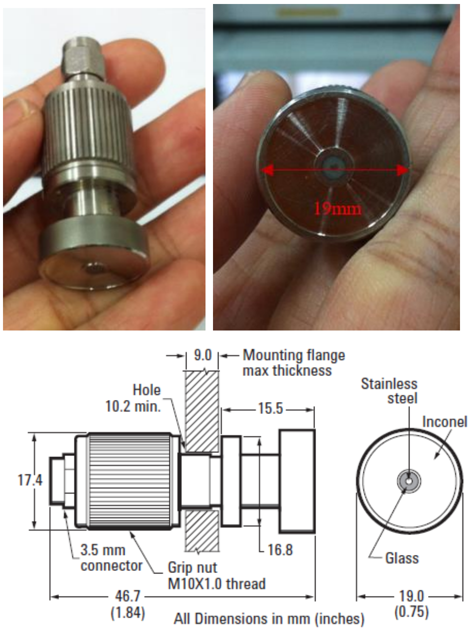
(c)

(d) (e)

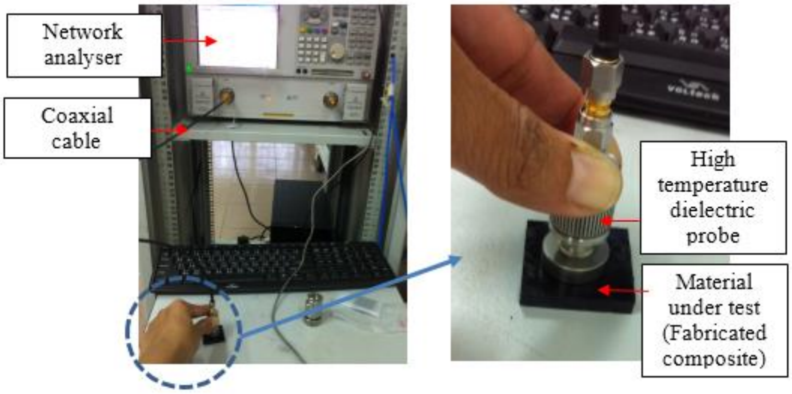
Figure 3. (a) Carbon conductive adhesive double sided tape that was mounted on the SEM stub (b) Removal of excessive CSAC powder by using rubber hand blower (c) Metalized the powder specimen with electrically conductive material (d) Coated specimens with platinum (e) Imaging process by using SEM

(a) (b) (c)

Figure 4. (a) Rocklabs Bench Top Ring Mill (b) Zirconia head ring mill (c) Example of the pulverized powder specimen



(a)



(b)

Figure 5. (a) The high temperature dielectric probe (b) Dielectric properties measurement setup using Agilent 85070E Dielectric Probe Kit and Agilent E8362B PNA series network analyzer

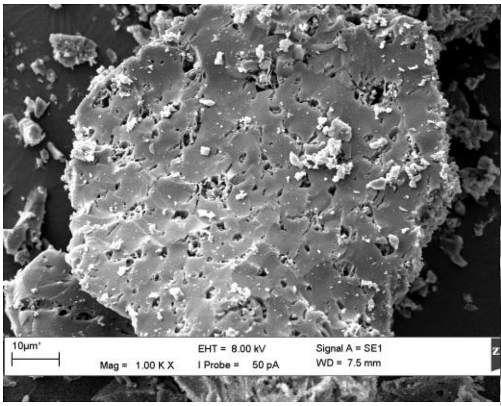
Table 2. Elemental composition of coconut shell activated carbon (CSAC).

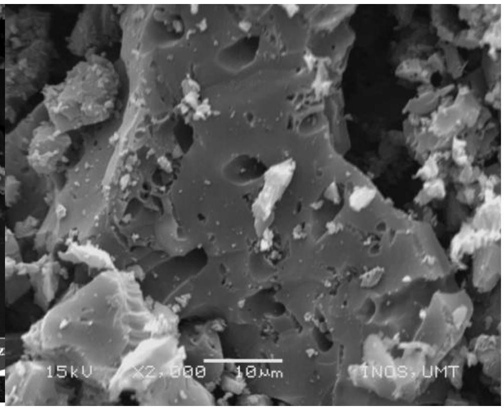
Composition	Carbon (C) %	Hydrogen (H) %	Nitrogen (N) %	Sulfur (S) %
Coconut shell activated carbon (CSAC)	83.94	1.263	0.86	0.175

3.2 Material Structural Characterization

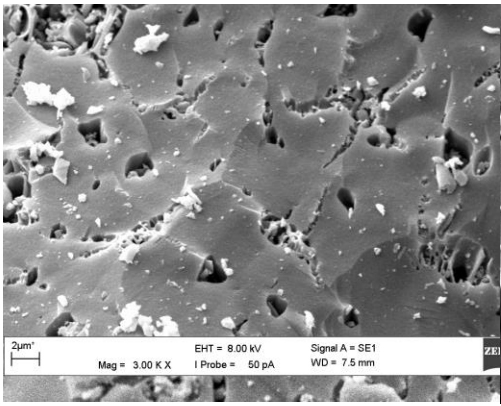
Figure 6 shows the morphology of the CSAC particles obtained from the SEM imaging analysis. In this work, the shapes and the porosity structure of CSAC particles were analyzed. It can be observed that the presence of irregular CSAC particles shape with porosity ranging from to 446.6 nm to 3.6 µm was detected at 5kX magnification. For activated carbon, the pore size distribution is used to describe the internal structures and the pore distance is represented by the differences in the size of the openings (Ilomuanya et al., 2017). According to IUPAC nomenclature on pore dimensions, porous materials can be classified as microporous, mesoporous and macroporous structures, with the corresponding pore sizes of < 2 nm, 2-50 nm and > 50 nm, respectively. Thus, the pore size of the CSAC particles that were used in this work correspond to macroporous structure. The irregular CSAC particles indicates a relatively larger surface area for higher conduction losses whereas the macroporous structure of the particle filler leads to interfacial polarization which can result in microwave multi-reflection and scattering to enhance the attenuation of the microwave energy within the β-SiC composite (Liu et al., 2011; Zhao et al., 2015).

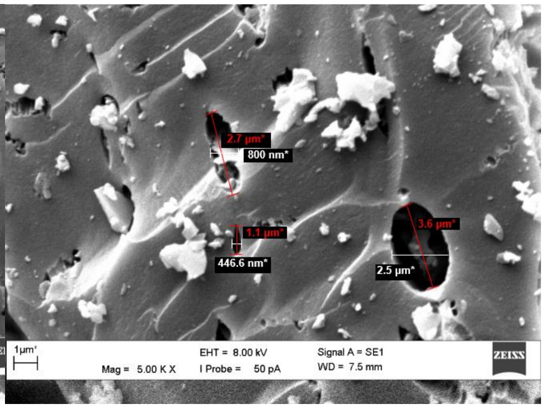
In this work, the composites that were fabricated are considered as partly amorphous (CSAC) and partly crystalline (β-SiC). The amorphous domain act as the conducting component and it is expected that the amorphous domain gives a broad diffraction peak from the crystallographic structure analysis. On the other hand, the crystalline domain act as a reinforcing grid and it is expected that the crystallinity domain give sharp narrow diffraction peaks. Fig. 7 shows the XRD patterns of the fillers and composites. By referring to Fig. 7(a), the XRD pattern of CSAC powder corresponds to amorphous structure. Presence of broad diffraction peaks are detected at 2ϴ= 23.985° and 23.985° which were similar to the peaks of crystalline carbonaceous structure such as graphite (Tangjuank et al., 2009). The XRD pattern of β-SiC nanopowder corresponds to pure and well crystalline structure. The XRD peaks of β-SiC (JCPDS 29-1129) with 2ϴ=35.574°, 41.336°, 59.908°, 71.628°, 75.403°, attributed to (111), (200), (220), (311) and (222) planes referred to JCPDS 29-1129. For crystallographic structure analysis of the composites, it can be observed that in Fig. 7 (b), the CSAC/β-SiC composites exhibit hybrid amorphous/crystalline XRD pattern. With increasing CSAC content, the peak intensities corresponding to β-SiC phase has decreased and leads to reduction of crystallization of β-SiC.





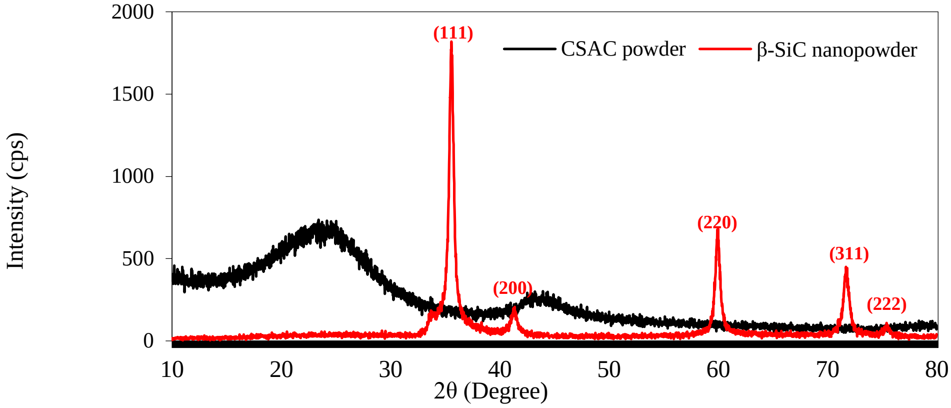
(a) (b)



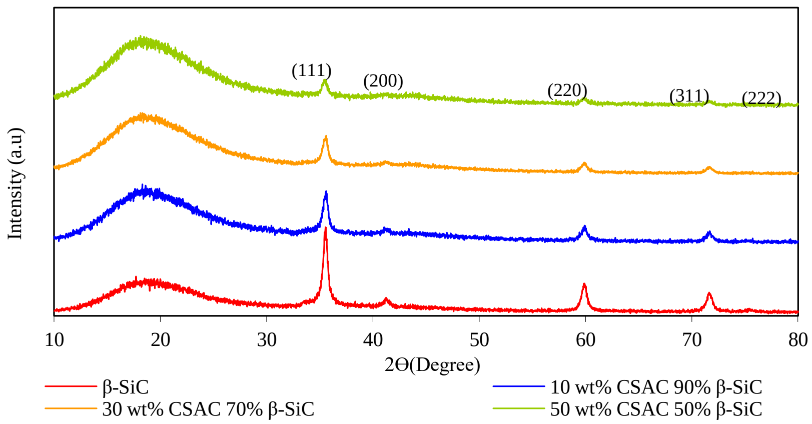


(c) (d)

Figure 6. CSAC particles morphology at magnification of (a) 1 KX (b) 2KX (c) 3KX (d) 5 KX



(a)



(b)

Figure 7 (a) XRD patterns of raw materials and pure CSAC and β-SiC composites (b) CSAC/β-SiC polymer composites with different compositions

3.3 Dielectric Properties

The dielectric properties of the composites were measured over broadband frequency range of 200 MHz- 20 GHz. Figure 8 shows the dielectric properties of the material presented in real (ε') and imaginary (ε'') permittivity respectively, plotted against the frequency. It is noticed that all the composites present typical frequency dependent permittivity (Cao et al., 2009). Noted that in Fig. 8, the inconsistency on the beginning and ending of each frequency dependent permittivity graph was due to the random fluctuation occurred during the measurement. Due to this reason, the discussion on the results obtained was considered from 4 GHz to 16 GHz only. ε' was found to decrease when frequency increases for the entire frequency range (4 GHz – 16 GHz) whereas ε'' showed the decreasing trend of frequency dependent permittivity ε" starting from 9 GHz to 16 GHz. According to the theory of complex permittivity, when an electromagnetic field propagates within a dielectric material, the electric field induces two types of electrical effects, i.e. displacement and conduction currents. The material response to real permittivity, ε', (dielectric constant) due to the effect arising from the interaction of displacement current or in other words the polarization mechanism, which may be electronic, ionic, dipole and space charge polarization; whereas an increase of the imaginary permittivity is due to the effect arising from the movement of free electrons (Micheli et al., 2010; Nautiyal et al., 2010; Zangina et al., 2016). Similar trends have been observed for all the curves at different CSAC filler weight percent addition for both ε' and ε". With the increase of CSAC loading, significant enhancement was achieved in both ε' and ε". This is due to the conductive behavior of the carbon powder (CSAC) inserted into the β-SiC reinforced polymer composites (Micheli et al., 2010). The insertion of conductive filler in the β-SiC based composites are favorable to capture and attract charges, which is mainly responsible for the polarization in the composites (Song et al., 2014); whereas the enhancement in ε" leads to the dissipation of heat losses which can be attributed to the enhanced electrical conductivity of the material (refer to subsection 3.4).

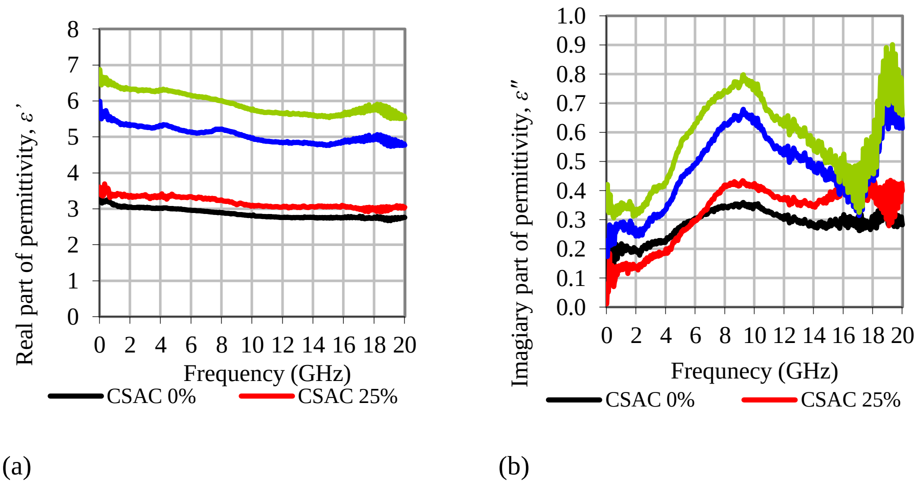


Figure 8. Frequency-dependent dielectric properties (a) Real part of complex permittivity (b) Imaginary part of complex permittivity (c) Loss tangent

Noted that from the dielectric properties measurement, there was fluctuation occurred during the measurement. One critical aspect that was ignored during the fabrication of the composites is achieving a random dispersion inside the matrix and the removal of voids that are due to air bubbles formation (Refer to Fig. 9). In this work, the CSAC and β-SiC fillers and matrix was blend into uniformly stirred mixture by using digital stirrer at moderate revolution per minute. The disadvantages of using the stirring process is due to the high viscosity of the epoxy resin. With the increased filler content within a matrix, the viscosity of the epoxy resin before curing is increased. It becomes difficult to expel the bubbles and to remove the voids in the composites (Choi et al., 2005; Micheli et al., 2010). Therefore, some means to inhibit the formation of void will be necessary, for example heat can be applied to draw air bubbles to the surface by curing the fabricated composites in an oven with a specified temperature and duration. Then, the composites that were completely cured should be stored in a desiccator prior measurement to eliminate the effects of humidity.

Figure 9. The formation of voids observed from the cross-sectional area of the composites/

3.3 Electrical Conductivity

When an electromagnetic (EM) field propagates through a dielectric material, conduction current that was induced from the movement of free electrons from the interaction of the material (conductive filler) with the electric field, gives rises to the dielectric loss within the material. The increase in imaginary permittivity is attributed by the enhanced dielectric loss or in other word, the enhanced conductivity of the dielectric material. The electrical conductivity, σ of a dielectric material is evaluated by using equation (2) (Micheli *et al.*, 2014).

$$=2\pi f \, \varepsilon_o \, \varepsilon'' \qquad (2)$$

Figure 10 shows the electrical conductivity of the composites plotted against the frequency. It is noticed that the insertion of CSAC increase the electrical conductivity of the composites in the function of frequency. This can also be translated in increasing of the dielectric losses (Micheli et al., 2010). The increase in conductivity is strongly dependent on nature, concentration of filler particles as well as type and morphology of the matrix. It is important to point that the conductive filler can induce interfacial polarization and contribute toward energy storage and losses. As the frequency of incident EM wave increases in the microwave region, the dipole of the polarization mechanism within a material fail to maintain in-phase movement with rapidly pulsating electric vector leads to molecular friction resulting in energy dissipation in the form of heat (Saini, 2013).

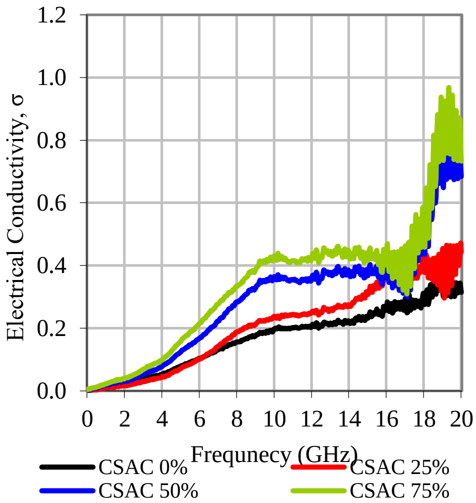


Figure 10. Frequency-dependent electrical conductivity

4. Conclusion

This work investigates the effect of adding the CSAC on the dielectric properties and electrical conductivity of the β-SiC based polymer composites. The dielectric properties and electrical conductivity of the CSAC/β-SiC composites were compared to the pure β-SiC polymer based composite. Experimental results show that the dielectric properties of the β-SiC composites show improved dielectric properties due to the presence of CSAC. The CSAC/β-SiC composites show typical dielectric relaxation at microwave frequency (GHz range) and were dependent on the fillers composition. The increase in the imaginary permittivity (ε") has increased the composite electrical conductivity at microwave frequencies, indicating the increasing of the dielectric losses. However, the dielectric properties measurement accuracy were affected by voids or air bubbles within the fabricated composites. The presence of different dielectric that is due to the air bubbles caused errors in the computation of the complex permittivity. From this work, it can be concluded that the natural based activated carbon, CSAC could be used as alternative "green" conductive filler for dielectric based MAMs but the degree of the homogeneity of a material to the incident microwave signal must be enhanced to improve the measurement accuracy on the dielectric properties.

Acknowledgements

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Evaluation of Greenhouse Gas Emissions from Municipal Solid Waste (MSW) Management: Case Study in Lampang, Thailand

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Abstract

The issue of municipal solid waste (MSW) disposal and greenhouse gas emissions are concerned on global warming. The greenhouse gas reduction of waste generation system is the one of management strategies from the National Economic and Social Development plans in Thailand. This project evaluated the greenhouse gas emissions from municipal solid waste system covering transportation and disposal in Lampang, Thailand. At the start of the data collection, greenhouse gas emissions were estimated based on the travel distance of the vehicles for transportation process by the vehicle emission model. As for disposal process was estimated from the model developed by Institute for Global Environmental Strategies (IGES). The results showed that the sanitary landfill released more GHG emissions than transportation process. The GHG emissions from sanitary landfill are highly contributed by the landfill methane (CH_4) emissions (20,346 tonnes CO_2eq/year). In addition, carbon dioxide (CO_2) was mostly emitted (226 tonnes/year) from transportation process. This evaluation found that GHG emissions calculation based on travel distance was lower than those based on fuel consumption (44%). Furthermore, changing diesel fuel to compressed natural gas of vehicles will reduce GHG emissions by approximately 7%.

Keywords: greenhouse gas; solid waste; municipal; emission; Lampang

1. Introduction

With urbanization, population growth and economic development are directly related to increase solid waste and it has become a major of environmental issue (Chen and Lo, 2016; ONEP, 2010; Woon and Lo, 2013). In Thailand, more than 266 Million tonnes of greenhouse gas was increasing from 2004 until now. Approximately 9.32 TgCO_2eq of GHG emissions emitted from wastes sector including disposal solid waste on land (4.86 TgCO_2eq) and waste water handling (4.43 TgCO_2eq) (ONEP, 2010). Therefore, the reducing of GHG emissions strategies as all sectors are encouraged and supported by the government in Thailand. However, the GHG emissions data of Municipal Solid Waste (MSW) management are not estimated of all cities in Thailand.

Municipal solid waste management includes waste collection, transportation, treatment and disposal. Solid waste is practically disposed from uncontrolled or open dumps method that affects to environment and human health in developing countries (Jain et al., 2016). In currently, solid waste disposal methods including open dump (OD), sanitary landfill, controlled dump, refuse-derived fuel: RDF, thermal treatment, composting and integrated systems are typically implemented at the municipals in Thailand (PCD, 2011). However, some of these are inappropriate and need to be disposed properly. In 2015, the pollution control department reported that the main operation systems of suitable waste disposal in Thailand are approximately 84 sites, 321 sites, 18 sites and 23 sites of sanitary landfills/engineered landfills, controlled dumps, incineration and integrated system, respectively (PCD, 2016).

From landfills and dumpsites, methane gas is emitted to the ambient air directly (Jha et al., 2007; Hoklis and Sharp; 2014; Scheutz et al., 2014). In addition, other main gases of greenhouse gases are carbon dioxide (CO_2) and Nitrous oxide (N_2O) that are also released from MSW management (Hoklis and Sharp, 2014). Percentage of 40-60 and 45-60 of the GHG released from landfills that were CH_4 and CO_2 emissions, respectively (Babel and Vilaysouk, 2015). In Thailand, the Intergovernmental Panel on Climate Change (IPCC) guidelines is mainly used for estimating the GHG emitted from MSW management (IPCC, 2006). According to the GHG calculation tool is developed by the Institute for Global Environment Strategies (IGES) for estimating the GHG emissions inventory aligned with IPCC 2006 guideline. The development of the GHG calculation tool is under the measurement, reporting and verification project for low carbon development in Asia countries. In addition, direct emissions and life cycle of GHG saving are calculated from the tool. The model is applicable for Asia Pacific countries by selecting the specific location of parameters at the preferred areas (Menikpura and Sang-Arun, 2013).

Lampang province has the highest amount of waste disposal sites (173 sites) in Thailand. However, these are only 22 sites for suitable waste disposal and the others are unsuitable sites operated. As for the Lampang municipality which is the large area in Lampang province that has an engineered landfill is properly operated. It was operating from 2001 until now in about 1 km2 of the area, but the area is 0.04 km^2 used and 0.03 km^2 currently used. In 2016, The total of waste generated and waste recovery were approximately 85% (88.08 tonnes/day) and 15% (15.50 tonnes/day), respectively (PCD, 2017). Furthermore, waste components are mainly waste of food, plastic and paper that matches as the previous studies from the Pollution Control Department (PCD) and Ministry of Energy (Ministry of Energy, 2017). These affects the amount of GHG emissions from landfill. The percentage of waste generated data from Lampang municipality is shown in Figure 1.

The GHG emissions were reported in each sector by the Ministry of Energy, Thailand including household, agricultural, industrial, business, transportation and others, however, the GHG emissions were only estimated from activities of combustion, coal mining fugitive and oil and natural gas fugitive. In 2011, Lampang municipality joined in the project of carbon footprint for low carbon cities operated by the Thailand Greenhouse Gas Management Organization (TGO). In 2012, the total GHG emissions of Lampang municipality was 128,596.61 tonnes CO_2eq released from household activities, transportation and waste management sector, respectively (TGO, 2015). Moreover, waste disposal management was approximately 25.23% of GHG emissions estimated from their activities (Sampattagul and Khomyan, 2016). Therefore, GHG emissions estimation is important to improve the data base for comparing to other studies and supporting the mitigation measures of GHG reduction.

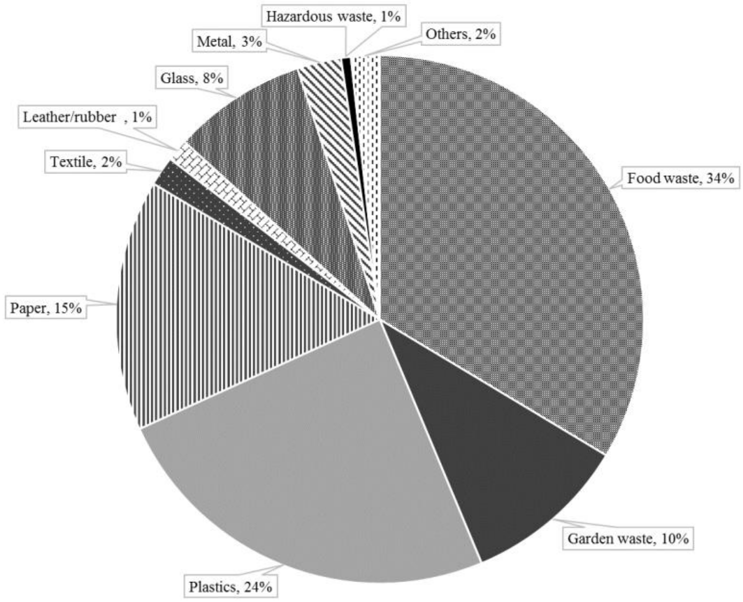

Figure 1. MSW composition in the Lampang municipality (Lampang municipality, 2012)

This study evaluated GHG emissions including CO_2, N_2O and CH_4 from transportation and waste disposal processes from MSW management in case of Lampang municipality. As for the GHG emissions from transportation process are estimated by GHG calculator for solid waste sector (IGES model) based on fuel consumption (L) and mobile source based on distance (km) emission model then compared. Moreover, GHG emissions from waste disposal process is calculated from IGES model based on total of waste (tonne). Finally, the difference scenarios are presented for reducing the GHG emissions relating with MSW management.

2. Material and Method

This study focuses on the main three gases including CO_2, N_2O and CH_4 of GHG emissions from MSW management. The data collections are from reports, organizations of government and field surveys. The GHG emissions of transportation and landfill are calculated from the IGES model. The international emission model or mobile source emission model is used to estimate the GHG emissions from transportation then compared to the GHG emissions transportation calculated by IGES model. The scenario is presented to reduce GHG emission from MSW management then the results of CO_2, N_2O and CH_4 emissions are compared to other studies. Moreover, CO_2, N_2O and CH_4 emissions are changed to the unit of CO_2eq (carbon dioxide equivalent) on the Global Warming Potential (GWP) of 100-year time horizon. These are 1, 310 and 21 of multiplication factors are used for CO_2, N_2O and CH_4, respectively (Lakeman, 1995). In the year of 2012 is selected as the base year and the percentage of recovery is zero.

Two methods of transportation and disposal processes are prepared for estimating the GHG emissions in the study as follows:

Method I: the GHG emissions from transportation process and disposal process are calculated by IVE model and IGES model, respectively.

Method II: the GHG emissions from transportation process and disposal process are calculated by IGES model. The concept of the study is shown in Figure 2.

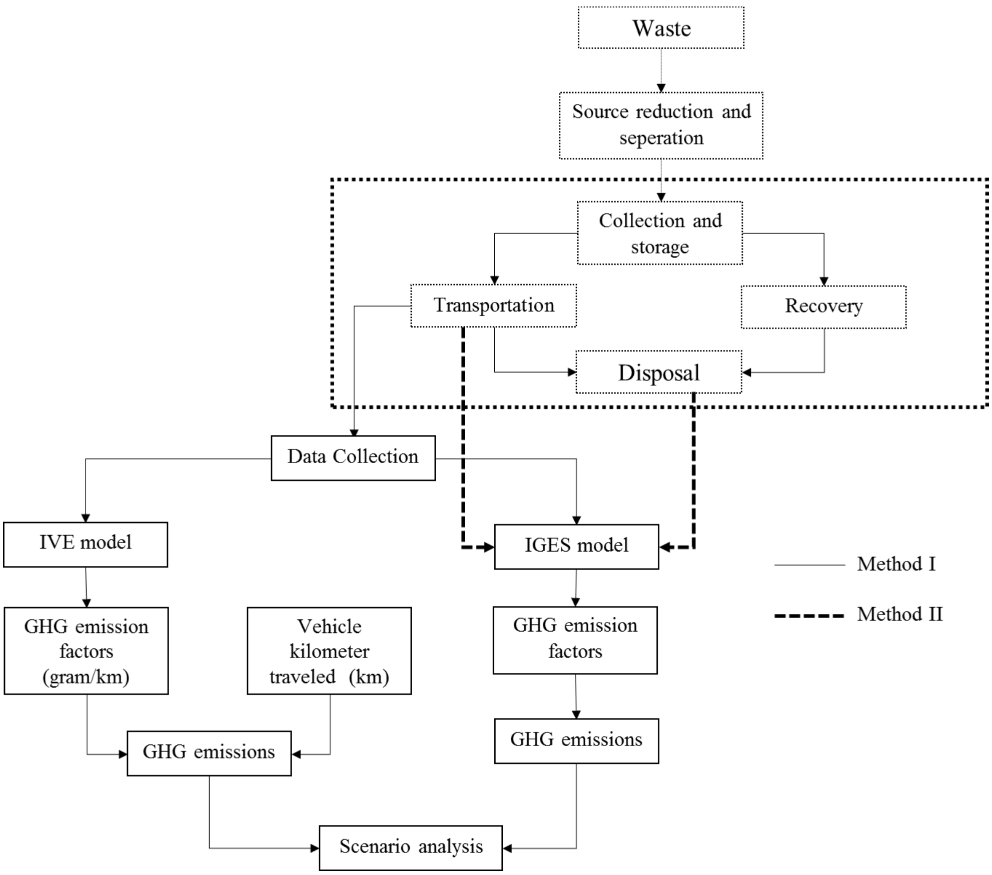

Figure 2. Conceptual framework in this study

2.1 Bottom up approach

Mobile source emission model

The International Vehicle Emission (IVE) model is used to calculate the GHG emission factors in this study. It was developed by the University of California at Riverside granted by US. EPA. Moreover, the IVE model is proper to use for developing countries including India, Mexico, Iran, Vietnam, Thailand, etc. Over 1200 engine technologies of vehicles that can be selected under the ones currently used in each area. The advantage of this model is that, other toxic air pollutants and general air pollutants are included and affected to air emission emitted from vehicles (ISSRC, 2008).

Emissions of motorcycles, heavy duty vehicles and all type of vehicles in Hanoi (Vietnam), Chennai (India) and Tehran (Iran), were estimated by the IVE model. The results found that the advance technology significantly reduced the air pollutants and GHG emissions emitted from the vehicles (Nesamani Institute, 2010; Oanh et al., 2012; Shafie-Pour and Tavakoli, 2013). Moreover, toxic air pollutants emissions emitted from all type of vehicles were estimated by IVE model in Bangkok urban area, Thailand. It was found that benzene emissions approximately 2 kilotons per year was reduced by using the better technology of vehicles (Outapa and Thepanondh, 2012).

The model has the 2 main parts of input data including location file and fleet file. As for the location file that are the data of driving pattern, average speed, characteristics of fuel, temperature and humidity. Fleet file is the characteristics of vehicles such as fuel type, size of vehicles, engine type, vehicles standard, etc. Bangkok driving cycle developed by the Pollution Control Department is also input to the model.

In this study, the 21 vehicles data for solid waste collected in the Lampang municipality area that are selected for estimating the GHG emissions at the part of waste transportation. In addition, the new vehicles for collecting waste from the study area in 2012 were using until now that are almost 5 years of age. The vehicles are categorized into 3 types by gross weight including light, medium and heavy that are shown in the Table 1. Moreover, the Euro III emission standard of all vehicles is used in this study.

Table 1. Gross weight and vehicle kilometer traveled (VKT) of vehicles

Size categorized	**Gross weight (kg)**	**Amount of vehicles**
Light	4,082-6,250	5
Medium	6,251-14,969	3
Heavy	>14970	13
Total		21

GHG calculator for solid waste sector (IGES model)

IGES model was developed for calculating GHG emissions including direct emissions and GHG savings from treatment technologies and integrated systems under life cycle approach (LCA) modified for improving the model. Moreover, GHG emissions of waste management technologies are adopted from IPCC 2006 guidelines. The parts of the model consist of transportation, mix waste landfilling composting, anaerobic digestion, mechanical biological treatment (MBT), recycling, incineration and open burning. In addition, the specific technology implemented can be selected and input to the model. Hence, the model is suitable for a bottom up approach of a nationwide GHG emission inventory (Menikpura and Sang-Arun, 2013).

The transportation and waste disposal processes are used for the GHG emissions calculation from MSW management in the study. As for transportation, the GHG emissions are calculated from the fossil fuel combustion including diesel fuel and compressed natural gas (CNG). Moreover, the major gas of GHG emissions from waste transportation is CO_2. The minor gases are CH_4 and N_2O emission by fuel combustion that are not considered in this model. Mathematical formula in this process is as follows:

$$Emission = \frac{Fuel\ (units)}{Waste\ (tonnes)} \times Energy\ \left(\frac{MJ}{unit}\right) \times Emission\ Factor\ \left(\frac{KgCO2}{MJ}\right)$$

Where:

Emissions = emissions from transportation (kg CO_2/tonne of waste transported)

Fuel = total amount of fossil fuel consumption per month, (diesel in liters and CNG in kg)

Waste = total amount of waste transported per month (tonnes)

Energy = energy content of the fossil fuel (diesel: 36.42 MJ/L, CNG: 37.92 MJ/kg)

Emission Factor = CO_2 emission factor of the fuel (diesel: 0.074 kg CO_2/MJ, CNG: 0.056 kg CO_2/MJ)

CH_4 is the major gas emission from waste disposal sites such as landfill that depends on factors including pH, moisture content, amount and mixture of waste and waste management implements. Methane gas generally increases with higher organic and moisture contents from waste disposal sites. Therefore, the composition of landfill is needed to input into the model e.g. food waste, garden waste, plastics waste, paper, textile, leather rubber, glass, metal, hazardous waste and others. Moreover, the total amount of mix waste (tonnes/month) and diesel fuel (L/month) are used for operating are also input to the model. The landfill type of MSW management needs to be selected for calculating GHG emissions.

The estimation of GHG emissions from landfill in the study, all parameters of mix waste are based on the model default values which are referred on IPCC model. The fractions of mixing waste input to the model are from waste data collected in the study area. In addition, approximately 10,146 L/month of diesel fuel consumption of transportation process was collected. As for disposal process, the total amount of mix waste input to the model was approximately 3,000 tonnes/month. However, the diesel fuel consumption used for operation of landfill is not considered in the study.

2.2 Scenario analysis

For improving and finding the suitable of transportation process from MSW management, the policy of energy is taken into consideration in this study. CNG is an alternative fuel for use in vehicles especially heavy duty vehicles such as trucks, buses, etc. Changing diesel fuel to CNG fuel is set as scenario development (CNG scenario). The assumption of the scenario might reduce the GHG emissions emitted from vehicles. Moreover, the baseline scenario is the MSW management current situation in Lampang municipality that is created and then compared to the CNG scenario. The data base for baseline scenario are shown in Table 2.

Table 2. The data used as the baseline scenario

Parameters	Baseline scenario	Base data
Transportation process		
VKT (km/year)		
○ **Light**	330,480	Method I
○ **Medium**	156,960	Method I
○ **Heavy**	167,760	Method I
Fuel amount (L/year): Diesel	121,756	Method II
Disposal process		
Waste amount (tonnes/year)	36,000	Method I,II

Remark: the data are estimated from Lampang municipality, 2012

3. Results and Discussion

The GHG emissions calculation are based on travel distance (km) and fuel consumption (L). As for the emissions of vehicles from transportation process using diesel fuel calculated by IVE model from 2012-2016 (1-5 years) are approximately 226-227 and 0.02-0.03 tonnes/year of CO_2 and N_2O, respectively. Results are shown in Figure 3. The GHG emissions are not significantly different in the study. By fuel consumption of CO_2 emission calculation emitted from vehicles that is about 328.14

tonnes/year calculated by IGES model. The result found that the GHG emissions calculated under emission factors based on travel distance (g/km) is higher than the GHG emissions calculated under emission factors based on fuel consumption. However, N_2O emission calculated by the IGES model is not considered. The GHG emission from sanitary landfill calculated by the model developed by Institute for Global Environmental Strategies (IGES) is highly contributed by the landfill methane (CH_4) emission (20,345.50 tonnesCO_2eq/year). The calculations take into account the fractions of mix waste generated including food waste, garden waste, etc.

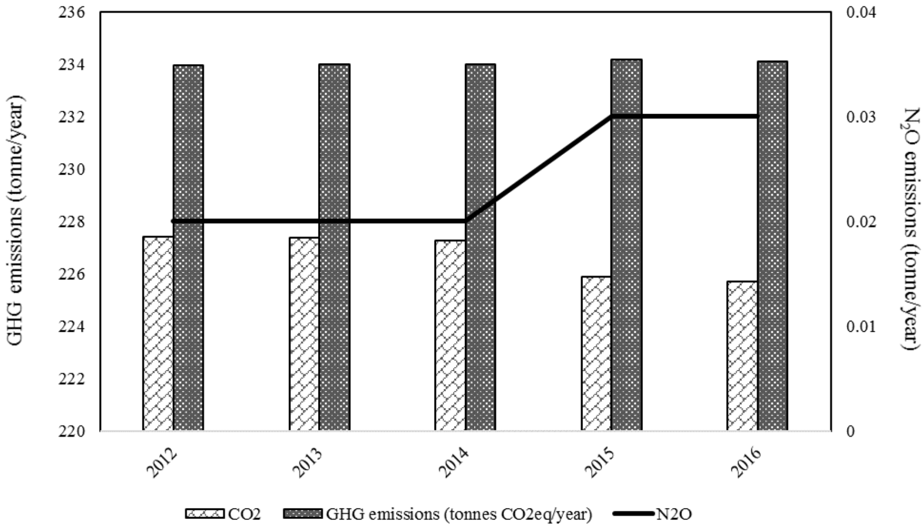

Figure 3. The GHG emissions emitted from vehicles in MSW management from 2012 - 2016

The CNG scenario is also assumed for all of new vehicles that are generated same as the baseline scenario. Result of the GHG emissions calculation found that CO_2 emission is decreased from the baseline. In this scenario, CH_4 emission is also estimated from the IVE model. It may result from CNG fuel evaporation being included. Total GHG emissions estimated from transportation process from CNG scenario is about 217 tonnes CO_2eq/year that is also the lowest compared with the others. The GHG emissions calculated under both methods and CNG scenario are shown in Table 3 and the total of GHG emissions of all processes are shown in Figure 4.

The comparison of results to Sampattagul and Khomyan (2016) studied found that the GHG emissions released from MSW management in Lampang municipality are approximately 58% (method I) and 57% (Method II) lower than those study (Figure 5). There are several methods for calculating the GHG emissions from MSW management that depending on the purposes of specific study.

Table 3. GHG emissions resulting from the models

Scenario	Transportation process (tonnes/year)				Disposal process (tonnes/year)
	CO_2	**N_2O**	**CH_4**	**CO_2eq**	**CO_2eq**
Baseline (Method I)	227.41	0.02	-	233.95	20,345.50
Baseline (Method II)	328.14	-	-	328.14	20,345.50
CNG	201.51	0.02	0.41	216.70	20,345.50

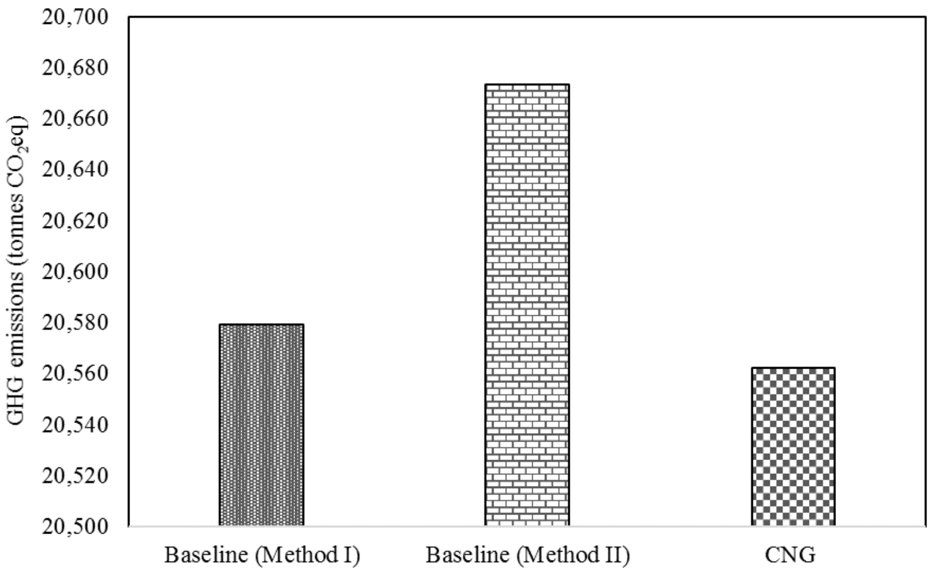

Figure 4. Total of GHG emissions released from MSW management under the scenarios

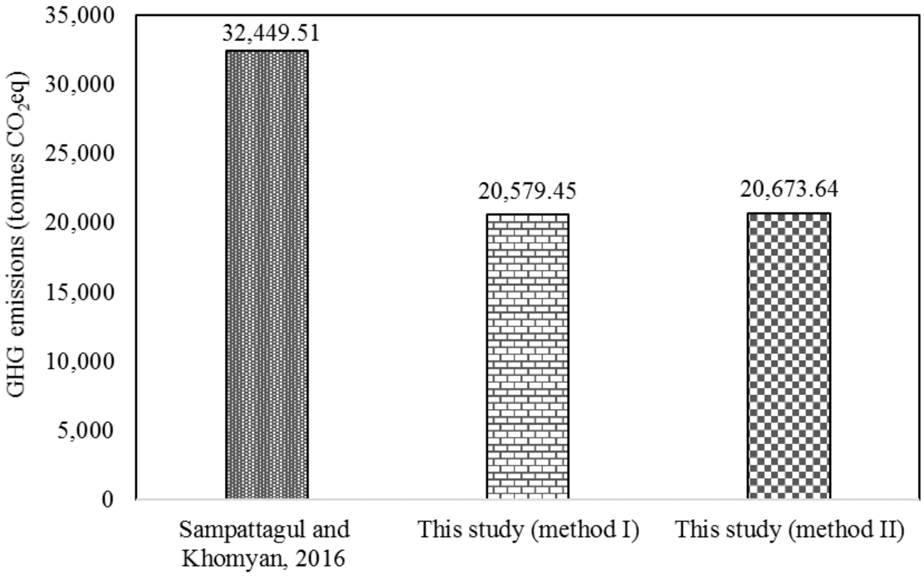

Figure 5. Total of GHG emissions released from MSW management in the Lampang municipality

4. Conclusion

This study is focused on greenhouse gas emissions from MSW management in Lampang municipality, Thailand. Two main processes including transportation and disposal are considered. The GHG emissions released from MSW management are estimated under two methods by the emission models. The GHG emissions calculation based on travel distance by IVE model takes into account the age, driving cycle and technology of vehicles. This model is one of the tool for estimating the GHG emissions emitted from vehicles in developing countries. Approximately 44% of the GHG emissions calculation based on travel distance is lower than those based on fuel consumption. GHG emissions released approximately 20,346 tonnes CO_2eq/year from Lampang municipality. This is lower than the GHG estimated from landfill of another study which used different methods. Total of the GHG emissions emitted from MSW Management in Lampang municipality are approximately 20,579.45 and 20,673.64 tonnes CO_2eq/year under method I and method II, respectively. Additionally, replacing CNG fuel to diesel fuel of vehicles will reduce GHG emissions by approximately 17 tonnes CO_2eq/year.

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Estimation of Air Temperature from Thermal Images by Low Flying and Shade Effect of Tree Crown for Mitigating Urban Thermal Circumstances

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Abstract

Tree effects for mitigating thermal circumstances in a town and determination factors of air temperature have been examined. We used aerial thermal images of ground surface temperature taken by flights of a hang glider and mobile observation of air temperature by a bicycle to evaluate the effective range that decides air temperatures. The average of grand surface temperature of 1 ha area, approximate radius is 55 m, has the highest correlation to air temperatures than the average of narrower area. The fluctuation of spatial differences of ground surface temperature was highest in a town area and lowest in a forest area. Tree shade effects on air temperature have been observed at an open field and a small forest in a town. The air temperature at a small forest showed comparatively lower at the time of highest temperature while showed comparatively higher at the lowest temperature. Accumulation of these results is important to create resilient cities for environmental disasters such as heat-related illnesses.

Keywords: heat stroke; global warming; urbanization; heat island; mobile observation

1. Introduction

The number of heat stroke death toll is increasing in this 10 years in Japan (e.g. Ministry of Health, Labour and Welfare, 2016). In particular, the death toll percentage of elderly person have been increasing. Global warming, urbanization and aging socialization are considered to be one of these reasons. The temperature rising in Tokyo was estimated by 3.2 degree Celsius in this 100 years (Japan Meteorological Agency, 2014), thermal environmental circumstances are one of the most urgent problems for the people’s health and the town planning. Although Yan and Mikami (2002) showed good relationship between surface temperature from Landsat TM thermal images and air temperature, this observation methods are difficult to apply to the town planning or specific countermeasures for thermal disasters because the spatial resolutions of TM images are too rough (60 to 120 m for the thermal image) to determine the specific effect to thermal circumstances. We observed spatial distribution of ground surface temperature precisely enough to distinguish roads, house, bare land and so on by low flying method and analyzed the determinants of air temperature.

2. Materials and Methods

2.1. Observation of ground surface temperature by a hang glider

We got thermal images of ground surface by a low-costed simple thermal camera (Flir One for Android, FLIR Systems Inc.) by binding it on a hang glider. The optical photos together with thermal photos can be taken with this Flir One thermal camera. The observation site was situated at Oomasu town Ishioka city, Ibaraki prefecture Japan (N36°11.5’, E140°17.5’, Figure 1). The facilities for flying with a hang glider are set in this town. A hang glider starts flying from the mountain side at the east of the town, lands at a landing point near the central of town (Figure 1(b)). Aerial photo is shown in Figure 1(c). The pilot of the hang glider took the thermal photo images manually. The location of a hang glider was detected and recorded with a handy GPS meter (Oregon 450TC, GARMIN). The observation have been done three times, 2015/Sep/30, 2015/Nov/22 and 2015/Dec/20. The thermal photos were combined together by checking optical pictures and aerial photos. The average height to the ground of the hang glider while taking the thermal images was about 100 m.

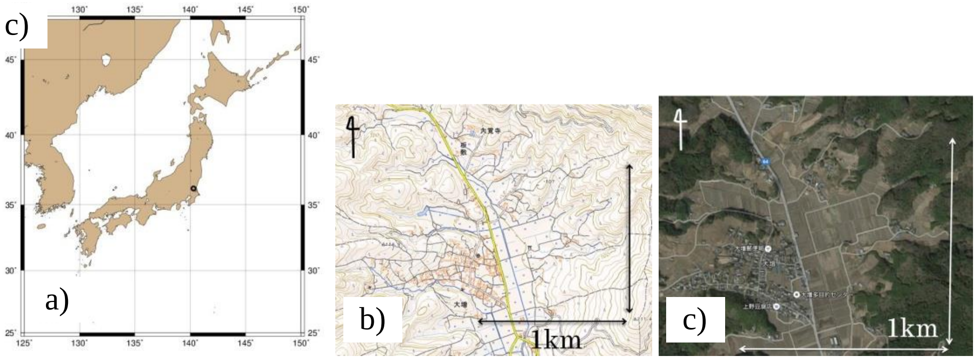


Figure 1. a) Location of study site, b) topographical map of study site and c) aerial photo of the town.

2.2. Mobile observation of air temperature

The air temperature was obtained with k-type thermocouples and recorded every 2 seconds. These thermocouples were set on a bicycle to get the spatial distribution of air temperature. Three thermocouples (20cm, 70cm and 150cm height from the ground) were installed on a bicycle (Figure 2). The observations were performed at the same place as the section 2.1. The location of the observation point (bicycle) was obtained by a GPS meter (Oregon 450TC, GARMIN).

Figure 2. a) K-type thermocouple with sunlight shade and data logger, b) installing thermocouples on a bicycle (Mobile temperature observation system).

2.3. Precise observation of air temperature at an open and small forested field

Air temperatures at height of 1.5m at an open and small forested field were obtained with ventilated platinum resistance thermometers inside the campus of Tokyo university of agriculture and technology, Fuchu city, Tokyo Japan (N35°41.0', E139°28.9'). The air temperature meter at the open field has been installed by Japan Meteorological Agency, a system named AMeDAS Fuchu. The small forest inside the university campus consists of deciduous broad-leaved trees. The zenith photos of both plots are shown in Figure 3. The distance of two points are about 100 m. Soil temperature at 4 depths, 5cm, 10cm, 20cm and 40cm were observed both open and small forested fields.

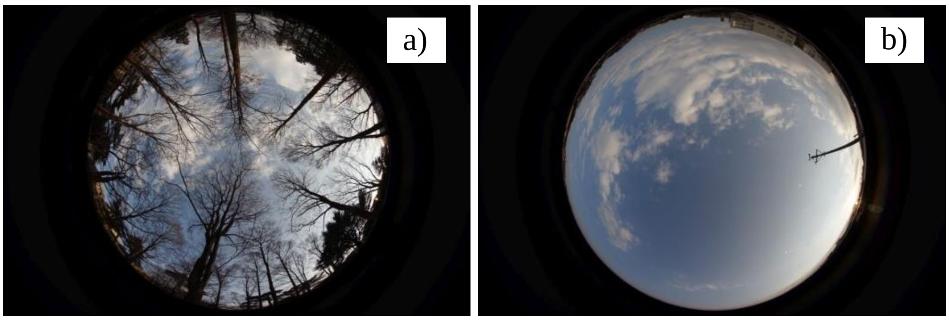


Figure 3. Zenith photos with fish-eye camera, a) at the open plot (AMeDAS Fuchu) and b) at the forested plot inside the university campus. Photos were taken on 2017/March/29.

3. Results and Discussion

Figure 4 shows the example picture of thermal image taken with a hang glider observation. We could detect the differences of ground surface temperatures among roads, house roofs, cultivated land and forest with the proposed low flying method.

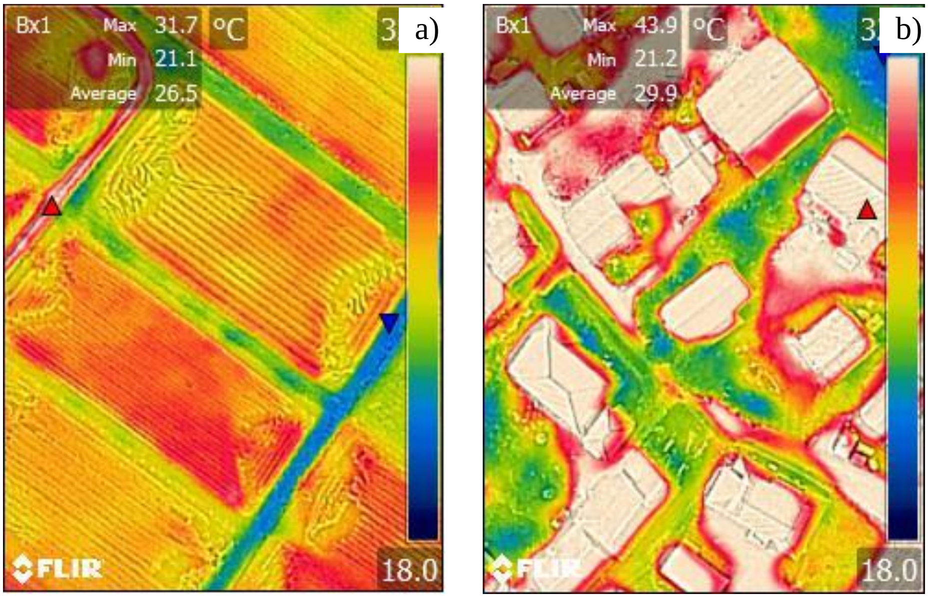
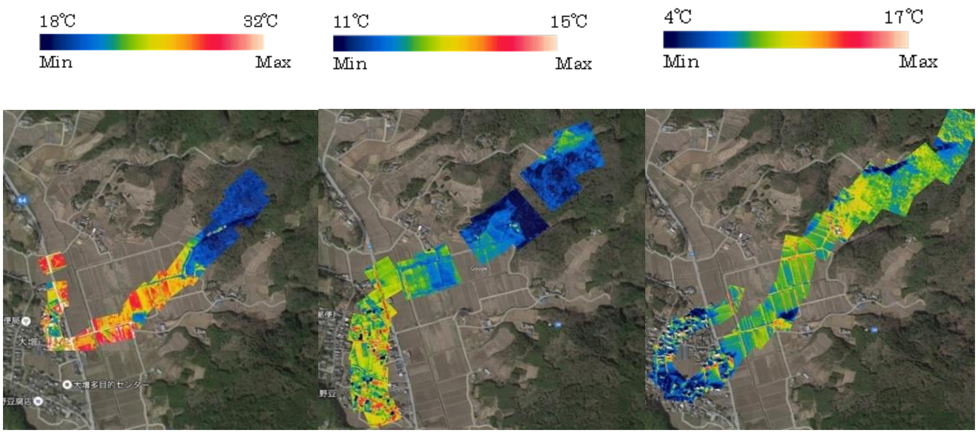


Figure 4. Examples of thermal images taken by a hang glider observation, a) paddy field (water in paddy field had been drained, b) urban area.



a) Sep/30 Fine day b) Nov/22 cloudy day c) Dec/20 fine day

Figure 5. Combined thermal images of three flight trials.

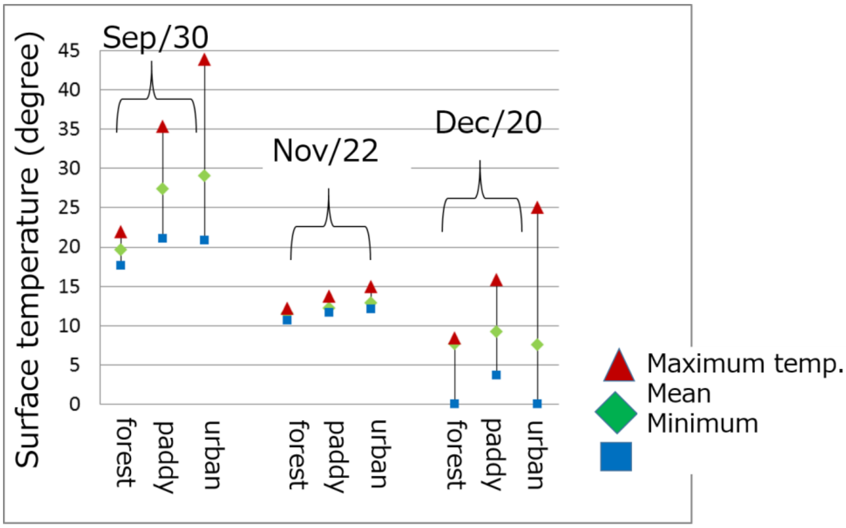


Figure 6. Fluctuation of surface temperature of forest, paddy field and urban area.

Figure 5 shows the distribution of surface thermal images taken by hang glider flights of three trials. The surface temperatures were comparatively lower in forest and higher in urban area. The fluctuation of surface temperature was high in a town and low in forested area (Figure 6). Some hot spots could be found in a town. In particular, pavement road and house roof showed higher surface temperature in a town. It is obvious that the heterogeneous structure in a town made high fluctuation on surface temperature. The surface temperature data in a cloudy day (Nov/22) shows small fluctuation of surface temperatures on forest, paddy field and urban area. The comparisons of air temperatures observed by a bicycle method and ground surface temperature showed that the correlation between average temperature of ground surface at range of 1ha (about 55m radius area) and air temperature was highest correlation than the narrower spatial averages.

Precise observation of air temperature conducted in a university campus, at the open and small forested field showed that temperature at these two plots were almost equal. However we could see a mitigation effect of temperature rising in the forested field by 2 degree Celsius at high air temperature (Figure 7). We could also see a mitigation effect while temperature decreasing in the forested field by one degree Celsius at low temperature during observation period. Thus the highest and lowest air temperatures were recorded at the open plot. The fluctuations of soil temperatures were higher in the open plot especially in the neighborhood of ground surface. The soil temperatures were lower at the forested plot. The differences of soil temperatures between open and forested at the same soil depth were high in the neighborhood of ground surface. The tree cover was more effective to the soil temperature.

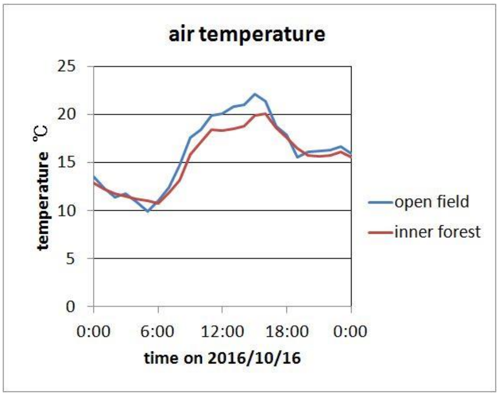


Figure 7. Example of daily change of air temperature

The air temperature is considered to be affected by a large scale surface temperature compare to the resolution of earth surface covering structure by convection of air.

4. Conclusion

We showed the possibility to estimate air temperature with low flying thermal images. However the generation of air temperature is affected with wide range of ground surface temperature. The relationship among ground surface cover, soil temperature and air temperature generation are important to evaluate the urban temperature circumstances. Accumulation of these information will be useful to simulate thermal environment and to create resilient urban planning.

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Impact of Acid Deposition on Plankton Population Variability in the Bangphra Reservoir Water Supply, Chonburi Province, Thailand

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Abstract

Eutrophication caused by cyanobacterial blooms in urban water supplies can affect freshwater ecosystems and become a human health concern. The objectives of this study were to understand how highly acidic rainwater may influence the freshwater in the Bangphra Reservoir and how it may seriously impact water quality and plankton diversity. Rainwater samples were collected daily during the wet (July-October 2010) and dry (November 2010-June 2011) seasons. The results indicate that, the annual precipitation for each season was 1,250 mm and 1,623 mm, and the annual volume-weighted mean pH of rainwater was 4.73 and 4.59, respectively. For anion accumulation, chloride and sulfate were the most abundant, compared to nitrate. Cation accumulation showed that sodium was the most abundant, followed by ammonium, potassium, calcium and magnesium. The freshwater in the Bangphra Reservoir was collected daily during the same time period. The freshwater pH and biological oxygen demand in the wet season were 8.05 and 0.72 mg/l; for dry season samples, averages were 6.73 and 0.48 mg/l. The total phytoplankton abundance in the wet season (216,468 cells/l) was found to be more than 7 times higher than in the dry season (27,826 cells/l). However, changes in the phytoplankton diversity index between wet and dry seasons did not show a significant difference (1.774 and 1.679). The most abundant genus in both wet and dry seasons was *Microcyctis* sp., while *Lyngbya* sp. was found only in the wet season and *Phacus* sp. was found only in the dry season. This corresponds both to the lower pH of freshwater in the dry season. Results presented here showed the abundance of zooplankton in the wet season (4,147 cells/l) was nearly twice as high as during the dry season (2,112 cells/l), while the changes in the zooplankton diversity index from wet to dry seasons did not show significant difference (1.496 and 1.577). The increase in phytoplankton during the wet season, especially of cyanobacteria, may influence the abundance of zooplankton and subsequently the water quality of the Reservoir.

Keywords: acid deposition; water quality; Bangphra Reservoir; phytoplankton; zooplankton; *Microcyctis* sp.; *Lyngbya* sp.; *Phacus* sp.

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1. Introduction

Acid deposition is a transboundary environmental problem. It can be used to identify substances long distances from their original emission sources. Acid rain usually contains high amounts of nitric and sulfuric acids. Nitric acid is formed by oxidation and dissolution of nitrogen oxides, primarily generated from vehicle exhaust. Sulfuric acid is the major source of acid rain in Chonburi province, Thailand, formed by sulfur dioxide emissions from fossil fuel combustion (Khuntong et al., 2008). After oxidation to sulfur trioxide, sulfuric acid is formed by dissolution in rainwater. Acid deposition can be categorized as either wet deposition (acid rain) or dry deposition (acidic particles and gases). The acidic particles and gases cause serious negative effects by quickly depositing in and on surface water and vegetation.

Plankton found in freshwater can be divided into either phytoplankton or zooplankton. Phytoplankton utilizes light and nutrients for growth, and is also a source of nutrients for zooplankton in the aquatic food chain. Nutrient-rich water facilitates the bloom of phytoplankton (Li et al., 2017; Wang et al., 2013; Mukherjee et al., 2010). The bloom of phytoplankton, especially cyanobacteria, causes eutrophication, a significant aquatic problem around the world (Xia et al., 2016; Smith. 2003). Eutrophication greatly alters the water quality and biodiversity in aquatic ecosystems. Toxic secondary metabolite compounds produced from overgrowth of cyanobacteria effect human and animal health. For example, *Lyngbya* sp. produces saxitoxin, a compound in a group of alkaloids that affect the nervous system (Hudon et al., 2016; Wink and Schimmer, 2009). Thus, the monitoring of phytoplankton growth and growth conditions near human populations should be considered of public health concern.

The Bangphra Reservoir, which is located in Amphoe Sriracha, Chonburi province, Thailand, is the major water supply for tap water, agriculture, aquaculture, fish breeding, as well as ecotourism, serving an area of 13.6 km^2. The rainfall and runoff water collected from this reservoir is the main water supply for Amphoe Sriracha, an area with a population of about 0.3 million people. The objectives of this study were to understand how highly acidic rainwater may influence the freshwater in the Reservoir and how it may seriously impact water quality and plankton diversity. This was done by analyzing the chemical composition of rainwater in the Bangphra Reservoir, and evaluating the potential effects of acid deposition on freshwater quality and subsequently, the phytoplankton community.

2. Materials and Methods

2.1 Sample locations

Due to the known impacts of acid deposition from rainwater on freshwater ecosystems (Davies et al., 2005: Layer et al., 2010), the sample collections were comprised of two parts, rainwater samples and freshwater samples.

For rainwater samples, the sampling site was located at Kasetsart University, Sriracha campus, Chonburi. It is classified by Polution Control Department as a national station, located at 13º 07′ 09.05′′ N and 52º 55′ 21.62′′ E (Fig 1*a*). The annual temperature of the site ranges between 21.5° - 31.6°C. The lowest temperature was 14.9°C in January 2010 and the highest was 37.5°C in March 2011. Annual precipitation was approximately 1376.4 mm (Meteorological Department of Thailand, 2010). The distinct summer wet season was May-October 2010, and the dry season was November 2010-April 2011. The automatic precipitation sampler (wet-only collector) (Fig 1*a*) was installed at the foothill of Khao Namsab, about 1 km away from the shore and close to Laem Chabang Industrial estate, oil refinery plants, deep sea ports *etc*. The distance between the rainwater sampling site and the Bangphra Reservoir was approximately 25 km.

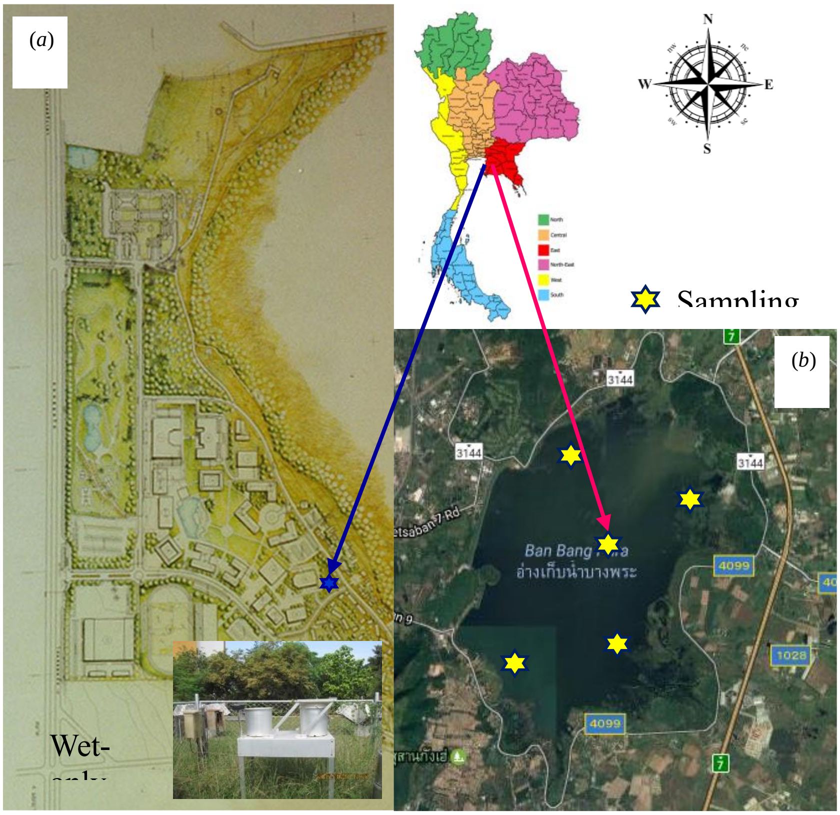

Figure 1. The map of the rain water sampling sites at Kasetsart University Sriracha Campus (a) and freshwater sampling sites in Bangphra Reservoir, Sriracha, Chonburi Province (b).

The Bangphra Reservoir (Fig. 1*b*) is located in Tumbon Bangphra, Ampoe Sriracha, Chonburi (13º 12′ 18′′ N and 100º 55′ 00′′ E). It is a 24 m high and 1720 m long dam, with a maximum capacity of 110,000,000 m^3. It has a 130 km^2 catchment area with an annual mean water flow of 54,600,000 m^3 for irrigation and agriculture (RID, 2017). At the time of sampling, the catchment area was surrounded by grassland and woodland. Since the scrub grassland and dry forest were closed to open water sources, the catchment area was the habitat of varieties of birds (Upton, 2014).

2.2 Sample collection

2.2.1 Rainwater sample collection

All rainwater samples were collected daily at 9 am using an automatic precipitation sampler (wet-only-sampler). The automatic 20 cm-diameter rain container (Fig 1*a*) was equipped with a rain sensor and a removable lid that immediately responded to activate its opening upon precipitation (≥ 0.5 mm raindrop diameter). Thymol (2-isopropyl-5-methyl phenol), was added to the collector as a biocide to prevent the possibility of microbial growth (Gillett and Ayers, 1991). A standard rain gauge was used to measure the amount of precipitation in order to estimate the efficiency of rainwater collection (Ames et al., 1987). The rainwater samples were immediately measured for volume, pH (Metrohm model 827) and electrical conductivity (EC) (Inolab Cond. Model 720). The field blank was conducted monthly by rinsing the container with deionized water. The rainwater samples and field blank were stored in cleaned polyethylene bottles and kept in darkness at 4°C prior to analysis of ionic species by Ion Chromatography (IC) (Khunthong et al., 2008).

2.2.2 Freshwater collection

Samples were collected at five locations along the Bangphra Reservoir. Sampling positions were randomized around the reservoir and confirmed by GIS (Fig. 1*b*). The physical parameters (pH, temperature, EC and dissolved oxygen), were each measured at half depth below the sample water column using YSI -60 Multimeter prior to sample collection. Each water sample was individually collected by grab sampling methods (APHA, 2005).

2.2.3 Sampling of phytoplankton and zooplankton

Phytoplankton and zooplankton samples were collected at depths of 6 m from the same 5 locations around the Bangphra Reservoir (Fig. 1b) Sampling was conducted during wet (July-October 2010) and dry seasons (November 2010-June 2011). Twenty 50 µm mesh size plankton nets (TN Science, Thailand) of 30 cm diameter and 90 cm length were used to collect phytoplankton and zooplankton. Samples were preserved in 5% formaldehyde solution (Himedia, Spain).

2.3 Analysis of rainwater samples

Ionic species were analyzed using a well-calibrated Shimadzu Ion Chromatograph, with Wako standard solution (Wako Pure Chemical Industries). The analyses of anions (SO_4^{2-}, NO_3^-, Cl^-) and cations (NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}) were performed by Shim pack IC-A3 and IC-C3, respectively, at 40 °C to maintain ionic dissociation. The eluent for anions was 8 mM mixed solution of *p*-hydroxybenzoic, *bis*-(2-hydroxyethyl) and aminotris (hydroxymethyl) methane. Oxalic acid (2.5 mM) was used as the eluent for cations. The eluent flow rate was 1.5 ml/min and a conductivity detector was used to measure the individually separated ions at 40 °C.

2.4 Determination of chemical compositions of freshwater samples

Biochemical and chemical parameters of Freshwater samples were determined by modified methods from Sawyer (Sawyer, *et al*. 2003) and Standard methods for examination of water and wastewater (APHA, 2005). Biological oxygen demand (BOD): -wet oxidation of biological organic matter - iodometry.

Nitrate: each water sample was filtered through 0.45 micron filter paper (Whatman) at room temperature. The filtered water was analyzed with the same procedure as nitrate ion in rainwater. Nitrite: sulfanilamide (1%; dissolve 5 g of sulfanilamide in small amount of conc. HCl and diluted with 500 ml of DI water) was added to the filtered water (50 ml), the mixed solution was left for 2 min (did not exceed 8 min). Nitrite was then complexed with *N*-(1-naphthyl)-ethylenediamine dihydrochloride (0.1%), left for at least 10 min (did not exceed 20 min). The absorption of the greenish-yellow complex was measured at 543 nm using a well-calibrated Shimadzu Spectrophotometer. Ammonium: the pH of each water sample (250 ml) was neutralized by NaOH (1 M) or H_2SO_4 (3 M). Boric acid and indicators (methyl red and methylene blue) were added into the receiving solution to trap free NH_3 (g) distilled from NH_4^+. The trapped solution was titrated with std H_2SO_4 to quantify the amount of NH_4^+. Nitrate, Nitrite, and Ammonium were combined to total nitrogen.

Phosphate was determined using an ascorbic method, modified from Doolittle (2014). The spectrophotometric determination for the blue color of potassium antimony tartrate and vanadium molybdate complex in ascorbic acid were performed after persulfate digestion, and measured at 880 nm.

The statistical methods were performed by IBM SPSS statistic analysis version 21.0.

2.5 Morphological classification of planktons

The compound light microscope (Olympus model CH-2, Japan) with 40x (high power) objective lens was used to observe phytoplankton and zooplankton morphology. A hundred micro liter of each sample preserved in 5% formaldehyde solution were dropped on the microscope slide and covered with cover slip. Phytoplankton and zooplankton samples were morphologically identified to the genus level according to Wongrat, L. (1999) and Peerapornpisal (2003).

2.6 Plankton abundance and diversity evaluation

Plankton populations were estimated using a Sedwick Rafter counting chamber following the standard protocol (Schoen, 1988; Wongrat and Boonyapiwat, 2003). Samples preserved in 5% formaldehyde solution were taken and pipetted in the counting chamber with a volume of 1 mL per sample. The total for all samples was calculated. The plankton diversity index was calculated using the Shannon-Wiener Index (H') equation: $H' = -\sum_{i=1}^{s}(\mathrm{n}_i/\mathrm{N})\ln(\mathrm{n}_i/\mathrm{N})$, where H' is the diversity index, n_i is the abundance of each genus, N is the total abundance of all genera, s is number of genera, and i is one through genus richness. The plankton abundance and diversity data from the 5 stations around the Bangphra Reservoir were analyzed by IBM SPSS statistic analysis version 21.0.

3. Results and Discussion

3.1 Amount and pH of rainwater

For acid deposition, data was collected over two consecutive years, over the same date ranges, to clarify the continuous impact of rainwater to the local freshwater aquatic ecosystem. The total rainy days of the two years, 2010 and 2011, were 92 and 91 days, and the total precipitation was 1,250 and 1,623 mm per year, respectively. The precipitation in 2011 corresponded with the worst flooding in Thailand in a half a century. The total rainwater that accumulated was approximately 35% higher than average from January to October resulting from La Niña (HAII, 2012) During the two years, a similar distribution was observed in lower precipitation: the higher amount of rainwater, the broader the range of distribution (Fig. 2*a*).

The pH of rainwater was slightly acidic with an annual volume-weighted mean (VWM) of 4.73 and 4.59 in 2010 and 2011, respectively. The lowest VWM pH through the study period is indicative of a critical impact from anthropogenic pollution to the rainwater in the east of Thailand. The pH ranges were 3.27 – 6.98 in 2010 and 3.51 – 6.51 in 2011. Furthermore, 12.04% of the recorded found that a pH below 4.0, indicating severe rainwater acidification from emission of SO_2 and NO_x (Fig. 2*b*). According to Galloway (1995), naturally occurring CO_2, NO_x, and SO_2 dissolving into clouds and droplets results in a pH value of rain in a clean atmosphere between 5.0 and 5.6. The pH of rainwater in this area was rarely higher than 5.6. Anthropogenic activities are the most likely cause of the acidity observed in rainwater.

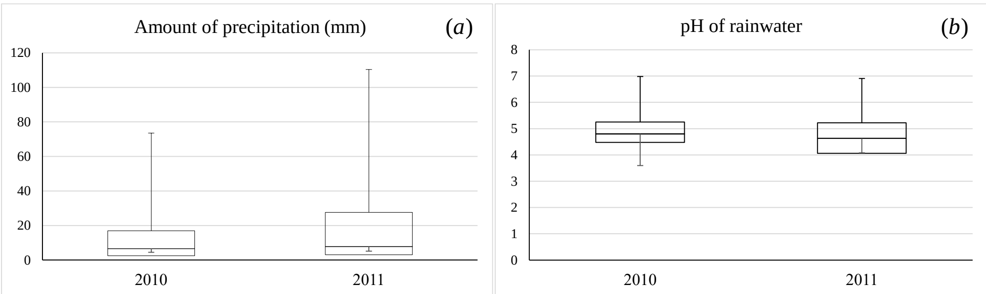

Figure 2. Amount (*a*) and pH of rainwater (*b*) in Chonburi, Thailand from daily data collected 2010 and 2011.

3.2 Ionic composition of rainwater samples

The composition of anions and cations were of those commonly found ions in a natural water reservoir, and annual total concentrations of major ions were quantified. The EANET program (EANET, 2000) was used to calculate the equivalence of individual ions. The total equivalence of individual ions in 2011 was slightly higher than in 2010 due to the higher amounts of precipitation. EANET calculations confirmed that SO_4^{2-} and Ca^{2+} originated from anthropogenic activities. Sodium and chloride were contributed by sea spray. Ammonium was dominant due to nearby utilization of nitrogen fertilizer, and from metabolic products of microorganisms, while potassium and magnesium were present as cluster ions. The alkali cations (Ca^{2+}, Mg^{2+} and K^{+}) suggested potential neutralization of acidic species in the rainwater samples. The ionic equivalence of individual ions is shown in Fig. 3.

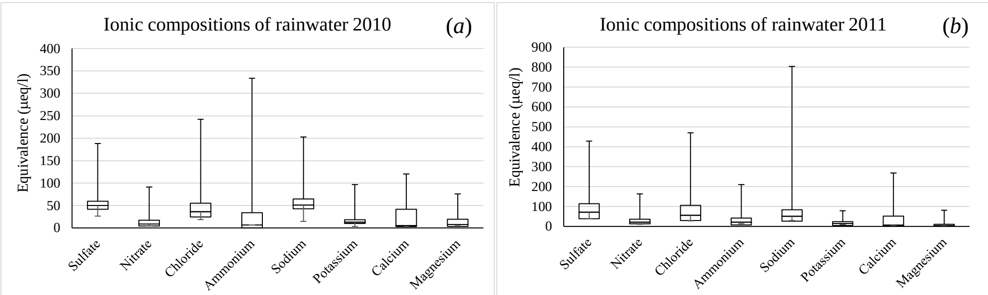

Figure 3. Ionic composition of rainwater in Chonburi, Thailand in 2010 – 2011.

Table 1. Summary of water quality parameters of the Bangphra Reservoir in wet and dry seasons.

Parameters	Average value (n=5)		Standard values[1]
	Wet season (Jul-Oct 2010)	Dry season (Nov 2010 -Jun 2011)	
pH	8.05 ± 0.10	6.73 ± 0.05*	5 - 9
Temperature (°C)	30.24 ± 0.09	27.42 ± 0.12*	-
Electrical conductivity (mS/m)	184.86 ± 3.92	166.72 ± 1.08*	-
Dissolved oxygen (mg/l)	4.46 ± 0.45	5.13 ± 0.43[ns]	6
Biological oxygen demand (mg/l)	0.72 ± 0.32	0.48 ± 0.27*	1.5
Total nitrogen (mg/l)	0.31 ± 0.04	0.07 ± 0.02*	-
Orthophosphate (mg/l)	0.02 ± 0.01	0.04 ± 0.01*	-

Note: (-) no standard values; [1] by Pollution Control Department, Ministry of Natural Resources and Environment, Thailand; * statistically significant; [ns] not statistically significant.

3.3 Water quality of the Bangphra Reservoir

The composition of rainwater was analyzed for two consecutive years to account for the transboundary impact of wet and dry deposition of acids, movement caused by ‘wash out’ and ‘rain out’, as well as ‘carry out’ of depositions over long distances from their original sources by wind. Results for all evaluated freshwater quality parameters are shown in Table 1.

Reduced precipitation in the dry season (November 2010-June 2011) lowered water levels and pH due to a higher concentration of hydrogen, resulting in the slight basicity measured in the wet season and near neutral pH in the following dry season. In addition to the pH of rainwater affecting the pH of reservoir water, other factors including water runoff, leaching from agricultural farms and wash-out from the quarry industry close to the reservoir, could contribute to neutralizing the acidity of rainwater effects and naturally occurring freshwater. Water temperatures recorded during the dry season were slightly lower than in the wet season, when the colder water carried higher dissolved oxygen than the warmer waters of the wet season. Characteristics of Bangphra Reservoir water were classified as Class II: clean fresh surface water resource used for consumption (only ordinary water treatment process required), aquatic organisms of conservation, fisheries and recreation (PCD, 2004). Nutrients (total nitrogen and phosphate) that impact number, type and diversity of phytoplankton and zooplankton will be explained below.

3.4 Phytoplankton abundance and diversity

The list of phytoplankton collected from the 5 stations around the Bangphra Reservoir during wet and dry seasons are shown in Table 2. Eighteen genera of 3 phylum of phytoplankton were identified after observation under light compound microscope. Phytoplankton in phylum of Chlorophyta, Chromophyta, Cyanophyta and Euglenophyta were found. *Lyngbya* sp. in phylum Cyanophyta was found only during the wet season (July-October 2010). *Phacus* sp. in phylum Euglenophyta was found only during the dry season (November 2010 – June 2011). The other 16 genera were found in both wet and dry seasons.

The most abundant phytoplankton in the wet season was *Microcystis* sp. (79,492 cells/l), followed by *Spondylosium* sp. (32,985 cells/l), *Aulacosera* sp. (29,888 cells/l), *Oscillatoria* sp. (25,657 cells/l), and *Staurastrum* sp. (17,157 cells/l). The most abundant phytoplankton in the dry season was *Microcystis* sp. (11,347 cells/l), followed by *Oscillatoria* sp. (3,133 cells/l), *Staurastrum* sp. (2,807 cells/l), *Closteriopsis* sp. (1,247 cells/l), and *Oocystis* sp.(1,040 cells/l). The abundance of *Lyngbya* sp., which was only found in the wet season, was 140 cells/l. The abundance of *Phacus* sp., which was only found in dry season, was 113 cells/l. The total phytoplankton abundance was measured at a high of 216,468 cells/l in the wet season, and a low of 27,826 cells/l in the dry season. Figure 3 shows that *Microcystis* sp. abundance was the highest in both wet and dry seasons and it was approximately seven times higher in the wet season than in the dry season. However, The abundance of total phytoplankton in the Bangphra Reservoir did not reach above 0.1 million cells/L, and therefore cannot be considered to have reached eutrophication levels.(Wang *et al*., 2013; Mukherjee *et al*., 2010; Oviatt *et al*., 1989).

Table 2. Phytoplankton found in the Bangphra Reservoir in wet and dry seasons.

Phylum	Phytoplankton genera	Season	
		Wet (Jul-Oct 2010)	Dry (Nov 2010 -Jun 2011)
Chlorophyta	*Closteriopsis* sp.	+	+
	Euastrum sp.	+	+
	Endorina sp.	+	+
	Oocystis sp.	+	+
	Pediastrum sp.	+	+
	Scenedesmus sp.	+	+
	Selenastrum sp.	+	+
	Spondylosium sp.	+	+
	Staurastrum sp.	+	+
	Tetraedron sp.	+	+
	Volvox sp.	+	+
Chromophyta	*Aulacosera* sp.	+	+
	Ceratium sp.	+	+
	Diatom sp.	+	+
Cyanophyta	*Anabaena* sp.	+	+
	Lyngbya sp.	+	–
	Microcystis sp.	+	+
	Oscilatolia sp.	+	+
Euglenophyta	*Phacus* sp.	–	+

Note: (-): not found; (+): found

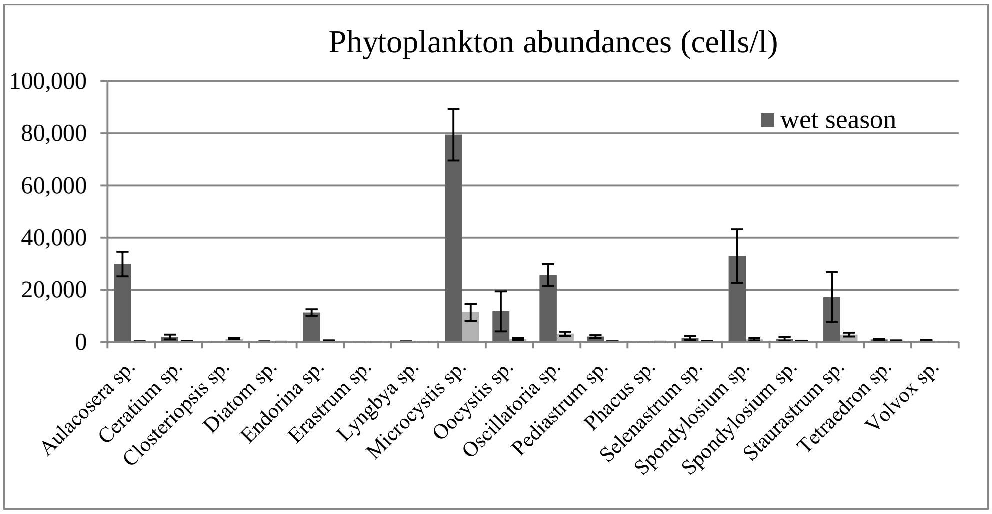

Figure 3. Phytoplankton species abundance around the Bangphra Reservoir, Chonburi, Thailand in wet and dry seasons.

Even though the abundance of phytoplankton did not reach eutrophication levels, monitoring of the abundance of some genera that produce phytotoxins is a concern. *Microcystis* sp. and *Lyngbya* sp. belong to the phylum Cyanophyta. These have been reported as producing toxic compounds harmful to humans and other animals. Saxitoxin is a toxic compound in a group of alkaloids produced by *Lyngbya* sp. (Lajeunesse, *et al*., 2012; Lévesque, *et al*., 2015; Onodera, et al., 1997). The toxin concentration produced by *Lyngbya* sp. is related to their growth rate and metabolism (Hudon, 2016). Microcystin, anatoxin, and geosmin, are toxic compounds produced by *Microcystis* sp., which also give a bad smell and bad taste to water (Wongrat, L. 1999; Hudon, 2016). This phytoplankton contains a gas vacuole that helps it to float on the surface of water better than other phytoplankton genera (Hudon, 2016). Therefore, monitoring of *Microcystis* sp. and *Lyngbya* sp. abundance is required to fully and accurately evaluate the environmental and human health risk of reservoir acidification.

The phytoplankton diversity index was 1.774 ± 0.027 in the wet season, and 1.679 ± 0.022 in the dry season (Table 3). However, these values were not found to be statistically significant by one-way ANOVA in SPSS statistical analysis. These phytoplankton abundance and diversity results indicated that, although the phytoplankton abundance was higher in the wet season than in the dry season, there was no difference in diversity index between wet and dry seasons. There were seventeen genera of phytoplankton presented in wet and dry seasons, but differed in the presence of two genera, which were *Lyngbya* sp. (found only in the wet season) and *Phacus* sp (found only in the dry season).

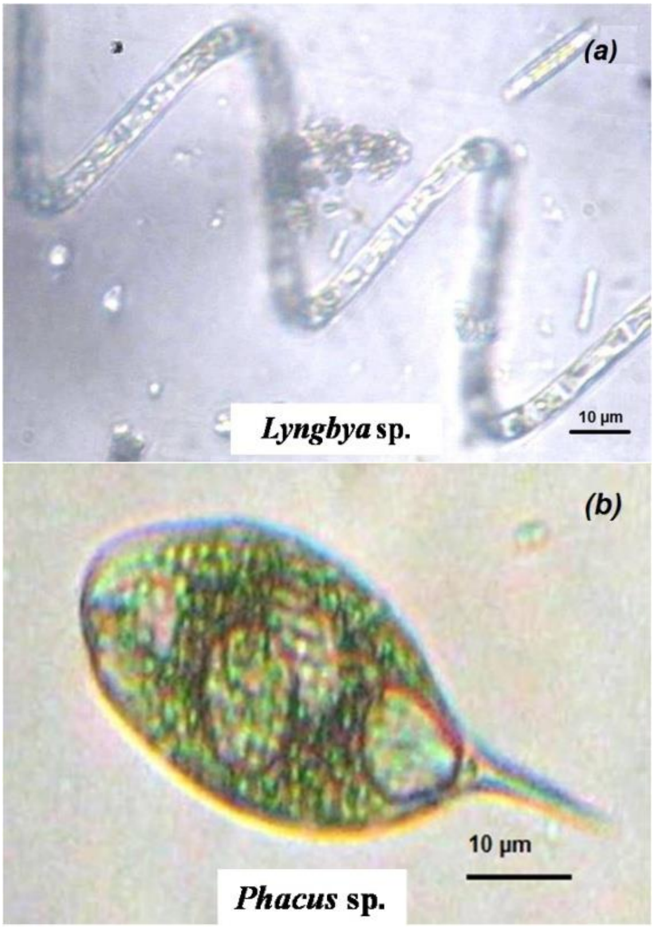

Figure 4. *Lyngbya* sp. (a) and *Phacus* sp. (b) from Bangphra Reservoir, Chonburi, Thailand, observed under compound light microscope with high power (40X) objective lens.

Nine genera of zooplankton were found in Bangphra Reservoir. *Bosmina* sp., *Brachionus* sp., *Ceriodaphnia* sp., *Cyclopoid* sp., *Cyclops* sp. and *Ogdeniella* sp. were found in the wet season, while *Arcella* sp., *Bosmina* sp., *Brachionus* sp., *Ceriodaphnia* sp., *Cyclopoid* sp., *Cyclops* sp., *Karatella* sp., *Lecane sp.*and *Ogdeniella* sp. were found in the dry season (Table 4).

The most abundant zooplankton found in the wet season was *Cyclopoid* sp. (1,507 cells/l) followed by *Cyclops* sp. (973 cells/l), *Bosmina* sp. (560 cells/l), *Ceriodaphnia* sp. (547 cells/l), and *Ogdeniella* sp. (367 cells/l). The most abundant zooplankton found in the dry season was *Bosmina* sp. (768 cells/l), followed by *Ceriodaphnia* sp. (304 cells/l), *Brachionus* sp. (293 cells/l), *Lecane sp.* (267 cells/l), and *Cyclopoid* sp. (187 cells/l), respectively (Fig. 6).

Table 3. The phytoplankton diversity indexes in wet (July-October 2010) and dry (November 2010-June 2011) seasons, Chonburi, Thailand.

Genera	Phytoplankton diversity index	
	Wet season (Jul-Oct 2010)	Dry season (Nov 2010 -Jun 2011)
Aulacosera sp.	0.270 ± 0.006	0.037 ± 0.006
Ceratium sp.	0.038 ± 0.010	0.050 ± 0.010
Closteriopsis sp.	0.002 ± 0.002	0.161 ± 0.020
Diatom sp.	0.003 ± 0.006	0.020 ± 0.006
Endorina sp.	0.157 ± 0.008	0.086 ± 0.008
Erastrum sp.	0.001 ± 0.003	0.004 ± 0.003
Lyngbya sp.	0.004 ± 0.000	0.000 ± 0.000
Microcystis sp.	0.362 ± 0.023	0.308 ± 0.023
Oocystis sp.	0.114 ± 0.035	0.135 ± 0.035
Oscillatoria sp.	0.250 ± 0.035	0.254 ± 0.035
Pediastrum sp.	0.045 ± 0.006	0.039 ± 0.006
Phacus sp.	0.000 ± 0.000	0.027 ±0.004
Selenastrum sp.	0.037 ± 0.014	0.048 ± 0.014
Spondylosium sp.	0.262 ± 0.028	0.124 ± 0.028
Spondylosium sp.	0.029 ± 0.011	0.065 ± 0.011
Staurastrum sp.	0.165 ± 0.038	0.246 ± 0.038
Tetraedron sp.	0.025 ± 0.021	0.073 ± 0.021
Volvox sp.	0.013 ± 0.003	0.004 ± 0.003
Totals	1.774 ± 0.027	1.679 ± 0.022

Note: ± standard error

Table 4. Zooplankton found in Bangphra Reservoir Chonburi, Thailand in wet and dry seasons.

Zooplankton genera	Season	
	Wet (Jul-Oct 2010)	Dry (Nov 2010 -Jun 2011)
Arcella sp.	-	+
Bosmina sp.	+	+
Brachionus sp.	+	+
Ceriodaphnia sp.	+	+
Cyclopoid sp.	+	+
Cyclops sp.	+	+
Karatella sp.	-	+
Lecane sp.	-	+
Ogdeniella sp.	+	+

Note: (-): not found; (+): found

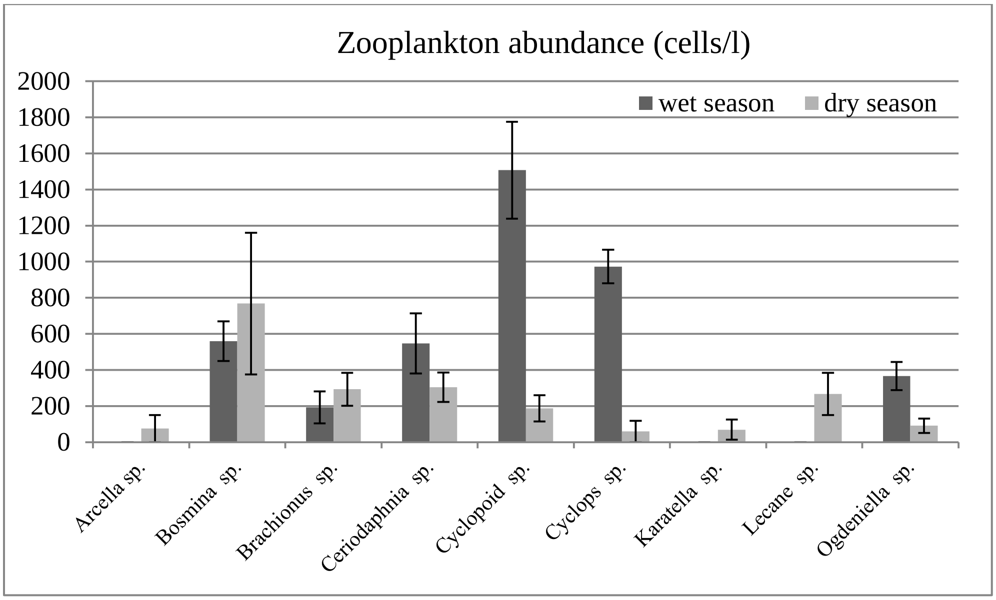

Figure 6. Zooplankton genus abundance of the Bangphra Reservoir, Chonburi Thailand, measured during wet (July-October 2010) and dry seasons (November 2010-June 2011).

The zooplankton diversity index was 1.496 ± 0.047 in the wet season and 1.577 ± 0.032 in the dry season. This was not found to be statistically significant (Table 5), even though 6 genera were found in the wet season and 9 genera were found in the dry season, because the diversity index is not only dependent on the genus variety but also the numbers of each genus. However, phytoplankton is a food source for zooplankton in aquatic food webs. Thus, zooplankton may have affected the abundance and diversity of phytoplankton in this study.

Table 5. The zooplankton diversity index in wet (July-October 2010) and dry seasons (November 2010-June 2011).

Genera	Zooplankton diversity index	
	Wet season (Jul-Oct 2010)	Dry season (Nov 2010 -Jun 2011)
Arcella sp.	0.000 ± 0.000	0.049 ± 0.049
Bosmina sp.	0.241 ± 0.026	0.305 ± 0.039
Brachionus sp.	0.124 ± 0.040	0.268 ± 0.028
Ceriodaphnia sp.	0.233 ± 0.052	0.256 ± 0.041
Cyclopoid sp.	0.352 ± 0.004	0.223 ± 0.060
Cyclops sp.	0.338 ± 0.007	0.043 ± 0.042
Karatella sp.	0.000 ± 0.000	0.094 ± 0.042
Lecane sp.	0.000 ± 0.000	0.206 ± 0.060
Ogdeniella sp.	0.208 ± 0.021	0.132 ± 0.049
Totals	1.496 ± 0.047	1.577 ± 0.032

Note: ± standard error

In general, phytoplankton diversity in freshwater reservoirs is affected by nutrient level and zooplankton predation (Yang *et al*., 2016; Hansson *et al*., 1998). In this study, the phytoplankton diversity indexes in wet and dry seasons were not statistically significant, as was also the case for zooplankton abundance and its diversity indexes. However, the total nitrogen and orthophosphorus measured in both wet and dry seasons were statistically significant. The total nitrogen was 0.308 ± 0.036 in the wet season, and 0.018 ± 0.003 in the dry season. The pH of freshwater in the Bangphra Reservoir was 8.05 ± 0.10 in the wet season and 6.73 ± 0.05 in the dry season. *Phacus* sp. abundance, which was present only in the dry season, corresponded to the low pH of freshwater in the Bangphra Reservoir in the dry season. According to Olaveson and Nalewajko (2000) and Ouboter (1993), Euglenophyta, such as *Euglena*, *Phacus* and *Trachelomonas*, were tolerant of acidic environments.

Water temperatures in wet and dry seasons were found to be statistically significant at 30.24°C ± 0.09 and 27.40°C ± 0.12, respectively, well-aligned with the temperature range of 27-39°C known to be favorable for growth of phytoplankton in general (Hudon *et al*., 2016; Sivonen, 1990).

4. Conclusion

Acidic rain influences the lowering of freshwater pH in the Bangphra Reservoir, the major water supply for various purposes in Amphoe Sriracha. The volume-weighted mean pH of rainwater in years 2010 and 2011 were 4.73 and 4.59, while the pH of freshwater in the reservoir was 8.05 in the wet season and 6.73 in the dry season. The lower pH of freshwater in the dry season influences the phytoplankton community. It should also be noted that phytoplankton is the major nutrient source for zooplankton, and the high abundance of phytoplankton in wet season likely influences the abundance of zooplankton. Results presented here show that *Phacus* sp., which is in the phylum Euglenophyta, was only found in the dry season. It can be concluded that *Phacus* sp. was tolerant of the acidic conditions. Of greater importance to public health, *Lyngbya* sp., found present only in the wet season, and *Microcystis* sp., found to be abundant during both seasons, are in the phylum Cyanophyta. Members of this phylum produce toxic compounds harmful to human and aquatic animals, such as saxitoxin, microcystin, anatoxin, and geosmin. Thus, the monitoring of these two genera in freshwater for human use must be a key concern.

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Estimation of Leachate Generated from Zimbabwe's Municipal Solid Wastes (MSW) Landfills Using a Simple Stochastic Water Balance Model

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Abstract

With twin concerns of air emissions and routine leaching of hazardous substances from unsanitary landfills in Zimbabwe, immediate corrective action is needed to avert further environmental degradation. Poor waste management practices largely due to the financial incapacitation of local authorities have taken a toll on the environment. The open dumping of municipal solid wastes (MSW) in most landfills is reportedly leading to groundwater contamination and toxic air emissions in certain areas. The lack of comprehensive MSW generation and collection data has made the quantification of MSW and resultant leachate difficult. This article attempts to estimate the leachate volumes released since year 1980 to date using a simple stochastic water balance method supported by 10 000 Monte Carlo iterations. Such information is essential when assessing the impact of the leachate on groundwater or a facility to which the leachate can be conveyed. The calculated 90% confidence interval indicates that 13 -16 million metric tons of MSW have been landfilled with about 41 – 128 million m^3 of leachate released since 1980.

Keywords: water balance; Monte Carlo; leachate; Zimbabwe; MSW; unsanitary landfill; estimation

1. Introduction

Landfilling has remained the most predominant method of MSW disposal for decades in Zimbabwe despite the lack of suitable leachate collection systems in most disposal sites. Approximately 98% of all dumpsites are not sanitary (Muchandiona, 2013) but are open dumps with little to no final cover and thus pose a serious threat to the environment. Recent studies on groundwater quality within the vicinity of some dumpsites reveal rising levels of trace elements such as lead mainly due to the unconfined leachate entering potable water sources (Chifamba, 2007; Kubare et al., 2010; Mark and Thomas, 2009). One of the challenges faced by local authorities is a lack of adequate infrastructure and financing. Waste management has historically been poor hence the determination of the amount of MSW landfilled, let alone the leachate generated therefrom is difficult. Zimbabwe is designated as a semi-arid country. At least 85% of the country receives no more than 800 mm of rain annually and rainfall is concentrated between November and March (Nyamapfene, 1989). Atmospheric precipitation can be expected to contribute to leachate generation as landfills are of substandard design. The Water

Balance Method (WBM) adopted here allows a relatively simple computation and has been widely used in scientific literature. WBM is particularly appropriate for landfills in which a relatively high permeable layer of soil is used as final cover. A markedly lesser quantity of water would infiltrate into a landfill if a low permeability synthetic membrane were used as covering.

2. Materials and Methods

2.1. Experimental Approach

A WBM model was developed on a spreadsheet equipped with Palisade's @Risk software package capable of performing Monte Carlo simulations. Total MSW generated since 1980 was estimated using urban population data provided by the World Bank and MSW generation per capita. The latter was estimated by first defining a probability distribution using @RISK's built-in distribution fitting feature on reported "per-capita" generation values shown in Table 1. The annual quantity of landfilled MSW was determined by multiplying together the following terms by 365: total population, rate of urbanization, per-capita MSW generation (probability distribution function) and collection efficiency.

Table 1. Reported MSW waste generation rates for Zimbabwe (Africa)

MSW Generation Rate (kg/capita/day)	Reference
0.70	(Simelane and Mohee, 2012)
0.50	(Mshandete and Parawira, 2009)
0.50	(Jingura et al., 2013)
0.53	(Hoornweg and Bhada-Tata, 2012)
0.31	(Practical Action, 1999)
0.50	(Jingura and Matengaifa, 2009)
0.79	(Mohee and Simelane, 2015)
0.29	(IPCC, 2006)
0.53	(Scarlat et al., 2015)
0.44	(Friedrich and Trois, 2011)
0.60	(Hoornweg et al., 2015)
0.42	(Muchandiona, 2013)
0.64	(IEA, 2016)
0.70	(Achankeng, 2003)

In simple terms WBM states:

$$L = P(A) - RO(A) - ET(A) - \Delta S - G \qquad (1)$$

where L = post closure leachate volume, P(A) = volume of precipitation per unit surface area of landfill, ET(A) = volume lost through evapotranspiration per unit surface area of landfill, RO(A) = volume of surface runoff per unit surface area of landfill, ΔS = gain in volume of moisture storage within soil and waste and G = volume of water consumed in landfill gas formation per unit surface area of landfill.

Thorntwainte's equation below was used to estimate ET. Instead of deterministic values for the terms in (2), probability distribution models defined from historical rainfall, temperature patterns and daylight hours were used. The Akaike Information Criterion (AIC) determined the best fitting distribution model.

$$PET = 16\left(\frac{L}{12}\right)\left(\frac{N}{30}\right)\left(\frac{10T_\alpha}{I}\right)^{\alpha} \qquad (2)$$

where PET is the estimated potential evaporation (mm/month), T_α is the average daily temperature of the month being calculated (°C), N is the number of days in the month being calculated, L is the average day length of the month being calculated (hours), $\alpha = (6.75 \times 10^{-7})I^3 - (7.71 \times 10^{-5})I^2 + (1.792 \times 10^{-2})I + 0.49239$, where $I = \sum_{i=1}^{12}\left(\frac{T_{ai}}{5}\right)^{1.514}$ is the heat index which depends on the 12 monthly mean temperature T_{ai}. ET was estimated by assuming a uniform distribution, with limits 0<ET< PET. ET is unpredictable but is always less than or equal to PET.

Typical reported values were used to determine RO. Ehrig's and Cossu et al. equations (Safari and Baronian, 2002) below were used to estimate G. The mass of water consumed per m^3 of landfill gas produced (W) is given by

$$W = \frac{(4a-b-2c+3d)\times(\frac{18}{4})\times 1000}{(12a+b+16c+14d)G_e} \qquad (3)$$

where Ge is the total gas quantity in m^3/ton of MSW ($C_aH_bO_cN_d$) given by Ge = 1.868 C (0.014 T+0.28). C is the Total Organic Content (TOC) (kg/Mg of MSW) and T is temperature in °C. An approximate chemical formula was calculated for MSW using typical ultimate analysis data and Zimbabwe MSW composition data reported by (Huvengwa, 2012; ILO, 2007; Jerie, 2014; Mangizvo, 2007; Mangizvo, 2008; Mangundu et al., 2013 ; Manyanhaire et al., 2009; Masocha, 2004; Mbohwa and Zvigumbu, 2007; Mwanza and Phiri, 2013 ; Sango, 2010 ; Takaedza, 2014;

Togarepi and Tsiko, 2012)). G was then calculated by dividing volume of water consumed by landfill surface area.

$$Landfill\ surface\ area\ = \frac{1}{depth\ of\ landfill\ (m)} \times \frac{landfilled-MSW\ (tons)}{density\ of\ waste\ (Mg/\ m^3)} \tag{4}$$

Uniform distributions for depth and landfilled-MSW density were used with limits of 3-6 m and 534-1000 kg/m^3, respectively. Rule of thumb approaches and assumptions were made in developing the model where data was lacking.

3. Results and Discussion

Results from 10 000 Monte Carlo iterations are shown in Fig 1 a-c) below.

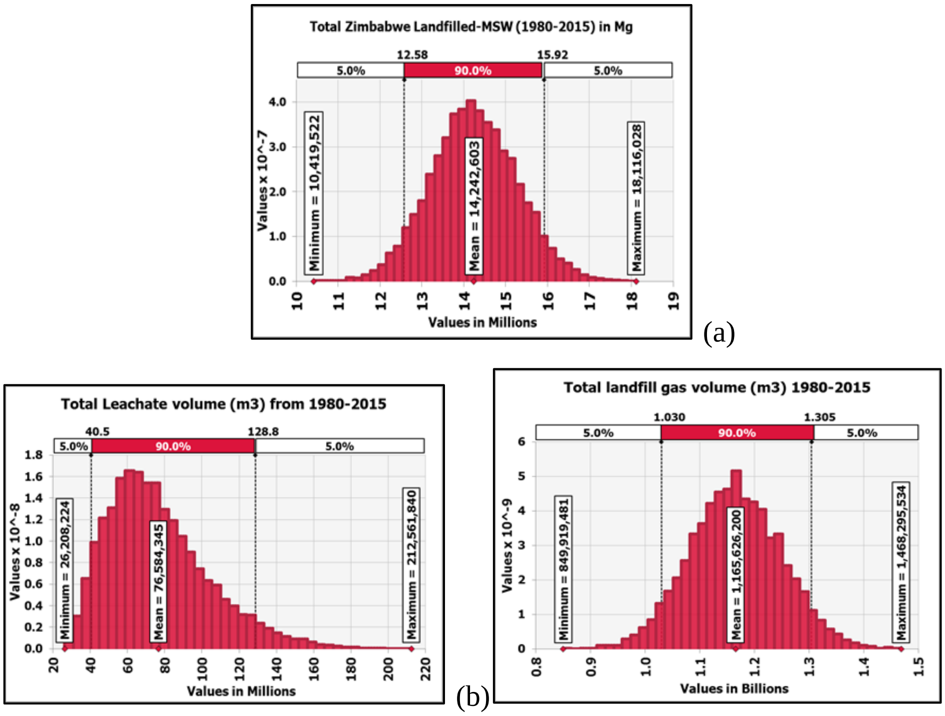

Figure 1. a-c) Distribution probability of a) landfilled MSW b) leachate volume c) landfill gas volume

As shown in Fig 1 a-c) 13-16 million Mg of MSW has been landfilled releasing about 1.0 - 1.3 billion m^3 of landfill gas. Analysis of reported values reveals an average MSW composition of 32.4 % putrescibles, 16.2 % plastics, 8.6%

miscellaneous, 19.9 % paper and cardboard, 6.9 % metals, 4.0 % glass and ceramics, 2.1 % leather and rubber, 3.1 % textiles, 4.1 % yard waste and 4.5 % wood. Reported MSW generation per capita (kg/capita/day) figures follow a normal distribution with μ and σ of 0.53 and 0.14, respectively. The calculated molecular formula in this study is C_{617} H_{1718} O_{620} N_{18} Cl_{7} and landfill gas (CO_2 and CH_4) quantity generated is 81.8 m^3/Mg-MSW respectively. Previously research reported 66.7 Nm^3-CH_4/Mg-MSW as generation rate (Scarlat et al., 2015). Calculated TOC and W are 74.7 kg/Mg of MSW and 1.24 kg water/m^3 of landfill gas. The total volume of leachate since 1980 is 41 – 128 million m^3. The high variability of leachate produced from the landfills can be attributed to the variation inherent to leachate generation which relies on hydrologic and climatic influences. Table 2 is a summary of the stochastic water balance.

Table 2. Annual water balance (mm per unit surface area of landfill) since 1980

Parameter	***Minimum***	***Mean***	***Maximum***	***90% confidence interval***
P	325	621	1195	454-817
PET	1056	1098	1148	1079-1117
ET	196	549	913	390-707
RO	71	249	752	142-378
ΔS	-1306	-654	423	-976 - (-281)
G	5	10	17	6-14
L	288	473	685	382-571

Number of iterations = 10 000

At a 90% confidence level, 382-571 mm per year of leachate can be expected. ET lies between 390-707 mm. In comparison, average annual ET in neighboring South Africa was estimated to be 303 mm (Jovanovic et al., 2015) for 2000–2012. This falls well within the range shown in Table 2 above. The stochastic WBM methodology for estimating leachate volumes avoids the limitations of most empirical models, fundamentally flawed by their deterministic nature. Most of the data required in WBM is stochastic or poorly defined (temperature, heat index, precipitation, runoff coefficients).

4. Conclusion

Using Monte Carlo simulations, a 90% confidence interval for the leachate generated in Zimbabwe in 37 years since 1980 is 41 – 128 million m^3. It is necessary to stress that this article is as an initial approximation of field data to determine leachate quality and quantity. Further study is needed to convey more reliable results.

The approximations from this study could be used in the preliminary design of leachate control systems or to assess the impact of leachate on the environment.

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Mass Balance of Hydrogen Cyanide and Hydrogen Sulfide Gases Removal by Dual Fixed-Film Bioscrubber

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Abstract

This study presents a practical mass balance calculations of hydrogen cyanide and hydrogen sulfide gases removal by dual fixed-film bioscrubber system. A mixed culture of *Agrobacterium tumefaciens* SUTS 1 and *Pseudomonas monteilii* SUTS 2 for hydrogen cyanide removal while a mixed culture of *Acinetobacter* sp. MU1_03 and *Alcaligenes faecalis* MU2_03 for hydrogen sulfide removal. The long-term system results showed high removal efficiency of hydrogen cyanide and hydrogen sulfide that was 99.06% and 98.66%, respectively. It revealed that mass-in and mass-out was 93.60 mg/m^3•h and 7.30 mg/m^3•h for hydrogen cyanide removal whereas the mass-in and mass-out for hydrogen sulfide removal was 177.40 mg/m^3•h and 14.80 mg/m^3•h, respectively. These found that the mass-in higher than the mass-out, it might be due to these bacteria could utilize the compounds such as cyanide, sulfide, or the by-product compounds for their growth.

Keywords: dual fixed-film bioscrubber; biodegradation; hydrogen cyanide; hydrogen sulfide; mass balance

1. Introduction

Hydrogen cyanide (HCN) and hydrogen sulfide (H_2S) gases are colorless, toxic and flammable gases. Hydrogen cyanide and hydrogen sulfide found in petroleum refining, wastewater treatment plant, chemical processing, incomplete combustion and industrial waste (Ebb, 2004; Dzombak et al., 2006). HCN and H_2S gases were similar toxicity to nervous system. It also affects to animal and environment. Both toxic gases were exposed by ingestion, skin absorption and inhalation this path way was high toxicity due to rapid absorb to target organ and systemic poison (National Research Council, 2002). These gases removal are various pathways such as physicochemical, biochemical and biological degradation (Dash et al., 2009). The biological degradation provides an alternative method for gas removal due to low cost operation and environmental friendly. This pathway will degrade, oxidize and/or transform the pollutant gases into intermediate and by-product. The intermediate and by-product from biodegradation of hydrogen cyanide and hydrogen sulfide might be various compounds mainly depending on type of substrates, type of microbes, type and performance of the systems. Biodegradation of hydrogen cyanide releases the nitrogen forms such as ammonia, nitrite, and nitrate while the hydrogen sulfide releases the sulfur form (Potivichayanon et al., 2006; Potivichayanon and Kitleartpornpairoat, 2010; Ebb, 2004 and Rattanapan et al, 2009). The bioscrubber system consists of two subunit namely an absorption unit and a bioreactor unit. In the absorption unit, input gases contaminants are transferred to the liquid phase. Gas and liquid phases flow counter currently within the column, which may contain the packing material (Mudliar et al., 2010). The main advantages of this technology are: (1) removal of reaction products by washing out, avoiding their possible inhibitory effect, (2) easy control of the biological process and (3) good adaptation capacity of microbial biomass (Kennes and Thalasso, 1998). In order to enhance the efficiency of wide variety of organic and inorganic compounds from polluted air streams removal and solve to the completion condition of microbial consortiums until increase the degrading rate. The advantages of two stage bioreactors are removal several of pollutants, stable of flow rate and using for single and mixed culture of biodegrading bacteria (Sercu et al., 2005). Mass balances are used widely in engineering environmental and biodegradation analysis due to can estimate in order to future operative removal process in the bioreactor system (Gao et al., 2012) and the mechanism of substance transform in bioreaction (Dash et al., 2009). A mass balance can evaluate the performance and quantitatively in removal process. It focuses not only on the mass of materials that enter or leave the bioreactor by air but also considerate of by-products that are produced or removed or transformed to biomass (Armeen et al., 2008). This paper presents a methodology to evaluate dual fixed-film bioscrubber system. It shows the methods of calculated values and the relation of mass-in, mass-out, accumulated-mass and biomass of hydrogen cyanide and hydrogen sulfide degrading bacteria. In addition, the results can be used to improve and apply mass balance for biodegradation process.

2. Material and methods

2.1. Microorganisms and immobilization

Cyanide degrading bacteria were isolated from cassava wastewater treatment system included *Agrobacterium tumefaciens* SUTS 1 and *Pseudomonas monteilii* SUTS 2 and then were cultivated in buffer media (Potivichayanon and kitleartpornpairoat, 2010). Sulfide degrading bacteria were isolated from an aeration tank of municipal wastewater treatment system included *Acinetobacter* sp. MU1_03 and *Alcaligenes faecalis* MU2_03 and then cultivated in thiosulfate media (Potivichayanon et al., 2006). The polypropylene tellerette ring as a packing media was 0.072 m in diameter and 105 m^2/m^3 in surface loading rate. The packing media was weighed and sterilized using UV light. After that, the sterile packing media was transferred into a media solution flask containing selected microbial growth at logarithmic phase (day 4) and then incubated at room temperature at 150 rpm on a rotary shaker for 4 weeks.

2.2. Fixed-film bioscrubber set-up

The dual fixed-film bioscrubber system is shown in Fig.1 Bioscrubber columns were made of glass 0.074 m in diameter and 0.40 m of height. The columns were packed with immobilized packing media to get the working height of 0.24 m (60% of bioscrubber height) or 0.16 m (40% of bioscrubber height) for finding optimum condition. The first bioscrubber column was hydrogen cyanide degrading column and the second was hydrogen sulfide degrading column. Hydrogen cyanide and hydrogen sulfide gases were introduced upward into column. The nutrient solution was pumped downward and recirculated during the experiment. The systems were divided into 2 steps: short-term and long-term operation as shown in table 1. The important parameters of mass-in were determined in form of HCN and H_2S gas concentration using gas detector whereas the mass-out in form of by-products were analyzed such as nitrate nitrogen (NO_3^-), nitrite nitrogen (NO_2^-), ammonia nitrogen (NH_3), residual cyanide (CN^-)and sulfate (SO_4^{2-}) according to standard methods for the examination of water and wastewater (APHA, AWWA and WPCF, 1995; Ebb, 2004; Potivichayanon et al., 2006; Potivichayanon and kitleartpornpairoat, 2010), In addition, cyanide and sulfide degrading bacteria growth were analyzed by the colony counting technique (APHA, AWWA and WPCF, 1995).

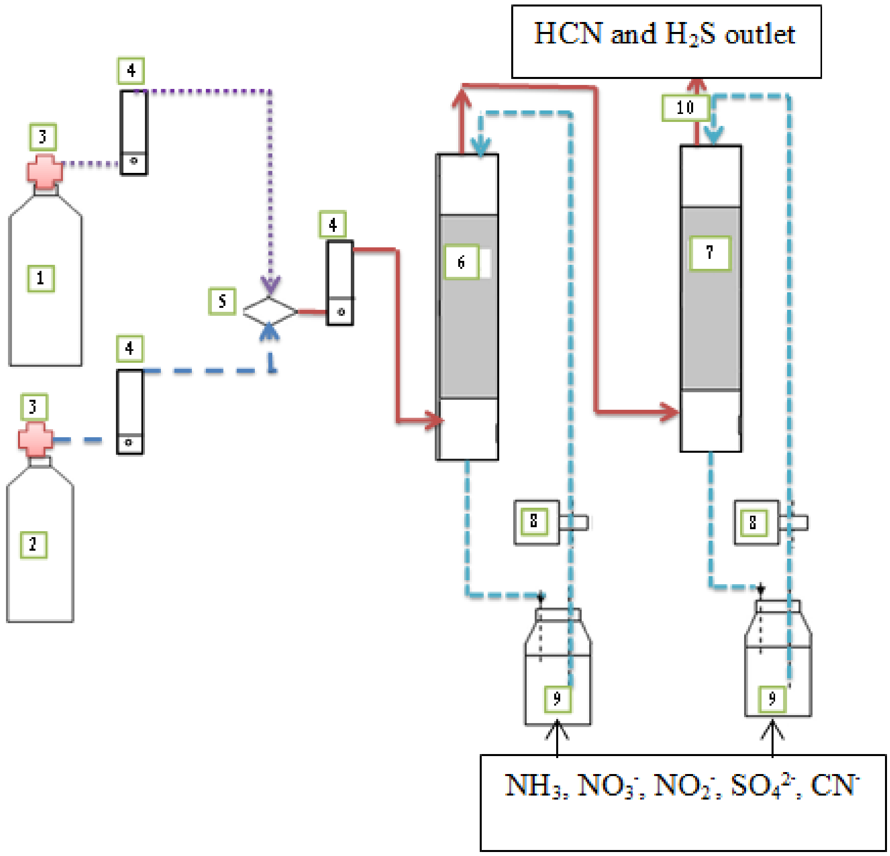

Figure 1. Schematic diagram of dual fixed-film bioscrubber system: 1. HCN gas; 2. H_2S gas; 3. Regulator; 4. Flow meter; 5. Connector tank; 6. Bioscrubber column 1 (cyanide degrading bacteria; 7. Bioscrubber column 2 (sulfide degrading bacteria); 8. Peristaltic pump; 9. Media tank; 10. Gas sampling points

Table 1. Experimental condition

Experiment	Gas concentration (ppmv)	Packing media height (m)	HCN gas flow rate (ml/min)	H_2S gas flow rate (ml/min)	Mixed-gases flow rate (ml/min)	Media solution flow rate (ml/min)	EBRT (sec)	Operation time (h)
Short term	5	0.16	24	84	90	16	132	3
		0.24	24	84	90	16	152	3
	15	0.16	35	156	204	16	132	3
		0.24	35	156	204	16	152	3
Long term	15	0.16	35	156	204	16	152	72

2.3. Data and Mass balance calculation

The performance of bioscrubber was reported as gas loading rate (GLR; mg/m^3·h) (Kennes el al., 2009), and the gas removal was represented by gas elimination capacity (GEC; mg/m^3·h) (Rattanapan et al., 2009), which is usually normalized by the gas volume of the bioscrubber. The efficiencies of dual fixed-film bioscrubber are commonly revealed in term of the removal efficiency (RE; %). These terms are defined in Eq. 1-3 as follows:

$$GLR = \frac{Q \times C_{in}}{V} \quad (1)$$

$$GEC = Q\left(\frac{C_{in-} C_{out}}{V}\right) \quad (2)$$

$$RE = \left(\frac{C_{in-}C_{out}}{C_{in}}\right) \times 100 \quad (3)$$

Where C_{in} is the inlet gas concentration (mg/ L), C_{out} is the outlet gas concentration (mg /L), Q is gas flow rate (m^3/h) and V is packing media volume in bioscrubber column (m^3)

The factors measured for the mass balance evaluation were gas inlet loading rate, gas outlet and concentration of by-product from oxidizing process in form of nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3), residual cyanide (CN^-) and sulfate (SO_4^{2-}). Over all of mass balance was presented in Eq. 4. The equations of mass balance calculation were applied in Eq. (5)-(8) (Armeen et al., 2008).

$$\text{Mass-in} = \text{Mass-out} + \text{Accumulated-mass} \quad (4)$$

Mass balance of HCN gas

The reaction of HCN oxidizing by biodegrading bacteria was shown in Eq. 5 and the calculation of mass was shown in Eq.6

$$6HCN_{inlet} + 7O_2 \rightarrow NH_3 + NO_3^- + 2NO_2^- + 4CO_2 + H_2O + HCN_{outlet} + CN^- \quad (5)$$

$$\frac{Q\times([HCN_{inlet}]\times 6)}{V_m} = \frac{Q\times[HCN_{outlet}]}{V_m} + \frac{([NH_3]+[NO^-_3]+([NO^-_2]\times 2)+[CN^-])\times V_w}{1000\times V_m} \quad (6)$$

Mass balance of H_2S gas

The reaction of H_2S oxidizing by biodegrading bacteria was shown in Eq. 7 and calculation of mass was shown in Eq.8

$$2H_2S_{inlet} + 2.5O_2 + CO_2 \rightarrow SO_4^{2-} + H_2S_{outlet} + H_2O + CO_2 \quad (7)$$

$$\frac{Q\times([H_2S_{inlet}]\times 2)}{V_m} = \frac{Q\times[H_2S_{outlet}]}{V_m} + \frac{[SO_4^{2-}]\times V_w}{1000\times V_m} \quad (8)$$

Where HCN_{in} is inlet HCN gas concentration (mg/L), HCN_{outlet} is outlet HCN gas concentration (mg/L), V_m is volume of packing media in bioscrubber (m^3), NH_3 is ammonia concentration (mg/ L), NO_3^- is nitrate concentration (mg/L), NO_2^- is nitrite concentration (mg/L), CN^- is residual cyanide concentration (mg/L), V_w is volume of solution media (ml/h), H_2S_{inlet} is inlet H_2S gas concentration (mg/L), H_2S_{outlet} is outlet H_2S gas concentration (mg/L) and SO_4^{2-} is sulfate concentration (mg/L).

3. Results and discussions

3.1 Removal efficiency of dual fixed-film bioscrubber in short term operation

In short term experiment, although the gas concentrations and loading rate were increased from 5 ppmv to 15 ppmv, the elimination capacities of dual fixed-film bioscrubber still increased and also it reached the highest removal efficiency (Fig. 2, Table 2-3). When the packing media height was decreased from 0.24 m to 0.16 m, the gas loading rate was increased. At 15 ppmv, especially, this bioscrubber exhibited very high elimination capacity. The HCN gas loading rate increased from 12.24 $mg/m^3\cdot h$ to 15.60 $mg/m^3\cdot h$ and the maximum elimination capacity reached 15.06 $mg/m^3\cdot h$. In addition, the H_2S gas loading rate increased from 69.73 $mg/m^3\cdot h$ to 88.70 $mg/m^3\cdot h$ and the maximum elimination capacity was 87.30 $mg/m^3\cdot h$ (Fig. 2). The results found that the removal efficiency of each gases achieved higher than 98%, it might be due to these gases can be oxidized and transformed to nitrogen and/or sulfate (Ebb, 2004).The HCN gas can be degraded by cyanide degrading bacteria, a mixed culture of *Agrobacterium tumefaciens* SUTS 1 and *Pseudomonas monteilii* SUTS 2. The by-product of this reaction might be ammonia (NH_3), nitrite (NO_2^-), and nitrate (NO_3^-) that be found in this bioscrubber. When the gas loading rate increased, the concentration of oxidizing products also increased such as NO_3^- was higher than NH_3 and NO_2^- These by-products could be easily utilized as nitrogen source by microbes, especially ammonia (Kunz et al., 1992; Wang et al., 1996; Kao et al., 2004; Dzombak, 2006). On the other hand, the H_2S gas can be utilized by sulfide degrading bacteria, *Acinetobacter* sp. MU1_03 and *Alcaligenes faecalis* MU2_03. The by-product of this reaction might be sulfate (SO_4^{2-}) which is a stable form of hydrogen sulfide oxidation reaction and show a higher concentration during the increasing loading rate. After this operation, the cyanide and sulfide degrading bacteria slightly decreased from 5.80×10^7 CFU/ml to 2.90×10^7 CFU/ml and 2.32×10^8 CFU/ml to 1.70×10^8 CFU/ml, respectively. However, these bacteria still exhibited very high efficiency when the optimum condition reached at 15 ppmv and 0.16 m of height with empty bed retention time (EBRT) of 132 sec which did suitable operation for this system.

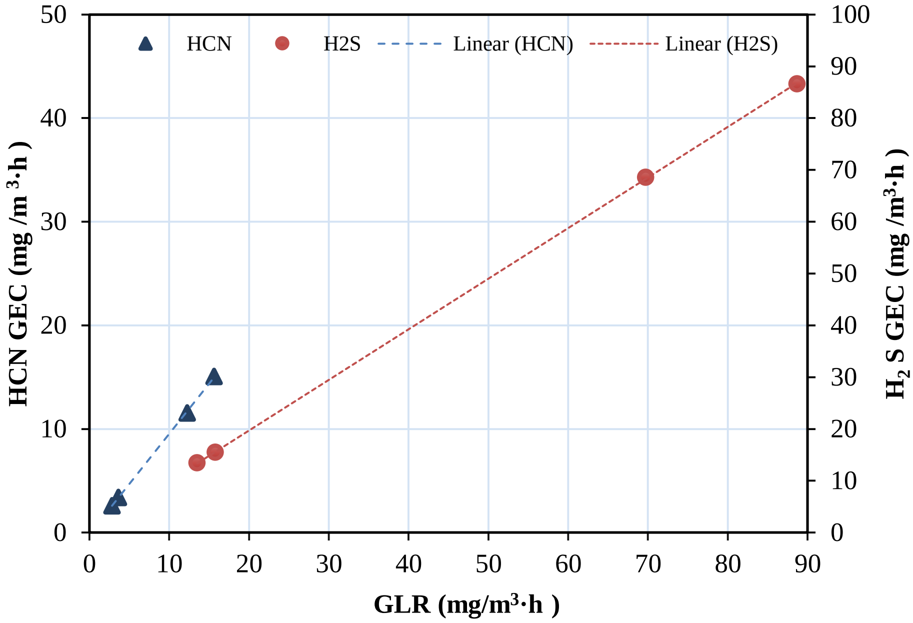

Figure 2. The relationship between HCN and H_2S gases loading rate and elimination capacity in each packing media height.

Table 2. Removal efficiency and oxidizing compounds of HCN removal in short term experiment.

Packing media height (m)	HCN inlet (ppmv)	HCN outlet (ppmv)	RE (%)	NH_3 (mg/L)	NO_2^- (mg/L)	NO_3^- (mg/L)	Residual CN^- (mg/L)
0.16	5	0.10	98.00	2.20± 0.4	0.1±0.03	3.60±0.50	2.20±2.20
	15	0.10	99.33	3.30±0.38	0.18±0.02	5.40±0.30	6.60±0.20
0.24	5	N.D.**	≥99.99	2.05±0.09	0.16±0.02	4.00±0.23	5.13±2.43
	15	0.10	99.33	2.28±0.13	0.09±0.02	5.00±0.20	8.00±2.56

*The values are shown in mean±S.D. and average in 1-3 h.

** N.D. indicates that the compound was not detected (at detection limit 0.01)

Table 3. Removal efficiency and oxidizing compounds of H_2S removal in short term experiment.

Packing media height (m)	H_2S inlet (ppmv)	H_2S outlet (ppmv)	RE (%)*	SO_4^{2-} (mg/ L)
0.16	5	0.20	96.00	26.40±2.45
	15	0.20	98 .44	29.60±0.36
0.24	5	N.D.**	≥99.99	17.90±4.34
	15	0.16	98.88	23.40±0.48

*The values are shown in mean±S.D. and average in 1-3 h.

** N.D. indicates that the compound was not detected (at detection limit 0.01)

Table 4. Mass balances in dual fixed-film bioscrubber for short term operations.

gas	Gas concentration (ppmv)	Packing media height (m)	Mass-in (mg/m^3•h)	Mass-out (mg/m^3•h)	Accumulated - mass (mg/m^3•h)
HCN	5	0.16	21.66	0.4	21.26
		0.24	16.98	0.4	16.58
	15	0.16	93.60	6.91	86.69
		0.24	73.44	5.31	68.13
H_2S	5	0.16	31.60	12.10	19.50
		0.24	27.02	5.60	21.42
	15	0.16	177.40	14.20	163.20
		0.24	139.46	8.50	130.96

3.1.1 Mass balances of gas concentration 5 ppmv

The degradation processes in dual fixed-film bioscrubber divided into two substrates that was hydrogen cyanide and hydrogen sulfide column, so the mass balance calculations were determined according to individual column. The mass balance of hydrogen cyanide followed equation 5 and 6 whereas hydrogen sulfide followed equation 7 and 8 depending on substrate or mass-in and by-product or mass-out (table 4). At packing media height 0.16 m, HCN mass-in was 21.66 mg/m^3•h and mass-out 0.4 mg/m^3•h that was approximately 2 % of total mass while H_2S mass-in was 31.60 mg/m^3•h and mass-out 12.10 mg/m^3•h that was approximately 38%. When the packing media height was increased to 0.24 m, the gas loading rate of each gas decreased to 16.98 and 27.02 mg/m^3•h of HCN and H_2S gas, respectively. This caused the mass-out of each column slightly decreased, especially for hydrogen sulfide column. Furthermore, some mass might be accumulated in the system and evaluated in term of accumulated-mass (Gao et al., 2012). Therefore, the accumulated-mass were determined and found that the accumulated-mass in HCN column was approximately 97-98% whereas the accumulated-mass in H_2S column was approximately 62-77%. In addition, the numbers of attached cells in biofilm were in the trend of increasing from 2.16× 10^8 CFU/ml to 2.90 × 10^8 CFU/ml. It means that the cyanide and sulfide degrading bacteria accumulated and utilized these compounds for their growth.

3.1.2 Mass balances of gas concentration 15 ppmv

At 15 ppmv, the increasing of gas loading rate revealed the mass-in, mass-out, and accumulated-mass were higher than that of 5 ppmv (table 4). In addition, the mass-out was in the trend of increasing, it means that the mass-out was depended on the gas loading rate. For example, the HCN mass-out at 0.16 m of packing height (loading rate 15.60 mg/m^3•h) was 6.91 mg/m^3•h higher than that of packing height 0.24 m (loading rate 12.24 mg/m^3•h). These results indicated that the mass was accumulated increasingly in the system. It might be due to the increasing of absorption rate of substrate and by-product in dual fixed-film bioscrubber system. However, this accumulation also related with the number of cells which found that the total cells of these bacteria slightly decreased from 2.45 × 10^8 CFU/ml to 2.00 × 10^8 CFU/ml during the increasing of loading rate. Therefore, when the gas concentration was increased from 5 ppmv to 15 ppmv, the substrate and oxidation reaction rate also increased which affected the concentrations of accumulated-mass and by-product from the oxidation processes (Armeen et al., 2008).

3.2 Long term operation and mass balances of dual fixed-film bioscrubber

This experiment was studied the optimum condition of gas concentration at 15 ppmv, packing media height at 0.16 m on 72 h of operation time. The mass-in of HCN and H_2S were 93.60 mg/m^3•h and 177.40 mg/m^3•h. The mass-out of HCN and H_2S increased within 24 h but it was slightly decreasing after that time (Table 5). The average of HCN mass-out was 7.30 mg/m^3•h while the H_2S mass-out was 14.80 mg/m^3•h. In addition, the hydrogen cyanide elimination capacity slightly decreased from 15.45 to 15.21 mg/m^3•h whereas the elimination capacity of hydrogen sulfide decreased from 88.32 to 84.70 mg/m^3•h. Therefore, these results affected the mass-out in all operations. On the other hand, the accumulation of mass was approximately 86.30 and 162.60 mg/m^3•h of hydrogen cyanide and hydrogen sulfide column, respectively. The compounds from degradation processes might be accumulated into the cell of bacteria. The hydrogen cyanide (HCN) was the best sources of carbon (C), hydrogen (H), and nitrogen (N). These are the major elements which serve either a structural or functional role in the bacterial cells (Singleton, 2004; Zimmo et al., 2004). Carbon is the main constituent of cellular material that is 50% of dry weight, hydrogen is the main constituent of organic compounds and cell water that is 8% of dry weight, and nitrogen is the constituent of amino acids, nucleic acids, nucleotides, and coenzymes that is 14% of dry weight (Alberts et al., 2002). Furthermore, if the bacteria is an aerobic microbe, oxygen will be the most importance for the degradation process because oxygen is an electron acceptor in aerobic respiration and it is 20% of dry weight of cell. The oxygen might be found in the form of water in bioscrubber system. For hydrogen sulfide (H_2S), in addition to hydrogen, sulfur is also the major element of cell. Sulfur is constituent of cysteine, methionine, glulathione, and several coenzymes that are approximately 1% of dry weight. Therefore, these elements could be utilized and accumulated in the bacterial cells. The number and weight of cyanide and sulfide degrading bacteria are shown in Fig. 3. The cyanide degrading bacteria, *Agrobacterium tumefaciens* SUTS 1 and *Pseudomonas monteilii* SUTS 2, was approximately 10^7 CFU/ml until the end of operation whereas the sulfide degrading bacteria, *Acinetobacter* sp. MU1_03 and *Alcaligenes faecalis* MU2_03, was in the trend of decreasing from 10^8 to 10^7 CFU/ml (Fig. 3). In addition, the removal efficiency of hydrogen cyanide (99.06%) was higher than that of hydrogen sulfide (98.66%). This might be due to the HCN serve as a sole source of carbon for the cell growth whereas H_2S reach only sulfur and hydrogen for the cell.

Table 5. Mass balances in long-term operation

Gas	Mass	6 h	24 h	36 h	72 h	Average (mg/ m^3•h)
HCN	Mass-out (mg/ m^3•h)	6.27	8.01	7.20	7.58	7.30
	Accumulated-mass (mg/ m^3•h)	87.33	85.59	86.4	86.02	86.30
H_2S	Mass-out (mg/ m^3•h)	14.55	16.85	15.14	12.74	14.80
	Accumulated-mass (mg/ m^3•h)	162.85	160.55	162.26	164.66	162.60

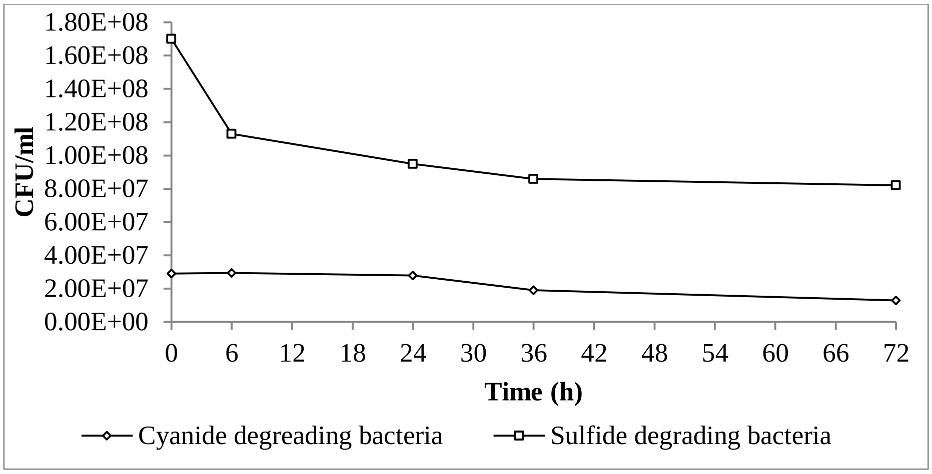

Figure 3. The number of bacteria cells in long term operation.

4. Conclusions

In this study the suitable condition was gases concentration 15 ppmv, packing media height 0.16 m, gases loading for HCN and H_2S gas were 15.60 and 88.70 mg/m^3• h respectively. The removal of HCN and H_2S gases by dual fixed-film bioscrubber achieved to 98% in short term system operation while in long term was exhibited more than 96%. In order to evaluate the biodegradation system performance, the mass balances should be applied not only mass-in and mass-out calculations but also the accumulated mass in the system. The degrading bacteria could utilize the toxic gases in oxidation form in nitrate, nitrite, ammonia and sulfate, it cause of height concentration of accumulated mass more than 70% in each experiment.

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Batch Reactor Design for Algal Biosorption of Mercury-Contaminated Acidic Water

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Abstract

The risk of mercury poisoning cannot be over-emphasized. Toxic mercury exposure can lead to fatal damage to the nervous, immune, respiratory, renal and digestive systems. However, despite stern warnings from environmental authorities, the rudimentary and unscrupulous operations of miners in Zimbabwe have resulted in its unprecedented release into potable water sources. Artisanal gold mining activities employing the mercury amalgamation process have resulted in a significant drop in the quality of water from Ngwabalozi River in Zimbabwe. Mercury levels as high as 0.31 mg l^{-1} have been reported in its waters with a pH as low as 3. The aim of this study is to develop a low-cost batch reactor for the removal of Hg from Hg contaminated acidic water to meet the WHO standard of 0.006 mg l^{-1} using algae. Algae (*Cladophora* sp.), a widely abundant natural biosorbent, is relatively cheaper than industrial synthetic adsorbents hence its choice in this study. Experimental results reveal a high affinity for total mercury removal in acidic water. More than 99% of the mercury in solution was removed within the first five minutes of contact and equilibrium was attained after ten minutes. High adsorption capacities (up to 805 mg kg^{-1} at pH 3) were obtained at the optimum Hg concentration of 1.0 mg l^{-1}. The experimental data fitted very well with the pseudo-second order kinetics model. The equilibrium isotherm capacity equations were used in the design of a 1000 l-batch reactor. Using the experimental equilibrium contact time of 10 mins, the batch reactor design model showed that the adsorbent mass required per batch is in the range 3.9 kg to 15.7 kg for minimum and maximum initial mercury concentrations of 0.25 mg l^{-1} and 1.0 mg l^{-1}, respectively.

Keywords: biosorption; algae; mercury; batch reactor; acidic water

1. Introduction

Abject poverty has fueled a rise in Artisanal and Small-scale Gold Mining (ASGM) activities in countries such as Zimbabwe, Mozambique and Colombia. These miners prefer mercury for their activities due to its high availability and ease of use as the amalgamation process does not require any sophisticated equipment (Steckling et al., 2014). Exposure is inevitable as mercury vapor is inhaled when the gold is smelted from the gold-mercury amalgam (Matchaba-Hove et al., 2001). Mercury is also dumped in the environment during mining, increasing mercury emissions.

Zimbabwe has roughly 300, 000 people involved in mining-related mercury use which is estimated to be about 25 Mg/yr (Telmer and Veiga, 2009). ASGMs activities, which are usually located as close to water sources as possible, cause anthropogenic mercury releases to the river system as well as increased siltation as evident in Ngwabalozi river were mercury concentration as high as 0.31 mg l^{-1} have been reported (Mudyazhezha et al., 2014). The tendency of mercury and its compounds to settle at the bottom of sediments in water bodies favors its conversion into methyl mercury (CH_3Hg^+) by anaerobic bacteria. Methyl mercury is a very toxic and soluble form of mercury, which is also easily taken up by plants and animals (Girard and Girard, 2014). Therefore, mercury removal before its biological methylation is important to prevent mercury hazards to the ecosystem. The aim of this study is to develop a low-cost batch reactor for the removal of mercury to meet the WHO standard of 0.006 mg l^{-1} using algae. Algae (*Cladophora* sp.), a widely abundant natural biosorbent, is relatively cheaper than industrial synthetic adsorbents hence it was tested in this study.

2. Materials and Methods

2.1. Reagents and procedures for algae culturing

Reagents used for the sorption studies were of analytical grade, except for standards used for quantification purposes which were high purity reagents (i.e. certified "heavy metals free"). All instrument standard solutions were prepared on the day of use. De-ionized water with an electrical resistivity of 18.2 MΩ cm (Millipore, USA) was used in reagent preparation. All vessels used in this study were acid washed following a cleaning protocol, adapted after Monperrus et al. (2005).

Algae samples were grown in an Acidic Bold-Basal Medium (ABM) culture (CCAP, 2014) for 2-3 days and then acclimated in distilled water at room temperature and natural light for a day before use for experiments (Ji *et al*., 2012). The solution was then autoclaved using a Precise Shaking Incubator WIS-30 (Daihan Scientific, Korea) at 121°C and 1000 Pa for 15 minutes so as to sterilise the culture media by inactivating microbial life such as bacteria (Barsanti and Gualtieri, 2006). Fourier Transform Infra-red (FTIR) Tensor 27, (Bruker, Germany) analysis carried out on *Cladophora* sp revealed the following functional groups: O-H (alcohol) observed at 3300-3600 cm^{-1}, N-H (amine) observed at 3200-3500 cm^{-1} and ν(C=O) observed at 1780-1680 cm^{-1} for carboxylic acids.

2.2. Experimental Approach

Batch experiments were carried out to determine the sorption kinetics at varying pH levels (3-8.5) and initial mercury concentration (0.25-1.0 mgl^{-1}). Effects of contact time (0-120 mins) and the presence of competing metal cations (Fe^{2+}, Cu^{2+}, $Zn^{2+}$and Co^{2+}) were also studied. Experiments were conducted in triplicate with a control containing the metal contaminant but lacking algae setup. Tests were performed in 250 ml-conical flasks and at different equilibrium times, 2 ml-aliquots (less than 10% of the initial volume) were drawn for analysis. Of the 2 ml volume collected during the batch tests, 500 µl were used for analysis. This volume was placed in acid-washed 15 ml- centrifuge tubes and made up to 10 ml. Total Hg in water and digested algae samples were determined using an automated Flow Injection-Cold Vapor Atomic Absorption Spectrometry system (FI-CVAAS) FIMS 400 (Perkin Elmer, USA) whereas the concentrations of competing metal ions (Fe^{2+}, Co^{2+}, Cu^{2+}, and Zn^{2+}) were obtained using an Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) instrument (SpectroGenesis, Germany). The equilibrium isotherm capacity equation was used in the modeling of a batch reactor in order to determine the mass of algae required to reduce mercury from initial concentrations of 0.25 - 1.0 mg l^{-1} to the WHO standard of 0.006mg l^{-1}.

2.3 Equilibrium adsorption capacity

The equilibrium adsorption capacities (q_e) were determined using:

$$q_e = V(C_o - C_e)/m \qquad (1)$$

Where; q_e $(mg\ g^{-1})$ is the amount of metal adsorbed per gram of adsorbent (algae), $V(l)$ is the volume of media, $C_o(mg\ l^{-1})$ is the initial metal ion concentration in media, $C_e(mg\ l^{-1})$ is the equilibrium metal ion concentration, $m(g)$ is the mass of adsorbent (algae) used.

2.4 The Langmuir isotherm model

The maximum adsorption capacity (q_m) was determined by using the following Langmuir isotherm equation:

$$q_e = (q_m b C_e)/(1 + bC_e\ ) \qquad (2)$$

Where; q_e $(mg\ g^{-1})$ is the amount of metal adsorbed per gram of adsorbent (algae), $q_m(mg\ g^{-1})$ is the amount of adsorption corresponding to complete monolayer coverage (i.e. maximum adsorption capacity), $b\ (\ l\ mg^{-1})$ is the adsorption constant related to binding energy and $C_e(mg\ l^{-1})$ is the equilibrium metal ion concentration in media.

2.5 Batch reactor design

In order to calculate the mass of algae required for each initial mercury concentration, the following assumptions were made; (1) equilibrium is reached in the batch adsorber, (2) the equilibrium saturation capacities are correlated by the

Langmuir equation; (3) 1000 l is to be treated per batch (4) maximum retention time is 10 mins.

Therefore, the mass balance Equation (1) is rearranged to give:

$$m = V(C_o - C_e)/q_e \qquad (3)$$

Equation (2) is substituted into Equation (3) to yield:

$$m(kg) = [V(C_o - C_e)(1 + bC_e)/1000 q_m bC_e\,] \qquad (4)$$

3. Results and Discussion

3.1 Effect of pH

Maximum Hg^{2+} adsorption was observed at pH 3 (Figure 1a), which is also point of zero charge for the algae (Yalçın et al., 2008). Due to the high adsorption capacity observed, it was concluded that under the given experimental conditions, the surface charge of alga at the point of zero charge (pH 3) developed as negative, thus more binding sites such as the carboxyl functional group, which are acidic, were available for mercury adsorption (Hg^{2+}). Though low pH values have been reported to result in a decrease in metal sorption due to the increased concentration of the hydrogen ions (H^+) which are preferentially adsorbed onto the alga surface compared to metal ions (Mehta and Gaur, 2005), the results obtained were in agreement with the findings of Le Faucheur et al. (2011) who concluded that Hg^{2+} uptake by algae seems to be stimulated by proton addition after investigating the influence of pH on Hg^{2+} uptake by a green, unicellular alga, *Chlamydomonas reinhardtii*. pH 3 was therefore chosen as the optimum pH.

3.2 Effect of contact time

The effect of contact time on the adsorption of Hg^{2+} by *Cladophora* sp. was investigated at the optimum pH and initial concentration of 1.0 mg l^{-1}. The concentration of Hg in solution rapidly decreased within the first 5 min, attaining more than 99% Hg removal (Figure 1b). Equilibrium was attained within the first 10 min, therefore an optimum contact time of 10 min was chosen. Carsky et.al. (2013) and Utomo et al.(2016) also reported rapid heavy metal adsorption by algae in their studies.

3.3 Effect of initial Hg^{2+} concentration

As the concentration of Hg^{2+} ions increased so was the amount adsorbed. This can be attributed to the increasing concentration of Hg^{2+} ions in solution that competed for the finite number of the binding sites on the algae surface. A maximum adsorption capacity of 805 mg kg^{-1} was attained at an initial concentration of 1.0 mg l^{-1} and optimum pH 3 (Figure 1c).

3.4 Effect of competing metal cations

The removal efficiency of Hg^{2+} decreased from greater than 99% in a single component to 67% in a multi component system (Figure 1d). Plaza et al. (2011) also reported a decrease (more than 50%) in Hg sorption by brown algae in the presence of competing metal cations; - lower than results of this study. Therefore, *Cladophora* sp. can be still used as a biosorbent material in environmental applications. The extraction efficiency was in the following order: $Hg^{2+} > Fe^{2+} > Cu^{2+} > Zn^{2+} > Co^{2+}$. The difference in sorption affinities can be attributed to differences in electronegativity of the atoms which also follows the same order. Therefore, the greater the electronegativity or ionic radii the higher the sorption affinity (Mohamed and Anita, 1998; Andrade et al., 2005; Abu Al-Rub et al., 2006).

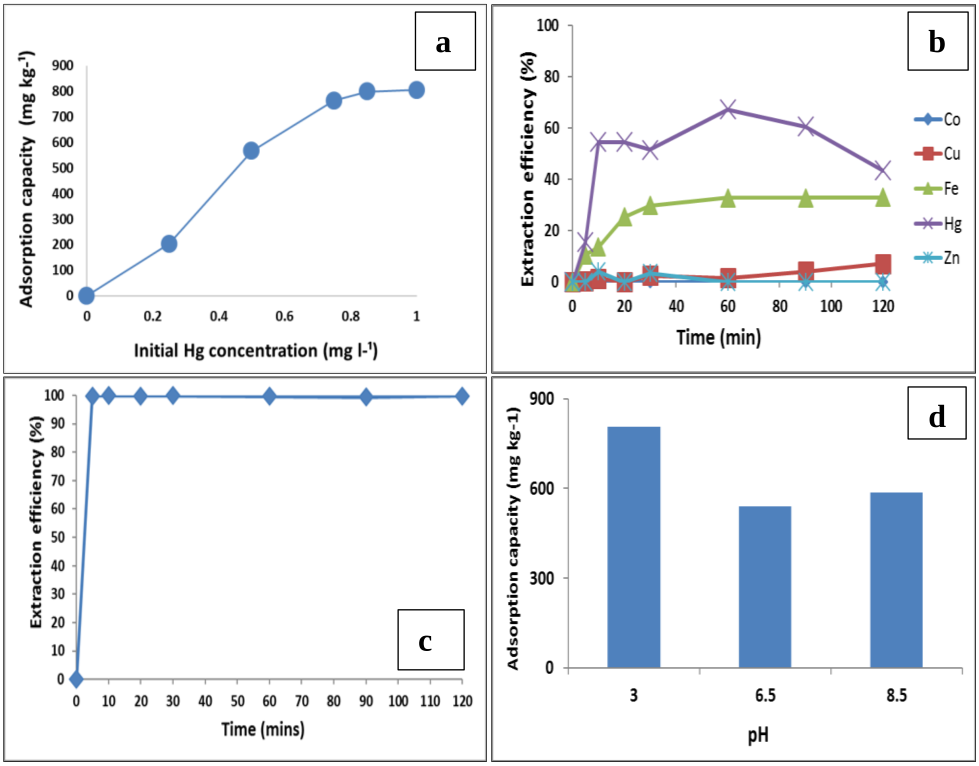

Figure 1. Effect of (a) pH (b) contact time (c) initial concentration (d) competing metal cations

3.5 Kinetic modeling

The kinetics of the adsorption of Hg^{2+} onto algae was investigated using the pseudo 1st and 2nd order models (Table 1). The pseudo-2nd order mechanism showed the best linearization with R^2=1. Thus, chemisorption was the rate limiting step in the interaction between Hg^{2+} ions and *Cladophora* sp. In addition, the calculated adsorption capacity (q_e) for the pseudo 2nd order model was 833 mg kg^{-1} and this was very close to the experimental value of 805 mg kg^{-1}.

Table 1. Pseudo 1st and 2nd order model results

Pseudo 1st order model			**Pseudo 2nd Order model**		
R^2	**k_1 (min^{-1})**	**q_e (mg kg^{-1})**	R^2	**k_2 (kg mg^{-1} min^{-1})**	**q_e (mg kg^{-1})**
0.92	0.01	1.06	1.00	0.29	833.00

3.6 Adsorption isotherm models

The data obtained from the study of the effect of initial Hg^{2+} concentration was used to fit both the Langmuir and Freundlich equilibrium isotherm models as shown in Table 2. The Langmuir equilibrium isotherm model best represented the results with an R^2 = 1.00 compared to R^2 = 0.02 in the Freundlich isotherm. The maximum adsorption capacity (q_m) of *Cladophora* sp. assuming a monolayer surface was found to be 1010 mg kg^{-1}.

Table 2. Coefficients of Langmuir and Freundlich isotherms

Langmuir isotherm			**Freundlich isotherm**		
R^2	**q_m (mg g^{-1})**	**B (l mg^{-1})**	R^2	**K_f (l g^{-1})**	**n (-)**
1.00	1.01	11.14	0.02	0.55	27.93

3.7 Batch reactor design

The mass of algae required to reduce the different initial mercury concentrations to the WHO standard of 0.006 mg l^{-1} increased with an increase in initial Hg concentration (Table 3). About 4.8 kg of *Cladophora* sp. per 1000-l batch is required to treat the water in Ngwabalozi River which has an initial Hg concentration of 0.31 mg l^{-1}. All R_L values obtained for Hg^{2+} adsorption onto algae were in the range of 0.08 to 0.26 (Table 3). These results show that favourable adsorption of Hg^{2+} will occur at the different model scenarios.

Table 3. Mass of algae required for the different model scenarios

C_O (mg l^{-1})	C_e (mg l^{-1})	b (l mg^{-1})	q_{max} (mg g^{-1})	Mass (kg)	R_L 1/(1+bCo)
0.25	0.006	11.14	1.01	3.85	0.26
0.31	0.006	11.14	1.01	4.80	0.22
0.50	0.006	11.14	1.01	7.80	0.15
0.70	0.006	11.14	1.01	10.96	0.11
0.85	0.006	11.14	1.01	13.33	0.10
1.00	0.006	11.14	1.01	15.70	0.08

4. Conclusion

Algae can be successfully used as a low cost but highly effective sorbent material for the removal of mercury from acidic waters. The observed rapid uptake of Hg^{2+} by algae at pH 3 suited well the intended purpose of the use of algae for Hg removal in Ngwabalozi River whose pH has also been reported to be 3. Furthermore, the shorter retention times observed (optimum time =10 mins) will result in huge operational cost savings during environmental applications. The abundance of *Cladophora* sp. in every season make them favorable in poor countries such as Zimbabwe. A high adsorption capacity of 805 mg Hg kg^{-1} algae was observed at the optimum pH of 3, for a concentration of 1.0 mg l^{-1}. A minimum and maximum mass of 3.9 kg and 15.7 kg of algae adsorbent is required for initial mercury concentrations of 0.25 mg l^{-1} and 1.0 mg l^{-1} respectively in a 1000 l- batch reactor.

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Health Risk Assessment of Nitrogen Dioxide and Sulfur Dioxide Exposure from a Developing Coal Power Plant in Thailand

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Abstract

Krabi coal-fired power plant is the new power plant development project of the Electricity Generating Authority of Thailand (EGAT). This 800 megawatts power plant is in developing process. The pollutants from coal-fired burning emissions were estimated and included in an environmental impact assessment report. This study aims to apply air quality modeling to predict nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) concentration which could have health impact to local people. The health risk assessment was studied following USEPA regulatory method. The hazard maps were created by ARC-GIS program. The results indicated the influence of the northeast and southwest monsoons and season variation to the pollutants dispersion. The daily average and annual average concentrations of NO_2 and SO_2 were lower than the NAAQS standard. The hazard quotients (HQ) of SO_2 and NO_2 both short-term and long-term exposure were less than 1. However, there were some potential risk areas indicating in GIS based map, the distribution of pollutions and high Hazard Index (HI) values were near the power plant site. Although this coal power plant is not constructed yet but the environment health risk assessment has been evaluated to be the information for the future coal plant development.

Keywords: health risk assessment; AERMOD; hazard map; coal fired power plant; Thailand; GIS

1. Introduction

The environmental impact of coal-fired power plant has been known as a major source of gaseous pollutants such as sulfur dioxide (SO_2), oxide of nitrogen (NOx), carbon monoxide (CO) and carbon dioxide (CO_2). The emissions contributed global warming phenomenon and directly cause of human unhealthy. The proposed coal-fired power plant received strong antagonism from the locals and non-government organizations (NGO). They claim that exposure of coal pollutants would threaten marine life and human especially harm to human health such as birth defects and gene mutations; cancer. (Finkelmana R.B., Orema, W., et al. 2002).

Therefore, the researcher needs to assessed health risk of population who living in the vicinity of a new krabi coal-fired power plant project because the crucial increasing of coal-consumption for power generation. This study is going to used air dispersion modeling to predict ambient air concentration of pollutants at particular receptor. In Thailand, American Meteorological Society/Environmental

Protection Agency Regulatory Model (AERMOD) has been accepted by department of pollution control as a tool to predict the pollution transportation in air for evaluated environmental impact. This method was similar practice to China (Zhao, Wang et al., 2010), Malaysia (Mokhtar, Hassim et al. 2014) and India (Kesarkar, Dalvi et al. 2007).Thus, this study is used AERMOD for prediction the dispersion of selected pollutants as Sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2). Secondly, Health risk assessment method of USEPA is used to evaluate heath risk from a model prediction data following four step as Hazard identification, Dose-response, Exposure assessment and Risk characterization. The EHIA is an Environmental Impact Assessment (EIA) with a health component included in the appraisal process. EIA has a defined methodology of its own, where health is often absent. EHIA goes against this trend by including health, as one component in the assessment. Normally, health assessment in EHIA includes health issues that can be measured, such as chemical and pollution exposure while focusing less on qualitative information such as community perceptions of health issues (WHO 2017).

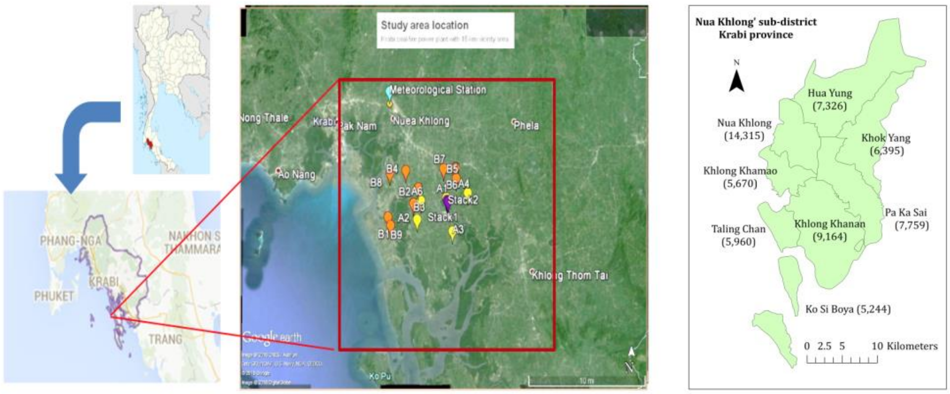


Figure 1. Study area location, covered 15 km radius from studied power plant (Left) and Nuaklong administrative sub-district location with the number of population in each sub-district (Right).

2. Materials and Methods

2.1 Study site

A new developed coal-fired power plant is located at KlongKanan sub-district, NueaKhlong district, Krabi province, covering an area of 200 acres, Figure 1. There are two communities within 5 km distance from this power plant; Khlongkanarn sub-district and Pakasai sub-district, including 18 villages within these communities . There are approximately population 14,000 people living in this area. There are two sub-district located within 20 km from power plant; Talingchan sub-district and Klongkhemao sub-district.

2.2 Descriptive of power plant

The new coal-fired power plant is planned to produce power 700 MW in addition to the old natural fuel oil 340 MW power plant. This new plant will use pulverized coal technology and high grade sub-bituminous with low sulfur content (EGAT 2014). This coal will be imported from Indonesia, Australian and South Africa by shipping through Andaman Sea .This new power plant unit could burn 7260tons coal per day or 2.3 million tons per year. Various air pollution control systems such as Electrostatic Precipitator, Flue Gas Desulphurization and Selective Catalytic Reduction were proposed to be installed to control particulate, acid gases and nitrogen oxide, respectively. Plant's specification was summarized in Table 1.

Table 1. A new-developed coal-fired power plant specification.

Parameter	Specification	
	The current fuel power plant	The new coal-fired power plant
Capacity (MW)	340	700
Number of stack	1	1
Stack height (m)	155	200
Stack diameter (m)	4.4	7.5
Stack velocity(m/s)	15.85	20.46
Exit gas temperature (K)	370	368
Flow rate gas (m^3/s)	241	733.34
Exit SO_2 rate (g/s)	145	53
Exit NO_x rate (g/s)	98	99

2.3 Air dispersion modeling

The American Meteorological Society Environmental Protection Agency Regulatory Model (AERMOD) modeling system used in this study was run with a commercial interface, AERMOD View (Version 8.8.9) (Lakes Environmental Software). The steps involved in AERMOD modeling are shown in Figure 2. The required meteorological data for AERMOD including wind direction, wind speed, ceiling height, total cloud cover, direct normal radiation and relative humidity were also obtained from measurement data by Thailand Meteorological Department. The input data, power plant emission in EHIA report, were provided by Electricity Generating Authority of Thailand. (EGAT 2016).

AERMOD is based on the steady state Gaussian dispersion equation. If the ground is taken to be the reference height ($z=0$), with the x axis of the co-ordinate system aligned along the wind direction at the source, empirical evidence indicates that the time averaged (typically one hour) concentration field can be described in terms of the Gaussian distribution. In this study, the pollutants ground level concentrations were generated from AERMOD by equation 1.

$$C_{(x,y,z)} = \frac{Q}{u} P_y\{y,x\} P_z\{z,x\} \quad (1)$$

Where: Q is the source emission rate,u is the effective wind speed, P_y and P_z are the probability density function (pdf) for the lateral and vertical concentration distributions, respectively.

2.4 Geographic information system

The Geographic Information System (GIS) has been used as a tool for hazard area identification (Teerapattarada, N., et al 2015). In this study, air pollution distribution and risk areas were mapping to compare short term and long term exposure risk areas. To measure distances, a geodesic calculator was used to convert Bath-Geo WGS84 projection coordinates (longitude/latitude) into the Universal Transverse Mercator (UTM) Zone 47(47N).Spatial data of stack's co-ordinates, predicted air pollution values from AERMOD, Exposure concentration and HI were prepared in spread sheet before upload in the GIS map using ARCGIS 10.2. The ordinary kriging running mode was selected for self-maps illustration (Childs, C. 2004).

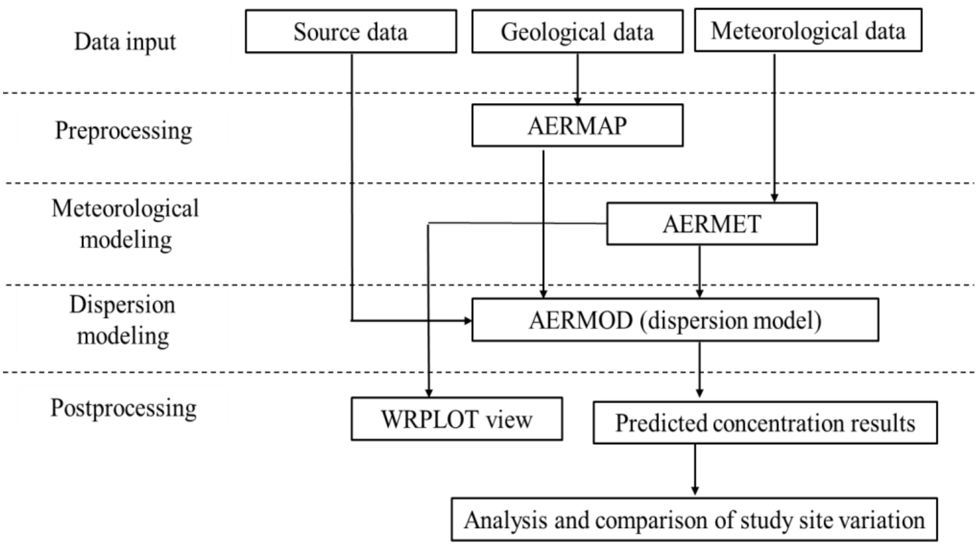


Figure 2. Flow in AERMOD modeling system.

2.5 Health risk assessment (HRA)

Inhalation Exposure concentration (EC_{inh}) is quantified as described in equation 2.

$$EC_{inh} = C \times ET \times EF \times ED / AT \tag{2}$$

Where: C: concentration of each pollutants, NO_2 and SO_2 ($\mu g/m^3$), were predicted from AERMOD; ET: exposure time (24 hours/day); EF: exposure frequency (350 day/year); ED: exposure duration (30 years); AT: average time (for non-carcinogens, AT = ED in years × 365 days × 24 hours/day; for carcinogens, AT= 70 years × 365 days × 24 hours/day)For non-carcinogenic health risk due to inhalation, risk characterization is performed by quantifying the hazard using the Hazard Quotient (HQ) equation (3) which is defined following the USEPA method (US EPA, 2009);

$$HQ = EC / RfC \tag{3}$$

$$HI = \sum \mathrm{HQ} \tag{4}$$

Where: EC = exposure air concentration ($\mu g/m^3$); RfC = reference concentration ($\mu g/m^3$). HQ of less than one (HQ <1) indicates that pollutant concentration is below the reference concentration (RfC) value whereby the potential risk is within acceptable levels. In this case, no action required to reduce the pollutant's level. Therefore, HQ < 1 is considered the area is not at risk. Nevertheless, it should be noted that HQ > 1 does not necessarily suggest a likelihood of adverse effects (US EPA, 2013). According to EPA's Integrated Risk Information System, IRIS report, RfC of NO_2 and SO_2 are not available (http://www.epa.gov/iris/subst/0080.htm) so we used WHO guideline values (WHO, 2006a) to calculate HQ by equation (3). To define the risk areas of NO_2 and SO_2, the hazard index (HI) is calculated from the sum of HQ as in equation (4). It is used to assess the overall potential for non-carcinogenic defects posed by more than one chemical. HI <1 indicates that there is no significant risk of non-carcinogenic effects. Conversely, HI >1 indicates the chance of non-carcinogenic effects occurring, with a probability of increasing health risk (US EPA, 2013a).

3. Results and discussion

3.1 The modeling results

The prediction results from AERMOD covered 15 km of radius a new developed coal-fired power plant including 2 stacks. One-hour average NO_2 and SO_2

concentration dispersion diagrams were represented in Figure 3 and Figure 4. Those diagrams are variated in wet season (May-October) and dry season (November-April), influencing by seasonal monsoon. In the wet season, pollutants are generally dispersed to the south of sources whereas the pollutants are obviously dispersed to the west of sources in dry season. Meanwhile, the diagrams illustrate dispersion of NO_2 and SO_2 in annual averaging time scale. However, the annual dispersion diagrams of both pollutants are likely dispersed in the same direction which are from the sources to the southwest.

In comparison of the maximum one-hour ground level concentration (GLC) of NO_2 and SO_2 in 15 km vicinity area, it was found that one-hour NO_2 concentration in wet season is 50.02 μg/m^3 and dry season is 48.83 μg/m^3, and one-hour SO_2 concentration in wet season is 135.00 μg/m^3 and dry season is 131.00 μg/m^3. For the annual average concentration, the maximum NO_2 and SO_2 GLC are 2.80 and 5.98 μg/m^3. The location of maximum concentration was found in the east of sources at 515870 N, 886561E (UTM system), which place out of selected sensitive area. When comparing predicted maximum ground level concentration with the National Ambient Air Quality limit, the highest ground level concentrations are very low and within the acceptable levels, as summarized in Table 2. However, when comparing to the standard from WHO guideline values, the maximum one-hour average concentrations of $SO_2$are slightly higher in the short-term concentration so that health risk assessment should be determined.

Table 2. Predicted maximum ground level concentration compared with WHO guideline values and The National Ambient Air Quality limit.

Pollutants	**1-hr average concentration (μg/m^3)**		**1-hr ambient air limit (μg/m^3)**	**Short-term concentration WHO guideline (μg/m^3)**	**Annual average concentration (μg/m^3)**	**Annual ambient air limit (μg/m^3)**	**Long-term concentrati on WHO guideline (μg/m^3)**
	wet season	**dry season**					
NO_2	50.02	48.83	320	400	2.80	57	40
SO_2	135.0	131.00	780	125	5.98	100	50

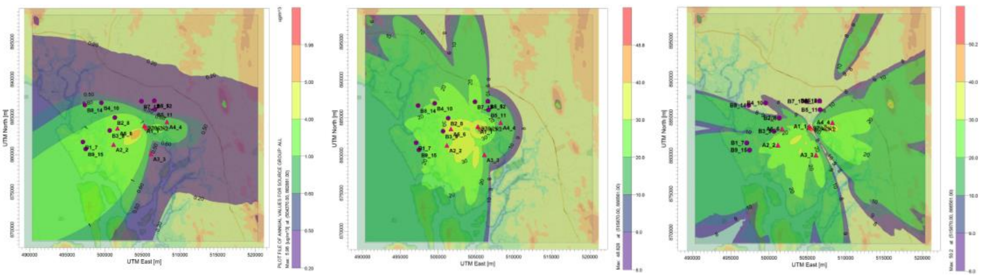
3.2 Health risk assessment

3.2.1 Hazard quotients

The HQs of NO_2 and SO_2 are calculated from equation 3. HQs of short-term (daily) and long-term (annual) non-carcinogenic health risks were shown in Table 3. All sites have HQ < 1 which could mean no potential adverse health effects exist during short term dispersion. The HQs of long term annual concentrations were within standard level and HQs were less than one.

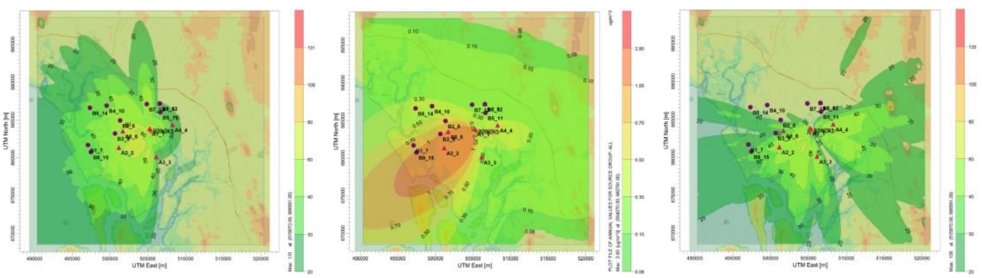
3.2.2 Hazard index

The hazard index (HI) summarized pollutants hazard quotient (HQs) of nitrogen dioxide and sulfur dioxide are computed to determine short-term (daily) and long-term (annual) non-carcinogenic health risks and showed in Table 4. Based on the hazard index (HI) obtained a potential for adverse health impact occurred during short-term dispersion of coal-fired power plant pollutants as the HI in any sensitive receptors are more than one. Short-term (daily) and long term dispersion showed acceptable level of pollutants concentration with hazard index (HI) less than one in all sensitive m. On the other hand, among 15 sites valuation A5 and B6 were performed less impact to health than the other sites due to located upwind position as shown on annual wind rose (Figure 5). Health risk estimation from coal power plant in other place also showed similar results.



a. One-hour average wet season b. One-hour average dry season c. Annual average

Figure 3. Dispersion of NO_2 concentration over Nua-khlong district, Krabi and vicinity.



a. One-hour average wet season b. One-hour average dry season c. Annual average

Figure 4. Dispersion of SO_2concentration over Nua-khlong district, Krabi and vicinity.

For example, Mokhtar 2014assessed health risk from exposure pollutants of coal-fired power plant in Malaysia. The air pollutants dispersion around their site study had a potential adverse health effects presenting in short-term exposure of sulfur dioxide (HQs) whereas the HQs value of Malaysia power plant were lower than Krabi power plant even though they have higher power generating capacity and coal consumption rate because Malaysia coal power plant located at location which meteorology difference as Krabi power plant located at clamed wind location. Hence, the comparison might be able to realize that a coal-fired power plant might be cause of human unhealthy in future

Table 3. HQs of short-term and long term exposure in Nua-khlong district, Krabi (WHO guideline SO_2 125 µg/m^3, NO_2 400 µg/m^3).

Risk Areas	**Name**	**Nitrogen dioxide (NO_2)**				**Sulfur dioxide (SO_2)**			
		Daily		Annual		Daily		Annual	
		EC (µg/m^3)	HQ	EC (µg/m^3)	HQ	EC (µg/m3)	HQ	EC (µg/m^3)	HQ
A1	Krabi power plant	6.79	0.07	0.21	0	14.33	0.51	0.43	0.02
A2	Kohpod village	5.91	0.06	1.67	0.02	10.9	0.39	2.99	0.11
A3	Ban khongwailek school	3.94	0.04	0.28	0	7.31	0.26	0.5	0.02
A4	Tungsakhon School	6.3	0.06	0.39	0	12.02	0.43	0.74	0.03
A5	Tungprasan village	2.75	0.03	0.19	0	4.64	0.16	0.35	0.01
A6	Huasok village	5.06	0.05	1.03	0.01	9.13	0.32	1.86	0.07
B1	Bankhlongrua school	3.48	0.03	0.81	0.01	6.07	0.22	1.43	0.05
B2	Klongkanarn temple	4.35	0.04	0.61	0.01	7.98	0.28	1.09	0.04
B3	Klongmark school	4.67	0.05	0.95	0.01	8.25	0.29	1.69	0.06
B4	Klongkanarn administration organization	3.19	0.03	0.35	0	5.54	0.2	0.61	0.02
B5	Pakasai village	3.54	0.04	0.25	0	6.02	0.21	0.45	0.02
B6	Tungprasarn hospital	2.76	0.03	0.19	0	4.66	0.17	0.35	0.01
B7	Nongpakcheak village	3.83	0.04	0.23	0	6.93	0.25	0.4	0.01
B8	Talingchan village	2.73	0.03	0.35	0	4.73	0.17	0.6	0.02
B9	Banklhongyuan school	3.68	0.04	1.02	0.01	6.49	0.23	1.81	0.06

Table 4: Hazard index of Pollutions in short-term and long-term.

Receptor	Name	Hazard Index (HI)	
		Daily	Annual
A1	Krabi power plant	0.58	0.02
A2	Kohpod village	0.45	0.12
A3	Ban khongwailek school	0.30	0.02
A4	Tungsakhon School	0.49	0.03
A5	Tungprasan village	0.19	0.01
A6	Huasok village	0.37	0.08
B1	Bankhlongrua school	0.25	0.06
B2	Klongkanarn temple	0.33	0.04
B3	Klongmark school	0.34	0.07
B4	Klongkanarn sub-district administration organization	0.23	0.03
B5	Pakasai village	0.25	0.02
B6	Tungprasarn hospital	0.19	0.01
B7	Nongpakcheak village	0.28	0.02
B8	Talingchan village	0.20	0.02
B9	Banklhongyuan school	0.27	0.07

3.3 Hazard map analysis

Evaluation of the interpolation method was used ordinary kriging method because of the best performance (Mitmark B. and Jinsart W.2016). Mapping the Hazard index of coal-fired pollutants from AERMOD modeling prediction was performed by ArcGIS. The results, the hazard map from ArcMAP ordinary kriging can describe the difference of hazard zone of pollutants exposure. The site distribution of hazard index (HI) in annual average wind rose was shown in Figure 5. HI of A2, A6 and B3where located within 5 kilometers' radius around emission sources may evaluate as high risk because of perceiving the highest coal-fired pollutants hazard index. These receptors may perceive higher pollutant concentrations than others due to non-distance from sources. Nevertheless, the annual average hazard index (HI) was acceptable risk for long-term exposure all area at Nua-khlong district because of the values less than 1. Although the annual exposure can be acceptable risk whereas the pattern of dispersion is resembling with dry season by the highest pollutants concentration present within 5 kilometers from emission sources. Consequently, these areas should be mark as some concerns levels of pollutants exposure.

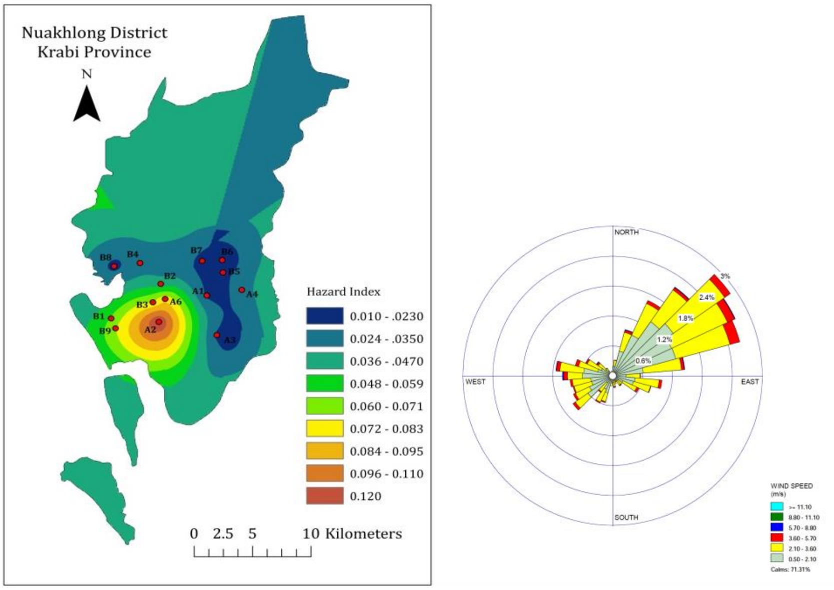


Figure 5. Site distribution of hazard index (HI) in annual average and annually wind rose, A1 represented power plant location.

4. Conclusions

The overall results and findings from this study aim to apply in health risk assessment to predict the impact from air pollution concentrations in Krabi province if the power plant has been operated in the future. The dispersion of emitted SO_2 and NO_2 from a new development planned coal-fired power plant, including two stacks were simulated by AERMOD. The forecasting results presented that the impact area from those pollutants were covered 15 km of radius vicinity area. The results of analysis indicated that the influence of the northeast and southwest monsoons result in pollutants dispersion in different seasons. The exposure concentrations (EC) were estimated from the AERMOD model. Therefore, the HI values are calculated from EC and its assumption. However, the assessment should be tested after the new power plant has been operated. Based on health risk assessment (HRA), the hazard quotient (HQ) was conducted to determine health assessment of nitrogen dioxide and sulfur dioxide exposure. As the non-carcinogenic health risk, a potential for adverse health risk was obtained by the HQs value >1 at any receptors. For the HQs of NO_2, and SO_2, these can be acceptable health risk at all receptors both short-term (daily exposure) and long-term (annual exposure) health effects. The risk areas were identified by hazard index (HI) and the impact sites were illustrated by Geographic Information System. These types of approaches and health impact illustrated maps area comprehensive strategy to the decision-making processes and the environmental management policy makers.

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Nutrient Removal Performance on Domestic Wastewater Treatment Plants (Full Scale System) between Tropical Humid and Cold Climates

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Abstract

Two full scale systems of oxidation ditch for domestic wastewater treatment plant (WWTP) were used as study sites: Phuket Province, southern Thailand (representative of tropical humid climate) and Plum Creek, Castle Rock, Colorado, United States of America (USA) (representative of cold climate). The treatment systems at both sites were designed for biological nutrient removal (BNR), extended activated sludge. Nitrogen is removed by nitrification-denitrification processes. The SRT for both treatment plants is ≥ 10 days as recommended by theory for complete nitrification in activated sludge wastewater treatment plant. Influents and effluents from these sites were compared and are discussed regarding flow rate, biochemical oxygen demand (BOD), organic nitrogen, ammonium, nitrate, total nitrogen, and phosphorus concentrations. High nutrient removal performances were found in both sites because there was sufficient carbon for denitrifying and phosphate accumulating organisms (PAOs). Furthermore, low dissolved oxygen concentration, long SRT, and high temperature could be key factors to promote the activity of some groups of bacteria to consume organic matter and nutrients in wastewater in the warm climate. For this reason, the plant design and operating procedures for wastewater treatment in a cold climate might not be always applied to a warm climate.

***Keyword**:* nutrient removal performance; Phuket wastewater treatment; Phuket; plum creek, Castle Rock; Colorado; USA

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1. Introduction

Nitrogen (N) and phosphorus (P) as nutrients from domestic wastewater are significant sources of water pollution. For this reason, these nutrients should be removed before they are discharged into the environment. The main concern is that these nutrients enhance eutrophication (algae bloom) of freshwater, lakes, estuaries, and oceans. Many nitrogen forms [e.g. ammonia (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-)] can have deleterious effects on aquatic life, human health, and the environment. The public health concern posed by nitrate is methemoglobinemia or blue-baby syndrome. Domestic sewage, agriculture, and industries are sources of N, but domestic sewage is the major source of this nutrient in Thailand (Noophan *et al.* 2007). In order to control excessive discharge of these nutrients, high efficiency treatment systems have been developed, but these are expensive to build and operate. Removal of both N and P from sewage could use a conventional biological nutrient removal (BNR) method, such as oxidation ditch, extended activated sludge, sequencing batch reactor treatment systems. However, removal of both P and N from wastewater solely with biological treatment might be difficult and quite complicated because bacteria do not convert phosphorus into a gas phase as they do with nitrogen.

The conventional approach for nitrogen removal in wastewater involves nitrification from NH_4^+ to NO_2^- on to NO_3^- followed by denitrification from NO_3^- to NO_2^- to nitric oxide (NO) to nitrous oxide (N_2O) and then to N_2 end product. The process of nitrification followed by denitrification is well known and is widely used for the treatment of municipal wastewater. The conventional approach for biological phosphorus removal employs phosphate accumulating organisms (PAOs) to effect anaerobic phosphorus release and aerobic or anoxic phosphorus uptake. Phosphorus is removed with sludge from the settling clarifier, making it quite difficult to remove phosphorus by using biological treatment (Sedlak 1991).

The goal of this study was to compare nutrient removal performance from two oxidation ditch WWTPs local in warm and cold climates. The Phuket WWTP was selected for study in a warm climate. For the cold climate Plum Creek WWTP, Castle Rock, Colorado, USA was chosen. The BOD:N and BOD:P ratios from influent in Phuket and Plum Creek WWTPs were calculated and compared with the theoretical optimum. Also, flow rate, BOD, ammonium, nitrate, total nitrogen, and phosphorus removals from these OD WWTPs were analyzed, compared, and discussed in terms of the design and operation of a biological nutrient removal system.

Oxidation Ditch Wastewater Treatment System

Oxidation ditch (OD) is often used for domestic wastewater treatment. However, the oxidation ditch system can also be used for industrial wastewaters. In theory, this treatment system can be designed for only organic matter removal or for both organic matter and nutrients. The oxidation ditch is a type of extended activated sludge for biological nutrient removal (BNR). The large tank volume and SRT $\geq$ 10 days are the keys to remove both organic matter and nutrients. Sufficient capacity is available to accommodate the nitrification and denitrification processes. The oxidation ditch system combines both anoxic and aerobic zones in a ring or oval-shaped channel. It is equipped with mixing devices in the anoxic zone (denitrification process) and mechanical aeration in the aerobic zone (nitrification process) (Alaya *et al.* 2010). Tchobanoglous *et al.* (2003) suggested that mechanical aeration/mixing should be used to create a velocity from 0.25-0.30 m/sec in the channel that is sufficient to keep the activated sludge in suspension. For this reason, the DO concentration should be decreases and maintained very low so that denitrification occur.

The OD system has many advantages, including the capability of removing organic matter and nutrients, consistent processing, quality effluent, simple and easy operation, low energy and chemical demand ability to treat shock loads, and low biosolids production. However, OD has some disadvantages, such as requiring a large footprint and/or huge structure, needing energy in aeration tank, and commanding a high initial investment. For these reasons, the oxidation ditch treatment system is not popular in huge cities, (e.g. Bangkok, Thailand) because there is not enough area to build this system.

Phuket Municipal Wastewater Treatment Plant, Southern Thailand

Phuket is a beautiful island in the southern part of Thailand. This island draws many tourists from around the world to enjoy the year-round tropical humid climate. The varied tourist businesses (guest houses, hotels, apartments, condominium, restaurants, etc.) are the main sources of domestic wastewater. Adequate biological nutrient removal from wastewater is very important for maintaining the beauty of this vacation destination to avoid any water pollution problems. The Phuket WWTP was selected to study in this research because there is high influent BOD as compared with BOD influent from other centralized WWTPs in Bangkok, Thailand. The main source of water pollution comes from domestic wastewater and also the nitrogen and phosphorus come from domestic sewage (Noophan *et al.* 2007 and Honda *et al.* 2010). The plant uses an oxidation ditch for wastewater treatment. The oxidation ditch in Phuket is capable of removing both organic matter and nutrients significantly. The plant was designed to treat around 28,000 m^3/day domestic wastewater.

Plum Creek Municipal Wastewater Treatment Plant in Castle Rock, Colorado, USA

The Plum Creek WWTP was selected to study because its configuration and operation are quite similar to the Phuket WWTP. Conversely, the weather in Colorado is cold in winter and only moderate in summer. This site can be used as representative of cold climate. The average of temperature for the whole year is around 16ºC. Moreover, in Colorado, there is always a shortage of water. For this reason, the effluent from wastewater treatment could be reused downstream. To facilitate reuse and to protect the environment, both nitrogen and phosphorus must be removed to very low concentrations. These removal requirements are quite similar to those in Phuket Thailand. The Plum Creek plant was designed to handle domestic wastewater to about 15,200 m^3/day.

2. Materials and Methods

2.1 Wastewater Treatment Sites for study between Warm and Cold Climates

Two oxidation ditch (OD) wastewater treatment plants (WWTPs) were selected for study: Phuket Province, southern Thailand and Plum Creek, Castle Rock, Colorado, USA. These were selected because of similar operation, domestic wastewater influent, volume capacity and other design parameters. However, the temperature of water at these WWTPs was not similar in summer and winter seasons. The performances of dissolved oxygen in anoxic and aerobic zones for both WWTPs were investigated by using DO meter (YSI model: 550A).

2.2 Quality of influent and effluent of wastewater quality

Influent and effluent wastewater quality was determined for the two WWTPs. Samples were collected every day for one year during 2013 and 2014. All samples were kept at 4°C until analysis. The quality of influent and effluent of wastewater was determined for biochemical oxygen demand (BOD), ammonium, nitrate, total nitrogen, and phosphorus according to *Standard Methods for the Examination of Water and Wastewater 1995*. Mixed liquor suspended solids from both anoxic and aerobic tanks were also analyzed. Temperature and pH were immediately measured in the field. The wastewater quality influent and effluent data from the two treatment plants were used to determine the efficiencies of both of N and P removals.

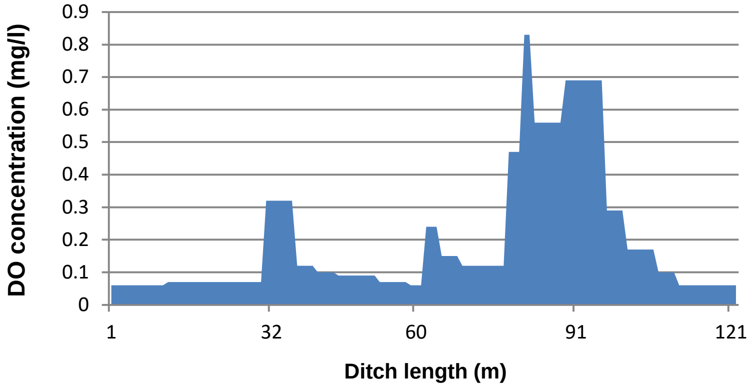
3. Results and Discussion

3.1 Performance of dissolved oxygen in both anoxic and aerobic zones in the Oxidation Ditch at Phuket and Plum Creek WWTPs

The operation modes of the dissolved oxygen in both anoxic and aerobic zones in the ODs at Phuket and Plum Creek WWTPs are shown in Figure 1. Plant operators at Phuket and Plum Creek tried to maintain dissolved oxygen in anoxic zone at 0.1±0.05 and 0.3±0.25, respectively. In the aerobic zone the plant operators tried to maintain dissolved oxygen around 1.2±0.4 and 1.7±0.5, respectively. Higher aeration zone dissolved oxygen is maintained at Plum Creek because this plant on online sensor equipment (such as DO controller, oxidation-reduction potential (ORP), NH_4^+, NO_3^-, and pH). The Phuket WWTP plant does not have these tools. The lack of sufficient supplied oxygen could be a significant issue in Phuket WWTP when a high loading comes into the plant. Insufficient oxygen would preclude conversion of NH_4^+ to NO_3^-.

Tchobanoglous *et al.* (2003) strongly recommended that SRT should be ≥ 10 days in aerobic zone of oxidation ditch for complete nitrification. For this reason, both plants were operated with SRT ≥ 10 days. In Phuket WWTP was operated to provide sufficient total SRTs for both anoxic and aerobic zones (30 days ≫ 10 days) including recirculation plus recycle flow in order to completely convert the NH_4^+ to NO_3^- in the aerobic zone.

(a) Phuket WWTP



(b) Plum Creek WWTP

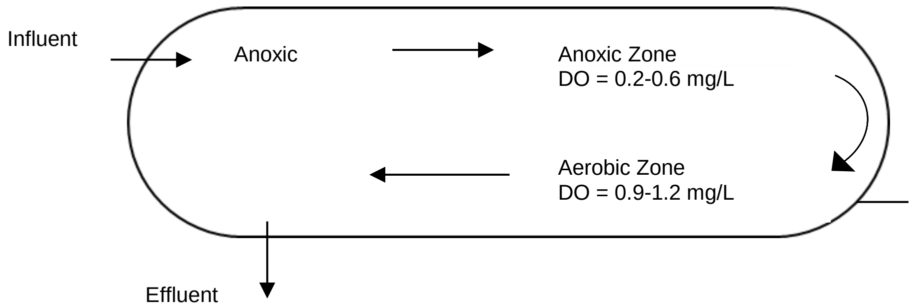


Figure 1. Schematic diagram of point aeration in the oxidation ditch at Phuket (a) and Plum Creek (b)

3.2 Design and operational parameters for the Oxidation Ditch WWTPs in Phuket and Plum Creek

For key design and operational parameters of oxidation ditch at Phuket and Plum Creek WWTPs are shown in Table 1.

Table 1. Some design and operational parameters for the Oxidation Ditch WWTPs in Phuket and Plum Creek

Parameter	**unit**	**Phuket**		**Plum Creek**	
		Aerobic	Anoxic	Aerobic	Anoxic
HRT	hour	24	24	19	5.7
SRT	day	15	15	12.3	3.7
DO	mg/L	1.2±0.4	0.1±0.05	1.7±0.5	0.3±0.25

3.3 Nutrient Removals Performance

Physical, chemical, and BOD, organic nitrogen, ammonium, nitrate, total nitrogen, and total phosphorus characteristics of influent and effluent at the Phuket and Plum Creek WWTPs are shown in Table 2.

Table 2. Characteristics of the oxidation ditch systems at the WWTPs in Phuket and Plum Creek

Parameters	Unit	Wastewater Treatment Plants	
		Phuket	Plum Creek
Treatment Process		OD	OD
Flow rate	m^3/day	28,735	15,160
Temp.	ºC	30	16
pH		7.2	6.7
BOD_{inf}	mg/L	174	336
$BOD_{eff.}$	mg/L	3.7	3.7
$NH_4^+{}_{inf}$	mg-N/L	15.9	35.8
TN_{inf}	mg N/L	25.3	56
$NH_4^+{}_{eff}$	mg-N/L	8.7	0.7
$NO_3^-{}_{eff}$	mg-N/L	3.2	3.2
MLSS	mg/L	7,180	2,330
TP_{inf}	mg-P/L	3.6	7
TP_{eff}	mg-P/L	0.9	0.3
Organic loading rates	Kg/day	5,000	5,094

All data values are average value through one year from 2103 to 2014

The BOD from Phuket WWTP is only about 25-30% that of the BOD from centralized WWTPs in Bangkok. Several factors may contribute to the low influent BOD to the Phuket plant as compared with the influent BOD to Plum Creek. First, each house or hotel, condominium, apartment, etc. in Phuket has a primary treatment system (such as septic tank, grease trap). Theoretically, the septic systems are able to remove some organic matter and BOD by about 40-50% Crites and Tchobanoglous 1998 and Sedlak 1991. Second, high wastewater temperatures may increase bacterial activity in sewage pipes. Third, infiltration and inflow could dilute the sewage. Finally, there are no food and garbage disposals to be dumped in wastewater. For these reason, the BOD at Phuket WWTP is lower than the BOD at Plum Creek WWTP.

3.4 Nitrogen and Phosphorus Removal Performances

High efficiencies of nitrogen and phosphorus removals in Phuket and Plum Creek WWTPs were found because of high influent ratios of BOD:N and BOD:P. In other words, there were sufficient sources or carbon for the denitrification and phosphate accumulating organisms. Nutrient removal efficiencies are shown in Table 3. Theoretically, appropriate BOD:N and BOD:P ratios for BNR should be higher than 4 (Renou *et al.* 2008) and 20-30 (Tchobanoglous *et al.* 2003). The influent ratios of BOD:N in Phuket and Plum Creek WWTPs were 6.9 and 6, respectively. The influent ratios of BOD:P in Phuket and Plum Creek WWTPs were 48.3 and 48, respectively.

Table 3. Nitrogen and Phosphorus Removal Efficiencies in Phuket and Plum Creek WWTPs

WWTPs	**Influent**		**Effluent**		**N Removal Efficiency**	**P Removal Efficiency**
	TN (mg N/L)	**TP (mg P/L)**	**TN (mg N/L)**	**TP (mg P/L)**		
Phuket	25.3±0.5	3.6±0.4	8.7±4.7	0.95±0.05	70-80%	72-75%
Plum Creek	56±5.5	7±1	7.1±2.8	0.28±0.07	80-90%	96-97%

All data values are average value through one year: (average±S.D.)

The nitrogen removal efficiency in Phuket WWTP was about 10-20% lower than nitrogen removal efficiency in Plum Creek WWTP. Also, the phosphorus removal in Phuket WWTP was 22-24% lower than phosphorus removal efficiency in Plum Creek WWTP. Solids retention time (SRT), hydraulic retention time (HRT), the recycle ratio of sludge, oxygen concentration, and temperature are possible factors affecting both N and P removals efficiencies in these WWTPs. Longer SRT (30 days) and HRT (24 days) were operated at Phuket WWTP. Oxygen concentration in aeration tank of Phuket WWTP (1.2 mg/L) was lower than oxygen concentration in aeration tank of Plum Creek WWTP (1.7 mg/L). Maintaining sufficient oxygen concentrations for nitrifying bacteria in aerobic zone (by using oxygen dissolved probe and DO controller) at Plum Creek is thought to be the main factor to account for high nitrogen removal efficiency at the Plum Creek WWTP. Occasional insufficient supplied oxygen for aerobic nitrification is likely the reason for incomplete NH_4^+ removal in Phuket WWTP, see Table 2 and Figure 1. The Plum Creek WWTP performance is consistent with an SRT $\geq$ 10 days, high recirculation plus recycle flows and sufficient oxygen to provide for complete nitrification and total nitrogen removal of > 90%. The sufficient recycle ratio would bring more nitrate as electron donor from aerobic tank to anoxic tank where organic matter can act as an electron donor so nitrate can be removed through denitrification. In Phuket WWTP, total nitrogen removal is over 70-80% because this OD system is operated at a sufficient SRT (30 days > >10 days) and recirculation plus recycle flow (because of oxidation ditch design) to completely convert the NH_3 to NO_3^- in the aerobic zone.

Despite varying conditions of operation in Phuket WWTP, such as lower dissolved oxygen in aerobic zone, longer solids retention time (SRT) and higher temperature, the nutrient removal at Phuket WWTP does not differ significantly from the nutrient removal at Plum Creek WWTP. Some of the common oxidizing bacteria could become acclimated, thus more active, with low dissolved oxygen concentration, long SRT, high temperature. It is noteworthy that Sinthusith *et al.* (2015) found the group of ammonia-oxidizing archaea (AOA) in Phuket WWTP but not at Plum Creek WWTP. Furthermore, Limpiyakorn *et al.* (2011) also found abundance of AOA in WWTPs in Bangkok. Almost all centralized WWTPs in Bangkok are operated at quite low dissolved oxygen in aerobic zone and temperatures of wastewater in these plants were significantly higher than Plum Creek WWTP. It is suggested that the activity of ammonia-oxidizing archaea (AOA) contribute to nitrogen removal efficiency at Phuket in this study.

The Phuket facility is a good example of a WWTP in a tropical humid climate that can significantly remove both N and P. In the influents to most warm climate WWTPs, there is not enough carbon sources (sufficient BOD concentration) for denitrification. For example, influents to most WWTPs in Bangkok have very low BODs (30-50 mg/L) which result in incomplete N and P removal (Noophan *et al.* 2009). It is common in the warm climate that BOD in domestic wastewater is quickly digested in the sewage pipe because the bacteria are so active at the higher temperature and sewage piping from point source to WWTP is very long.

The Plum Creek WWTP is a good representative for a cold climate facility because it can significantly remove NH_4^+. The NH_4^+ in effluent at this WWTP is quite low (0.7 mg N/L). In most cold climate WWTPs, low temperature can affect nitrification process because ammonium oxidizing bacteria cannot oxide NH_4^+ to NO_2^- well. Ammonium oxidizing bacteria oxide NH_4^+ to NO_2^- well when there is high temperature (around 30ºC) (Tchobanoglous *et al.* 2003). However, in Plum Creek there is sufficient oxygen to promote complete nitrification.

Furthermore, in both Phuket Province of Thailand and Castle Rock area of Colorado, not only is wastewater pollution a significant problem, but demand for water supply is also a pressing issue. To solve the problems of water shortage and wastewater treatment, stakeholders from the two fields must be encouraged to talk and work together. Otherwise, wastewater treatment problems cannot be solved and the supply of fresh water will not be realized. In the future, wastewater treatment and reuse will be universally important. The effluent from both WWTPs in this study could be used for wastewater reclamation. The oxidation ditch system might be recommended as a system to treat domestic wastewater in other areas.

However, the appropriate wastewater treatment system for each area, community, country, and region still must be determined and developed. However, the oxidation ditch might be one choice to select if tertiary treatment is needed and if there is enough area to build a plant. In Phuket Province and Castle Rock area, Colorado, tertiary treatment is significantly needed because the possibility for eutrophication still exists at water resources (e.g. lake, estuary, and ocean).

4. Conclusion

This study confirms that if the influent ratios of BOD:N and BOD:P at the municipal WWTP are higher than 4 and 30, respectively both N and P removed sufficiently with proper plant operations. The influent ratios of BOD:N and BOD:P in Phuket WWTP were 6.9 and 48.3, respectively. The influent ratios of BOD:N and BOD:P in Plum Creek WWTP were 6 and 48, respectively.

Significant N and P removals were found at the Phuket and Plum Creek WWTPs because there were sufficient carbon sources for denitrifying and phosphate accumulating organisms. The activity of some bacteria in warm climate can be promoted in surviving conditions such as low dissolved oxygen in aerobic zone, longer solids retention time (SRT), high temperature. Further studies might be needed to specify design parameters and operating conditions for warm climate WWTPs because many groups of bacteria can survive at high temperature and could promote different nutrient removal efficiencies.

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Adsorption of Cadmium (II) Ions from Synthetic Wastewater onto Fly Ash

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Abstract

Fly ash, a solid waste material obtained from MaeMoh themal power plant in Thailand, is used to investigate as an adsorbent for the removal of cadmium (II) ions from synthetic solution. As much as 99.97 % removal of cadmium is possible in about 24 h. The adsorption studies were carried out in a batch experiment using Atomic Absorption Spectroscopy (AAS) Technique, covering different process parameter such as the effect of contact time, amount of adsorbent and precipitation under constant stirring condition and an initial Cd (II) ions concentration. Amount of 20 g of adsorbent was sufficient for the optimum removal of Cd (II) ions. The material exhibits good adsorption capacity and the equilibrium adsorption data follow the Freundlich model better than the Langmuir model. Therefore, the removal mechanism of cadmium ions in the present study is followed adsorption.

Keywords: fly ash; adsorption; heavy metal; cadmium

1. Introduction

A serious environmental issue is toxic heavy metals contamination of water. Heavy metals are non-biodegradable pollutants and they are very difficult to eliminate naturally from the environment. Heavy metal ions are released into water from many industries such as mining, chemical manufacturing, battery manufacturing, plating, coating and pigment (Srivastava *et al.*, 2008). Cadmium is a toxic heavy metal of significant environmental and occupational concern. Cadmium has been classified as a human carcinogen and teratogen, impacting the lungs, kidneys, liver and reproductive organs (Waalkes, 2000). A number of acute and chronic disorders, such as ital-ital disease, renal damage, emphysema, hyper tension and testicular atrophy are harmful effects of Cd (II) (Tilaki and Mahmood, 2004). According to the World Health Organization (WHO) criteria, the permissible limit of cadmium in wastewater is 0.01mg/L.

The conventional methods to remove heavy metal ions from wastewater include chemical precipitation, ion exchange, solvent extraction, reverse osmosis, filtration and adsorption. However, the application of these methods restricted due to technical complexity and economical constraint. Adsorption process has been developed as one of the most common methods for the removal of heavy metals from wastewater because of its low cost, simplicity and high efficiency (Ruiz *et al.*, 2008; Gupta *et al.*, 2003; Pentari *et al.*, 2009). Activated carbon has been widely used in adsorption process to be a highly effective adsorbent, but the high cost of activated carbon restricts use for the removal of heavy metal pollution in developing countries. The application of low cost and easily available materials in wastewater treatment has recently attracted great interest. In recent years, Fly Ash has received considerable attention for the development of an efficient material as an adsorbent, clean and cheap technology for heavy metal removal from aqueous solution and soil (Mishra and Patel, 2009).

The Mae Moh power plant is the largest lignite coal-burning power plant in Thailand. The generation of electricity through combustion produces a huge amount of waste such as fly ash, bottom ash and boiler slag. Therefore, the utilization of fly ash as inexpensive adsorbents has also been widely attempted for flue gas cleaning (Davini, 1995; Kastner *et al*., 2002; Lu and Do, 1991) and removal of toxic metals (Ayala *et al*., 1998; Bayat, 2002; Dasmahapatra *et al*., 1996; Panday *et al*., 1985), dyes (Gupta *et al.*, 2004; Mohan *et al*., 2002), and organics (Aksu and Yener, 2001) from wastewaters.

The objective of the present study is to evaluate the efficiency of fly ash in the removal of Cd (II) ions from synthetic solutions by adsorption. Laboratory batch isotherm studies were conducted to determine the adsorption capacity of fly ash.

2. Materials and Methods

2.1 Preparation of Adsorbent

Raw Fly ash in this study was obtained from Mae Moh power plant in Thailand. It ware sieved to 200 mesh and dried in oven at 110ºC for 2 h the prepared material was keep in dry storage for further use.

2.2 Chemicals

All chemicals used were analytical reagent (AR) grade. Cadmium nitrate tetrahydrate ($Cd(NO_3)_2.4H_20$) was procured from Fluka, Switzerland. Nitric acid (HNO_3) was procured from Merck, India. Stock solution of Cd (II) was prepared by dissolving exact amount of Cadmium nitrate in distilled water. Ethylendiaminetetraacetic acid, EDTA were used to prepare solutions meant for dislodge the exchangeable of heavy metal.

2.3 Adsorption studies

The batch experiments were examined from 150 ml of the solution containing cadmium ions with an initial concentration of 10 mg/L with 30 g adsorbent (Mayura, 2014) in 250-ml conical flask. All experiment stirring on a shaker at 200 rpm for different contact time of 15 min, 1, 3, 6, 12, 24 and 48 h at room temperature. After adsorption, the solution containing metal was filtered through filter paper GF/C. The effect of adsorbent amount was obtained by varying it in the range of 1 g to 30 g with an initial concentration of 10 mg/L and 24 h as contact time. The residual concentration of cadmium ions was determined using an atomic absorption spectrometer (AAS) after HNO_3-H_2O_2 digestion and pH was adjusted to 3 with 2% HNO_3 for avoiding any precipitation.

In order to investigate the adsorption capacity, the percentage (%) of metal ions on the adsorbent was calculated by following equation:

$$\% = ((C_0 – C_e)/C_o) \times 100$$

Where, C_0 and C_e (mg/L) are the initial and final heavy metal ion concentration of the solution, respectively.

2.4 Precipitation studies

For this purpose, the stock solution of fly ash was prepared by mixing 200 g of fly ash in 1 L of distilled water and then filtered through filter paper GF/C for further use. The experiment was carried out from 500 ml of mixture solution on fly ash and the solution containing cadmium ions (concentration=10 mg/L). The mixture solution 150 ml was added in conical flask, stirring in shaker at 200 rpm for 24 h at room temperature. After experiment, the solution was filtered through filter paper GF/C and the supernant solution was determined using atomic absorption spectrometer (AAS) after HNO_3-H_2O_2 digestion. The pH was adjusted to 3 with 2% HNO_3 for avoiding any precipitation. Analyze the same as above to investigate the effect of precipitation under EDTA addition before run the test.

2.5 Adsorption Isotherm

Adsorption isotherm can explain the equilibrium relationship between adsorbent and adsorbate, and determine the maximum capacity of adsorption. The common isotherm models are the Langmuir and Freundlich isotherms.

The Langmuir isotherm is the simplest theoretical model, obtained under an assumption that the adsorption occurs at a specific homogeneous surface of the adsorbent. It is expressed as follow:

$$C_e/q_e = C_e/q_m + 1(q_m b)$$

Where, q_e (mg/g) is the amount of metal ions adsorbed on adsorbents, b is binding constant, q_m (mg/g) is equilibrium concentration of metal ins in solution.

The freundlich isotherm is an empirical equation which is used for the heterogeneous system and is expressed as follow:

$$\mathrm{Log}q_e = \log K + (1/n)\log C_e$$

Where, K is the indicative of the extent of the adsorption, and n is the adsorption intensity

2.6 Metal ion analysis

The concentration of metal ions were determined by atomic absorption spectrometer (Perkin Elmer Model 3110) using air acetylene flame. The metal standards prepared were checked with standard reference material obtained from the National Bureau of Standards (NBS), USA before each metal analysis and the deviation found was insignification.

3. Results and Discussion

This research is to investigate the possibility of using fly ash as an adsorbent for wastewater containing heavy metals, two set adsorption experiments of Cd (II) ions were carried out. The experiments were studied. Determination of the adsorption kinetics and the relationship between the adsorption of Cd (II) and Cd (II) with EDTA on fly ash at various time, were studied.

The effect of contact time on the removal of Cd (II) ions was shown in Fig. 1. The batch experiments showed that the adsorption rate increased rapidly at the beginning and then almost became linearly constant after 12 h. It can be observed that the equilibrium time was to be 24 h in the present work. The effect of pH on the solution increased with a further increase in time because additional fly ash.

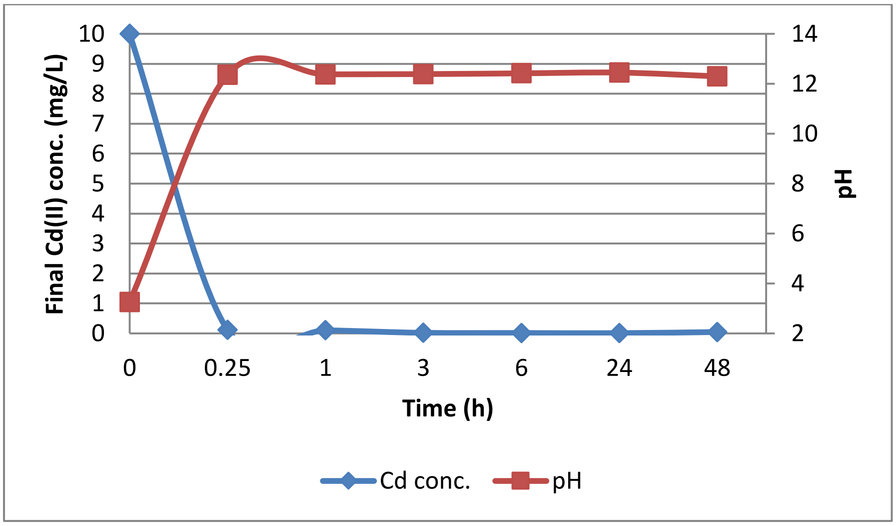

Fig.1. Effect of contact time and final pH on the adsorption of Cd (II) ions onto fly ash

Effect of contact time on the removal of Cd (II) ions with EDTA is shown in Fig. 2. It can be observed that amount of the concentration of Cd (II) ions on fly ash kept constant (linearly up to 0 mg/L.) with rise in contact time. The pH increased continuously. This can be proposed that all amounts of Cd (II) ions on fly ash were extracted and the precipitation cannot be occurred during test.

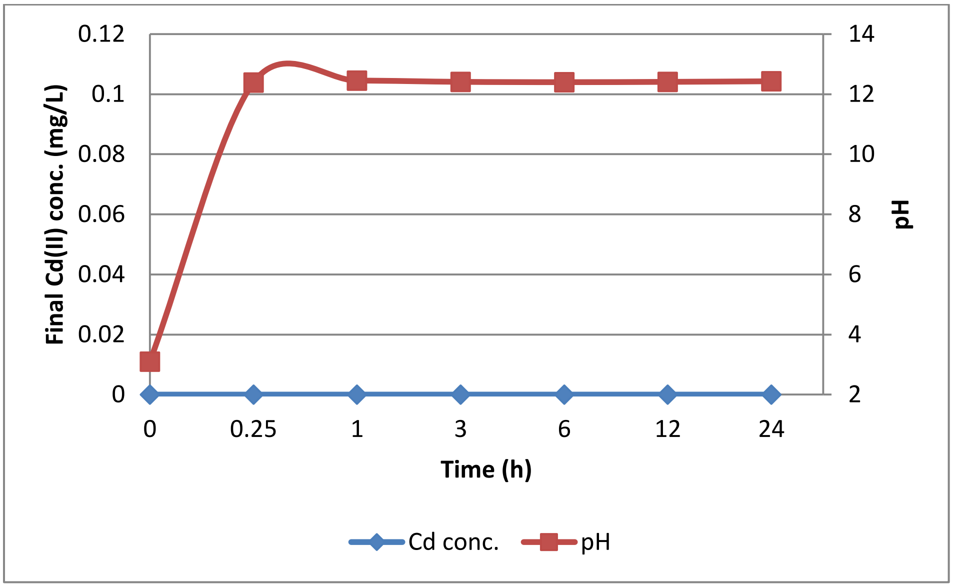

Fig.2. The removal of Cd (II) onto fly ash with EDTA

Effect of fly ash adsorbent dose on the removal of Cd (II) ions from synthetic solution with an initial cadmium concentration 10 mg/L for 24 h have been depicted in Fig. 3. It can be observed that amount of Cd (II) ions removed increased with the increasing amount of fly ash added and the final Cd (II) ions concentration in the solution decreased also.

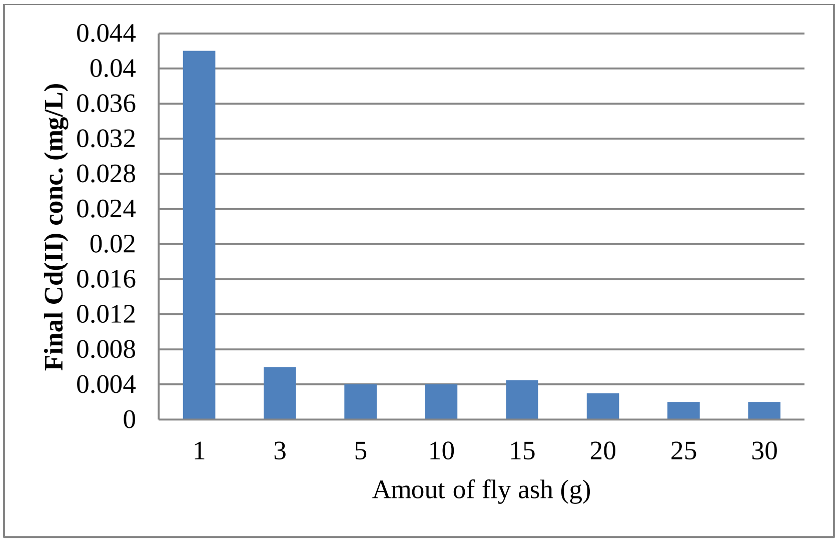

Fig.3. The effect of variation in the residual concentration of CD (II) ions removal from synthetic solution and final pH against amount of fly ash within 24 h.

Table 1. The effect of adsorption and precipitation of Cd (II) ions on fly ash

The experiment	Treatment	Final pH	Initial concen tration (mg/L)	Final concen tration (mg/L)	% removal of heavy metal
Adsorption	Cadmium+ 30 g of fly ash	12.49	10	0.006	99.94
	Cadmium+EDTA+30 g of fly ash	12.41	10	-0.006	0.00
Precipitatio n	Cadmium+Solution of 30 g of fly ash	12.46	10	4.075	59.25
	Cadmium+EDTA+Solution of 30 g of fly ash	11.97	10	0.047	0.00

During the adsorption on fly ash test the precipitation may be occurred, so the chemical precipitation could be studied. As shown in Table 1, the effective of Cd (II) ions removal and Cd (II) ions removal with EDTA was 99.94% and 0.00%, respectively. The effective of Cd removal on precipitation from the solution on 30 g fly ash was 59.25% and addition of EDTA was 0.00%, it can be observed that the removal kinetic of cadmium onto fly ash was obtained only adsorption.

The results obtained in batch adsorption experiment were fitted to Freundlich adsorption isotherm as shown in Fig. 4 and the coefficient of regression (R^2) were found to be 0.83

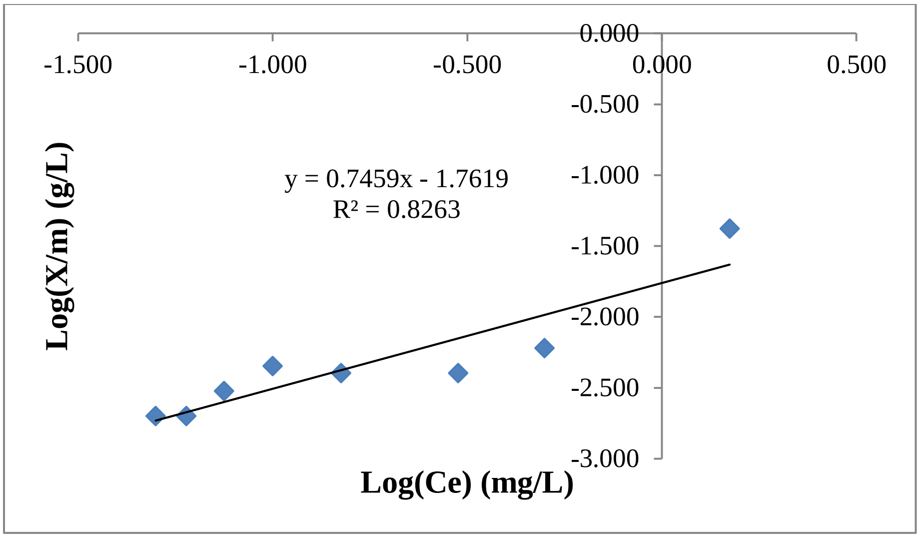

Fig. 4. Freundlich adsorption isotherm of Cd (II) ions from aqueous solution onto fly ash adsorbent.

Table 2. Langmuir and Freundlich constant for the adsorption of Cd (II) ions onto fly ash

Heavy metal	Langmuir Isotherm			Freundlich Isotherm		
	Q_m	b	R^2	K_F	1/n	R^2
Cadmium	9.99	3.26	0.01	0.02	0.75	0.83

As shown in Table 2, the value of adsorption capacity (K_F) was found to be 0.02 mg/g. It can be used as relative indicator of the affinity of adsorbent towards adsorbate.

4. Conclusion

The results suggest that fly ash can be use as an adsorbent for the removal of Cd (II) ions from the solution. The equilibrium contact time on the adsorption onto fly ash was around 24 h. The adsorption capacity increased with increasing time at room temperature. The optimum amount of adsorbent for removal of Cd (II) ions from synthetic solution was as 20 g. The percentage of removal efficiency was

99.97%. The adsorption equilibrium data fitted to Freundlich isotherm model more than the Langmuir Isotherm. Therefore, the coefficient of regression (R^2) of Freundlich isotherm was close to unity when compared with that of Langmuir Isotherm. This can be proposed that the adsorption occurred on heterogeneous surface of fly ash. Moreover, the adsorption of Cd (II) ions from synthetic wastewater onto fly ash was obtained only adsorption.

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Predicting Energy Consumption Using Artificial Neural Network (ANN): A Case Study in a Cold Store in the North Island of New Zealand

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Abstract

This study wasdeveloped to predict energy usage, based on the amount of fruit stored and environmental factors, using an artifitial neural network model (ANN) in a New Zealand cold store. In this study, after investigating several transfer functions and structures, an ANN model was developed to reduce margins of error in energy auditing projects in a ccold store. The final ANN model developed was based on weekly numbers avocado and kiwifruit bins and outside temperatures. The comparison between different models demonstrated the amount of stored fruits have more sensitivity than the outside temperatures in cold stores. Comparing actual and predicted energy usage in the studied cold store showed that the ANN model could be fitted to energy usage data and accounted for around 95% of the variance.

Keywords: energy saving; energy auditing; artifitial neural networks; cold store

1. Introduction

Concern about increasing energy costs and environmental impacts has significantly increased in recent years (Azhar *et al.*, 2010). Awareness about the best operation of constrictions is important for decreasing energy usage. Optimising the energy consumption of buildings needs to improve current energy monitoring and energy auditing systems (Juan *et al.*, 2010). In many energy auditing projects energy savings are quantified based on the current energy usage and the previous year's energy usage (Brandon and Lewis, 1999; Abrahamse *et al.*, 2005; Safa *et al.*, 2017). Because of different factors especially the environmental situations and changing occupation, energy consumption in different years could change significantly. Therefore, modelling energy consumption based on historical data can provide more accurate energy saving estimations.(Safa *et al.*, 2014). The main objective of this study was to develop a simple model to forecast cold store energy consumption to estimate energy savings during energy auditing projects.

Demand for cold stores is increasing with consumers'increased spending capacity. For example, in the U.S.A. the refrigerated storage industry is expected to grow annually by approximately 3.4% between 2014 and 2019 (Jones Lang LaSalle, 2014). At a global level the frozen foods market was forecast to increase from an estimated $165.4 billion, in 2009, to $199.5 billion by 2014 (Rogers, 2012). Refrigerated and frozen food are the majority (88%) of products stored in cold storage (Jones Lang LaSalle, 2014). However, refrigeration was similarly essential for other sectors, such as pharmaceuticals and petro-chemicals (Rogers, 2012).

According to Evans et al. (2014), there are around 1.5 million cold stores in Europe, including small stores with a capacity of 10-20 $m^3$to large distribution warehouses of hundreds of thousands of m^3. Cold chainscausearound 2.5% of total greenhouse gas emissions through energy usage globally(Guilpart, 2008). In a typical cold store 60-70% of the electrical energy is consumed for refrigeration (Evans et al., 2014).In comparison, 20-50% of household energy consumption, on average, goes into cooling houses and that accounts for 5-15% of the house owner’s carbon footprint (Sustainable Baby Steps, 2015).

The International Institute of Refrigeration (IIR) estimated that cold stores consumed between 30 and 50 kWh/m^3/year (Duiven and Binard, 2002). This energy consumption is likely to increase two-fold (Evans and Gigiel, 2007, 2010). There is mounting pressure to reduce energy usage in cooling systems, as it might help save money and decrease carbon footprint outputs(Sustainable Baby Steps, 2015). In fact, reducing energy consumption in cold stores isconsiderable (Evans et al., 2014). This calls for an appropriate strategy that keeps the product cold at a reasonable cost (Rogers, 2012).

Energy saving in cold stores has been investigated in a few projects. The performance of 38 cold stores were inspected in an European research project,to understand how much energy could be saved, areas of common problems and the opportunities that could be implemented to reduce energy usage(Evans et al., 2014). Some of the important factors that neededinvestigationto save energy consumption included air flow, variable speed drives, heat conduction transfer (Mulobe and Huan, 2012), control parameters (Zhang et al., 2009), condenser design (Liu et al., 2010), design of cold store docks (Zhang, 2011)and free cooling systems (Al-Salaymeh and Abdelkader, 2011).

Current information, however, regarding energy savings in cold stores in inadequate. One of the most comprehensive recent studies compared the performance of 34 cold stores in New Zealand. It was estimated that,on average, 15 and 26% of energy savings could be achieved by applying best practice technologiesin cold stores(Werner *et al.*, 2006; Evans *et al.*, 2014). Energy savings of 30–40% werereachable by optimising the energy consumption of cold stores, fixing current facilities and by replacing old facilitieswithmore energy efficient equipment (Evans and Gigiel, 2007, 2010).

Electricity usage has been analysed in several studiesusing different types of buildings. However, mostly because ofthe lack of advanced metering technologies in most primary energy modelling studies, monthly power bills were used to investigate energy usage in buildings (Kavousian *et al.*, 2013; Safa *et al.*, 2014).

For the first stepininvestigating energy consumption in cold stores, it was important to determine which parameters were most significant for energy usage. Kavousian, et al. (2013) categorised four main groups of factors in most buildings: weather and location, appliances and electronic stock, physical characteristics of the building, and occupation.However, Issacs, et al. (2010)categorised different sectores in theirstudy based on business sector and activities, staff numbers, client numbers and operating periods.Islam et al. (2013) categorised the main environmental factors that would affect the inside temperature and energy consumption in cold stores, including relative humidity (RH), outside temperature, watering and inside RH.

Energy use pattern in different buildingscould be totally different,based ontheir design, construction, occupation and activity, which made it very difficult to classify small numbers of them to represent the majority of similar buildings (Korolija *et al.*, 2013a; Safa *et al.*, 2017). A comparison of severalprojects showedthat environmental parameters would be the main parameters used in most studies for predicting energy consumption in most types of buildings. Temperature, humidity and lux levelswere the main environmental factors that directly affected energy usage in typical buildings (Gugliermetti *et al.*, 2004; Isaacs *et al.*, 2010). However, cold stores were usually insulated much better than other buildingsand had a minimum number of windows. Therefore, outside environmental factors would affect the energy consumption in cold stores less than in other buildings.

Predicting energy consumption in energy savingplans and sustainability projectswas a very important challenge. Several optimisation methods have been developed for energy consumption estimation and a variety of modellingtechniques have been establishedoverthe last decade (Mathews *et al.*, 2001; Rubinstein *et al.*, 2001; Roche and Milne, 2005; Wang *et al.*, 2005; Magnier and Haghighat, 2010; Mukherjee *et al.*, 2010; Pandharipande and Caicedo, 2011; Vakiloroaya *et al.*, 2011; Üçtuğ and Yükseltan, 2012).

2. Model

In this study, a cold store close to Tauranga in the North Island of New Zealand was studied (Figure 1). Horticultural production is the backbone of the district's economy. The warm, humid climate and rich soils provide great conditionfor kiwifruit, avocados and citrus fruit production. Energy usage was investigated based on the available historical weekly data. The cold store used had mostly been used to store kiwifruits pallets and avocado bins.

Multiple linear regression models (MLR)have been used more than other techniques to predict energy consumption in different types of buildings(Gugliermetti *et al.*, 2004; Catalina *et al.*, 2008; Neto and Fiorelli, 2008; Lam *et al.*, 2010; Athienitis *et al.*, 2012; Suganthi and Samuel, 2012; Catalina *et al.*, 2013; Korolija *et al.*, 2013b; Safa *et al.*, 2014). Compared with many nonlinear models,MLR models were easier to use and more practical foransweringthe various questions(Catalina *et al.*, 2013) that arose.While, in the past, regression analysis was the common modelling technique for energy studies, the use of neural networks (NN) has been on the rise (González and Zamarreño, 2005; Yang *et al.*, 2005; Karatasou *et al.*, 2006; Sözen, 2009; Safa and Samarasinghe, 2011b; Ahmad *et al.*, 2014; Safa *et al.*, 2017). Because of the power of NNs to model complex nonlinear systems in a flexible and adaptive manner, they are increasingly being used for solving a variety of scientific and engineering problems (Jebaraj and Iniyan, 2006). Their primary advantage is their ability to use existing information (historical data related to underlying processes) to develop an accurate representation of the process or relationship of interest (Safa and Samarasinghe, 2011a). However, since NN architecture differs from the architecture of a microprocessor, ANNs must be produced as specific replicas, which makes developing a large neural network very time consuming (Ahmad *et al.*, 2014).

Figure 1. Site location of the cold store investigated on the map of New Zealand

When the input is processed by the network, each neuron in the first layer (hidden layer) runs the weighted input values through a transfer function in order to produce the output. Transfer functions, which may be either linear or nonlinear, include logistic, hyperbolic tangent, Gaussian, and sine versions. The output, which is dependent on the particular transfer function used, is then sent to the neurons in the next layer through weighted corrections. These neurons then complete their output by processing the sum of the weighted input values through their transfer functions. When this layer becomes the output layer, the output of the neurons is the predicted output of the model (Hornik *et al.*, 1989; Heinzow and Tol 2003; Jebaraj and Iniyan, 2006; Safa and Samarasinghe, 2011b).

The model was in a nonlinear form to represent the link between the out put and the input variables. After running the model, predictions on the data were estimated. In this study, the model wasdeveloped with a minimum possible number of variables,to capture energy consumption in as simple a form as possible. After investigating several variables, outside temperature and number of stored kiwifruit and avocado binswere selected as the independent variables with which to develop the models. The weekly temperature was collected from a national weather database (NIWA) and property managers provided the number bins.

Several methods of error estimation were proposed. The mean square error (MSE) over all the training patterns (Eq. 1) was the most commonly used error indicator. MSE was very handyfor comparing different models; as it showeda network's capability to predict the output variables. The MSE can be written as:

$$MSE = \frac{1}{2N}\sum_{i}^{N}(t_i - z_i)^2 \qquad (1)$$

where t_i and $z_i$were the actual and predicted outputs for the i^{th} training pattern, and N is the total number of training patterns (Samarasinghe, 2007; Catalina *et al.*, 2013). The root mean square error (RMSE) was another error estimation method, which showed the error in the units of the actual and predicted data.

In most studies, a feed-forward multi-layered perception (MLP) paradigm, consisting of one or more inputs, hidden layers and an output layer trained by back propagation learning method (BP), have been used (Hornik *et al.*, 1989; Heinzow and Tol 2003; Jebaraj and Iniyan, 2006). In the processing of inputs by the network, each neuron in the first layer (hidden layer) processes the weighted inputs through a transfer function to produce an output. The transfer functions may be a linear or nonlinear function. Some popular transfer functions include: Logistic, Hyperbolic-tangent, Gaussian and Sine. The output of a neuron depends on the particular transfer function used. This output is then sent to the neurons in the next layer through weighted connections and these neurons complete their outputs by processing the sum of the weighted inputs through their transfer functions. When this layer becomes the output layer, the neuron output becomes the predicted output. After testing different the learning algorithms, neuron activation functions and network structures, a modular network with two hidden layers was developed, as shown in Figure 2. In the modular network structure, the model was characterised by a series of independent neural networks after the input layer, which operated on the inputs to achieve several subtasks of the task the network expected to perform. These subtasks were trained separately using different examples from the samples and their outputs were summed in the output layer. This structure of the model made it possible for the network to simultaneously use different neuron activation functions. In the final model, a Sine function was used for the input layer;a linear function was selected for the output layer , also aSine function was used in the first hidden layer, and a GaussBell was applied for second hidden layer (Figure 2).

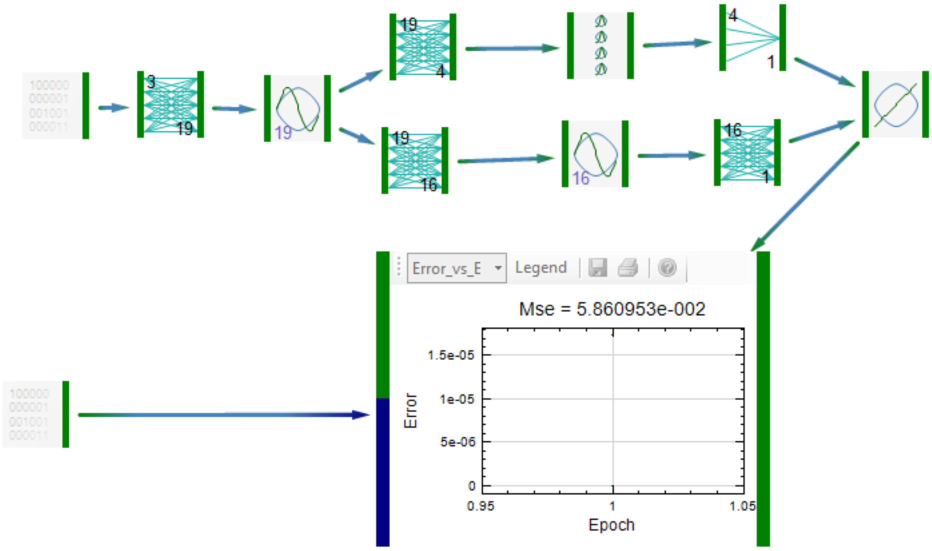

Figure 2. Structure of the modular network and number of neurons in each layer

In this study, several models with different input variables were developed and compared to find the best fit between the predicted data and the actual data. As shown in Figure 2, the final model was developed based on 104 weeksof available historical data.It was notable that the model developed,based only on outside temperature and number of stored kiwifruit pallets and avocado bins,was accurate with a very high correlation coefficient between the actual and predicted energy usage.

3. Results

The results showed that the weekly energy usage in cold stores can be predicted by the outside temperature and the numbers of stored pallets. The energy usage mostly depended on the number of kiwifruit pallets and the number of avocado bins. The low usage in summer would be influenced mostly by the harvesting season for avocado and kiwifruit. It should be noted that energy usage in the cold stores would also be affected by a number of other parameters. Figure 2 shows that the predicted and actual data matched in most cases.

Several different models were developed to find the best model to predict energy usage based on the numbers of kiwifruit pallets, numbers of avocado bins, and the outside temperature.The final ANN model was developed based on available weekly data overalmost two years. The results show a final ANN model could be fitted to the energy usage data and estimated approximately 95% of the variance (Figure 3).

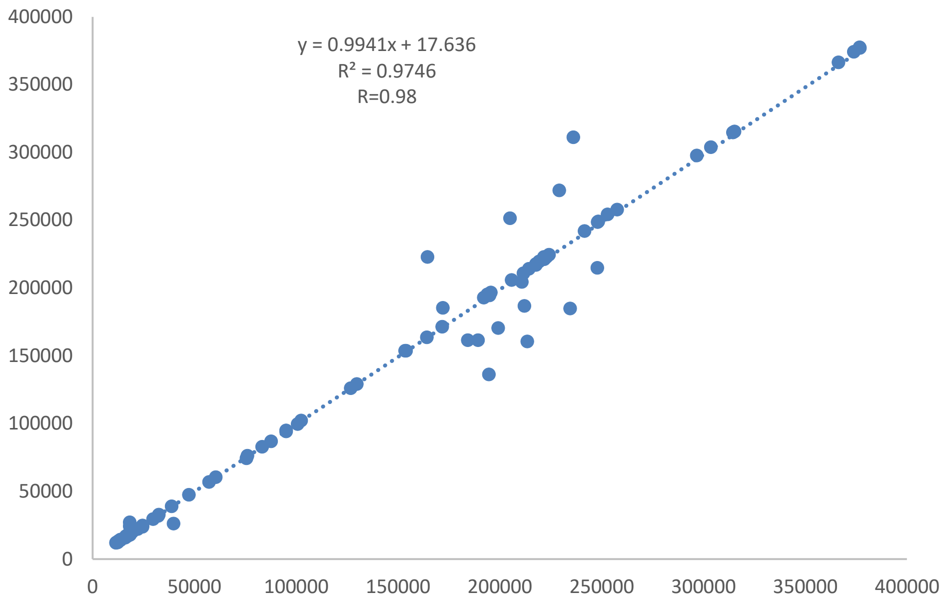

Figure 3. Relationships between observed and predicted energy usage

Figure 4 shows the how actual and predicted data matched together. It appeared the main difference would be in the peaks of energy usage. It was clear that the predicted and actual data were correlated significantly and the ANN model can predict energy use with an acceptable error. Figure 4 present the capability of a perfect ANN model to predict energy usage with minimum input variabels.

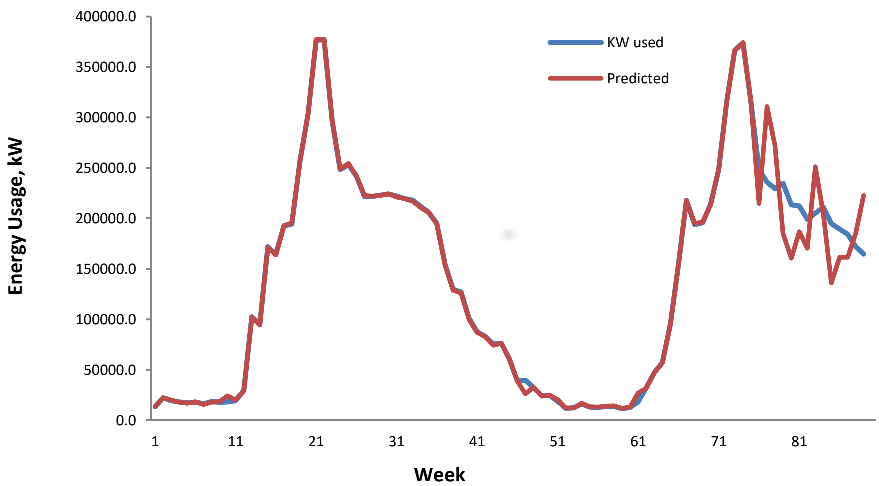

Figure 4. Actual and predicted energy usage during 90 weeks project

As mentioned before, few models with different input variables ans structures have been investigated. These models; however, showedthat the stored bins would be the most important factors affecting energy usage in cold stores. Moreover, the outside temperature, even in fully insulated cold stores, would also be an important factor. The ANN model could be fitted to the energy usage andestimatedbetween 98%, of the variance. The final MSE and RMSE were calculated as 148183455.7, and 12173 kW.h, respectively.

The high sensitivity forthe numbersof stored bins showed it would be too difficult to develop a model estimate even forsimilar cold stores. The final ANN modelaccurately compared the actual and predicted energy usage and estimated energy auditing in buildings.

4. Conclusion

This study presented anenergy prediction method to estimate energy savings in cold storesshould be investigated based on different factors. The results showedthat the ANN model with basic inputvariablescan predict energy usage within acceptable errors. The accuracy of the historical data would be a critical factor in developingamodel with a minimum margin of error. The main challenge of this method was finding accurate data overan acceptable period of time. The models show stored fruits were the main factors for predicting energy usage in cold stores.

This ANN model can be used by owners, managers, and energy consultants to control and audit energy usage in cold stores. The method used in this study can be developed for other similar projects. Future studies to compare other modelling methods and other input variables is strongly recommended. However, the study show each cold store is a very unique project and should be investigated indivisually.

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An Investigation of Urban Cool Island in Bangkok and Its Possible Causes

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Abstract

This study examines a number of aspects of urban heat island (UHI) in Bangkok, with a focus on urban cool island phenomenon. Observed 3-hourly temperature data from two surface weather stations (urban and rural) were used, covering the period of 10 years (2006-2015). It was found that UHI intensity (UHII) varies diurnally with similar patterns in both seasons. UHII is relatively high during nighttime and relatively low during daytime. Dry-season UHII is approximately normally distributed but wet-season UHII is slightly heavy-tailed to the left of distribution. To look into UCI more closely, UHII was partitioned into 3 cases (UHI ≥ 0: non-negative, UHII < 0: mildly negative, and UHII < –1: largely negative). Negative UHII is present at all hours and becomes most intensified in the mid-afternoon (16 LT) in both dry and wet seasons. The times of day at which (very) negative UHII events found most (about 90% or larger, of all events) are 10-19 LT, with the peak time found at 16 LT. To examine the roles of certain weather variables in negative UHII, the average values of each of cloud cover, rain, urban wind speed and found that the difference between the mean of cloud cover at the urban station and that at the rural station changes substantially for the dry season, i.e., consistently increasing from UHI ≥ 0, UHII < 0 to UHII < –1. The differences in mean for cloud cover between the two stations are statistically significant but no such substantial changes were seen in the other weather variables. These help suggest cloud cover as a potential controlling factor for negative UHII in the dry season. For the wet season, no suggestion can be readily drawn.

Keywords: urban heat island; urban cool island, cloud cover, temperature, urbanization

1. Introduction

Urban heat island (UHI) is a phenomenon where urban temperature is higher than rural temperature, and the degree of UHI is measured as the difference between urban and rural temperatures (Oke, 1973; Roth, 2013), i.e.,

$$\Delta T_{u-r} = T_u - T_r, \qquad (1)$$

where T_u is the urban temperature, and T_r is the rural temperature. UHII reflects the degree of urbanization and also how much local climate in a city is influenced by urbanization and heat emissions. The above temperature difference is technically referred to as UHI intensity (UHII). Different definitions of UHI have been proposed: surface UHI, canopy layer, and boundary layer (Roth, 2013). In this study, canopy UHI was applied, which uses near-surface air temperature within the urban canopy in comparison. Generally, UHI is intensified most during the night, between a few hours after sunset and before sunrise, in contrast to UHI, urban cool island (UCI) can occur, which is the phenomenon where rural temperature is higher than urban temperature (Roth, 2013). Chow and Roth. (2006) reported that the UCI occurs during daytime with higher magnitudes around noon. However, Rasul et al. (2016) reported that the UCI (based on land surface temperature) was higher in late morning than in the afternoon for the semi-arid city of Erbil, Iraq. Gaffin et al. (2008) examined trends in UHI in New York City and found the UHII spatially varies, with UCI occurrences over certain sites or areas. Bangkok, the capital of Thailand, is located in the central region of Thailand. Bangkok and its neighboring provinces (Nonthaburi, Pathumthani, Nakhon Pathom, Sumat Prakarn, and Sumut Sakhon) administratively form Bangkok Metropolitan Area (BMA), representing the largest economic center of the country. Urbanization in the BMA has continued with time, with Bangkok being the most urbanized as well as the other provinces rapidly developing. Thus, it is expected that Bangkok stores and emits a great amount of heat due to large infrastructures (buildings, housing, and roads) and relatively large energy consumption from various sectors. To the authors' knowledge, UHI for Bangkok have been studied but still in a limited manner (e.g., Boonjawat et al., 2000), and no studies have yet looked into UCI over Bangkok. In fact, UCI has not been much addressed and far less studied than its counterpart (UHI). These has essentially motived the current effort to examine whether UCI is present in Bangkok and, if yes, to what degree. Further, its characteristics for a number of aspects, including its variability at different time scales, frequency of its occurrence, and its potential causes, using observed (near-)surface air temperature (hereafter, temperature) data over recent years.

2. Study areas and temperature data

Geographically, Bangkok (13°45′ Lat. and 100°28′ Lon.) is situated in the central plain, the alluvial basin of the Chao Phraya River. Bangkok is also adjacent to the Gulf of Thailand to the south. The elevation is about 2.3 m above mean sea level (MSL) and does not vary greatly over the BMA. The climate of BMA is like most part of Thailand, which is influenced by two regional monsoons (southwest and northeast) (TMD 2017). The southwest monsoon brings about the wet season, spanning approximately from May to October. The northeast monsoon prevails during November-February, bringing cool dry air masses from mainland China and corresponding to the dry season. The dry season can be further divided into two parts: winter and summer. Winter spans from October to February. March-April, the transitional period of the monsoons, has a relative warm weather (i.e., summer), with April usually being the warmest month. During these two months, no strong influence from the two monsoons and the southerly winds from the Gulf of Thailand are generally dominant. Here, two weather stations in the BMA were considered for investigation, one (WMO 484550) is located in a highly urbanized area of Bangkok and the other (WMO 484510) in a rural area of Nakhon Pathom province (Figure 1).

Both are hereafter referred to as the urban and rural stations, respectively. The urban site is in a highly urbanized area of Bangkok. The rural site is in a green area of Nakhon Pathom, with much less development. In identifying the urban and rural sites, The amount of total designated built-up areas, based on a recent land use/land cover database of the Land Development Department (LDD, 2009), was also determined by a GIS (geographical information system) technique using a radius of 10 km from a station (as buffered area), which equals about 83% (as built-up) for the urban station and 22% (as built-up) for the rural station. A field survey and a satellite image examination (using Google Earth) were also conducted to assess the overall background of each station. The urban background is generally a business area surrounded by buildings, houses, parks, and streets whereas the rural background is generally an open green area. A fish-eye photo was also taken at each station at a height of 1 m above ground. Sky-view factor, defined as the ratio of sky area received by a planar surface from the sky to that received from the entire hemispheric radiating (Svensson, 2004), was estimated, which equals about 60% for the urban station and 80% for the rural statio. The weather data at the two stations includes temperature, rain, cloud cover and wind speed, obtained from the Thai Meteorological Department (TMD) and the National Centre of Environmental Information (https://www.ncdc.noaa.gov/isd). The data have a three-hourly resolution and cover a period of 2006-2015. Quality checking were performed after data compilation, e.g., removing implausible values and reviewing basic descriptive statistics. In any statistical computation, non-missing valid values must be present by more than 20%.

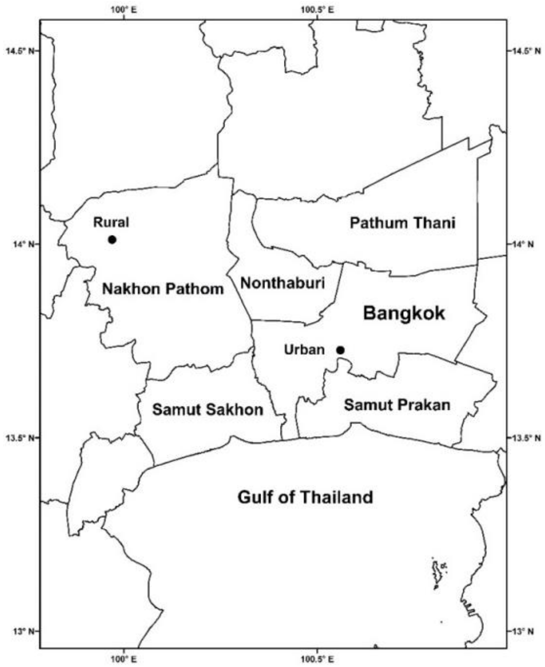

Figure 1. BMA, including Bangkok and its neighboring provinces. The filled circles denote the urban and rural stations considered in the study.

3. Results and Discussion

The diurnal variations of UHII (average over all years) in the dry and wet seasons are shown in Figure 2. The patterns in both seasons are similar. UHII is relatively high during the night and relatively low during the day. In the dry season, UHII gradually increase over late nighttime hours and peaks at 7 LT. As the day continues and solar intensity increases, temperature at both stations increases. As a result, UHII decreases and becomes lowest at 16 LT. In the wet season, UHII is lowered at all hours, and near-zero and negative UHII (in terms of average) is also observed at 16 LT. Notice that, during 7-10 LT, UHII decreases with a faster rate for both seasons, which may be attributed to certain potential factors. Firstly, greater heat could be stored in the urban area and it would take a longer time for urban temperature to increase. Secondly, given the smaller sky-view factor at the urban station, incident solar radiation may be significantly mitigated for the urban area during 7-10 LT (when solar altitude is still not large time) because solar radiation could be blocked or obscured more effectively by manmade objects and buildings. Given the above results, it is of further interest to specifically look into the diurnal variation of negative UHII. In doing so, UHII was partitioned into 3 cases (UHI ≥ 0: non-negative, UHII < 0: mildly negative, and UHII < -1: largely negative), each of which was then averaged for each hour over all years. For both seasons that negative UHII occurs at all hours and becomes most intensified in the mid-afternoon (16 LT) (Figure 3). Notice that the diurnal patterns of negative UHII are not much different in both seasons, with the ranges of 0-2ºC (in magnitude). As for frequency of occurrence (Figure 4), dry-season UHII is more or less normally distributed while wet-season UHII is slightly heavy-tailed to the left of distribution. Negative UHII (UHII < 0) occurs by 17% and 23% (of all hours) in the dry and wet seasons, respectively, and very negatively UHII (UHII < -1) occurs by about 10% (of all hours) in each season. The times of day at which (very) negative UHII events found most (about 90% or larger, of all events) are 10-19 LT, with the peak time found at 16 LT. However, they were found relatively limited in the nighttime and early morning (Figure 5). Accordingly, what are the potential causes for negative UHII occurring most often during 10-19 LT? The influences of cloud cover, rain, and wind speed were hypothesized. We then computed the average values of each weather variable, corresponding to each UHII case and found that the difference between the mean of cloud cover at the urban station and that at the rural station ($\Delta CC_{u\text{-}r}$) changes substantially for the dry season, i.e., consistently increasing from UHII > 0 to UHII < 0 to UHII < -1 (Figure 6). The differences in mean for cloud cover between the two stations are statistically significant (at a 0.05 level), based on the Mann-Whitney-Wilcoxon test. No such substantial changes were seen in the other weather variables (not shown). These help suggest cloud cover as a potential controlling factor for negative UHII in the dry season. For the wet season, no suggestion can be readily made given no distinct or substantial changes/differences found. Nevertheless, it is noted that the wet season corresponds to more rain, and the surface tends to be wet or moist more than in the dry season. Surface moisture, when present, and its time duration on the surface can regulate air temperature in a complex manner through surface energy balance directly, with less sensible heat and more latent heat.

Therefore, it is still difficult at this point to identify the potential factors of negative UHII in the wet season.

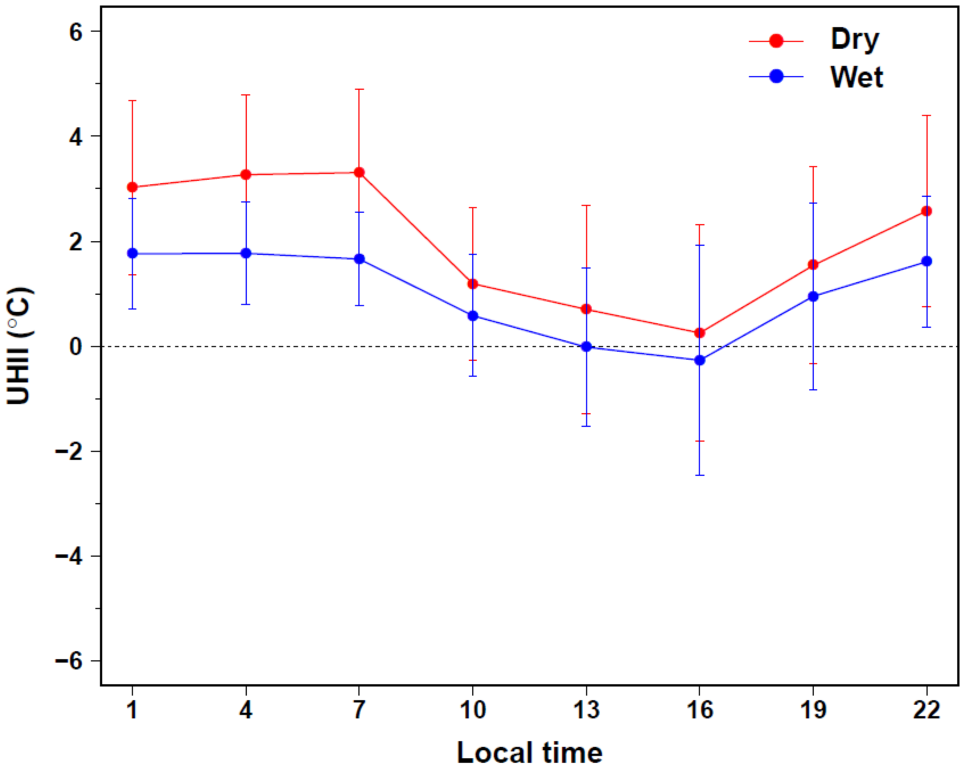

Figure 2. Diurnal variation of UHII by season, based on data in 2006-2015. Each vertical bar denotes standard deviation.

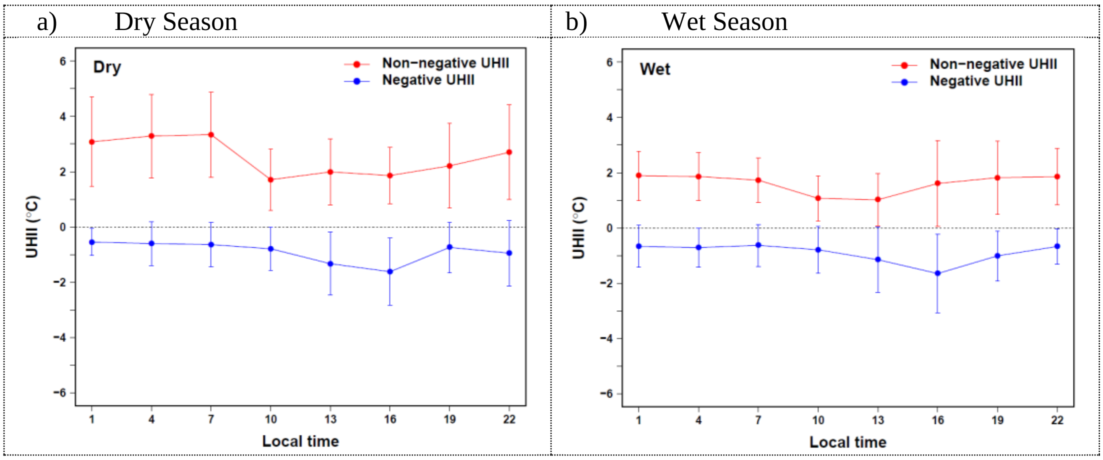

Figure 3. Diurnal variation of non-negative and negative UHII by season.

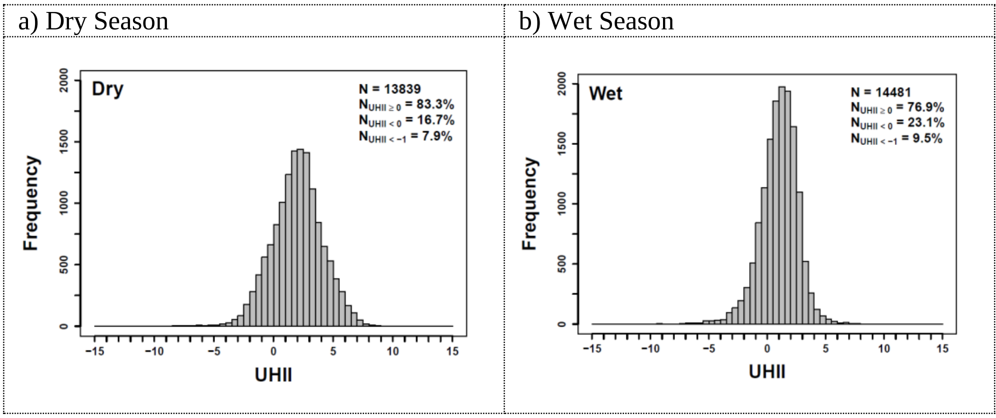

Figure 4. Histogram of UHII by season.

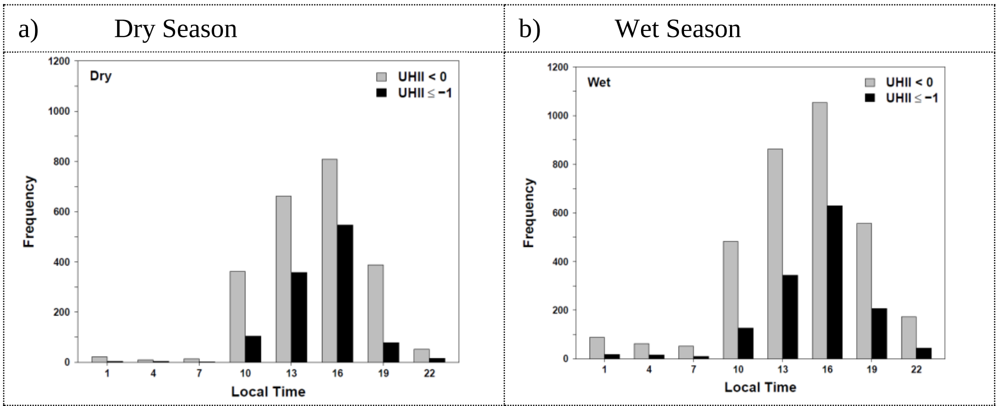

Figure 5. Diurnal variation of frequency of (very) negative UHII event by season.

4. Conclusions

Urban cool island (UCI) is the phenomenon where rural temperature is higher than urban temperature. In this study, we examined a number of aspects of urban heat island (UHI) in Bangkok, with a focus on UCI. Observed 3-hourly temperature data from two surface weather stations (urban and rural) were used, covering the period of 10 years (2006-2015). The urban station is in Bangkok, and the rural station is Nakhon Pathom. It was found that UHI intensity (UHII) varies diurnally with similar patterns in both seasons. UHII is relatively high during nighttime and relatively low during daytime. Dry-season UHII is approximately normally distributed but wet-season UHII is slightly heavy-tailed to the left of distribution. To look into UCI more closely, UHII was partitioned into 3 cases (UHI ≥ 0: non-negative, UHII < 0: mildly negative, and UHII < -1: largely negative). Negative UHII is present at all hours and becomes most intensified in the mid-afternoon (16 LT) in both dry and wet seasons. The times of day at which (very) negative UHII events found most (about 90% or larger, of all events) are 10-19 LT, with the peak time found at 16 LT. To examine the roles of certain weather variables in negative UHII, the average values of each of cloud cover, rain, urban wind speed and found that the difference between the mean of cloud cover at the urban station and that at the rural station changes substantially for the dry season, i.e., consistently increasing from UHI ≥ 0, UHII < 0 to UHII < –1. The differences in mean for cloud cover between the two stations are statistically significant but no such substantial changes were seen in the other weather variables. These help suggest cloud cover as a potential controlling factor for negative UHII in the dry season. For the wet season, no suggestion can be readily drawn. It is noted that this study is part of an ongoing research, and the results presented are thus subject to future detailed analysis.

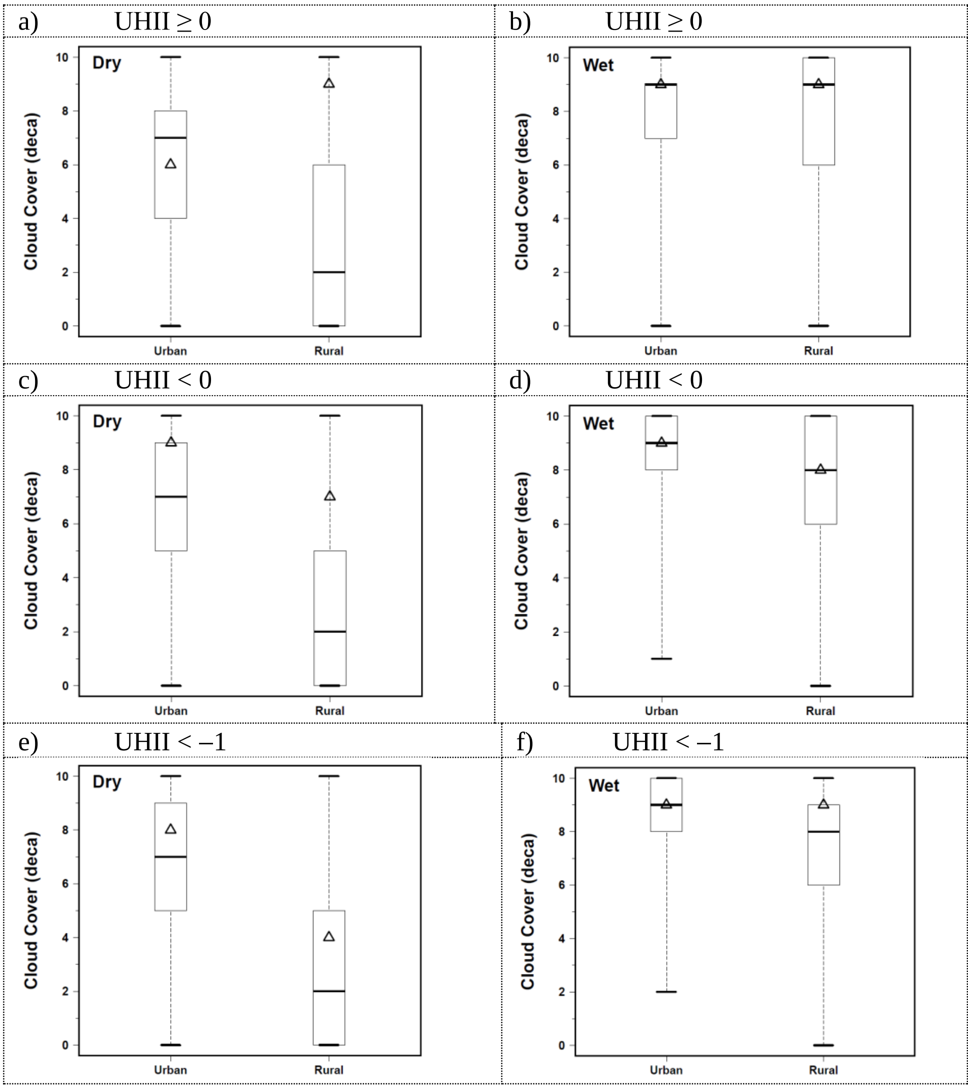

Figure 6. Box-whisker plots of cloud cover observed during 10-19 LT at the urban and rural stations by UHII case and by season. The top and bottom horizontal bars denote the maximum and the minimum, respectively. The top, middle, and bottom lines of each box denote the 3rd quartile, median, and the 1st quartile. Each triangle denotes the average.

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A New Mechanical Compressed Trash Can for Waste Volume Minimization

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Abstract

The amount of garbage produced of each day currently has more than the capacity of the trash can. One of the methods to solve the system for collecting solid wastes is to use the trash can which is able to increase the amount of waste discarding into the tank more in order to reduce the waste collection frequency. The objective of this research is to invent the mechanical compressed trash can to reduce the waste volume generated. Solid wastes in KMUTNB, Rayong campus were collected and analyzed the waste types. The operational performance of the compression of the invented trash can was investigated. The results showed that using the compressed trash can, compared with using the conventional trash can, could collect the wastes of plastic bags, plastic bottles and mixed wastes more than a 3.4, 2.0, and 2.1 times, respectively and contributed to reducing GHG emissions per year of waste collection vehicle to 70%, 50%, and 53%, respectively.

Keywords: mechanical compressed trash can; waste volume; waste minimization; waste collection

1. Introduction

Municipal solid waste (MSW) management in Thailand has long been considered as one of the most severe environmental problems. As the rapid population growth and economic development in Thailand, the quantity of MSW has also increased so that the current MSW generation rate was 1.14 kg/capita/day *(Pollution Control Department, 2016)*. Hence, in some places, the amount of garbage disposed of each day exceeds the capacity of the public trash cans. This causes an unpleasant smells from the garbage left in surrounding area, especially in the areas where are difficult to collect the MSW or to be rarely done, such as crowded area or tourist attractions, e.g., island, high mountain.

The collection of MSW is a public service that has important impacts on public health and the appearance of towns and cities (United Nations Human Settlements Programme, 2011). Thus, the inadequate collection of MSW trash can cause the accumulation of MSW at collection points and a great impact on the environment. This problem is mainly caused by costs of collection vehicle, labor, fuel, and operation.

In many areas of Thailand, the local governments improve their MSW collection by outsourcing to the private sector on contract basis. The waste collection services are either by door-to-door in dwellings or through the communal system in some areas where public trash cans are used for MSW collection. Nevertheless, many areas have still faced problems of 1) irregular frequency and inconstant schedule in waste collection, (2) lack of sufficient number of trash cans at collection points, (3) lack of proper maintenance of motor vehicle and (4) lack of motivation of workers. Furthermore, many local governments must have spent a huge budget to collect MSW because cost of MSW collection contributes over 70% of the total cost of MSW management (Coleman and Nghiem, 2010). The MSW management budget is mostly in fuel and labor cost (Bilitewski et al, 1997 and Tavares et al, 2009) and the most fuel-intensive process is in the step of waste collection (Jaunich et al, 2016).

One of the methods to solve the system for MSW collection is to use the compressed trash can that is designed to be able to increase the amount of waste discarding into the bin at waste site. This is beneficial from both economic and environmental standpoints (Coleman and Nghiem, 2010 and Vroom et al, 2016). By utilizing compressed trash can, it will help to reduce the waste collection frequency, reduce the fuel cost of waste collection vehicle, reduce the volumes of waste collected and sent to the landfills, and reduce CO_2 emission from the waste collection vehicle. This greenhouse gas (GHG) is emitted from the MSW collection vehicle varying based on factors such as truck type, fuel type, efficiency, and route characteristics. According to Perez et al. (2017), the carbon footprint of MSW collection vehicle in Spain using the difference fuel between compressed natural gas (CNG) and diesel were 25.1 kg CO_2 eq/$t_{MSW\text{- collected}}$ and 29.7 kg CO_2 eq/$t_{MSW\text{ collected}}$ respectively.

Currently, the compressed trash can with electrical system has been developed for using in house kitchen of high-income communities. For in public area, the compressed trash can with solar cell has been an emerging technology and been used mostly in the developed country. However, in the developing country, this is difficult for a local government to secure a budget to buy and operate such this trash can. For this reason the mechanical compressed trash can should be considered for working practically and a suitable choice of especially the area without electricity.

Therefore, this research aims to invent a new trash can without any electricity with a simple, safe and easy to use mechanical system to reduce waste volume. In addition, the releasing of greenhouse gases from waste collection vehicle for transportation to the final treatment comparing between using the invented trash can and the conventional trash can was studied.

2. Methods

2.1 Waste samples

Solid wastes in KMUTNB Rayong campus were collected and analyzed the waste types. The proportion of each waste type was calculated from weight of each waste type divided by total weight of all waste. We found that the waste composition of the campus had the highest proportion of food wastes accounted for 27% followed by 19% plastic bags, 14 % plastic bottles, 14% other plastics, 9% paper, 4% wood, 3% glass bottles, 1% metal, and 9% others. Food wastes were separated out for other utilization whereas other wastes were collected in order to reuse, recycle and finally be sent for further disposal. Some plastic bags and plastic bottles were separately experimented on the compression performance of the invented trash can. For mixed wastes used in experimental, they consisted of 26% plastic bags, 19% plastic bottles, 20% other plastics, 13% paper, 3% glass bottles, 5% wood, 2% meal, and 12% other wastes.

2.2 Mechanical compressed trash can

Figure 1 shows our compressed trash can which was designed and invented by considering with regard to the increase of waste amount discarding into the tank more, easy to use, safe, no electricity involved, and low cost. The mechanism of this trash compactor is a mechanical system using a crankshaft rotation. When the crankshaft is rotated, the shaft connecting to a plate slides down to compress the waste in the tank and this makes more space for waste collection.

The efficiency of waste compression is calculated from the difference of waste volume with no compression and waste volume with compression divided by waste volume with no compression and multiplied by 100. The ratio of waste compression of invented trash can is calculated from waste volume with no compression divided by waste volume with compression.

Fig. 1. Mechanical Compressed Trash Can (Thailand petty patent no. 12377)

2.3 Greenhouse gas (GHG) emission from waste collection vehicle

In order to compare the different of using the mechanical compressed trash can and the conventional trash can, the GHG emissions of the vehicle for the collection of plastic bags, plastic bottles and mixed wastes are separately calculated. The evaluation of GHG emission considers based on distance, waste loading per ton of waste collected and transported to the final treatments, and emission factor. The GHG emission of truck with no load is calculated by using equation 1 and for truck with full load the GHG emission is calculated by using equation 2.

Truck with no load:

$$\text{GHG emission (kgCO}_2\text{eq)} = \text{Distance (km)} \times \text{Emission factor (kg CO}_2\text{eq / km)} \quad (1)$$

Truck with full load:

$$\text{GHG emission (kgCO}_2\text{eq)} = \text{Weight of waste collected (ton)} \times \text{Distance (km)} \times \text{Emission factor (kgCO}_2\text{eq / tkm)} \quad (2)$$

Emission factors of the garbage truck when running with no load (0%) and with full load (100%) are 0.4892 kg CO_2 eq/km and 0.0472 kg CO_2 eq/tkm, respectively (MTEC, 2015). The diesel garbage truck with loading weight of 1.5 tons and garbage transport distance of 11.3 kilometers were used for calculation.
Percentage of GHG emission reduction is calculated from the difference of GHG emission of garbage truck resulting from waste collection in the conventional trash can and GHG emission of garbage truck resulting from waste collection in the invented trash can divided by GHG emission of garbage truck resulting from waste collection in the conventional trash can and multiplied by 100.

3. Results and Discussion

The results of operational performance of the mechanical compressed trash can are shown in Table 1. From sampling wastes, other than food wastes, plastic bags had the highest proportion of total wastes. Due to its low density, plastic bags were collected in our trash can more than plastic bottles and mixed wastes. When comparing with using the conventional trash can, plastic bags were collected in the compressed trash can more than 3.4 times. Whereas the collection of plastic bottles of the invented trash can could be done as double of the conventional trash can. For mixed wastes collected in the invented trash can, the result showed that the compression efficiency of the mixed wastes approximated to that of the plastic bottles. This may be because there were 19% plastic bottles in the mixed wastes.

The use of the mechanical compressed trash can, as compared to the use of conventional trash can is able to increase the amount of wastes discarding into the bin. Therefore, it helps to reduce the waste collection frequency or to reduce the number of transportation. This results in the reduction of GHG emission per year. The results of GHG emissions of the vehicle for the collection of plastic bags, plastic bottles and mixed wastes, comparing between using the mechanical compressed trash can and the conventional trash can are as indicated in Table 2. The use of compressed trash can is able to reduce the GHG emissions per year by 994, 706 and 745 kg CO_2eq for collection of plastic bags, plastic bottles and mixed wastes, respectively.

Table 1. Efficiency of waste compression and ratio of waste compression for plastic bags, plastic bottles, and mixed wastes using the mechanical compressed trash can

	Waste volume with no compression (m^3)	Waste volume with compression (m^3)	Ratio of waste compression	Efficiency of waste compression (%)
Plastic bags	0.291	0.085	3.43 : 1	70.8
Plastic bottles	0.171	0.085	2.01 : 1	50.2
Mixed wastes	0.181	0.085	2.13 : 1	53.1

Table 2. GHG emissions of the vehicle for the collection of plastic bags, plastic bottles and mixed wastes comparing between using the mechanical compressed trash can and the normal trash can

Type of wastes	Containers	Number of transportation per year	GHG emission per year (kg CO_2 eq)	Reduction of GHG emission per year (%)
Plastic bags	Conventional trash can	104	1404	
	Compressed trash can	30	410	70.8
Plastic bottles	Conventional trash can	104	1404	
	Compressed trash can	52	698	50.2
Mixed wastes	Conventional trash can	104	1404	53.1
	Compressed trash can	49	658	

Since the frequency of garbage collection of using the compressed trash can decreases, this makes the expenses for fuel and labor decrease. Therefore, the expenses of transportation of plastic bags, plastic bottles and mixed waste products decrease to 70%, 50% and 53%, respectively, as compared to the waste collection of the conventional trash can.

4. Conclusion

We succeed to invent the compressed trash can with a simple, safe and easy to use mechanical system without any electricity to reduce waste volume and increase the amount of waste discarding into the trash can up to 70%. Using the trash compactor can reduce the number of transportation; therefore, it can also help to decrease the amount of greenhouse gas emission more than 50% of using the conventional trash can. This new compressed trash can is registered under no.12377 of the Thailand petty patent.

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A Comparison of the Effect of Effective Microorganisms Application in Aeration Tank of Activated Sludge System from a Sausage Product Production Factory

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Abstract

Different wastewater quantity and wastewater collection duration for treating pH, biological oxygen demand (BOD), suspended solids, and grease & oil for wastewater treatment from a sausage product production factory in aeration tank of activated sludge system (AS) was investigated using Effective Microorganism (EM) with and without sand filter in the final treatment by using wastewater samples from a sausage product production factory in Phitsanulok Province. The study showed that the efficiency of EM without sand filter in the final treatment for wastewater treatment with different wastewater quantity of the second to the fourth experiment was average pH at 7.6, 7.625 and 7.575; average BOD of 65.94%, 66.48% and 61.85%; average suspended solids of 96.50%, 96.39% and 95.42% and average grease & oil of 61.01%, 71.66% and 65.19%, respectively. And the efficiency of EM with sand filter in the final treatment for wastewater treatment with different wastewater quantity of the second to the fourth experiment was average pH at 7.525, 7.55 and 7.5; average BOD of 74.15%, 74.03% and 73.14%; average suspended solids of 96.37%, 97.21% and 96.87%; and average grease & oil of 78.28%, 86.65% and 92.91%, respectively. The efficiency of EM for wastewater treatment of 4 parameters and according to different wastewater collection duration of 4 parameters of the both have and haven't sand filter in the final treatment were statistically insignificant difference, but the efficiency of EM with sand filter more than without sand filter in the final treatment. The wastewater quality from this factory did not meet standard levels of the Promulgate of Ministry of Industry Issue No.3 B.E.2539, except pH. The wastewater treatment cost by using EM in the fourth experiment was lower than the other experiments.

Keywords: effective microorganism (EM); aeration tank; activated sludge system (AS); sand filter; wastewater treatment; sausage product

1. Introduction

Sausage product production factory is one of many types of industrial operations requiring copious amounts of water to process products such as pork sausage, Chinese sausage, and so on. As a result, effluent from the process would contain high volumes of organic waste, which when drained into the environment, cause environmental toxicity.

Most production factories in Thailand had already built their wastewater treatment plants as activated sludge process (AS), requires a system administrator with high skills to get the system to effectively treat wastewater. Such a system must probably use a high-cost maintenance system, which is a burden to the factory to be carried forever, and if the more powerful with no treatment, it is better to owe more to the problems that have occurred in several issues, such as the environmental impact. If no action is taken regarding complaints of people about the impact of wastewater on health, business will be affected the eventually.

More than 80% of biological wastewater treatment plants (WWTPs) are based on the principle of activated sludge process, in which suspended bacteria oxidize the carbonaceous and nitrogenous compounds to produce an effluent in accordance with legal standards, and that corresponds to a minimal environmental impact (Metcalf and Eddy, 2003).

Zacharias et al. (2005) emphasized that sustainable water management which incorporates both socio-economic and environmental perspectives is a difficult but essential task in order to prevent potential environmental deterioration. Various conventional methods are in practice for purification of water and removing the pollutant contaminants, but most of them are costly and non-ecofriendly (Dhote and Dixit, 2008).

One of the promising ways for improving water quality of rivers and lakes, is the effective microorganism (EM) technology which has been much appreciated comparative to other conventional methods because of its ecofriendly nature, and requires less inputs, cost and capital. The concept of EM was developed by Professor Dr. Teruo Higa, University of Ryukyus, Okinawa, Japan in 1980. There are three types of microorganisms which are categorized into decomposing or degenerative, opportunistic or neutral and constructive or regenerative. EM belongs to the regenerative category whereby they can prevent decomposition in any type of substances and thus maintain the health of both living organisms and the environment (PSDC, 2009). Effective microorganisms are a mixture of groups of organisms that have a reviving action on humans, animals, and the natural environment (Higa & Parr, 1994). It has also been described as a multiculture of coexisting anaerobic and aerobic beneficial microorganisms. The main species involved in EM are: lactic acid bacteria, photosynthetic bacteria, yeasts, actinomycetes and fermenting fungi (Szymanski and Patterson, 2003). There are many ways in which EM can be applied (Sangakkara, 2001).

The principle of EM is the conversion of a degraded ecosystem full of harmful microbes to one that is productive and contains useful microorganisms. This simple principle is the foundation of EM technology in agriculture and environmental management (Higa, 1993). The basis for using these EM species of microorganisms is that they contain various organic acids due to the presence of lactic acid bacteria, which secrete organic acids, enzymes, antioxidants and metallic chelates. The creation of an antioxidant environment by EM assists in the enhancement of the solid-liquid separation, which is the foundation for cleaning water (Higa & Chinen, 1998). The use of EM to treat wastewater in essence simulates the role of biological treatment. It makes use of bacteria and other microorganisms to remove pollutants and impurities from water by digesting them; thereby getting rid of impurities in the water (Schultz, 2005). The bacteria consume and digest the organic material present in the wastewater and through their metabolism, the organic material is changed into cellular mass which is no longer in solution, but is settled at the bottom of a settling tank or container (Roisin, 2008).

To solve the problem, timely action is required. It is necessary to find solutions to the existing systems and if possible, improving them to effectively reduce costs, to reduce the impact of contamination, and for businesses to continue with the stability. Effective Microorganisms (EM) is an attractive alternative to be applied to the existing wastewater treatment system instead of treatment with bacteria that require an aeration pond for aeration in the treatment area. Because it is a digestion of organic microbes that decomposes organic matter without the use of oxygen in the degradation, it is effective in the removal of smell, is harmless to living organisms and environment, and is inexpensive. Likewise, using EM together with and without sand filter in the final treatment is an attractive alternative to be applied to the existing wastewater treatment system instead of treatment.

2. Materials and Methods

This study was an experimental research using AS model of wastewater treatment system and wastewater samples taken from a sausage product production factory in Phisanulok Province, Thailand.

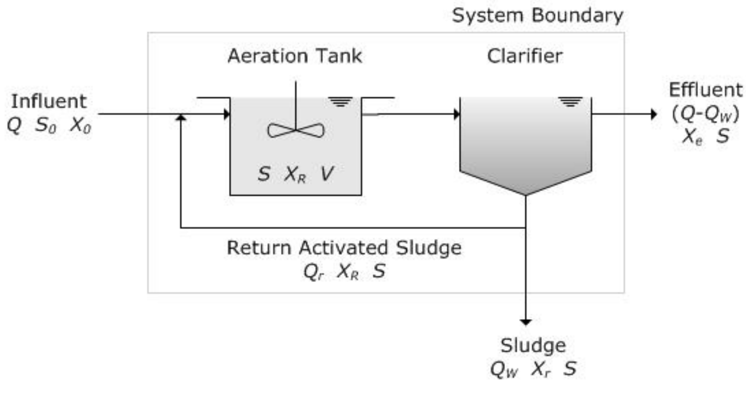

Figure1. AS model (Scale - Simulation System: Real System; 0.1: 1 m.)

As Figure1 the AS model consists of water retention ponds, wastewater aeration, sedimentation ponds, and wells into the water, respectively. To make a comparison between the image rights in wastewater treatment in each set of experiments and the quality of wastewater, effluent standards in accordance with the law on environmental protection has been provided for the variables of the study, that is, pH, BOD, suspended solids, and oil and grease.

2.1 Population and sample

2.1.1 *Population* is all the waste water from the production process of a sausage product production factory in Phisanulok Province, Thailand

2.1.2 *Sample* is collected from wells blend of the sausage factory before entering wastewater treatment system in the simulation system and is divided into four experiments with four different wastewater collection duration each. Care was taken to ensure the quality of 16 wastewater samples collected for each duration before entering the wastewater treatment system(Influent), and 16 wastewater samples after passing the treatment system step 2(Effluent) without chlorination before release to the public water source.

2.2 The research tools

2.2.1 *Wastewater*; waste water samples used in the experiments was collected from the waste water storage tank of a wastewater treatment system at the sausage factory.

2.2.2 *EM-Liquid to be expanded* is in the form of leavening produced by The Kyusei Nature Farming Center, Kaeng Khoi district in Saraburi province, Thailand, and the fermentation System Model.

2.2.3 *System Model* consists of main equipment, including hydraulic retention pond aerated ponds, settling ponds, and water storage ponds, and the water.

2.3 Experimental

2.3.1 Wastewater used in the experiments is a drain from the manufacture of sausage products at a production rate of 10-15 cubic meters/day. The samples were then brought to the system simulation experiments at the rate 10 liters/day, every day in each set of experiments.

2.3.2 The preparation of microorganisms were used in

1) The preparation of EM used in the first experiment; use of microorganisms for acute microbial powder that the factory used routinely to pour as dressing into the aerated tank by using the ratio of acute microbial powder 1 gram per 10 liters of water (1 g: 10,000 ml).
2) The preparation of EM-Liquid to be expanded and used from the second to the fourth experiment;

- Fermented EM to expand with ratio of leavening: Molasses: water (1: 1: 20) is rested for 7 days and used within 7 days**.**
- The fermented EM is poured into the aeration tank, with ratio as follows: 1) Using EM-Liquid to be expanded 1 ml per 10 liters of water (1 ml: 10,000 ml) used in the second experiment; 2) Using EM-Liquid to be expanded 0.67 ml per 10 liters of water (1 ml: 15,000 ml) is used in the third experiment; and 3) Using EM-Liquid to be expanded 0.5 ml water per volume of waste water 10 liters (1 ml: 20,000 ml) used in the fourth experiment.

2.3.3 Preparation of wastewater for experimental simulation system: wastewater collection is by Grab Sampling that is put into a storage tank in the simulation system. This was then let into an aeration tank at the rate of 10 liters per experiment from the first to the fourth experiment and the flow rate of wastewater from a storage tank into an aeration tank as well as the actual system (10-15 cubic meters/day) was calculated for each experiment.

2.3.4 Experimental Procedure

1) The simulation system and test operation of the system were check with clean water. 40 liters of wastewater a day was collected from the mixing tank.
2) Pour 40 liters of wastewater into a 70 liters plastic bucket. Tankers were used to transport the buckets to the place of experiment. The first round of experiments was conducted for all four experiments with wastewater that was aerated for 1-2 hours every 4-5 hours for 4-8 hours/day. Usually, most wastewater treatment process of AS is designed to use the conventional rate of treatment with a period in the aeration tank of 4-8 hours/day, 24 hours in the treatment by EM, followed by sedimentation.
3) The collected water samples were sent to the wastewater quality analysis laboratory to determine the values of pH, BOD, suspended solids, and oil and grease.
4) Conducted experiments form the second to the fourth time for all four experiments.

2.4 Data collection

2.4.1 collecting wastewater samples for the water quality analysis

1) Wastewater was collected before entering the wastewater storage tank (Influent) from the trash of the simulation system and stored by sterile technique to prevent contamination of bacteria from an external source; the input sampling device was immersed in ice and taken to the laboratory immediately.

2) The sample was stored after treatment (effluent) at the end of the simulation system drain and was stored by sterile techniques to prevent the contamination of bacteria from outside laboratory sources; the sample was frozen in the ice immediately, and the wastewater samples were collected at 10.00 O'clock.

2.4.2 Data on all the information of the plant including general information of the factory was collected, production process data was obtained by questionnaire administered to the managers, wastewater quality analysis data from a laboratory of the factory was collected by using existing records.

2.5 An analysis of the factory

2.5.1 Descriptive statistics were used to offer percentage, mean and standard deviation to determine the efficiency of wastewater treatment.

2.5.2 The efficiency of wastewater treatment in each experiment was compare by using statistics, that is, One Way ANOVA: Scheffe (Significance Level 0.05, Confidence Intervals are 95 %).

3. Results and Discussion

As shown in Table 1

In the first round (without sand filter): The results in adjustment were: pH 7.3, 7.3, and 7.3; removal efficiency of BOD 60.64%, 64.47%, and 63.6%; removal efficiency of SS 95.82%, 92.84%, and 92.36%; and removal efficiency of oil and grease 12.68%, 39.6%, and 35.4%, respectively, compared to 7.2, 61.2%, 96.2%, and 50.2% , respectively, in the first experiment. However, the efficiency of EM for wastewater treatment with different EM dose in each experiment of the first round was average pH of 7.3 (S.D.=0.3304); average of BOD 64.48 (S.D.=23.94); average of suspended solids 96.69 (S.D.=1.54), and average of oil and grease 63.54 (S.D.=24.25), respectively.

In the second round (without sand filter): The results of adjustment were: pH 7.5, 7.5, and 7.6; removal efficiency of BOD 86.63%, 84.63%, and 85.4%; removal efficiency of SS 96.72%, 98.3%, and 96.06%; and removal efficiency of oil and grease 43.53%, 56.3%, and 39.7%, respectively, compared to 7.6, 83.96%, 98.57%, and 59.06%, respectively, in the first experiment. However, the efficiency of EM for wastewater treatment with different EM dose in each experiment of the second round was average pH of 7.5 (S.D.=0.2944); average of BOD 65.94 (S.D.=21.49); average of suspended solids 96.50 (S.D.=0.92), and average of oil and grease 61.02 (S.D.=40.2), respectively.

In the third round (without sand filter): The results in adjustment were: pH 7.6, 7.7 ,and 7.5; removal efficiency of BOD 38.1%, 37.98%,and 22.02%; removal efficiency of SS 95.62%, 96.65%, and 95.61%; and removal efficiency of oil and grease 97.89%, 99.67%, and 98.61%, respectively, compared to 7.5, 31.91%, 94.9%, and 98.97%, respectively, in the first experiment. However, the efficiency of EM for wastewater treatment with different EM dose in each experiment of the third round was average pH of 7.6 (S.D.=0.2986); average of BOD 66.48 (S.D.=20.80); average of suspended solids 95.38 (S.D.=2.46), and average of oil and grease 71.66 (S.D.=28.43), respectively.

Table 1. Value of pH, BOD, suspended solids, and oil and grease of influent and effluent and the efficiency of wastewater treatment without sand filter in the all round of all four experiments.

Parameter	Influent	Effluent (without sand filter)							
		Experiments/ The efficiency of wastewater treatment (%)							
		Exp. 1	%	Exp. 2	%	Exp. 3	%	Exp. 4	%
Round 1									
pH	6.1	7.2	-	7.3	-	7.3	-	7.3	-
BOD_5 (mg/l)	3,760	1,460	61.2	1,480	60.64	1,336	64.47	1,370	63.6
SS (mg/l)	1,676	63	96.2	70	95.82	120	92.84	128	92.36
Oil & Grease (mg/l)	19.8	9.86	50.2	17.29	12.68	11.96	39.6	12.8	35.4
Round 2									
pH	6.2	7.6	-	7.5	-	7.5	-	7.6	-
BOD_5 (mg/l)	13,500	2165	83.96	1805	86.63	2,075	84.63	1975	85.4
SS (mg/l)	17,198	246	98.57	529	96.72	293	98.3	677	96.06
Oil & Grease (mg/l)	299.88	122.77	59.06	169.33	43.53	131.18	56.3	180.79	39.7
Round 3									
pH	6.1	7.5	-	7.6	-	7.7	-	7.5	-
BOD_5 (mg/l)	4,700	3,200	31.91	2,910	38.1	2,915	37.98	3,665	22.02
SS (mg/l)	5,492	280	94.9	238	95.62	184	96.65	241	95.61
Oil & Grease (mg/l)	306.36	3.17	98.97	6.45	97.89	1.02	99.67	4.25	98.61
Round 4									
pH	6.2	8	-	8	-	8	-	7.9	-
BOD_5 (mg/l)	8,460	1,620	80.85	1,830	78.37	1,790	78.84	2,000	76.36
SS (mg/l)	13,361	388	97.1	320	97.6	299	97.76	312	97.66
Oil & Grease (mg/l)	106.95	57.84	45.92	10.73	89.97	9.56	91.06	13.85	87.05
Round 1-4									
pH	6.15	7.575	-	7.6	-	7.625	-	7.575	-
BOD_5 (mg/l)	7,605	2,111	64.48	2,006	65.94	2,029	66.48	2,253	61.85
SS (mg/l)	9,432	244	96.69	289	96.44	224	96.39	340	95.42
Oil & Grease (mg/l)	183	48	63.54	50.95	61.02	38	71.66	53	65.19

Note: When the EM dose was in the first experiment *(EM 1 mg of local microorganism of the factory per 10,000 ml of wastewater*), in the second experiment *(EM 1 ml per 10,000 ml of wastewater)*, in the third experiment *(EM 1 ml per 15,000 ml of wastewater)*, and in the fourth experiment *(EM 1 ml per 20,000 ml of wastewater)*

In the fourth round (without sand filter): The results in adjustment were: pH 8.0, 8.0, and 7.9; removal efficiency of BOD 78.37%, 78.84%, and 76.36%; removal efficiency of SS 97.6%, 97.76%, and 97.66%; and removal efficiency of oil and grease 89.97%, 91.06%, and 87.05%, respectively, compared to 8.0, 80.85%, 97.1%, and 45.92%, respectively, in the first experiment. However, the efficiency of EM for wastewater treatment with different EM dose in each experiment of the fourth round was average pH at 8.0 (S.D.=0.2500); average of BOD 61.85 (S.D.=28.02); average of suspended solids 95.42 (S.D.=2.22), and average of oil and grease 65.2 (S.D.=32.31), respectively.

The study showed that (1) the efficiency of EM for wastewater treatment with different wastewater quantity from the second to the fourth experiment had an average pH at 7.6, 7.625, and 7.575; average of BOD 65.94, 66.48, and 61.85; average of suspended solids 96.44, 96.39, and 95.42, and average of oil and grease 61.02, 71.66, and 65.19, respectively; (2) the efficiency of EM for the four parameters for wastewater treatment showed a statistically insignificant difference. The efficiency of EM for wastewater treatment according to different wastewater collection duration of four parameters showed a statistically insignificant difference. However, except for pH, these results did not meet the control level of wastewater quality from the factory according to the Promulgate of Ministry of Industry Issue No.3 B.E.2539. Comparing the cost of wastewater treatment, wastewater treatment using EM in the fourth experiment showed a lower cost than the other experiments that same with sand filter (Boonda, 2015).

As shown in Table 2

In the first round (with sand filter): The results in adjustment were: pH 7.6, 7.6, and 7.5; removal efficiency of BOD 63.51%, 64.36%, and 60.96%; removal efficiency of SS 96.30%, 96.84%, and 96.48%; and removal efficiency of oil and grease 22.93%, 74.90%, and 88.50%, respectively, compared to 7.6, 61.90%, 97.02%, and 89.90% , respectively, in the first experiment. However, the efficiency of EM for wastewater treatment with different EM dose in each experiment of the first round was average pH of 7.6 (S.D.= 0.1708); average of BOD 71.36 (S.D. =20.09); average of suspended solids 98.1 (S.D.= 1.39), and average of oil and grease 93.74 (S.D. =3.84), respectively.

In the second round (with sand filter): The results of adjustment were: pH 7.2, 7.3, and 7.3; removal efficiency of BOD 93.91%, 92.10%, and 93.04%; removal efficiency of SS 99.48%, 99.31%, and 98.90%; and removal efficiency of oil and grease 99.40%, 99.40%, and 99.65%, respectively, compared to 7.3, 94.40%, 99.30%, and 97.93%, respectively, in the first experiment. However, the efficiency of EM for wastewater treatment with different EM dose in each experiment of the second round was average pH of 7.6 (S.D.= 0.2217); average of BOD 74.15(S.D.=17.82); average of suspended solids 96.37 (S.D.=3.67), and average of oil and grease 78.28 (S.D.=36.95), respectively.

In the third round (with sand filter): The results in adjustment were: pH 7.6, 7.6 ,and 7.5; removal efficiency of BOD 55.32%, 57.13%,and 55.11%; removal efficiency of SS 91.24%, 93.70%, and 93.94%; and removal efficiency of oil and grease 95.92%, 96.41%, and 94.38%, respectively, compared to 7.5, 48.83%, 96.78%, and 95.99%, respectively, in the first experiment. However, the efficiency of EM for wastewater treatment with different EM dose in each experiment of the third round was average pH of 7.6 (S.D.= 0.1732); average of BOD 74.03 (S.D.=16.1); average of suspended solids 97.21 (S.D.=2.59), and average of oil and grease 86.65 (S.D.=14.76), respectively.

Table 2. Value of pH, BOD, suspended solids, and oil and grease of influent and effluent and the efficiency of wastewater treatment with sand filter in the all round of all four experiments.

Parameter	Influent	Effluent (with sand filter)							
		Experiments/ The efficiency of wastewater treatment (%)							
		Exp. 1	%	Exp. 2	%	Exp. 3	%	Exp. 4	%
Round 1									
pH	6.1	7.6	-	7.6	-	7.6	-	7.5	-
BOD_5 (mg/l)	3,760	1,434	61.90	1,372	63.51	1,340	64.36	1,468	60.96
SS (mg/l)	1,676	50	97.02	62	96.30	53	96.84	59	96.48
Oil & Grease (mg/l)	19.8	2.0	89.90	15.26	22.93	4.97	74.90	2.28	88.50
Round 2									
pH	6.2	7.3	-	7.2	-	7.3	-	7.3	-
BOD_5 (mg/l)	13,500	760	94.40	822	93.91	1,068	92.10	940	93.04
SS (mg/l)	17,198	119	99.30	89	99.48	119	99.31	189	98.90
Oil & Grease (mg/l)	299.88	6.20	97.93	1.81	99.40	1.84	99.40	1.06	99.65
Round 3									
pH	6.1	7.5	-	7.6	-	7.6	-	7.5	-
BOD_5 (mg/l)	4,700	2,405	48.83	2,100	55.32	2,015	57.13	2,110	55.11
SS (mg/l)	5,492	177	96.78	481	91.24	346	93.70	333	93.94
Oil & Grease (mg/l)	306.36	12.28	95.99	12.49	95.92	11.00	96.41	17.23	94.38
Round 4									
pH	6.2	7.7	-	7.7	-	7.7	-	7.7	-
BOD_5 (mg/l)	8,460	1,665	80.32	1,365	83.87	1,480	82.51	1,400	83.45
SS (mg/l)	13,361	93	99.30	206	98.46	134	99.00	248	98.14
Oil & Grease (mg/l)	106.95	9.50	91.12	5.50	94.86	29.02	72.87	11.65	89.11
Round 1-4									
pH	6.15	7.525	-	7.525	-	7.55	-	7.5	-
BOD_5 (mg/l)	7,605	1,566	71.36	1,415	74.15	1,476	74.03	1,480	73.14
SS (mg/l)	9,432	110	98.10	210	96.37	163	97.21	207	96.87
Oil & Grease (mg/l)	183	7	93.74	9	78.28	12	85.90	8	92.91

Note: When the EM dose was in the first experiment *(EM 1 mg of local microorganism of the factory per 10,000 ml of wastewater)*, in the second experiment *(EM 1 ml per 10,000 ml of wastewater)*, in the third experiment *(EM 1 ml per 15,000 ml of wastewater)*, and in the fourth experiment *(EM 1 ml per 20,000 ml of wastewater)*

In the fourth round (with sand filter): The results in adjustment were: pH 7.7, 7.7, and 7.7; removal efficiency of BOD 83.87%, 82.51%, and 83.45%; removal efficiency of SS 98.46%, 99.00%, and 98.14%; and removal efficiency of oil and grease 94.86%, 72.87%, and 89.11%, respectively, compared to 7.7, 80.32%, 99.30%, and 91.12%, respectively, in the first experiment. However, the efficiency of EM for wastewater treatment with different EM dose in each experiment of the fourth round was average pH at 7.6 (S.D.= 0.1633); average of BOD 73.14 (S.D.=18.03); average of suspended solids 96.87 (S.D.=2.2), and average of oil and grease 92.91 (S.D.=5.21), respectively.

Table 3. Efficiency comparison of BOD treatment with 16 wastewater samples after passing the treatment system step 2(Effluent) without chlorination before release to the public water source

BOD_5(mg/l)	**Without Sand Filter (%)**	**Different (%)**	**With Sand Filter (%)**
(1) Round 1/ Exp.1	61.2	0.7	61.9
(2) Round 1/ Exp.2	60.64	2.87	63.51
(3) Round 1/ Exp.3	64.47	-0.11	64.36
(4) Round 1/ Exp.4	63.6	-2.64	60.96
(5) Round 2/ Exp.1	83.96	10.44	94.4
(6) Round 2/ Exp.2	86.63	7.28	93.91
(7) Round 2/ Exp.3	84.63	7.47	92.1
(8) Round 2/ Exp.4	85.4	7.64	93.04
(9) Round 3/ Exp.1	31.91	16.92	48.83
(10) Round 3/ Exp.2	38.1	17.22	55.32
(11) Round 3/ Exp.3	37.98	19.15	57.13
(12) Round 3/ Exp.4	22.02	33.09	55.11
(13) Round 4/ Exp.1	80.85	-0.53	80.32
(14) Round 4/ Exp.2	78.37	5.5	83.87
(15) Round 4/ Exp.3	78.84	3.67	82.51
(16) Round 4/ Exp.4	76.36	7.09	83.45

The study showed that (1) the efficiency of EM for wastewater treatment with different wastewater quantity from the second to the fourth experiment had an average pH at 7.525, 7.55, and 7.5; average of BOD 74.15, 74.03, and 73.14; average of suspended solids 96.37, 97.21, and 96.87, and average of oil and grease 78.28, 86.65, and 92.91, respectively; (2) the efficiency of EM for the four parameters for wastewater treatment showed a statistically insignificant difference. The efficiency of EM for wastewater treatment according to different wastewater collection duration of four parameters showed a statistically insignificant difference. However, except for pH, these results did not meet the control level of wastewater quality from the factory according to the Promulgate of Ministry of Industry Issue No.3 B.E.2539. Comparing the cost of wastewater treatment, wastewater treatment using EM in the fourth experiment showed a lower cost than the other experiments that same without sand filter.

The study showed that the efficiency of EM without sand filter in the final treatment for wastewater treatment with different wastewater quantity of the second to the fourth experiment was average pH at 7.6, 7.625 and 7.575; average BOD of 65.94, 66.48 and 61.85; average suspended solids of 96.50, 96.39 and 95.42 and average grease & oil of 61.01, 71.66 and 65.19, respectively. And the efficiency of EM with sand filter in the final treatment for wastewater treatment with different wastewater quantity of the second to the fourth experiment was average pH at 7.525, 7.55 and 7.5; average BOD of 74.15, 74.03 and 73.14; average suspended solids of 96.37, 97.21 and 96.87; and average grease & oil of 78.28, 86.65 and 92.91, respectively. The efficiency of EM for wastewater treatment of 4 parameters and according to different wastewater collection duration of 4 parameters of the both have and haven't sand filter in the final treatment were statistically insignificant difference, but the efficiency of EM with sand filter more than without sand filter in the final treatment. However, these results did not meet control level of wastewater quality from the factory according to the Promulgate of Ministry of Industry Issue No.3 B.E.2539 except pH. With comparison of the wastewater treatment cost, wastewater treatment by using EM in the fourth experiment had the cost lower than the other experiments.

By showing efficiency comparisons of BOD treatment as Table3 and Figure2, efficiency comparisons of suspended solids treatment as Table4 and Figure3, efficiency comparisons of grease & oil treatment as Table5 and Figure4

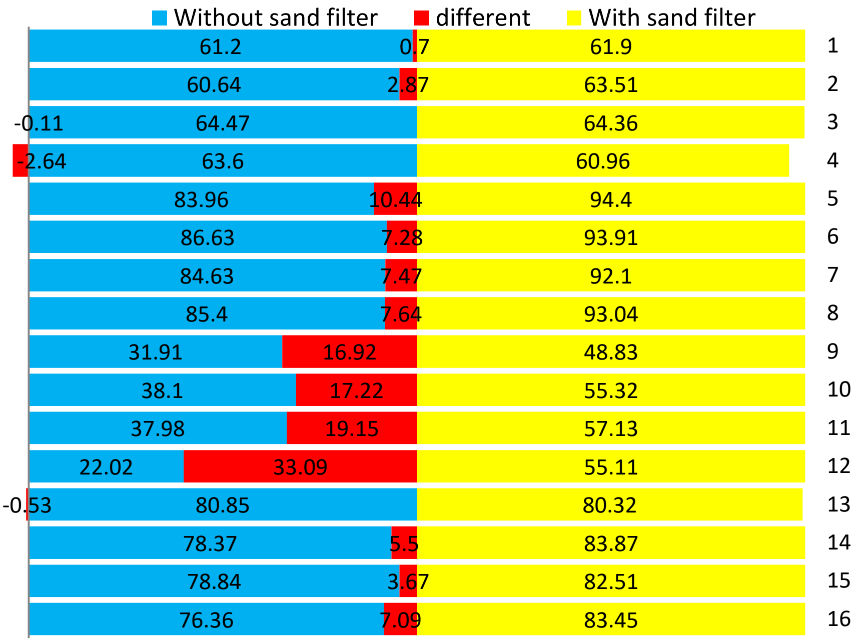

Figure 2. Efficiency comparison of BOD treatment with 16 wastewater samples after passing the treatment system step 2(Effluent) without chlorination before release to the public water source

Table 4. Efficiency comparison of SS treatment with 16 wastewater samples after passing the treatment system step 2(Effluent) without chlorination before release to the public water source

SS(mg/l)	Without Sand Filter (%)	Different (%)	With Sand Filter (%)
(1) Round 1/ Exp.1	96.2	0.82	97.02
(2) Round 1/ Exp.2	95.82	0.48	96.3
(3) Round 1/ Exp.3	92.84	4	96.84
(4) Round 1/ Exp.4	92.36	4.12	96.48
(5) Round 2/ Exp.1	98.57	0.73	99.3
(6) Round 2/ Exp.2	96.72	2.76	99.48
(7) Round 2/ Exp.3	98.3	1.01	99.31
(8) Round 2/ Exp.4	96.06	2.84	98.9
(9) Round 3/ Exp.1	94.9	1.88	96.78
(10) Round 3/ Exp.2	95.62	-4.38	91.24
(11) Round 3/ Exp.3	96.65	-2.95	93.7
(12) Round 3/ Exp.4	95.61	-1.67	93.94
(13) Round 4/ Exp.1	97.1	2.2	99.3
(14) Round 4/ Exp.2	97.6	0.86	98.46
(15) Round 4/ Exp.3	97.76	1.24	99
(16) Round 4/ Exp.4	97.66	0.48	98.14

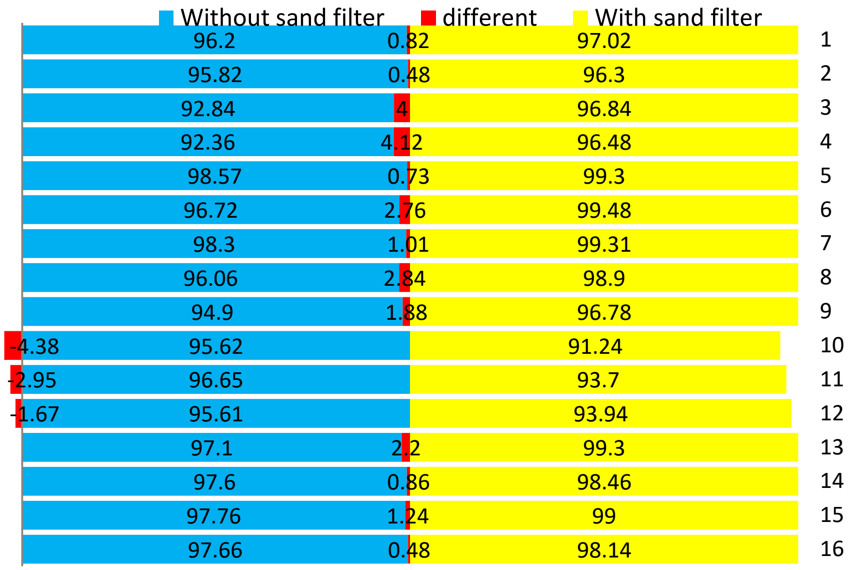

Figure 3. Efficiency comparison of SS treatment with 16 wastewater samples after passing the treatment system step 2(Effluent) without chlorination before release to the public water source

Table 5. Efficiency comparison of Oil & Grease treatment with 16 wastewater samples after passing the treatment system step 2(Effluent) without chlorination before release to the public water source

Oil & Grease(mg/l)	Without Sand Filter (%)	Different (%)	With Sand Filter (%)
(1) Round 1/ Exp.1	50.2	39.7	89.9
(2) Round 1/ Exp.2	12.68	10.25	22.93
(3) Round 1/ Exp.3	39.6	35.3	74.9
(4) Round 1/ Exp.4	35.4	53.1	88.5
(5) Round 2/ Exp.1	59.06	38.87	97.93
(6) Round 2/ Exp.2	43.53	55.87	99.4
(7) Round 2/ Exp.3	56.3	43.1	99.4
(8) Round 2/ Exp.4	39.7	59.95	99.65
(9) Round 3/ Exp.1	98.97	-2.98	95.99
(10) Round 3/ Exp.2	97.89	-1.97	95.92
(11) Round 3/ Exp.3	99.67	-3.26	96.41
(12) Round 3/ Exp.4	98.61	-4.23	94.38
(13) Round 4/ Exp.1	45.92	45.2	91.12
(14) Round 4/ Exp.2	89.97	4.89	94.86
(15) Round 4/ Exp.3	91.06	-18.19	72.87
(16) Round 4/ Exp.4	87.05	2.06	89.11

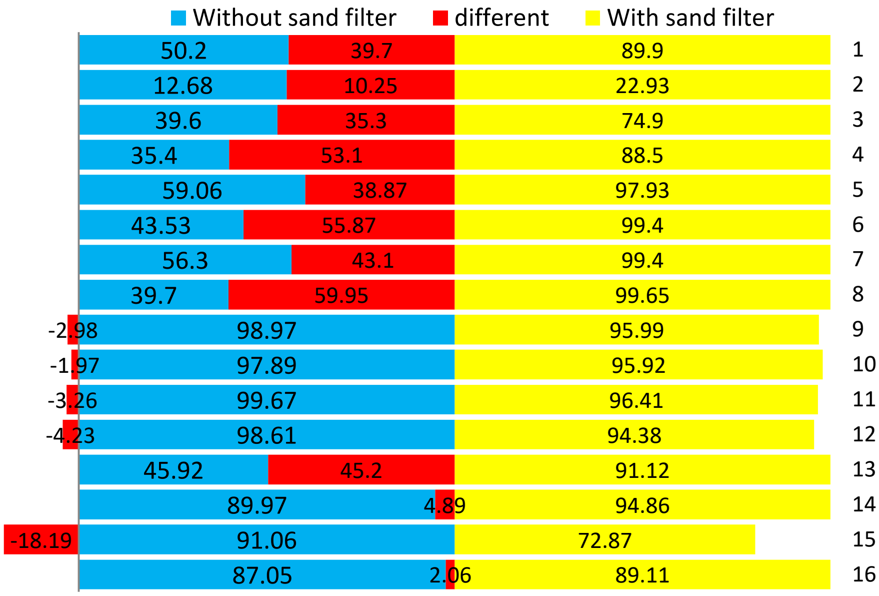

Figure 4. Efficiency comparison of Oil & Grease treatment with 16 wastewater samples after passing the treatment system step 2(Effluent) without chlorination before release to the public water source

4. Conclusion

4.1 Research results

Hypothesis 1: EM has the potential for wastewater treatment from sausage product production factory in aeration tank of activated sludge system (AS) with sand filter more than without sand filter.

From the experimental results of EM for wastewater treatment from the second to the fourth experiment, it could be concluded that EM has the potential for treatment of wastewater from a sausage product production factory in the aeration tank of the AS system with sand filter more than without sand filter. The first experiment (EM 1 mg of local microorganism of the factory per 10,000 ml of wastewater) that used acute microbial powder that the factory used routinely can be used to treat wastewater from the factory as well. Therefore, it is to be based on the assumption that is specified.

Hypothesis 2: The different amount of EM has an effect on the wastewater treatment in the aeration tank of activated sludge system (AS) with sand filter and without sand filter. With different EM amounts, the efficiency average adjusted pH in the trials show a statistically insignificant difference on the effect to adjust the pH, treatment efficiency average of BOD, suspended solids, and oil and grease. All the experiments are effective in the treatment of the BOD, suspended solids, and oil and grease, but did not show a statistically insignificant difference when the amount of EM differed. Therefore, it can be concluded that the different amounts of EM has no effect on the wastewater treatment in the aeration tank of activated sludge system

(AS) with sand filter and without sand filter of sausage product production factory, which is not in accordance with hypothesis 2.

Hypothesis 3: The different wastewater collection duration has an effect on the EM wastewater treatment in the aeration tank of activated sludge system (AS) with sand filter and without sand filter. From the statistical analysis of the values pH, BOD, SS, and oil and grease, the efficiency of EM for wastewater treatment according to different wastewater collection duration of four parameters show a statistically insignificant difference. In summary, EM has no effect on the wastewater treatment on the different duration of wastewater collection in the aeration tank of activated sludge system (AS) with sand filter and without sand filter, which is not in accordance with hypothesis 3.

When compared to other standards, with sand filter and without sand filter found that these results did not meet the control level of wastewater quality from the factory according to the Promulgate of Ministry of science, technology and environment Issue No.3 B.E.2539. In addition, according to the Promulgate of Ministry of Industry Issue No.2 B.E.2539., only the value of SS with sand filter in the first round of the first experiment has the value according to the standard, which is 50 mg/l. The oil and grease with sand filter in the first round of the first, third ,and fourth experiment showed a value according to the standard, which is 2.0 mg/l, 4.97 mg/l, and 2.25 mg/l, respectively, and wastewater treatment in the second experiment of the fourth round showed a value of is 1.81 mg/l, 1.84 mg/l, and 1.06 mg/l and without sand filter in the third round of the third ,and fourth experiment showed a value according to the standard, which is 1.02 mg/l and 4.25 mg/l, respectively, which is not more than 5.0 mg/l.

The value of the pH in all the experiments in each round of each trial with sand filter and without sand filter showed that it was in accordance with the industry standard.

4.2 Comments

The implication of the research for the use of EM by comparing costs of with sand filter and without sand filter in the treatment and the impact on the environment when compared to the cost of each of the four wastewater treatment trial found that in trial 1, which used a type of acute microbial powder that the factory used routinely to pour dressing in the aerated tank, the wastewater treatment costs are higher than experiments 2-4, in which EM-Liquid was used in the treatment where the adjusted performance of pH, BOD, SS, and oil and grease are not statistically different. A different type of organism in the acute powder used in the first experiment with higher costs EM-Liquid to be expanded in the treatment that used in the second-fourth experiment with 40.9 times (97.6%), 60 times (98.3%) and 75 times (98.7%), respectively.

The researchers suggest that the factory use EM-Liquid in the treatment applied in the actual system and have to done with sand filter in the final treatment. Observation showed that the color and smell of the water are treated in comparison with a type of acute microbial powder that the factory used previously. The treated wastewater can be used to water lawns of the houses around the area of the factory but wastewater treatment system of the factory needs to take care of septic systems and more so water retention (Equalizing Tank) because water was treated mainly with unsteady temperature. It affects the therapeutic efficacy of EM directly.

It is concluded that EM-Liquid should be used in the treatment as in the fourth experiment, using the ratio of EM 1 ml per 20,000 ml of wastewater, and the wastewater treatment plant of the sausage product production factory, using EM in the aeration tank of activated sludge, can treat wastewater. It is an easy, convenient, and economical treatment for administrators or owners. It is a beneficial to replace acute microbial powder that the factory used routinely to pour dressing in the aerated tank in the wastewater treatment with higher costs and also need to add with sand filter at the end of the treatment for better performance. In order to research integrity clear and are useful in applied in wastewater treatment. Further study should focus on finding and comparing the aeration time and duration of biodegradation.

Acknowledgments

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Utilization of Citric Acid Manufacture Residue for Producing Mortar and Insulation

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Abstract

At present, there are various ways for industrial waste management. For instant, waste can be reused as an alternative material for the products to replace natural resources. This study investigated the suitable citrogypsum proportion for cement mortar and insulation products. For cement mortar, at ages 28 days, cement : sand : water ratio was 1 : 3 : 0.5 and cement was replaced by 25% (G25) and 50% (G50) of citrogypsum, the average value of compressive strength of G25 and G50 were 16.21 MPa and 6.41 MPa. For insulation properties, thermal conductivity, thermal diffusion and specific heat were 0.39 W/mK, 0.34 mm^2/s and 1.14 MJ/m^3K, respectively. However, a flexural strength was lower than standard, according to EN 13279 (1 MPa). In conclusion utilization of citrogypsum utilization, is suitable to use as a raw material in producing insulation.

Keywords: citrogypsum; cement mortar; insulation; waste utilization

1. Introduction

In 2013, a total industrial solid waste was approximately 2.7 million tons in Thailand (Ministry of Natural Resource and Environment) and the quantity of industrial solid wastes continue increasing that effect on human health and environment. There are many ways to decrease waste such as incineration, sanitary and secure landfill, waste minimization, recovery and transformation and waste utilization. Many industrials adopt waste utilization for improving solid waste. It is a possibility to blend of solid wastes and construction materials. Solid wastes such as fly ash, steel-making slag, non-ferrous metal slags, bottom ash of municipal solid waste incineration, and others had been used in building construction as mixture in concrete (Qiao et al., 2010). In addition, the cities growth is one of the many factors of rising buildings construction while the number of natural resources such lime and gypsum as a cement admixtures are decreased.

Citric acid synthesis is a fermentation process by which some microorganism use the carbohydrate to produce citric acid and use lime as a precipitator. A citric acid factory in Prachenburi province produces citrogypsum as by-products for more than 600 tonnes per day. At present, this by-product is took to open-dumped for waste management that is a direct effects to the environment as water and air pollutions which means that the human health may be at risk, for example, the particle of gypsum powder is directly linked to respiratory tract disorder. Moreover, the leachate from dumping site is able to contaminate underground water. In this study, effect of citrogypsum as a composition in cement mortar on compressive strength and in insulation on thermal transfer's value has been investigated for an appropriate ratio of citrogypsum utilization.

2. Materials and Methods

Citrogypsum was used as raw material for mortar and insulation with different preparing and production. The process and testing in this study was summarized in Figure 1.

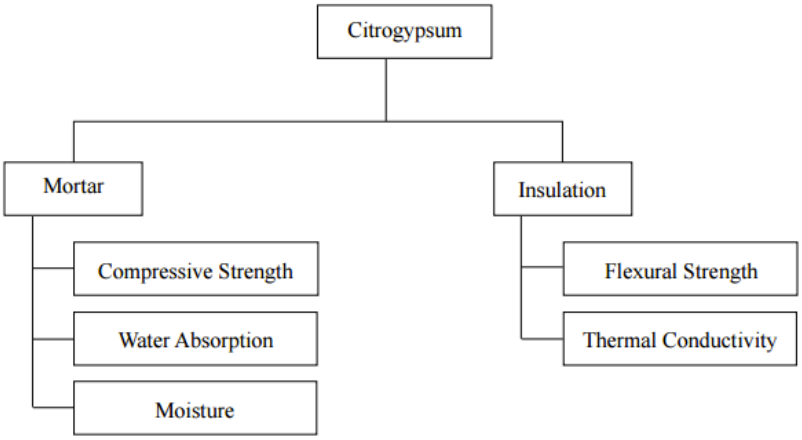

Figure 1. Experiment procedure

2.1. Raw material

2.1.1 Ordinary Portland cement type I

The cement used in this study is ordinary Portland cement (OPC) type I obtained from the Siam Cement Public Company Limited.

2.1.2 Citrogypsum

Citrogypsum was dried at 105 ^{o}C for 24 hours before grinding with mortar and pestle. The chemical characterization was determined by X-ray fluorescence (Bruker model S8 Tiger) and amount of heavy metal was determined by Atomic Absorption Spectrophotometer (Agilent 240AA, U.S.A.).

2.1.3 Sand

A gradation of aggregates by sieve analysis (ASTM C136-01) was used in this study.

2.1.4 Water

Tap water available in the laboratory with pH value of 7.23 was used for mixing mortar and curing the mortar specimens as well.

2.2. Production of cement mortars

According to ASTM C 109/C 109M (2008), a procedure of specimens preparation was used, the mortars were casted by mixing cement with specified sand and water at a ratio of 1:3:0.5 into 50 mm x 50 mm x 50 mm metallic cube molds. The percentage of the replacement of ordinary portland cement (OPC) with citrogypsum are 0 wt% (REF), 25 wt% (G25), 50 wt% (G50), 75 wt% (G75) and 100 wt% (G100). A tamper was used for compaction of the mortar filled cubes. These cubes were demolded after 24 hours and samples were cured in water at room temperature (about 27 °C) before testing. Samples were determined at the ages of 3, 7 and 28 days. Three cube specimens were used for the determination of average compressive strength which were tested by compressive testing machine as shown in Table 1.

Table 1. Proportions of mixture citrogypsum with OPC and water

No. of sample	Ingredient	Specimen age	No. of mortar specimens
REF(3d) REF(7d) REF(28d)	OPC	3 days 7 days 28 days	3 3 3
G25(3d) G25(7d) G25(28d)	OPC + 25%Gypsum	3 days 7 days 28 days	3 3 3
G50(3d) G50(7d) G50(28d)	OPC + 50%Gypsum	3 days 7 days 28 days	3 3 3
G75(3d) G75(7d) G75(28d)	OPC + 75%Gypsum	3 days 7 days 28 days	3 3 3
G100(3d) G100(7d) G100(28d)	OPC + 100%Gypsum	3 days 7 days 28 days	3 3 3

2.3. Production of citrogypsum insulations

For citrogypsum insulation manufacturing, water and dried citrogypsum were mixed until a homogeneous paste, using a water/gypsum ratio of 0.8–0.9 and doses of super-plasticizers in water 5% by weight of citrogypsum. The paste obtained was placed in 2.5 x 2.5 cm x 30 cm mold for bending test. A different shape of sample (1 cm x 5 cm x 5 cm) was used in thermal conductivity tests. The samples were demolded after 24 h and left to cure at ambient temperature for 28 days.

2.4. Testing

2.4.1 Mechanical testing

A compressive strength of cement mortar was measured by compressive strength machine (Amsler 20 tons). According to ASTM C 109/C 109M, calculated the compressive strength as follow:

$$fm = P/A \qquad (1)$$

where fm = compressive strength in psi or MPa

P = total maximum load in Ibf or N

A = area of loaded surface in^2 or mm^2

A flexural strength of citrogypsum insulation specimens was evaluated using with support span range 250 mm (Amsler 30 tons) and calculate the flexural strength for a rectangular sample under a load in a three-point bending setup. According to ASTM C 78, if the fracture initiates in the tension surface within the middle third of the span length, calculate the flexural strength as follow:

$$R = PL/bd^2 \qquad (2)$$

where R = flexural strength in psi or MPa

P = maximum applied load indicated by the testing machine in Ibf or N

L = span length in in. or mm.

b = average width of specimen in in. or mm, at the fracture

d = average depth of specimen in in. or mm, at the fracture

2.4.2 Physico-chemical properties

pH: The pH was measured relative to EN 12859 (EN 12859, 2001), the 2 grams of sample had taken from each panel and was added 20 gram of water. After 5 minutes, the pH of solution was analyzed.

Water absorption capacity (WA): WA was measured relative to TIS 243 (TIS 243, 1977). The value of WA is calculated according to the following Eq. 3

$$WA (\%) = 100 \times (M1 - M2) / M2 \qquad (3)$$

where M1 is a weight of sample after immersing in the water for 5 minutes and a weight of sample after heated at 40 °C until a constant mass was obtained is represent by M2.

Thermal Conductivity: The insulation sample was cut into 5 cm quadrangle and 1 cm thick for two pieces. Both surface sides of samples must be smooth before investing by Thermal Conductivity Analysis technique. Hot Disk Thermal Constant Analyser with disk type: Kapton insulation (Sensor No. C7577, Radius = 2.001 mm.) was used. From this measurement it is possible to determine the value of thermal conductivity, thermal diffusivity and specific heat.

3. Results and Discussion

3.1 Characterization of raw materials

The major chemical compositions of citrogypsum were almost identical to those in flue-gas desulfurization (FGD) gypsum and commercial gypsum (CGp) which were used as a raw material in the insulation and a retarding agent in mortar (Li et al., 2015). The major component of three different types of gypsum were SO_3 and CaO. Low proportion of SiO_2, Al_2O_3, MgO, Fe_2O_3 and K_2O were shown in citrogypsum. Only SrO was detected in citrogypsum. The analysis of heavy metal in leachate obtained from Waste Extraction Test (WET) reported zinc, copper, manganese had 0.0108 mg/l, 0.0045 mg/l, 0.0008 mg/l, respectively. Furthermore, cadmium, lead, and iron had less than 0.1 mg/l. According to the Ministry of Industry guidance for disposal of waste or used materials established in 2005 (Ministry of Industry Thailand, 2005), the concentration of heavy metals in the citrogypsum were not classified as a hazardous waste. Furthermore, according to TIS.188-2004, the percentage of chemical compositions in citrogypsum were in the range of the limit, which can be used in building purpose. From the result, the main compositions of three types of gypsum were almost identical. It can be concluded that the citrogypsum waste obtained from the citric acid production plants, can be advantageous for mortar and insulation production.

3.2 Mortar

3.2.1 Compressive strength

The result of compressive strength (in Figure 2) showed that the average values of REF (0% of citrogypsum) were 23.41, 27.46 and 29.94 MPa for the ages of 3, 7 and 28 days, respectively. For G25 (25% of citrogypsum), the compressive strength was 7.39 MPa at 7 days and more than doubling to 16.21 MPa at 28 days. G25 had the highest average value for all ages in three different ratios of citrogypsum. The compressive strength tended to increase moderately in all the ratio. There was a huge difference which can be considered between the result of the compressive strength of

REF and G25. Moreover, while the citrogypsum was added in double percent, the compressive strength almost halved. The highest compressive strength of the mortar G25, G50 (50% of citrogypsum) and G75 (75% of citrogypsum) obtained an average compressive strength of 16.21, 5.32 and 3.70 MPa, respectively, at 28 days. At 3 and 7 days of G100, the specimens could not measure because they cracked at under limited value. The highest value of G100 was 3.45 MPa at 28 curing days, can be clearly seen that 100% replacement of citrogypsum in OPC (ordinary Portland cement) was not suitable for cement mortar's production. The specimen before testing the compressive strength was shown in Figure 3.

As a result of decreasing of OPC's proportion in each specimen, the compressive strength dropped significantly because the main composition in OPC, namely, tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite, enhance directly the compressive strength in mortar. Therefore, the more replacement of citrogypsum in OPC, the lower that compressive strength was decline.

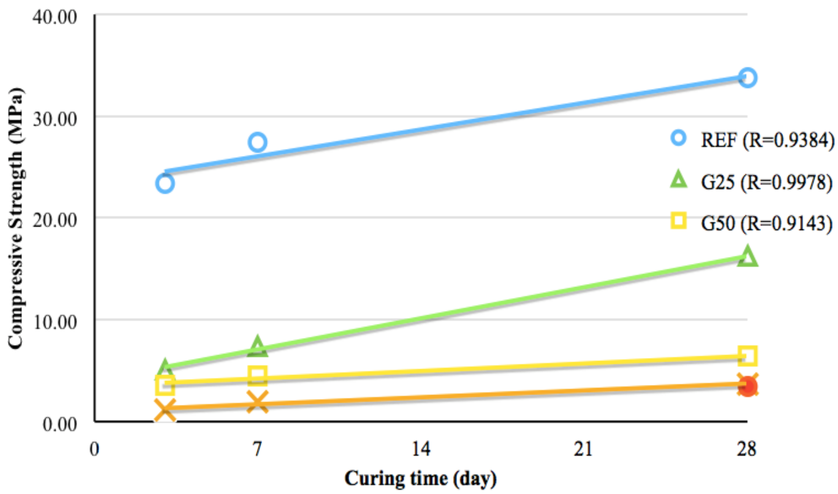

Figure 2. Relationship between compressive strength (MPa) and curing time (day)

The content of silica oxides should range between 18.6 - 23.4 percent by weight which effect to enhancement of compressive strength. According to composition of citrogypsum showed percent of silica oxides accounted for 0.2% which caused decreasing in compressive strength. According to ASTM C1329, the compressive strength of REF, G25 and G50 were higher than the values specified for the ages at 7 and 28 days which can use as a cement type N. It used for general purpose and non-load bearing wall which excellent for use in stucco and plaster applications and for laying glass block. However, all specimens that were replaced with citrogypsum had lower compressive strength than standard of mixed cements (TIS 80 - 2550) that should be more than 6.9 MPa and 11.8 MPa at 3 and 7 days, respectively.

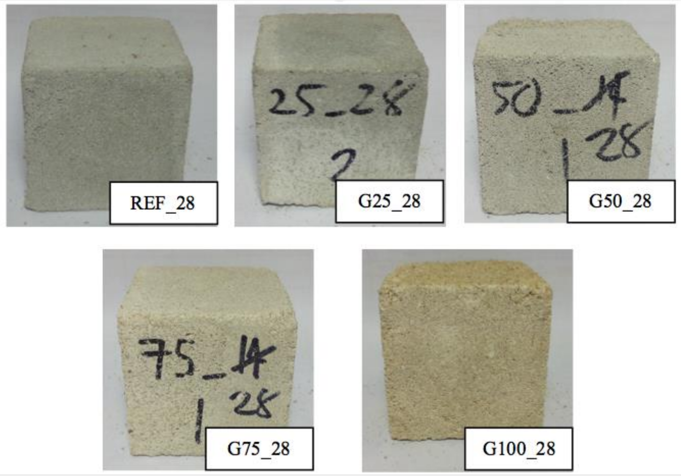

Figure 3. Specimen before testing the compressive strength

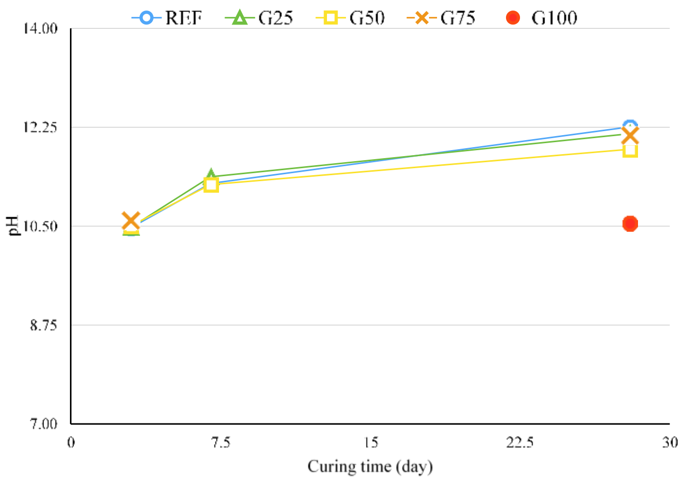

Figure 4. Relationship between pH and curing time (day)

3.2.2 pH

The range of pH from specimen powder was 10.47 to 12.26 which was alkalinity. The different of pH unrelated to ratio of citrogypsum and curing days. For instance, the higher of pH value, the larger number of curing time (Fig 4). As a consequence of this, in a watery solution calcium is mainly present as Ca^{2+} (aq), but it may also occur as $Ca(OH)_2$ (aq).

3.2.3 Water adsorption

Figure 5 shows water absorption of G50 was the highest value, in contrast, there was a lowest percent in REF. At 3 days of curing, G50 and G75 started at above 23% before dropping approximately 6% at 7 days of that. The specimen of G100 can be measured at only day 28th due to cracking of specimen before testing. The variations of water absorption with age and different percent of citrogypsum showed that the water absorption for all specimens decreased with increasing curing time which corresponded to those reported by Siddique (2013) that increasing the curing time resulted in decline of the water absorption value.

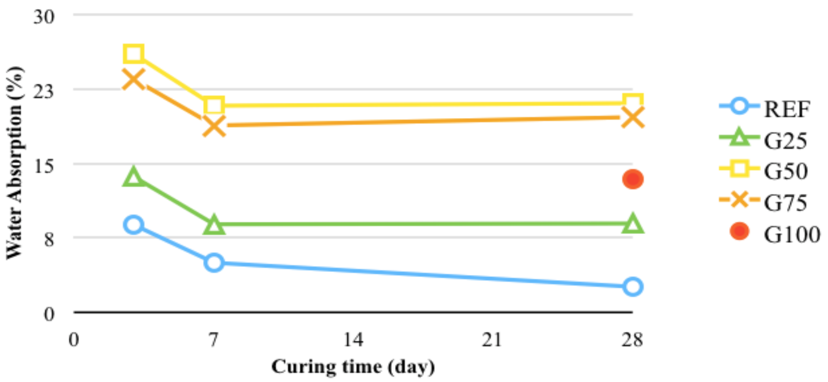

Figure 5. Effects of curing time on water adsorption (%)

3.2.4 XRD pattern

Each crystalline phase has a unique diffraction pattern that is investigated by X-ray diffraction (Bruker AXS). The XRD pattern of G25, G50, G75 and G100 at 28 days (Figure 6), the peak almost matched the REF pattern, hence, the different ratio of citrogypsum had no significant effect on mineral phase of cement mortars. The presence of gypsum ($CaSO_4$. $2H_2O$), quartz (SiO_2), microcline ($K_{0.95}N_{0.05}$) $AlSi_3O_8$ and portlandite ($CaO \cdot H_2O$), not only was detected in REF but also found in G50. Other specimens, G25 had not gypsum while G75 and G100 had no portlandite. The highest peak was quartz that found in all specimens because of sand.

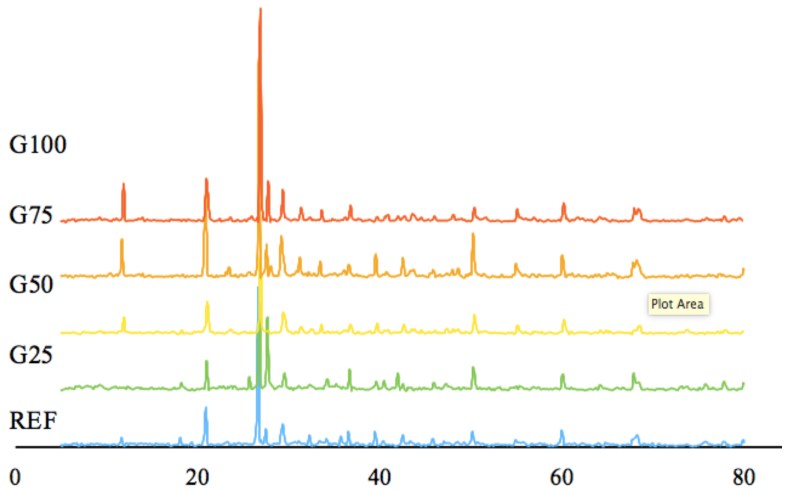

Figure 6. XRD patterns of cement mortar in varying ratio of citrogypsum

3.3 Insulation

3.3.1 XRD pattern

The hydration of calcium sulphate hemihydrate ($CaSO_4 \cdot 0.5H_2O$) resulted in the crystallization of gypsum (calcium sulphate dihydrate – $CaSO_4 \cdot 2H_2O$) shown in Figure 7 (Singh and Middendorf, 2007).

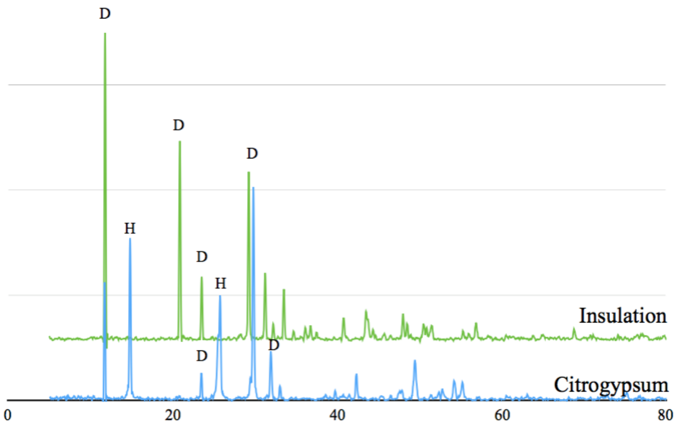

Figure 7. XRD pattern of insulation and citrogypsum

3.3.2 Flexural strength

The flexural strength of the 100% citrogypsum insulation products were range from 0.2 to 0.4 MPa, which was lower than the standard value (1 MPa) required by EN 13279 regulations for gypsum panels. Li et al. (2015) revealed the presence of hemihydrate affected to strength of specimen. The specimen before and after flexural testing was shown in Figure 8. For this reason, the flexural strength had a minimal value because insulation producing turned all of the hemihydrate to dihydrate by hydration reaction which shown in XRD pattern of insulation. Consequently, the amount of water should be limited causes to less chance of hemihydrate converts to dihydrate.

Figure 8. Specimen before (left) and after (right) flexural strength testing

3.3.3 Insulating properties

The main parameters that express the thermal performance of an insulation material are thermal conductivity, thermal diffusivity and specific heat. The citrogypsum was mixed with tap water and superplasticizer which had 0.394 W/m K. Insulation products had thermal conductivity between 0.02 and 0.40 W/m K (He, 2005). Furthermore, thermal conductivity evaluated for the citrogypsum insulation was much lower than for cement, 0.9 W/m K while it was almost the same with perforated brick (0.387 W/m K) (La Rosa et al., 2014). The results showed not as much thermal conductivity in citrogypsum insulation as in plaster while thermal conductivity of citrogypsum and block were identical value. Owing to a high thermal diffusivity, heat moves rapidly through it because the substance conducts heat quickly relative to its volumetric heat capacity (Parker et al., 1961), in proponent way for thermal conductivity, which excessive thermal conductivity results in the amount of heat through material. The insulation would be more effective, if the thermal conductivity and thermal diffusivity was marginally. For specific heat, it express the ability of the material to store thermal energy which necessary in the measurements of the thermal conductivity and thermal diffusivity (Shariq et al., 2010).

According to TIS 1384, thermal conductivity of citrogypsum insulation was higher than standard (0.042 W/mK) but it was similar to thermal conductivity of block. Moreover, there was not as heavier in citrogypsum insulation as in block. The multi-layer of insulation can improve thermal properties of insulation (Schiavoni et al., 2016), hence, installation of citrogypsum insulation should be more than one layer.

4. Conclusion

The application of citogypsum waste was investigated on the compressive strength of mortar using compressive strength machine with different mortar mixture. Additionally, thermal conductivity analysis technique is used to evaluate citrogypsum insulation. The results have indicated that the main composition of citrogypsum was CaO and SO_3. The specimens at 28 of curing day can be measured even though their average value was 3.45 MPa which lower than standard (6.2 MPa). The compressive strength of all specimens tended to increase gradually by rising the curing times.

According to ASTM C1329, a quarter and half replacement of citrogypsum in OPC had higher value than standard for cement mortar as type N cement. G25 had 7.39 MPa for 3 days and 16.21 MPa for 28 days. G50 had 4.48 MPa for 3 days and 6.41 MPa for 28 days. Thermal properties of citrogypsum insulation were satisfied level. The thermal conductivity, the thermal diffusivity and specific heat had 0.3937 W/mK, 0.3442 mm2/s and 1.1440 MJ/m3K, respectively. However, their flexural strength were not in an acceptable value. From this study, production of insulation is suitable for citrogypsum utilization than cement mortar due to requirement of simple process and materials.

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Effect of *Trichoderma Asperellum* Culture Conditions on Inhibition of Plant Pathogens and Kinds of Bioactive Compounds

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Abstract

Plant diseases are a major limiting cause in yield loss of agricultural production. Using of chemical microbiocides in plant disease control is harmful to human and environment. Therefore, the biological control is required. This study was investigated the effect of the culture conditions of *Trichoderma asperellum* culture on the production of bioactive compounds and the inhibition of plant pathogens. *T. asperellum* was isolated from soil of the naturally grown bamboo in Songkhla Province, Southern Thailand (accession no. LC152196). It was cultivated in 20% PDB broth for 28 days at 30°C in the static and the shaken conditions (100 rpm). The culture broths were extracted using ethyl acetate and the crude extracts were used to evaluate the minimum inhibition concentration (MIC), minimum fungal concentration (MFC) and minimum bacterial concentration (MBC) with 7 fungal plant pathogens (*Rigidoporus microporus, Aspergillus parasiticus, Fusarium culmorum, F. merismoides, F. oxyporum f.* sp. *gladioli*, *Verticillium albo-atrum* and *V. dahlia*) and 3 bacterial plant pathogens (*Agrobacterium tumefaciens*, *Erwinia carotovora* subsp. *carotovora* and *Xanthomonas oryzae*) by resazurin microtiter plate assay. The crude extract was analyzed by gas chromatography mass spectrometry (GC-MS). The result indicated that the crude extract from the static culture inhibited plant pathogens more than the crude extract from the shaking culture. Seven compounds (Cyclohexene-1-Methyl-4-(1-methylethenyl), 4H-pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl, 5-Hydroxymethyl, 2-Furancarboxaldehyde, 6-Pent-1-enylpyran-2-one, 1,2-Benzenedicarboxylic acid, dibutyl ester, 9,12-Octadecenoic acid and Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro-3-(phenylmethyl)) from the crude extract of the static culture were reported to have many activities such as antimicrobial, anticancer and antioxidant etc While only one compound from the crude extract of shaken culture as 1,2-Benzenedicarboxylic acid, dibutyl ester was reported to have a bioactivity.

***Keywords*:** bioactive compounds; Resazurin assay; plant pathgens; *Trichoderma asperellum*

1. Introduction

In agriculture, plant diseases are a major limiting cause in yield loss of agricultural production and result in economic losses. Thus, chemicals microbiocides and pesticides are used in plant disease control (Thi *et al*., 2012). However, microbiocides contained high sulphur doses are particularly harmful to beneficial microorganisms and insects, lead to deteriorating human health and cause environmental pollution (Elkot and Derbalah, 2011). Therefore, the biological control is required to prevent plant diseases. *Trichoderma* species are well-known biological control agents. *Trichoderma asperellum* has a potential to act as a biological control agent against plant pathogenic microorganisms (Brito *et al*., 2011).

The biological control properties are based on the activation of multiple mechanisms which can be divided into direct and indirect mechanisms (Bae *et al*., 2016). Direct effects consist of nutrient and space competition, volatile and non-volatile antibiotic production, cell wall degrading enzyme production and mycoparasitism (Mukherjee *et al*., 2012; Vinale *et al*., 2012 and Yang *et al*., 2013). Indirect effects consist of all aspects that biochemical and promote morphological changes in the host plant, such as induction of resistance to diseases, stress responses and nutrient availability (Hafez *et al*., 2013). Raut *et al*., (2014) used culture filtrate which were produced from *T. asperellum* T57 and T83 strains to inhibit the mycelial growth of *Fusarium graminearum*, *Pythium umtimum* and *Rhizoctonia solani*.

The aim of this study was to investigate the effect of the culture conditions of *T. asperellum* culture on the production of bioactive compounds and the inhibition of plant pathogens.

2. Materials and Methods

2.1 **T.** *asperellum and pathogens*

T. asperellum F14 was isolated from soil of the naturally grown bamboo in Songkhla Province, Southern Thailand (accession no. LC152196). The reference isolate of *R. microporus* was obtained from the Office of Agricultural Research and Development Region 8, Songkhla, Thailand. Three pathogenic bacteria, *Agrobacterium tumefaciens*, *Erwinia carotovora* subsp. *carotovora* and *Xanthomonas oryzae* and six pathogenic fungi, *Aspergillus parasiticus*, *Fusarium culmorum*, *F. merismoides*, *F. oxyporum f.* sp. *gladioli*, *Verticillium albo-atrum* and *V. dahliae* were obtained from the stock culture of Toyama Prefectural University, Toyama, Japan.

2.2 Preparation of crude extract from culture filtrate of T. asperellum and **effect** *on growth of bacterial and fungal pathogens*

T. asperellum was cultured on a PDA plate at 30°C for 2 days. The margin of mycelia was cut by using a sterilized cork borer (5 mm diameter). Twenty plugs of *T. asperellum* were inoculated into a 2-L flask containing 1 L of 20% PDB, and incubated at 30°C in shaker (100 rpm) and static conditions. After 28 days, mycelia and spores were removed from the culture broth by filtration through filter paper (Whatman No. 1). The culture filtrate was extracted with 1L of ethyl acetate.

The mixtures were shaken well and separated using a separating funnel. The solvent phase was collected and evaporated to dryness at 40°C by the vacuum rotary evaporator. The crude extracts were kept at -20°C.

The crude extracts were dissolved in 10% dimethyl sulfoxide (DMSO) until the concentration as 50 mg/mL. The minimal inhibitory concentration (MIC) was measured using resazurin 96-well microtiter plate (Zubair *et al*., 2011). Fifty μL of crude extracts was transferred into the secondary row of the sterile 96-well microtiter plate and diluted in two-fold dilution in other wells. Fifty μL of nutrient broth and potato dextrose broth for bacterial and fungal plant pathogens were added into each well and mixed well. Finally, 10 μL of bacterial or fungal suspension were added to each well to achieve a concentration of approximately 10^6 CFU/mL or 10^6 spore/mL. Streptomycin sulfate and miconazole nitrate at 50 mg/mL were used as antibacterial and antifungal agents for a positive inhibitory control. Negative control used 10% DMSO solution. The 96-well microtiter plate were incubated at 30°C. After one day of incubation, 10 μL of resazurin solution (270 mg of resazurin powder in 40 mL sterile Mili-Q water) was added to each well and the microtiter plates were incubated further for 24 h and 48 h for bacteria and fungi, respectively (Sarker *et al*., 2007). The color change was then assessed visually. The microbial growth was indicated using color change from blue to pink (or colorless). The lowest inhibition concentration at which color change occurred was taken as the MIC value (Hussain *et al*., 2011).

The minimal bactericidal concentration (MBC) and minimal fungicidal concentration (MFC) were determined by taking sample from the test dilution (used in MIC) onto fresh solid medium and were incubated further for 24 h and 72 h, respectively. MBC and MFC were defined as the lowest concentration of the compound to kill the microorganisms.

2.3 Analysis of bioactive compounds

The crude extract was reconstituted in 5 mL of ethyl acetate and 1 µl the extract was injected using a micro-syringe into the gas chromatography-mass spectrometry (GC-MS) using Agilent 5975C Inert XL EI/CI MSD with a triple-Axis Detector at 70 eV for analysis of bioactive compounds (Kuwahara *et al*., 2011). This was coupled to the 7890A gas chromatography (GC) system equipped with a DB-5MS column (30m x 0.25 mm; 0.25 μm, Agilent J&W) operated in the split-less mode at 60°C for 2 min, then programmed to increase at 10°C/min to 290°C, which was maintained for 5 min. Helium was used as the carrier gas at a flow rate of 1 mL/min. GC and GC-MS data were processed using ChemStation (Agilent Technologies Inc.) with reference to an MS database (Wiley 9th/NIST 2011 MS Library; Hewlett Packard Co.). All bioactive compounds showing mass spectra with match factors ≥ 90% were put on a "positive list" of tentatively identified metabolites. Retention indices were calculated under the present GC conditions, as described by Bodner and Raspotnig (2012).

2.4 Statistics

All experiments were carried out in triplicate. Analysis of variance (ANOVA) was performed and means comparisons were run by Duncan's multiple range test (DMRT) at 0.05 significant levels. Analysis was performed using a SPSS package (SPSS 16.0 for windows, SPSS Inc, Chicago, IL, USA).

3. Results and discussion

3.1 Effect of Trichoderma asperellum culture conditions on growth of plant pathogens

The crude extracts were prepared by extracting of the culture broths of *T. asperellum* with and without shaking using ethyl acetate and tested for antifungal and antibacterial activities by microtiter plate assay. The crude extract under the static culture condition (2.6085 g) and the crude extract under the shaken culture condition (2.1934 g) were maintained after vacuum evaporation from 1 L of culture broth. Fig. 1 and 2 showed the color change of resazurin dye from blue to pink or colorless when there was the microbial growth. Resazurin, an oxidation-reduction indicator, has been used to evaluate viability of microorganisms by reduce resazurin to resorufin and finally colorless dihydroresorufin (Mann and Markham, 1998). The results were compared between the cultures of the shaken condition and the static condition as shown in Table 1.

The MIC ranges of the crude extract from static culture of *T. asperellum* against fungi and bacteria were 0.78-3.13 and 0.39-3.13 mg/mL, respectively. Meanwhile, the MIC ranges of the crude extract from the shaken culture against fungi and bacteria were 1.56-12.50 and 6.25 mg/mL, respectively (Table 1). The crude extract from the static culture had the lowest MIC value (0.78 mg/mL) and the lowest MFC value (1.56 mg/mL), against *F. culmorum*, *F. merismoide* and *V. dahlia*. Meanwhile, the lowest MIC and MBC values were 0.39 mg/mL, against *A. tumefaciens*. The crude extract from the shaken culture had 12.50 mg/mL as the highest of MIC and MFC values, against *R. microporus*. While, the lowest of MIC and MBC values were 6.25 mg/mL, against *A. tumefaciens*. Therefore, it could be concluded that the crude extract of *T. asperellum* under the static culture inhibited pathogenic fungi and bacteria better than the crude extract of the shaken culture.

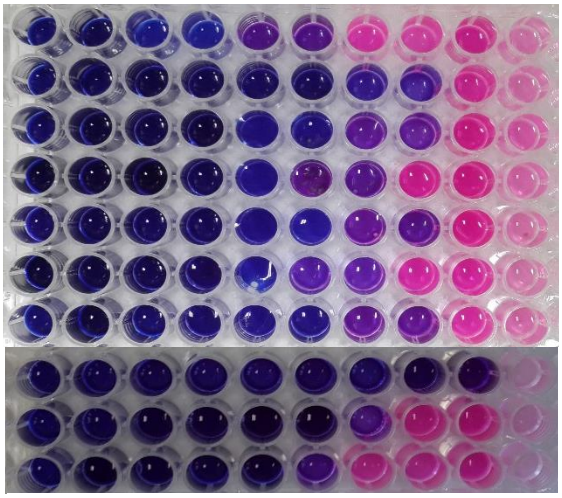

Figure 1. Evaluation of resazurin microtitre assay results of crude extract from *Trichoderma asperellum* culture in the static condition against plant pathogens. Rows: 2 - 9 as crude extract concentrations using a two-fold dilution series from 50 mg/mL - 0.39 mg/mL, C = 10% DMSO as negative control and P = Streptomycin sulfate and miconazole nitrate as positive control for bacteria and fungi.

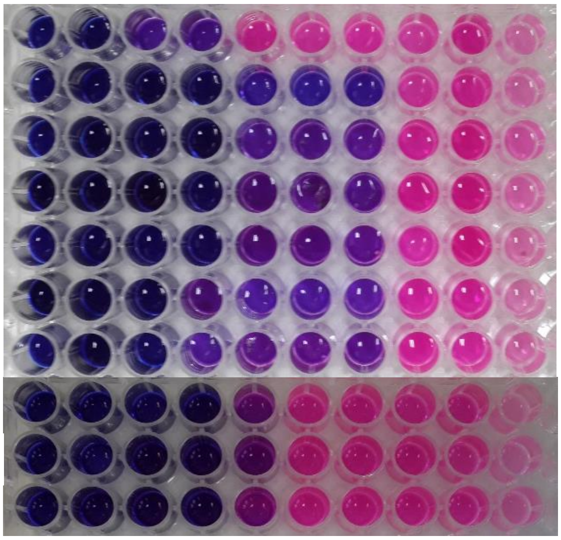

Figure 2. Evaluation of resazurin microtitre assay results of crude extract from *Trichoderma asperellum* culture against plant pathogens in the shaken condition at 100 rpm. Rows: 2 - 9 as crude extract concentrations using a two-fold dilution series from 50 mg//mL - 0.39 mg/mL, C = 10% DMSO as negative control and P = Streptomycin sulfate and miconazole nitrate as positive control for bacteria and fungi.

Table 1. MIC, MBC and MFC values of crude extract from culture filtrate of *Trichoderma asperellum* F14 under static and shaken conditions against plant pathogens.

Pathogenic fungi	**Static (mg/mL)**		**Shaken (mg/mL)**	
	MIC	**MFC**	**MIC**	**MFC**
R. microporus	3.13	12.50	12.50	12.50
F. culmorum	0.78	1.56	1.56	6.25
F. merismoides	0.78	1.56	1.56	3.13
A. parasiticus	1.56	6.25	1.56	6.25
F. oxysporum f. sp. *gladioli*	0.78	3.13	1.56	3.13
V. albo-atrum	1.56	3.13	1.56	6.25
V. dahliae	0.78	1.56	1.56	3.13
Pathogenic bacteria	**Static (mg/mL)**		**Shaken (mg/mL)**	
	MIC	**MBC**	**MIC**	**MBC**
A. tumefaciens	0.39	0.39	6.25	6.25
E.carotovora subsp. *carotovora*	1.56	1.56	6.25	12.50
X. oryzae	3.13	3.13	6.25	12.50

According to the result of Asad *et al*. (2015) reported the effect of the crude extract from the shaken culture of *T. asperellum* at 100 rpm on the inhibition of the mycelia growth of *Rhizoctonia solani*. The result showed that the crude extract of *T. asperellum* inhibited 97.7% of *R. solanimycelia* growth. Sadykova *et al*. (2015) described that *T. asperellum* produced the antibiotic active compounds which inhibited the pathogens.

3.2 Bioactive compounds from T. asperellum at static and shaken conditions

Table 2. Bioactive compounds from crude extract of *Trichoderma asperellum* culture under static condition.

Peak	**Chemical**	**Formula**	**RT (min)**	**MW**	**%**
1	Cyclohexene-1-Methyl-4-(1-	$C_{10}H_{16}$	6.897	136.13	0.075
2	methylethenyl)-	$C_5H_4O_3$	7.277	112.08	0.048
3	2-Furancarboxylic acid	$C_7H_{10}O_2$	8.251	126.16	0.105
4	2-Cyclopenten-1-one,3-ethyl-2-hydroxy-	$C_6H_8O_4$	8.682	144.13	0.517
5	4H-pyran-4-one,2,3-dihydro-3,5-	$C_6H_6O_3$	9.871	126.11	0.719
6	dihydroxy-6-methyl-	$C_8H_8O_2$	10.148	136.15	0.210
7	5-Hydorxymethyl, 2-	$C_6H_{10}O_3$	10.456	130.14	0.690
8	furancarboxaldehyde-	C_8H_7N	10.948	117.15	0.137
9	Benzeneacetic acid	$C_8H_8O_4$	11.902	168.15	0.273
10	2H-Pyran-2-one, tetrahydro-4-hydroxy-	$C_8H_{10}O_2$	12.743	138.17	5.878
11	4-methyl-	$C_{10}H_{14}O_2$	13.153	166.22	1.054
12	1H-Indole	$C_{10}H_{16}O_2$	13.759	168.15	1.210
	2H-Pyran-2,4(3H)-dione,3-acetyl-6-				
13	methyl-	$C_{10}H_{12}O_2$	13.995	164.20	2.115
14	Benzeneethanol, 4-hydroxy-	$C_{15}H_{24}$	15.307	204.36	8.391
	6-Amyl.alpha.pyrone				
15	(3R,3aS,7aR)-3a,4,5,6,7a-Tetrahydro-	$C_{15}H_{17}N_2$	15.533	225.14	2.169
16	3,6-dimethylbenzofuran-2(3H)-one	$C_7H_{10}N_2O_2$	16.692	154.17	1.124
17	6-Pent-1-enylpyran-2-one	$C_{17}H_{16}$	18.374	220.32	4.587
18	(3R,3aS,7aR)-1,4-dimethyl-7-prop-1-en-	$C_{16}H_{22}O_4$	18.723	278.35	0.094
19	2-yl=1,2,3,3a,4,5,6,7-octahydroazulene	$C_{18}H_{32}O_2$	20.364	280.45	0.824

20	2,9-dihydro-1,9-dimethyl-1H-carbazole-	$C_{18}H_{36}O_2$	20.415	284.48	0.419
21	3-carbonitrile	$C_{12}H_{16}N_2O_2$	20.630	220.27	0.205
22	Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahhydro-	$C_{20}H_{16}O_5$	22.220	336.34	0.193
23	2,3,10-Trimethylphenanthrene 1,2-Benzenedicarboxylic acid, dibutyl	$C_{14}H_{16}N_2O_2$	22.548	244.29	0.329
24	ester 9,12-Octadecenoic acid	$C_{17}H_{16}O_5$	23.656	300.31	5.377
25	n-Octadecanoic acid	$C_{24}H_{36}O_4$	23.769	390.56	1.938
26	3-Benzyl-1,4-diaza-2,5-dioxobicyclo[4.3.0]nonane 2-Formyl-1-methoxy-4-(2-methylprop-2-enyloxy) anthraquinone Pyrrolo[1,2-a]pyrazine-1,4-dione,hexahhydro-3-(phenylmethyl)- 1-oxa-2-oxa-3,8-dihydroxy-6-methyl-acenaphthylo[4,5-b] (1-oxa-4,45trimethyl-cyclopentane) Phthalic acid, bis(2-ethylhexyl)ester 2,6,10,14,18–Pentamethyl-2,6,10,14,18-eicosapentaene	$C_{25}H_{42}$	25.953	342.61	0.391

The crude extracts from the culture filtrate of *T. asperellum* both the static culture and the shaken culture were prepared by extracting with ethyl acetate. These crude extracts were analyzed by GC-MS. Twenty-six compounds were detected in the crude extract from the culture filtrate of *T. asperellum* cultivated in the static culture as shown in Table 2. The main compounds were (3R,3aS,7aR)-1,4-dimethyl-7-prop-1-en-2-yl=1,2,3,3a,4,5,6,7-octahydroazulene (8.39%), benzeneethanol, 4-hydroxy-(5.88%), 1-oxa-2-oxa-3,8-dihydroxy-6-methyl-acenaphthylo[4,5-b], (1-oxa-4,45trimethyl-cyclopentane) (5.38%) and 2,3,10-trimethylphenanthrene (4.59%). In addition, many detected compounds showed bioactivity by the other studies (Table 4) such as Cyclohexene-1-methyl-4-(1-methylethenyl) (0.08%) as antimicrobial (Mohammed *et al*. 2016), 4H-pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl (0.52%) as anti-inflammatory, antimicrobial, antiproliferative (Ramalakshmi and Muthuchelian. 2011), 5-Hydroxymethyl, 2-furancarboxaldehyde (0.72%) as preservative, antimicrobial (Jadhav *et al*. 2014), 9,12-octadecenoic acid (0.82%) as hypocholesterolemic cancer preventive, hepatoprotective, nematicide, anti-inflammatory, insectifuge, antieczemic, antihistaminic, antiacne, 5-alpha reductase inhibitor, antiandrogenic, anticoronary, antiarthritic, insectifuge (Rajeswari *et al*. 2012), 6-Pentyl-2H-pyran-2-one (2.12) as Antifungal (Thi *et al*. 2012), Pyrrolo[1,2-a]pyrazine-1,4-dione,hexahydro-3-(2-methylpropyl) (0.33) as Antifungal (Itamar *et al*. 2014) and 1,2-Benzenedicarboxylic acid, dibutyl ester (0.09%) as antimicrobial (Aly *et al*, 2013) as shown in Table 4. Meanwhile, the crude extract from the culture filtrate of *T. asperellum* cultivated in the shaken culture were detected 14 compounds as shown in Table 3. The main compounds were 2- butoxyethanol (5.54%), 5-tert-butyl-3,4-dimethoxybenzaldehyde (3.56%) and 2H-pyran-2,4(3H)-dione,3-acetyl-6-methyl-(3.13%). In addition, only one compound, 1,2-Benzenedicarboxylic acid, dibutyl ester (2.86%) showed bioactivity (Aly *et al*, 2013) (Table 4).

Table 3. Bioactive compounds from crude extract of *Trichoderma asperellum* culture under shaken condition.

Peak	Chemical	Formula	RT(min)	MW	%
1	2-Butoxyethanol	$C_6H_{14}O_2$	4.764	118.18	5.543
2	2-alpha-Methyl-4-chloro-trans-	$C_{18}H_{13}ClO_2$	5.533	296.75	0.369
3	styrylchromone	$C_6H_{13}NO_2$	10.630	131.17	0.261
4	N-(1-Hydroxy-3methylbutan-2-	$C_{10}H_{20}O_4$	11.800	204.27	2.404
5	yl)-formamide	$C_8H_8O_4$	11.902	168.15226.36	3.125
6	2-(2-Butoxyethoxy)ethyl	$C_{14}H_{26}O_2$	12.466	152.15	1.142
7	acetate	$C_8H_8O_3$	12.579	166.22	0.373
8	2H-Pyran-2,4(3H)-dione,3-	$C_{10}H_{14}O_2$	13.154	168.15	2.288
9	acetyl-6-methyl-	$C_{10}H_{16}O_2$	13.759		1.033
	2,4,7,9-Tetramethyldec-5-yne-			164.20	
10	4,7-diol	$C_{10}H_{12}O_2$	13.995	164.20	0.624
11	4-Methoxybenzoic acid	$C_{10}H_{12}O_2$	14.354	225.14	0.486
12	(3S,3aS,7aR)-3,6-dimethyl-	$C_{15}H_{17}N_2$	15.533	222.28	1.378
13	3a,4,5,7a-tetrahydro-3H-	$C_{13}H_{18}O_3$	15.625	278.35	3.555
14	(3R,3aS,7aR)-3a,4,5,6,7a-	$C_{16}H_{22}O_4$	18.723		2.861
	Tetrahydro-3,6-				
	dimethylbenzofuran-2(3H)-one				
	6-Pent-1-enylpyran-2-one				
	3-Methoxy-2-prop-2-				
	enylphenol				
	2,9-dihydro-1,9-dimethyl-1H-				
	carbazole-3-carbonitrile				
	5-tert-Butyl-3,4-				
	dimethoxybenzaldehyde				
	1,2-Benzenedicarboxylic acid,				
	dibutyl ester				

Four bioactive compounds from crude extract of *Trichoderma asperellum* culture which were produced from both static and shaken conditions were 2H-Pyran-2,4(3H)-dione,3-acetyl-6-methyl, 6-Pent-1-enylpyran-2-one, 2,9-dihydro-1,9-dimethyl-1H-carbazole-3-carbonitrile and 1,2-Benzenedicarboxylic acid, dibutyl ester.

4. Conclusion

The crude extract of *T. asperellum* from the static culture showed more inhibitory against plant pathogens than the crude extract from the shaken culture. Furthermore, 7 of 26 compounds as Cyclohexene-1-methyl-4-(1-methylethenyl), 4H-pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl, 5-Hydroxymethyl, 2-furancarboxaldehyde, Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro-3-(phenylmethyl), 9,12-Octadecenoic acid and 1,2-Benzenedicarboxylic acid, dibutyl ester from the crude extract of the static culture have been reported to have bioactivity, while 1 of 14 compounds as 1,2-Benzenedicarboxylic acid, dibutyl ester from the crude extract of the shaken culture have been reported to have bioactivity.

Table 4. Reported of bioactivities of the identified bioactive compounds from *Trichoderma asperellum* by GC-MS analysis.

Compound	Bioactive compound
Cyclohexene,1-methyl-4-(1-methylethenyl)-,(R)-	Antimicrobial (Mohammed *et al*. 2016)
4H-pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl-	Antimicrobial, anti-inflammatory, antiproliferative (Ramalakshmi and Muthuchelian. 2011)
5-Hydorxymethyl, 2-furancarboxaldehyde-	Antimicrobial, preservative (Jadhav *et al*. 2014)
Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro-3-(phenylmethyl)-	Antimicrobial (Prasanna *et al*. 2012)
9,12-Octadecenoic acid	Anti-inflammatory, hypocholesterolemic cancer preventive, hepatoprotective, nematicide, insectifuge, antihistaminic, antieczemic, antiacne, 5-alpha reductase inhibitor, antiandrogenic, antiarthritic anticoronary, insectifuge (Rajeswari *et al*. 2012)
1,2-Benzenedicarboxylic acid, dibutyl ester	Antimicrobial (Aly *et al*, 2013), antifungal, antioxidant (Vimalavady and Kadavul, 2013), antimalarial (Khatiwora *et al*, 2012)
6-Pentyl-2H-pyran-2-one	Antifungal (Thi *et al*. 2012)

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Effect of Acid-Alkaline and Thermal Pretreatment on Cassava Pulp Feed Batch Reactors in Optimization of Bio-Methane Yield

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Abstract

Cassava starch mills in Nakhon Ratchasima province operate biogas plant to harness renewable energy from surplus cassava pulp by Anaerobic Digestion (AD) technologies but the industry encounters fluctuated biogas yields and digestion failure due to the lack of effective digester configuration and understanding on specific properties of cassava pulp substrate. This study used acid-alkaline and thermal pretreatment to modify the cassava pulp substrate to enhance biogas yield. Concentrated 36N sulfuric acid (H_2SO_4) and 20 N sodium hydroxide (NaOH) had been chosen as acid-alkaline pretreatment to adjust pH of hydrolyzed substrates, and 200˚C for 45 min was given as thermal pretreatment. Extreme pH adjusted substrates such as T1, T2, T12 and T13 required both acid and alkaline in high volume, and inhibition occurred from both acid and alkaline resulting retarded fermentation executed by hydrolytic bacteria upon digestion started, fewer volatile fatty acid to total alkalinity ration (VFA:TA), more reducing sugars depletion and lesser bio-methane yield. The results showed Soluble Chemical Oxygen Demand (SCOD) obtained from decomposition of lignocellulosic structure of fresh cassava pulp by combined thermal-chemical pretreatment, was found highest in T2 which was pretreated to pH 2 having more than 100 g/l. Though SCOD could be enhanced by acid-alkaline pretreatment, it led to inhibition driven by radicals of acid and alkaline. Three different mixing ratios, i.e. 3%, 5%, and 10% (w/v) were compared for batch process, and found 5% Total Solid (TS) was most suitable after subjected to acid-alkaline pretreatment and produced biogas yield at 4125.2 ml/kg TS in batch digestion for 21 days. The pretreated results were compared against without pretreated samples, and found biogas could be produced up to 6 folds than without pretreated samples.

***Keywords*:** cassava pulp, acid-alkaline, thermal pretreatments, anaerobic digestion, SCOD.

1. Introduction

Energy plays pivotal role in driving world economy, and the world is attempting any mean to ensure energy security from reliable energy resources. However, the combination in massive extraction of fossil fuel and its dwindling reserve plus environmental costs has changed the world with the concept of energy reliance from exhaustible energy sources such as coal, petroleum and natural gas to rather sustainable and renewable sources like biomass, solar, wind, hydroelectric and geothermal. In this regard, to promote the renewable energy sector of the country, Thailand attempts to harness energy from biomass to reduce heavily dependence on energy import (AEDP 2015). The development from agricultural to agro-industrial phase enables Thailand with great potential to harness renewable energy from agro-industrial byproducts. With the steadily increase in cassava (tapioca) cash crop production annually, Thailand ranks the top cassava and its related foodstuff production in the region, South East Asia. According to Thai Tapioca Starch Association's figure the production surpassed 33 million tons in 2015/2016. The industry generates massive quantity of numerous by-products in its starch production chains which trigger environmental burdens in term of a mounting obligation to industrial waste management in starch mills. On average, for each ton of cassava starch, it produces 1.4 – 1.6 tons of highly fibrous carbon source enriched cassava pulp and 19 – 22 m^3 of wastewater (Chavalparit and Ongwandee, 2009). Low protein content in cassava pulp makes them unattractive to animal feeds manufacturer to make use of common food source for livestock. Therefore, they are being left fermented triggering environmental burdens in starch factories.

Anaerobic Digestion (AD) technology for energy production in either bio-methane (CH_4) or bio-ethanol (CH_3CH_2OH) is proven technology to resolve piling agro-industrial residues for energy recovery from diverse biodegradable biomass (Karlsson et al., 2014). However, the technology includes numerous restrictions and limitations for developers to harness dependable and stable energy recovery under the constraints of cost and benefit analysis. In brief, anaerobic digestion process starts with hydrolysis, acidogenesis, acetogenesis and methanogenesis in order through symbiosis of diverse anaerobic bacteria and synthesized products of each phase (Pavlostathis and Giraldo-Gomez et al., 1991). Biomass having carbohydrates, proteins and lipids in complex polymer are subjected to decompose by mean of hydrolysis converting them into monomers in term of amino acids, sugars, alcohols and fatty acids (McCarty and Mosey, 1991; Pavlosthatis and Giraldo-Gomez, 1991; Gallert and Winter, 1999). In acidogenesis stage, the products of hydrolysis are transformed into intermediary products such as acetate, propionate, ethanol and lactate (Gerardi, 2003). Acetogenesis is responsible for converting these intermediary products into predominant acetic acid (CH_3COOH), hydrogen (H_2) and Carbon dioxide (CO_2) (Pavlosthatis and Giraldo-Gomez, 1991; Veenstra, 2000; Gerardi, 2003). Final products such as methane (CH_4) and (CO_2) are produced in final stage, methanogenesis (Veenstra, 2000; Metcalf & Eddy, 2003). The success of biogas process and biogas plant also depend on design parameters such as temperature, loading rate, retention time, solids concentration, C/N ratio, alkalinity, pH, inhibitors and stimulators (Anderson and Yang, 1992). The selection of digestion system is based on the availability of resources and plant capacity. Despite plenty of studies have been conducted on both bio-methane potential of different biomasses and review on anaerobic digestion technology, especially specific research regarding cassava pulp is yet to be elucidated.

All type of biomass in general composed of cellulose, hemicellulose, and lignin which in combination are known as lignocellulose (Zhao et al., 2012). Each individual biomass possesses distinct structural configuration and composition making them difficult to break down during AD processes (Taherzadeh and Karimi, 2008). Although cellulose of common biomass are insoluble in water and hemicellulose with lignin chains are sensitive to thermal and chemical, upon subjected to suitable pretreatment, they start to dissolve enriching nutrient content of the feedstock material. Therefore, different pretreatments depend on type of biomass arose for the objective of enhancing substrate solubility and enzymes attack for better substrate degradability. Out of several pretreatment options available, while thermal, chemical, and ultrasonic method were proved effective, time saving, and economically feasible, whereas the biological and enzymatic methods remains unattractive because of complexity and slow rate (Leu and Zhu, 2013). Selection of pretreatment methods rely on the properties of individual biomass and applicability. In recent years, researchers had been focusing on diverse ranges of biomass, specifically from forest, agricultural residues, herbaceous grass to municipal waste (Linné et al. 2008; Barakat et al., 2012; Björkmalm, 2013; Carrère et al., 2010). But cassava crop residues remain to be studied as no other Country produces tapioca as commercial cash crop and develops cassava pulp feed biogas plant than Thailand.

Several authors reported application of pretreatment methods for cassava waste to produce diverse ranges of product from bio-ethanol to hydrogen. Phowan and Danvirutai (2014) reported that hydrogen yield of 432 ml H_2 g^{-1} $COD_{reduced}$ and hydrogen production rate of 2281 ml H_2 L^{-1} d^{-1} was achieved by using dilute sulfuric acid pretreatment up to 5% within reaction time 30 mins and temperature at 121˚C. Similarly, for fuel ethanol, a studies conducted by Srinorakurata and Kaewvimol et al. (2007), by using combination of dilute sulfuric acid of 0.2 -5.0 M and enzyme type of α-amylase at the temperature of 60-120 ˚C for 30 min, maximum ethanol production was found 3.62% (w/v) in 10L fermenter at 24 hrs. Also, Kosugi and Kondo et al., (2009) conducted pretreatment of cassava pulp to produce ethanol by using hydrothermal and enzymatic hydrolysis. In the studies, the researchers used H_2SO_4 having concentration 0.1 or 2.0 %, K7 strain, and heated at 120 to 180 ˚C for 1h, proving ethanol could be produced up to 40 g/liter within 7 days of fermentation. With regard to NaOH addition, Penaud et al. (2006) proved that upon hydrolyzing biomass COD for 30 min at 140 ˚C and pH 12, COD could be increased to 71% of any substrates. Although there are plenty of researches relating to pretreatment methods to enhance liquid biofuels, in the field of biogas the novel researches remain to be explored.

This study fills this gap highlighting optimization of biogas yield from cassava pulp feed batch rectors by concentrated acid-alkaline and thermal pretreatment. Cassava pulp were subjected to strong sulfuric acid (H_2SO_4), sodium hydroxide

(NaOH) and thermal hydrolysis prior to execute anaerobic digestion in batch reactors in term of different pH ranges and 3 different solid contents, i.e. 3% TS, 5% TS and 10% TS. The influence of acid-alkaline and thermal pretreatment results and digesters' performance were compared against control sets. The study intends to enhance biogas yield in existing cassava pulp feed biogas plants in cassava industry by applying the findings and modify current practice of directly feeding them as common feedstock through mixing cassava pulp with mill effluent.

2. Experiment

2.1. Materials and methods

Fresh cassava pulp were collected from Korat Starch Factory located in Nakhon Ratchasima province in northeastern Thailand. Qualitative surveying was made prior to collect in determining cassava tuber variety from local farmers, and found four major species, namely CMC 76, KU 50, Rayong 60, and Rayong 90 are cultivated commercially in this province. Upon proximate analysis done for each individual sample collection, fresh cassava pulp of all variety was found having moisture contents between 55-70% on wet basis, 60-65% of starch and 15- 18% of fiber respectively (AOAC, 1990). Wastewater from the starch mill had been chosen for hydrolysis and stored under 4˚C in cold storage until used. APHA standard methods (1995) were used to determine Total Solid (TS), Total Dissolved Solid (TDS), Volatile Solid (VS), Total Phosphate (TP), Volatile Fatty Acids (VFA), Soluble Chemical Oxygen Demand (SCOD), Total Kjeldahl Nitrogen (TKN), alkalinity, Carbon to Nitrogen ratio (C/N), and reducing sugars. Inoculum was taken from parent biogas plant, maintained at 35 ˚C and utilized within 12 hours of collection time. Inoculum properties having pH value about 7.5-8.0. Laboratory samplings were done prior to start anaerobic digestion in batch reactors.

2.2. Acid-alkaline and thermal pretreatment

Cassava substrates were made in 3% TS, 5% TS and 10 % TS (w/v) by mixing solid cassava pulp with 1000 ml effluent wastewater from starch mill. Concentrated sulfuric acid (H_2SO_4) of 36 N and sodium hydroxide (NaOH) of 20 N were used to adjust desired pH ranging 1-13 denoting pretreatments from T1 to T13 shown in figures. Since the boiling point of the substrates which is the combination fibrous cassava pulp and mill effluent starts at 150 ˚C, and for practical approach to biogas plant, temperature and reaction time for acid-alkaline and thermal pretreatment were set at 200 ˚C for 45 min on hot plate, and left for cooling and further acid-alkaline attack for 6 hrs. Finally hydrolyzed samples were neutralized back to pH value of 7.5 for digestion. Therefore, the whole pretreatment mechanism includes forward and backward neutralization to each desired pH set before and after thermal pretreatment. Two control samples, one in natural wastewater with neither acid-alkaline nor thermal pretreated (C1) and one with only being adjusted to pH 7 (C2) but was not subjected to thermal pretreatment, were compared with against all acid-alkaline and thermal pretreated sample sets (T1-T13). For trial investigation on the effect of acid-alkaline and thermal pretreatments, sampling were run on 3% TS, and then integrated the results for remaining 5% TS and 10% TS.

2.3. Biogas potential assay and statistical analysis

To obtain optimum gas yield from the batch reactors of each set, batch reactors were set up in polypropylene bottles of 650 ml content. The head space was largely eliminated by adding 300ml of prepared substrate and 300 ml of inoculum. Batch reactors in three different solid contents, i.e. 3% TS, 5% TS and 10% TS were set up separately and compared. The Food to Microbial ratio (F/M) was set at 0.5 and anaerobic digestion was maintained under 33 ˚C (+/- 2) in thermo-control room. Digestion period (HRT=SRT) was set 3 weeks (21 days). Biogas was collected in water displacement system and the total biogas yield was measured at the end of digestion period. To avoid possible interferences, the variances between each samples during laboratory investigation of control parameters were eliminated by triplicating each individual sample set.

3. Results and Discussion

3.1. The effect of chemical pretreatment on pretreatments and substrate properties

The effect of acid-alkaline pretreatment contributes not only in accelerating solubility of carbon source attached in lignocellulosic structure of biomass but also in adjusting desired pH upon addition of relevant acid or base. The stronger the acid or base, the quicker changes in pH during hydrolysis. The effect of thermal treatment at 200 ˚C did not substantially impact to changes in pH. The original pH of substrate which is the mixture of cassava pulp and mill effluent was found at approximately at pH 4.3. The addition of strong acid (H_2SO_4) and alkaline (NaOH) in hydrolysis catalyzed chemicals attack for decomposition of lignocellulosic structure of cassava pulp. The demand of acid and alkaline for 3% (w/v) was reported in Figure 1. While higher solid contents required much volume of chemicals, resulting high solubilisation of COD that led to excessive loading for batch digester for this study causing inhibition for microbial to initiate AD process. The overall w/v of substrate was ultimately maintained by using strong acid and base in hydrolysis since uniform substrate volume is necessary to control prior to start digestion within the specified solid to liquid ratio and food to microbial (F/M) ratio of 0.5.

The experimental results revealed the extreme pH treated substrates which demanded substantial volume of both strong NaOH and H_2SO_4 of equivalent up to 4000 mg/l of sodium and 2500 mg/l of sulfate (figure 1), were found having inferior digestion performance in comparison to those substrates treated with neutral ranges. This is due to the fact that both sodium ion (Na^+) and Sulfate ion (SO_4^{2-}) inhibition co-occurs during anaerobic digestion. Even though, strong acid and alkaline can enhanced solubility of degradable organic fraction, the increased in soluble COD was also related to the combination of both thermal and chemicals effect. While thermal pretreatment of above 150 ˚C for more than 30 min can exterminate the effects on enzymes, fungus and microbial exist in the substrates, weaker acid and alkaline can significantly change final solid to liquid ratio (w/v) by adding more base and acid volume, then subsequently affects F/M ratio and modifies into new solid content of the digester. Therefore, despite thermal pretreatment could enhance solubilisation of carbon source in the substrates, it required higher F/M ratio for AD process to be initiated.

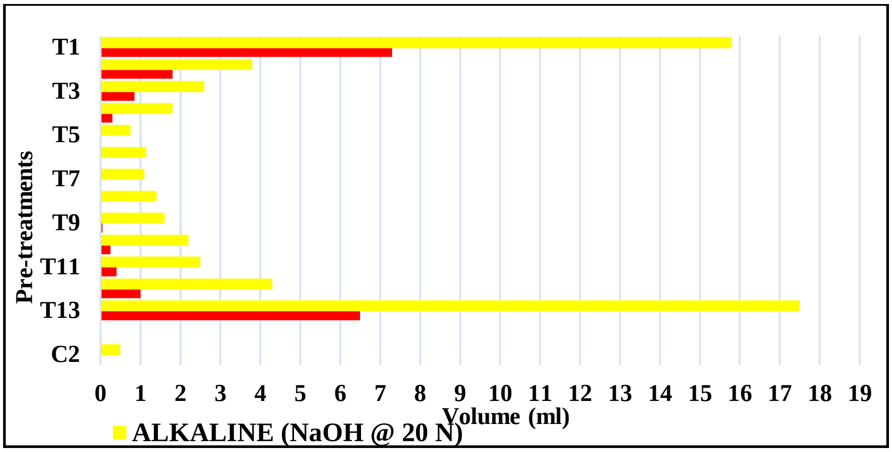

Figure 1. Demand of acid and alkaline volume for hydrolysis of 3% (w/v) of cassava pulp.

3.2. The influence of thermal-chemical pretreatments on SCOD

Based on experiment results, substrates subjected to pH 2 (T2) was found producing highest soluble chemical oxygen demand (SCOD) of more than 100,000 mg/l (Fig. 2). With the exception of substrates treated to pH 13 (T13), the remaining sample sets produced SCOD ranging between 70, 000 to 90,000 mg/l. It can be concluded that highly acid subjected substrate had higher SCOD formation than those alkaline treated samples. In addition, the formation of SCOD varied inversely proportional to the TSS and VSS since complex polymer compounds of cassava pulp were dissolved during hydrolysis. In contrast, SCOD production increased as increased in total solid contents in the raw substrates. Since, the physiochemical properties of cassava pulp is highly enriched with carbohydrate, total solid contents of more than 5% was found inhibition effects on microorganisms to initiate biogas fermentation processes. Control sets, C1 was found producing no noticeable amount of SCOD to its original SCOD values of 25,000 mg/l and C2 being only acid-alkaline pretreated produced 580,000 mg/l. Thus, the experiment revealed that SCOD originated from cassava pulp which is as major source for biogas production in this studies could be enhanced either by applying either acid-alkaline or thermal pretreatment. But the combined pretreatment proved producing higher SCOD yield.

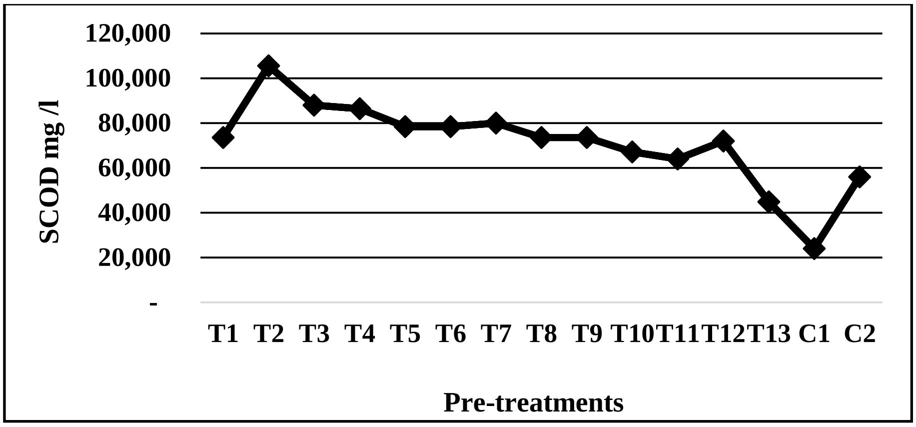

Figure 2. SCOD produced by acid-alkaline and thermal pretreatment of cassava pulp in 60 min of 3% (w/v).

3.3. The impact of pH changes on C/N ratio across each pretreatment

Due to the strong chemicals attack, samples having lower pH has lesser C/N ratio. T1 and T2 which were subjected to pH 1 and 2 respectively were found having minimum C/N ratio of 36.6 and 36.9 respectively. Then, the ratio became normalized between 40-44 as increased in pH. Observed C/N ratio according to the effect of pH in each treatment is summarized in figure 3. While the origin of C/N ratio in C1 marked the highest at 45, upon hydrolyzed, C/N ratio of cassava pulp were ranging between 40-44 and which is moderately higher than optimal range (20-30:1) for anaerobic digestion (Maishanu et al, 1991,Bardiya and Gaur,1997). It can be assumed that the solubilisation of COD and C/N ratio are interconnected since higher SCOD production results lesser C/N ratio remains in substrates. Therefore the results highlights nitrogen supplementation is highly necessary. Since physiochemical composition of individual cassava variety is identical within different cassava verities, sampling results can represents overall 4 varieties used in the industry (Anunputtikul, M. W. 2004).

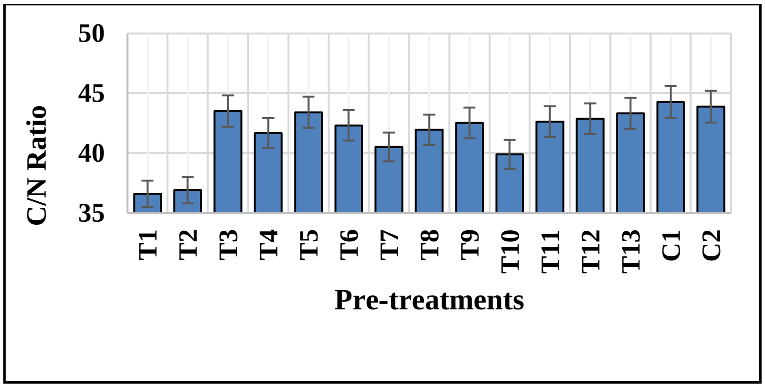

Figure 3. Impact pH on C/N ratio of cassava pulp 3% (w/v) by thermal-chemical pretreatments.

3.4. The Effect of Hydrolysis on VFA to TA Ratio and Reducing Sugars

This studies revealed that the ratio of Volatile Fatty Acids (VFA) to Total Alkalinity (TA) values of all hydrolyzed samples were ranging between 0.15-0.31 with the exception of C1 having 2.69. Although the syntrophic action of hydrolytic, acidogenic or fermentative bacteria of anaerobic groups generate volatile fatty acids as their synthesized products (Bitton, 1994; Milono et al., 1981), this group of bacteria was not active in pretreatment stage. Therefore, the addition of acid and alkaline are only factors that modify the total alkalinity of individual substrates depend on consumption during acid-alkaline pretreatment. The VFA found in this stage was associated to residual VFA present in fresh cassava pulp. Therefore, the addition of acid and alkaline pertains as critical role in maintaining VFA to TA ratio.

The results from the experiment indicated extreme pH treated samples, i.e. T1 and T2 required higher alkaline, NaOH which caused higher TA and VFA disintegration resulting slightly lower VFA to TA ratio than those treated with neutral pH. T12 and T13 treatments had been found having highest total alkalinity at 7300 and 7500 mg/L $CaCO_3$ respectively, and with lower VFA : TA at 0.15 (Fig.4). Treatments between T2 and T10 which are having from pH 2 – pH 10 were found having higher residual VFA than remaining samples. Since all the samples were neutralized back to pH 7.5, total alkalinity of all samples were quite identical ranging between 6500-7500 mg/l as $CaCO_3$. Although the optimum alkalinity for the success of reactor during anaerobic digestion being 2500 – 5000 mg/L as $CaCO_3$, the observed alkalinity of pretreated substrates were slightly higher than optimum range (Graef and Andrews, 1974). However, this contra amount helps in buffering and reserving for pH drop when fermentation progresses during acidogenesis stage. Taking as a whole, the VFA: TA ratio of all samples were ranging between 0.1 – 0.36 which is in ideal range for healthy biogas fermentation, and all pretreated substrates were found suitable to proceed for AD process (Buswell and Mueller, 1952). Likewise VFA, more reducing sugars depletion were found in extreme pH treated substrates. Except T1, T11, T12 and T13, the reducing sugars contents of samples were ranging between 10-14 mg/100g (Fig. 5). Highly alkaline and acid treated samples yielded reducing sugars as low as 5g/100 mg dry pulp basic.

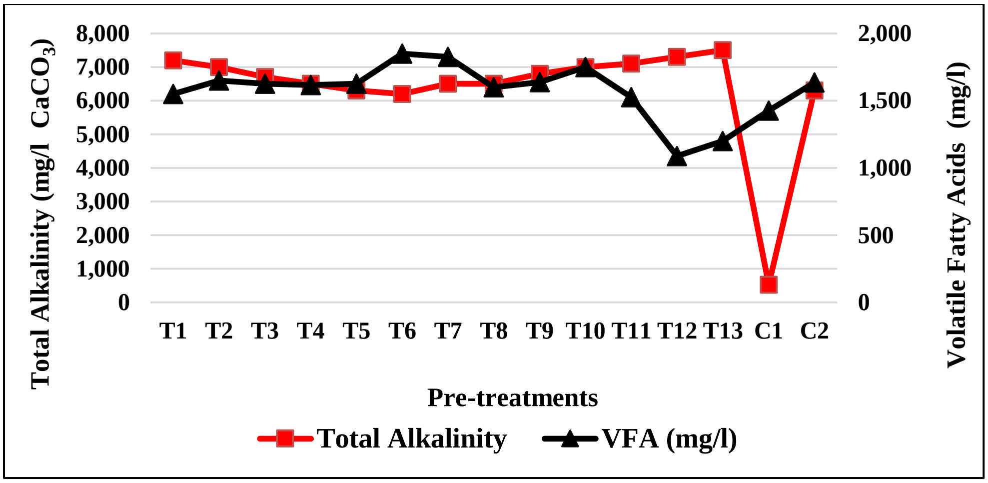

Figure 4. Effect of thermal-chemical pretreatment on VFA: TA of 3% (w/v) of cassava pulp.

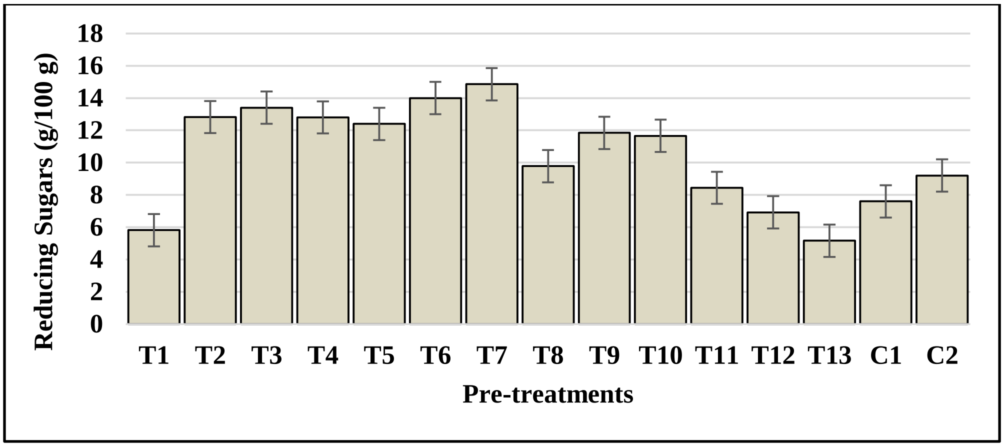

Figure 5. Effect of thermal-chemical pretreatment on reducing sugars of 3% (w/v) of cassava pulp.

3.5. Anaerobic digestion of Different Solid Contents and Biogas Yields

The total biogas yields were calculated at the end of digestion periods of 21 days. Three different solid ratios such as 3% TS, 5% TS and 10% TS were investigated (Fig. 6). The results indicated that batch reactors in which substrates were subjected to both much acid and alkaline, i.e. T1, T11, T12, and T13 pretreated batch reactors produced lesser gas yield than those were subjected moderately as shown in figure 1 and 6. This was due to the fact that they encountered excessive inhibition on microorganisms triggered by sodium and sulfate from alkaline and acid. Upon the digestion period ended, their biogas yields were found below 1000 ml/kg TS. This conditions occurred in all solid contents.

The batch reactors in which substrates were treated to neutral pH ranges (pH 7- pH 10) which are T7-T10 proved better biogas fermentation and yielded more than 3 folds of those treated with extreme pH. Substrates which had been treated to pH 9 (T9) and pH 10 (T10) have highest biogas yield of 4125.2 and 3539.7 ml/kg TS for 5% TS and 3% TS respectively. Maximum biogas yield for 10% TS was found in T9 which is pH 9 treated samples at 524.7 ml/kg TS. The results provides evidence that solid content of 5% provided best performance under acid-alkaline (H_2SO_4 and NaOH), and thermal pretreated cassava pulp with 4125.5 ml/kg TS biogas yield under digestion period of 21 days in batch reactors.

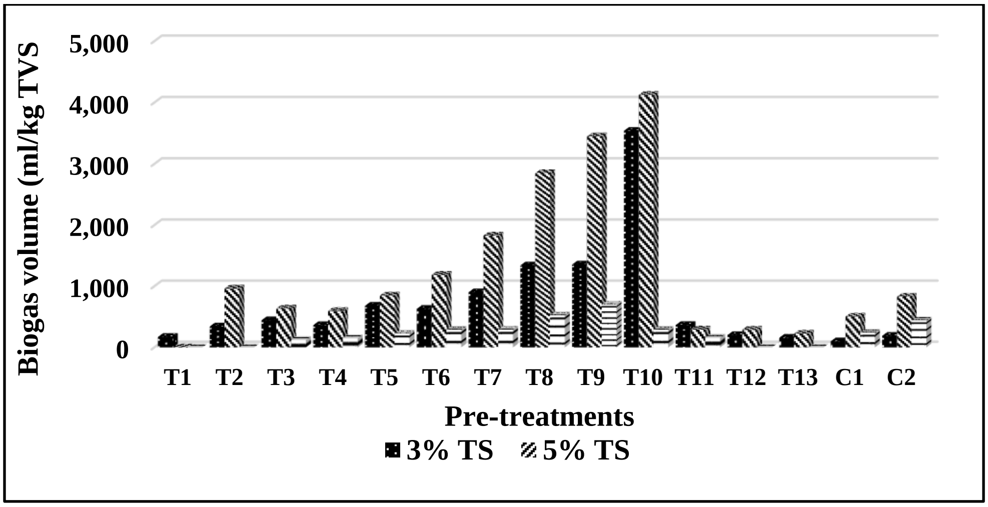

Figure. 6. Performance of batch reactors in different solid contents on each pretreatment.

4. Conclusion

Although anaerobic digestion is an effective mean to manage mounting agro-industrial waste in factories, the lack of research and development tailored to individual biomass hinders biogas developers to generate environmentally friendly and reliable bioenergy from cash crop residues. This studies proved there is high potential to produce higher biogas yield than conventional practice by using either/both acid-alkaline or thermal pretreatments prior to execute biogas fermentation. Having high C/N ratio presents in cassava pulp even after hydrolysis, provides evidence that nitrogen source supplementation or co-digestion with other nitrogen rich substrate is strongly recommended to maintain good digestion performance. In addition, even though highly acidic pretreated substrates produced higher SCOD, SO_4^{2-} and Na^+ toxicity was observed upon undergoing AD process and obtained lesser biogas yield than those substrates treated to pH 9 (T9) and pH 10 (T10). Therefore, this study compromised volume of acid-alkaline addition while selecting of H_2SO_4 and NaOH as common chemical pretreatment to cassava pulp in different solid contents versus range of pH to extract optimum biogas volume. Although plenty of literature had proved acid and alkaline make better disintegration of lignocellulose properties of biomass, in the case of cassava pulp in the studies, combination of both moderately higher than neutral pH by alkaline-acid pretreatment, thermal pretreatments for 45 min at 200˚C, and 5% TS produced best outcome from batch mode of AD fermentation.

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Impact of Land-Use Activities on Surface Water Quality in the Pazuntaung Creek, Myanmar

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Abstract

The aim of the present study is to assess the impact of land-use activities on physico-chemical parameters and some heavy metals of water in the Pazuntaung Creek which is a major drainage channel and outflows to the Yangon and Bago Rivers. Water samples were collected from fifteen sampling stations by representing three main land-use activities: forest, industries and household. The results showed the physico-chemical parameters of water as follows: pH (6.3-6.9), TSS (5.25-446.00 mg/l), DO (2.84- 6.53 mg/l), BOD (3.00-24.07 mg/l), nitrate (6-50 mg/l), phosphorous (0.05-4.50 mg/l), temperature (27-31ºC) and salinity (0.0-0.1 ppt). The ranges of heavy metal concentrations were Cd, from 0.122± 0.271 mg/l to 0.148 ± 0.293 mg/l , Cr, from 0.176 ± 0.144 mg/l to 0.191 ± 0.184 mg/l, Cu, from 0.001 ± 0.004 mg/l to 0.006 ± 0.004 mg/l, Zn, from 0.289 ± 0.059 mg/l to 0.317 ± 0.059 mg/l. TSS (273.40±80.35 mg/l), BOD (17.53±2.16 mg/l), nitrate (34.00±12.25 mg/l) and salinity (0.1 ±0.0ppt) values are higher in the industries-dominated sites ($p<0.05$) than those in the forest-dominated sites. Moreover, the concentration of TSS (357.80±74.29 mg/l)**,** DO (4.42±0.58 mg/l), salinity (0.1±0.0ppt), nitrate (36.60±14.63 mg/l) values are higher in the household-dominated sites ($p<0.05$) than those in the forest-dominated sites. In contrast, the forest-dominated sites had high level of DO and low levels of nitrate compared to those from industries and household-dominated sites. All in all, the study indicates that the industries- and household-dominated land-uses were the main factors affecting to the surface water quality and it could be recommended that the two areas need an urgent waste water management to prevent the discharge of the pollutant loads into the creek.

Keywords*:* Pazuntaung creek; land-use; heavy metal; surface water quality

1. Introduction

Outweighing the demand of food, housing and energy by booming population creates an overloaded pressure on water resources, especially on water quality. Water quality in developing countries is declining by unsystematic land-use transform of anthropogenic activities: expending urban, agricultural land and irrigation system, industrial development, mining and recreation (Abbaspour, 2011). Increases in nutrients and heavy metal loads that degrade the water quality were observed as natural land-use to artificial land-use, especially in urban and industrial land-use forms (Tong, 1990; Teixeira et al., 2014; Yu et al., 2014). The most significant changes in surface water environment including physical characteristics, nutrient concentrations, in-stream habitat, riparian ecosystems and biodiversity are caused by urban land-use, as observed by Huang et al. (2006). Wilson and Weng (2010) and Miserendino et al. (2011) found that human activities from residential, commercial, industries, transportation, and developed/ open space had impacts on BOD, DO, nitrate, pH and TSS within an urban watershed. Osibanjo et al. (2011) observed that wastewater discharged from industrial area had negative impacts on surface water quality polluted by nitrate, total phosphorous, chloride, total solids, oil and grease.

Modernized land-use practices as increasing material goods for short-term supplies, may undermine many ecosystem services in the long term, even on regional and global scale (Foley et al., 2005). Generally, agricultural land- use where use of chemical fertilizers has strong influence on nutrients such as nitrogen and phosphorus contents in river, stream and creek water (Pieterse et al., 2003; Ngoye and Machiwa, 2004; Woli et al., 2004). Both industrial and urban land-uses are associated with upgrading in organic pollution, as well as heavy metals and nutrients (Hirst et al., 2001). As the negative effects of spontaneous land-use pattern such as uncontrolled land-use and damage of the natural resources along with the urban environmental problems of the mega-size urban area can be minimized in advance by a forsighted concept of efficient framework for land utilization pattern of future urban expansion in the Yangon City (Moe, 2009).

Yangon city served at 8% of the total union population and with the present population growth rate of 3.4%, the populations will hit around 10 million in year 2030 (Tin, 2005; Moe, 2009). Between1960's and1980's, urban areas have expanded mainly northwards from Central Business District (CBD) due to two natural barriers, the Hlaing River and the Pazundaung Creek, according to data from Department of Human Settlement and Housing Development (DHSHD), Ministry of Construction. Regarding to the land-use pattern in 2012, agricultural area occupied 51% of the total area, followed by 22% of urbanized areas. Moe (2009) found that the main causes of Land Use and Land Cover Change (LULCC) of Yangon Mega City is rapid urbanization, in contrast, vegetation, cultivated land decreased, vegetation area decreased remarkably from 1061.08 to 566.2 square kilometer between 1996 and 2006 (Tin, 2005).

The study area of the Pazundaung Creek which flows across to the downtown area of Yangon in Myanmar is important not only for water usage but also for the region economic by transporting and restoring biodiversity species due to the major drainage channel and outflows to the Yangon and Bago Rivers. Nevertheless, the creek has less water and waste management, whereas spreading of urbanization, industries and agricultural activities threat to the creek water quality and the potential pollution loads are expected to increase with the modernization and expansion of the population. Therefore, the present study is to investigate the current water quality situation based on impacts of different land-use activities in the Pazuntaung Creek.

2. Material and Methods

2.1 Study Area and sampling stations

The study was conducted in the Pazuntaung Creek (Figure 1) which is mainly located in Northern part of Yangon and joined with the Yangon River at Monkey point, the Southern part of Yangon. It is located in Latitude 16° 46'14" North and Longitude 96°11'41" East. The Pazuntaung Creek flows from the Nga Moe Yeik Reservoir and it has a length of 47.66 km and drainage area of about 1,487 km^2. The flow rate of upstream is 249 m^3/s and down stream flow rate is 202 m^3/s (Boblme, 2011). About 3% of population growth results in an increasing demand for arable lands leading to the extension of cropped areas. The upstream of the creek is forest-dominated site where is in Paung Gyi Province, the middle stream industries-dominated site is in Thuwanna and Tharkaetha Townships of downtown area and the last downstream household-dominate site is in Pazuntaung and Dawpone Townships.

The major land-use in the upstream sites are plantation and agricultural areas though some parts are covered by topical savanna forest type. The local resident grow different kinds of farms for example, fruit crops, tropical fruits, leafy salad crops, cole crops, root crops and a variety types of fruits and seeds (peas, beans, sweet corn, squashes, melons, tomatoes). At agricultural area, rice is grown in May and harvest around October. During the few months of rice growing, famers pump water from the Pazuntaung Creek. As an agricultural based country and developing country, 80% of the surface water is used for agriculture, 10% for industries and the last 10% for household.

In the middle stream, the dominant land-use activities are industrial zones and small scale factories. There are three main industrial zones along the Pazuntaung creek, namely North Okkalapa industrial zone, Tharkayta industrial zone and South Dagon industrial zones with total number of small and medium industries of industrial zones are of 137, 89 and 1484 respectively (MIA, 2012). In the downstream, the influence land-use activities are big terminal and poultry market and small scale factories like ban and soap factory.

Water samples were conducted in three main areas of 15 sampling sites. The sampling sites were chosen based on the upstream forest-dominated area; the middle stream industries-dominated area and the downstream municipality household-dominated area (Table 1).

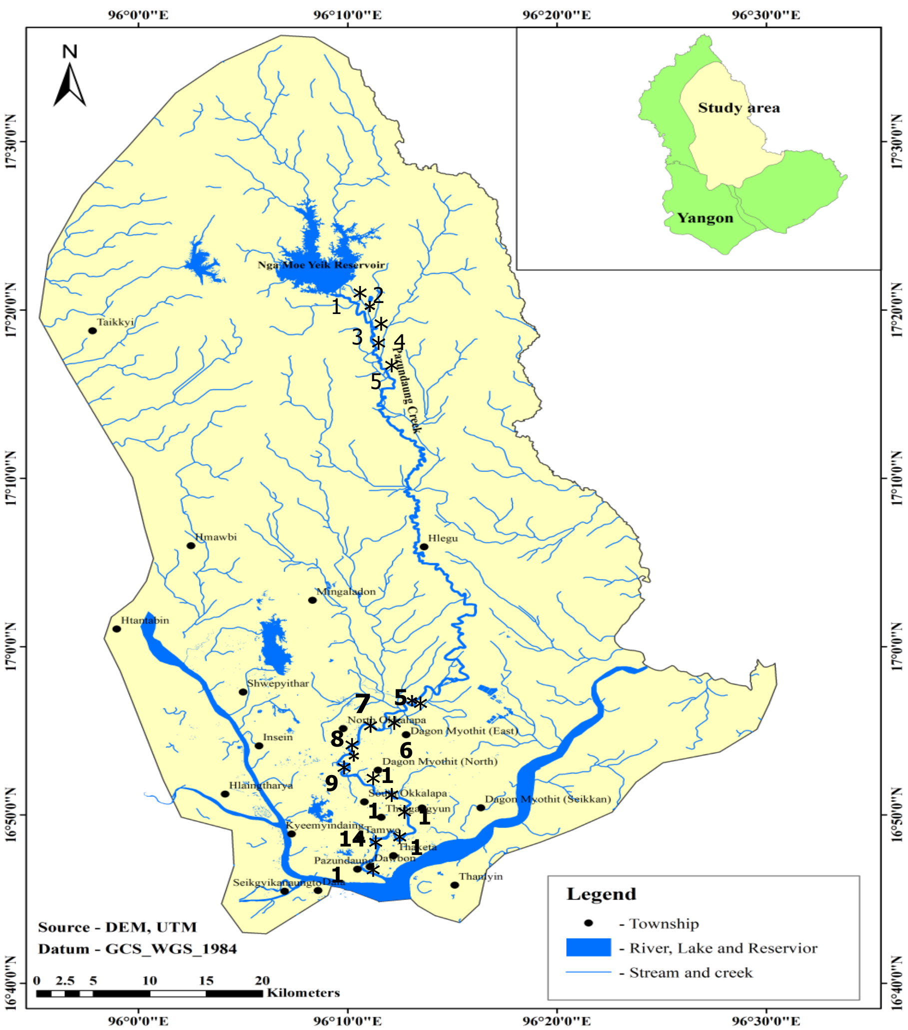

Figure 1. Map of the Pazuntaung Creek showing the drainage system and sampling station

2.2 Sample collection and analysis

The fifteen water samples were collected during September to November, 2016. Eight physico-chemical parameters of water such as temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), nitrate, phosphorous, total suspended solid (TSS) and salinity and four heavy metals i.e., Cadmium (Cd), Chromium (Cr), Copper (Cu) and Zinc (Zn) were collected. Water samples for physico-chemical analysis were collected at one meter deep below surface water with the 500 ml sampling vessel in the middle and the left and right banks of the creek width in each sampling site. The two parameters, i.e., temperature and pH were measured in the field immediately. For other physico-chemical parameters, the water samples were collected by sampling vessel and moved to the 1 liter (1000 ml) bottle directly without filtering the sample. After that, the water samples were stored in the ice chest at 4°C and sent them to the laboratory within 24 hours (Jason, 2012).

Table 1. Description of the land-use activities in the Pazuntaung creek at different stations

Land-use types	Sampling station number and name	Description of the land use
Forest area	1_Paung Gyi Area	Tropical savanna forest type, bamboos trees are most populated and the plantation area with growing fruit crops like limes, papayas, pineapples, bananas trees and root crops like radishes, carrots, potatoes, sweet potatoes, etc.
	2_Paung Gyi Area	Tropical savanna forest type, near plantation area with growing fruit crops like limes, papayas, pineapples, bananas trees and root crops like radishes, carrots, potatoes, sweet potatoes, etc.
	3_Paung Gyi Area	Tropical savanna forest type, near vegetation farming area where mainly grows lettuce, spinach, cabbage, watercress, etc.
	4_Paung Gyi Area	Tropical savanna forest type, the sampling area is quite far from paddy field.
	5_Paung Gyi Area	Tropical savanna forest type, the sampling area is quite far from paddy field and close to the residential area.
Industrial area	6_South Dagon industrial zone	Total 1484 industries, i.e., 622 machines and machinery equipment factories, 37 for transport vehicle factories, and 825 for miscellaneous factories Discharged wastewaters into the river.
	7_Thuwanna Township	Near the discharge line of South Dagon industrial zone; Total 1484 industries, i.e., 622 machines and machinery equipment factories, 37 for transport vehicle factories, and 825 for miscellaneous factories and meander (a winding curve or bend of a creek) point.
	8_ Tharkayta industrial zone	Total 137 industries, i.e., 16 clothing, apparel and wearing factories, 2 construction materials factories. 5 electrical goods factories, 32 food and beverages factories, 10 household goods factories, 2 industrial raw materials factories, 6 machines and machinery equipment factories, 4 mineral and petroleum products factories, 9 printing and publishing factories, 30 transport vehicles factories and 21 miscellaneous and ship breaking place. Discharged wastewater into the river.

	9_Thingangyun	In front of the Tharkayta industrial zone; total 137 industries, i.e., 16 clothing, apparel and wearing factories, 2 construction materials factories. 5 electrical goods factories, 32 food and beverages factories, 10 household goods factories, 2 industrial raw materials factories, 6 machines and machinery equipment factories, 4 mineral and petroleum products factories, 9 printing and publishing factories, 30 transport vehicles factories and 21 miscellaneous and ship breaking place and meander point of the creek.
	10_Tharkayta Township	Near the Tharkayta industrial zone; total 137 industries, i.e., 16 clothing, apparel and wearing factories, 2 construction materials factories. 5 electrical goods factories, 32 food and beverages factories, 10 household goods factories, 2 industrial raw materials factories, 6 machines and machinery equipment factories, 4 mineral and petroleum products factories, 9 printing and publishing factories, 30 transport vehicles factories and 21 miscellaneous and ship breaking place. Discharged wastewater into the river.
Household or Municipality Area	11_Pazundaung Township	Residential area where municipal waste (domestic and urban runoff) discharged to the creek.
	12_Pathein Nyut ward	Sandy area and waste discharge point from the household and small scale factory near the ban and soap factory (SME).
	13_Upper Pazuntaung	Building area where household waste discharged.
	14_Pazuntaung Township	Pazuntaung market creek where discharged wastewater from terminal markets and municipalities.
	15_Botahtaung Township	A residential area with boat building area quite close to the Maha Bandula Bridge.

Water temperature (Temp, ^{o}C) and pH were measured by using thermometer and pH meter in the field. Dissolved oxygen (DO, mg/l) and biochemical oxygen demand (BOD, mg/l) were measured by using Jenway Dissolved Oxygen Meter (Model 970) and salinity by refractometer. Total Suspended Solid (TSS, mg/l) was determined by oven-drying method and Lovibond Spectrodirect Method No. 265, 267 was used to measure nitrate and Lovibond Spectrodirect Method No.320, 321 was used to measure phosphorous in the laboratory. The analysis of water parameters in the laboratory followed National Emission Guideline for wastewater effluent standard, which were provided by Ministry of Environmental Conservation, Myanmar.

For heavy metal analysis, water samples were collected from the three sampling points in the left, middle and right banks of the creek width at each sampling station by vessel and moved to the 1 L (1000ml) bottle by filtering with 0.45 μm cellulose acetate membrane filter. During pouring to the bottle, the samples were added with 10% nitric acid until the sample concentration turn to pH<2 to minimize precipitation and adsorption on container walls and the sampling bottle was stored in the ice chest at 4°C to prevent changes in volume due to evaporation before analyzing in the laboratory (Diagomanolin et al., 2004). The amount of Cadmium, Chromium, Zinc and Iron that are contaminated in water were analyzed by using Atomic Absorption Spectrometer (Perkin Elmer AAnalyst 800) after digesting with Microwave Digestion System.

The analysis of variance (ANOVA) was run to compare variation of different land use activities on the eight physico-chemical parameters and four heavy metals of water quality and the post hoc test was used to compare the differences among means.

3. Result and Discussion

3.1 Physico-chemical quality of water in the Pazuntaung Creek

According the study result, the mean and standard deviations of the creek surface temperature varied 30.40 ± 0.55, 28.70 ± 0.45 and 27.60 ± 1.34 ºC at the upstream of forest-dominated site, the middle stream of industries-dominated sites and the downstream of municipal household-dominated sites, respectively. The average temperature of the upstream 30 ºC is slightly higher than that obtained from middle 28.7ºC and downstream 27.6ºC of the creek. The situation may be due to the difference time of sample collection and reduced the forest or vegetation covered of the creek. The analysis of variance (ANOVA) indicated that there were significant differences between three main land-use activities; forest, industries and household dominated areas.

The mean and standard deviations of the creek water pH were 6.44 ± 0.22, 6.64 ± 0.51 and 6.74 ± 0.09 at forest-dominated sites, industries-dominated sites and household-dominated sites, respectively. A slight drop of upstream pH value was observed at station numbers 1, 4 and 5 of forest-dominated sites. This may be a shallow width, depth and waste affected from some plantation area. With comparing three main land-use activities, the analysis of variance (ANOVA) showed that there is no significant in the pH value at areas of different land-uses.

The mean and standard deviations of dissolved oxygen (DO) values were 5.48 ± 0.59, 3.66 ±1.10 and 4.43 ±0.58 mg/l at forest-dominated sites, industries-dominated sites and household-dominated sites, respectively. The lowest DO value 2.84 mg/l of industries-dominated site is higher than those obtained from upstream 5.48 mg/l and downstream 4.42 mg/l. That ma3`y be due to not only the place lies Tharkayta Industrial zone waste discharged point but also the point source. This may be owing to the discharging of industries waste directly discharge to the water and DO evaluation plays an important role for the survival of aquatic organisms and in establishing the standard of freshness of a river (Ngoye et al., 2004). The organic waste cause depletion of receiving waters by oxygen consumption as a result of organic materials decomposition in water (Nana-Amankwaah and Bosque-Hamilton, 2001). The analysis of the variance (ANOVA) stated that there were significantly difference in forest-dominated and industries-dominated areas.

The mean and standard deviations of biochemical oxygen demand (BOD) values were 5.12 ± 3.76, 17.53 ± 2.16 and 13.37 ± 7.26 mg/l at forest-dominated sites, industries-dominated sites and household-dominated sites, respectively. To the study results, the highest BOD value 24.07 mg/l that was founded in station number 11 of the downstream household-dominated site is higher than those obtained from upstream 5.12 mg/l and middle stream 17.53 mg/l. This may be due to directly input of sewage and pollutant load from residential area where municipal waste (domestic and urban runoff) discharge to the creek (Samantray et al., 2009). In addition, the analysis of variance (ANOVA) indicated that there were significant differences between three main land-use activities; forest, industries and household dominated areas.

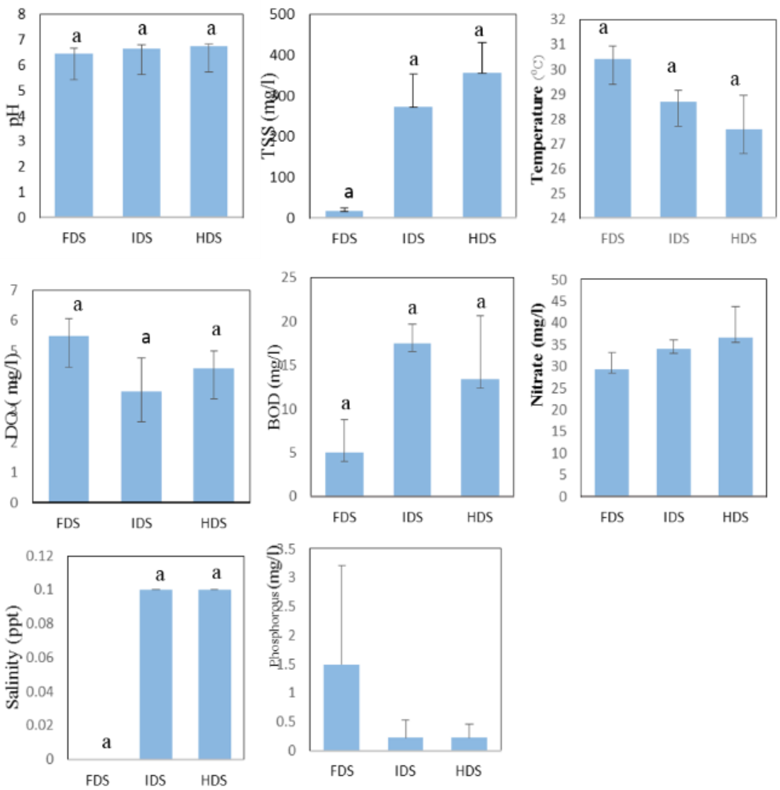

Figure 2. Mean ± standard error values for the water quality parameters among forest-dominated sites (FDS), industries-dominated sites (IDS) and household-dominated sites (HDS). The analysis of variance results of significant differences ($p<0.05$) are indicated by letter “a”.

The mean and standard deviations of nitrate values were 29.40 ± 15.73, 34.00 ± 12.25 and 36.60 ± 14.64 mg/l at forest-dominated sites, industries-dominated sites and household-dominated sites, respectively. The highest nitrate value 50 mg/l which was obtained from the station number 14 of the household-dominated site are higher than those obtained from upstream 29.40 mg/l and middle stream 34.00 mg/l. High volume of untreated municipal household waste and terminal market waste discharges via small stream was considered as the main factor of pollutant and point source for increasing the nitrate concentration in water. There were no significant difference between the land-use activities to the ANOVA analysis result.

The mean and standard deviations of phosphorous values were 1.49 ± 1.72, 0.22-0.30 and 0.22-0.23 mg/l at forest-dominated sites, industries-dominated sites and household-dominated sites, respectively. The highest phosphorous mean value 4.50 mg/l at station number 2 were observed at the forest-dominated that is higher than those obtained from middle stream 0.22 mg/l and downstream 0.22 mg/l. In that case, the high concentration of phosphorous may be because of the input of animal manure and soil erosion which may be the main factors (USGS, 2016). According to the ANOVA analysis, there were no significant between three main land-use activities.

The mean and standard deviations of total suspended solids values were 17.06 ± 6.93, 273.40 ± 80.35 and 357.80 ± 74.29 mg/l at forest-dominated sites, industries-dominated sites and household-dominated sites, respectively. The highest value of total suspended solids were found at the station 12 (446.00mg/l) and 13 (420.00 mg/l) of household-dominated site that values are higher than those obtained from upstream 17.06 mg/l and middle stream 273.40 mg/l. At certain locations, the cause of high suspended solids could be in which water body that indicate turbulence during sampling and because of the prolonged non-settleable suspended-solid and because of the household untreated waste water discharge point. The high concentration of total suspended solid may be included a wide variety of material along with dispersing much of silt, decaying plant and animal, human wastes, industrial wastes and sewage and that may retard the water quality and aquatic life. High concentrations of bacteria, nutrients, pesticides, and metals in the water are the indicators of increasing concentration of total suspended solid. These pollutants may attach to sediment particles on the land and be carried into water bodies with storm water (Federal Interagency Stream Restoration Working Group, 1998). The analysis of the variance (ANOVA) showed that there were significant in all land use activities: forest, industries and household dominated areas.

The mean salinity values varied ranged between 0.0 and 0.1 ppt. The value of creek salinity are not significantly different and quite similar at each station. According to the ANOVA analysis, there were no significant between three main land-use activities.

3.2 Concentration of four heavy metals distribution in the Pazuntaung creek

According the study result, the ranges of heavy metal concentrations were Cd from 0.122 ± 0.271 mg/l to 0.148 ± 0.293 mg/l, Cr from 0.176 ± 0.144 mg/l to 0.191 ± 0.184 mg/l, Cu from 0.001 ± 0.004 mg/l to 0.006 ± 0.004 mg/l and Zn from 0.289 ± 0.059 mg/l to 0.317 ± 0.059 mg/l. The mean and standard deviations of heavy metals concentrations were Cd (0.052 ± 0.011), Cr (0.006 ± 0.029), Cu (0.003 ± 0.003), Zn (0.275 ± 0.015) at forest-dominated site, Cd (0.057 ± 0.011), Cr (0.164 ± 0.028). Cu (0.006 ± 0.002), Zn (0.333 ± 0.019) at industries-dominated sites and Cd (0.298 ± 0.023), Cr (0.366 ± 0.029), Cu (0.004 ± 0.003), Zn (0.298 ± 0.010) at household-dominated sites.

Concerning with the heavy metal concentrations in household-dominated sites, it was found that high level of Cd (1.159 mg/l) and Cr (0.419 mg/l) were higher than those obtained from the upstream Cd (0.052 mg/l) and Cr (0.006 mg/l) and middle stream Cd (0.298 mg/l) and Cr (0.366 mg/l) concentrations. The high Cr concentration (0.419 mg/l) may be due to the small scale business such as metallurgical and refractory, stainless steel welding activities along the creek as they are the main activities in residential area. High Cd concentration (1.159 mg/l) might be due to directly discharge of untreated food wastes from terminal markets near the creek that used pigment and stabilizer (Tchounwou, 2012). The analysis variance (ANOVA) showed that Cr concentrations were significantly different in all three land-uses activities.

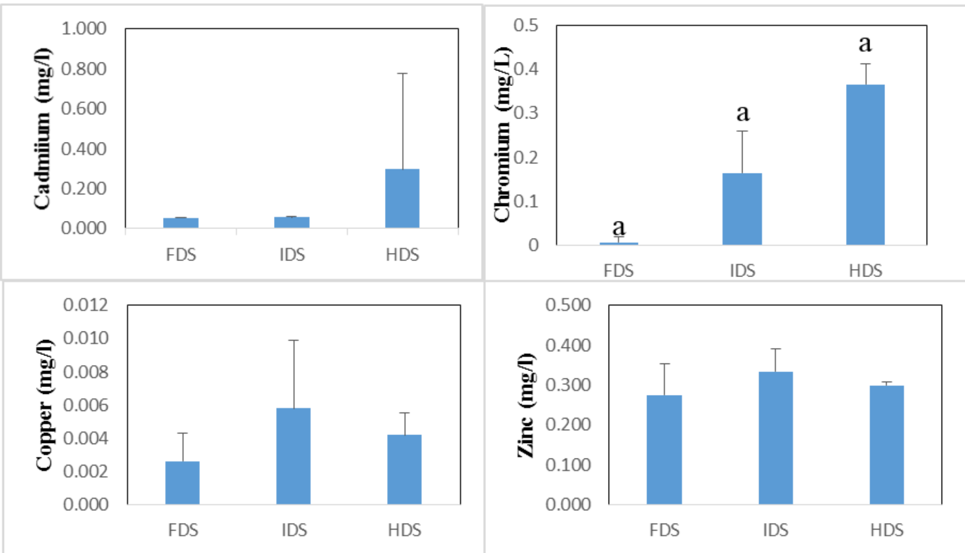

Figure 3. Mean ± standard error values for Cd, Cr, Cu, Zn heavy metals concentration among forest-dominated sites (FDS), industries-dominated sites (IDS) and household-dominated sites (HDS). The analysis of variance results of significant differences ($p<0.05$) are indicated by letter “a”.

4. Conclusion

The result of the present study is concluded that the most affected land-use is household-dominated sites from DO, BOD, TSS, nitrate, Cd and Cr. Industries-dominated sites are also polluted by TSS, BOD, nitrate, Cu and Zn. This means that the water quality is unsafe for human consumption, agricultural usage and aquatic species due to exploitation by industries and household wastewaters. The result confirms the need to install wastewater treatment system in industries and household dominated areas. In addition, future creek restoration and management should limit the nutrients, heavy metals and organic matter discharges from the industries and household-dominated sites to prevent the contamination spreading into the creek.

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Reproductive Toxicity and Acetylcholinesterase Inhibition of Profenofos on Japanese Medaka, *Oryzias latipes*

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Abstract

Effects of low doses of profenofos on the reproduction and acetylcholinesterase enzyme activity of Japanese Medaka, *Oryzias latipes* (Temmick & Schelgel, 1846) were examined. Spawning fish were exposed to 0.005, 0.03 and 0.2 mg/L profenofos for 7 days. Total egg production and fertilization rate were recorded. Embryos collected were incubated to monitor hatching days and survival rate. Fish were decapitated at the end of the exposure and brains were removed for acetylcholinesterase enzyme assay. Egg production, fertilization, embryo hatching days and embryo survival were found to be affected by profenofos. Hatching days and survival rate of the embryos were 8.81, 9.44, 9.52, and 10.86 days, and 95.2, 85.8, 73.4, and 42.2 % for control, low, middle and high exposure group, respectively. Developmental toxicity in relation to behavior and interactions with the targeted enzyme were also assessed. Acetylcholinesterase activity in fish brain was competitively inhibited in a dose-dependent manner.

Keywords: Japanese medaka; pesticide; profenofos; embryo survival; fecundity; acetylcholinesterase; enzyme kinetics

1. Introduction

Pesticides include insecticides, herbicides, fungicides, rodenticides, fumigants, growth regulators and other substances to control pests. Approximately 545 million kg of pesticides are sold annually with about 70% used in production agriculture, 23% in forestry, industry and government programs, and 7% in the home and garden (US EPA, 1986).

The increasing use of pesticides has become a concern to environmentalists and many researchers. When a pesticide is applied to soil, it may undergo microbial decomposition, photodecomposition, chemical degradation, volatilization, plant uptake or adsorption. It may be transported in surface runoff or sediment or be leached through the soil profile.

The organophosphates (OPs), a class of compounds with many diverse members, are noted for high biological activity (Fest and Schmidt, 1973). They are best known as insecticides with a few members having activity as herbicides and plant-growth regulators. Biological activity of insecticidal organophosphates is not limited just to insects; they are also toxic to mammals and other organisms, particularly those in which cholinesterase plays a vital role (Fest and Schmidt, 1973; Fukuto, 1957; Davies *et al*., 1975).

The organophosphates have come to be used extensively as insecticides replacing many of the older compounds. Among the reasons for their increased use are: (a) more effective against some species of insects: (b) the development of resistance of some insects toward organochlorine compounds; and (c) the presumed environmental safety of the organophosphates. These pesticides are frequently used against pest because of their high insecticidal property low mammalian toxicity, less persistence and rapid biodegradability (Bhandare *et al*., 2011). These also affect non-target organisms either directly or indirectly. In rice land agroecosystem, all organisms including fishes can be affected (Roger and Bhuiyan, 1990). At lower concentrations, physiological functions are affected. Indiscriminate and prolonged use of pesticides may lead to mortality and depletion of the fish population (Ravindran *et al.*, 2012).

Profenofos is an organophosphate pesticide which has been extensively used, resulting to widespread distribution in aquatic and terrestrial ecosystems (Jabbar *et al.*, 1993). Alburo (2015) reported that 0.49ppm of Profenofos was detected in river water samples collected from Dalaguete River, Dalaguete, Cebu. US EPA (1998) reported several instances of fish mortality due to profenofos. In fact, Worthing and Walker (1987) reported profenofos as very toxic and published 96–h median lethal concentration (LC50) values to three aquatic species ranging from 80 to 300 ppm.

Pamanji *et al*. (2015) looked at the toxicity effects of profenofos on embryonic and larval development of zebrafish (*Danio rerio*) and obtained LC50 values of 2.04 ppm, 1.58 ppm, 1.57ppm and 1.56 ppm for 24h, 48h, 72, and 96h, respectively. However, there are no published reports on the dose of profenofos that caused reproductive toxicity and inhibition of acetylcholinesterase on Japanese medaka (*Oryzias latipes*). Japanese medaka is one of the few species established by the Organization for Economic Co-operation and Development (OECD) to be used for environmental toxicity studies due its sensitivity (Cooper, 1986; Wisk and Cooper, 1988), its daily production of eggs, clear chorionic membranes and well-characterized developmental stages (Kirchen and West, 1976). These characteristics make the Japanese medaka ideally suited for the study of tissue and organ specific developmental toxicants. Hence, the primary objective of this study is to assess the reproductive toxicity and acetylcholinesterase inhibition of profenofos on Japanese Medaka (*Oryzias latipes*). Specifically, the study aims to investigate the changes in egg production and fertilization, monitor hatchability and survival rate of embryos, quantify inhibition in the acetylcholinesterase enzymatic activity, and examine the mode of action of the test chemical to the acetylcholinesterase enzyme.

2. Materials and Methods

2.1. Experimental Approach

Adult male and female Japanese Medaka were separated by visually examining their anal fin. Female Japanese Medaka has a tapering anal fin and it has a bigger, plump body shape compared to male Japanese Medaka which in contrast has a parallelogram-shaped anal fin. The fishes were visually inspected to be free of macroscopically discernable symptoms of infection and diseases. A pair of male and female fishes were transferred in a 1L tank. Light exposure was set to 14 hours' light and 10 hours' dark exposure using fluorescent lamp. There were 5 tanks per exposure concentration. Temperature and Dissolved Oxygen were maintained at 26 ±1 °C and above 4 ppm, respectively.

Normal embryo production of the selected breeding pairs was monitored for at least 5 days, prior to exposure. The fish were fed with commercial diet ad libitum. Total daily egg production and number of fertilized eggs were noted. Eggs were collected daily during the renewal of exposure solvent. Water, together with the fish were passed through a 0.5mm mesh, allowing the solvent to pass through. Adhering eggs in the anal fin of the female fish were carefully stripped to avoid damage to the organism's abdomen. The breeding pair were then transferred to a newly-renewed exposure solvent.

After the monitoring of normal embryo production, the pairs were exposed to their respective concentrations for 7 days. Three test solutions containing profenofos (0.005, 0.03 and 0.2 ppm) were prepared from profenofos stock solution (2000 ppm in acetone). In the control solution (0ppm profenofos) only 100µL of acetone was added. The final acetone concentrations in the exposure test water were less than 0.01%.

Collected embryos were individualized by carefully rubbing it in moistened tissue for a few minutes, then disinfected with 5% H_2O_2 and washed with dechlorinated water. They were then stored in 24-well plates for incubation. The same light photoperiod was maintained in the incubator and the temperature was set at 24° C.

Water used in the incubated embryos were renewed daily. Unfertilized eggs were removed after visually inspected using a compound microscope, while dead embryos found during incubation were removed from the wells. Development of the embryo was monitored daily, hatching time for the embryos were also recorded. Breeding pairs at the end of the exposure period were anesthetized with 2-phenoxyethanol (0.7mL/L H2O) and the brains were carefully removed, weighed and stored in a microtube for acetylcholinesterase enzyme activity assay and protein content assay.

2.2. Acetylcholine Esterase (AChE) Enzyme Assay

Whole brain was extracted and stored in a pre-weighed 1.5mL microtube (Nippi, Japan). Each sample was individually homogenized using Power masher II (Nippi, Japan) homogenizer fitted with a Teflon pestle after the addition of ice cold 0.1M Phosphate Buffer (pH 8.0; 20 mg fresh tissue mL^{-1}). Homogenate was centrifuged at 10,000 g for 15 min at 4°C. The resulting supernatant was collected and was used as the enzyme source for the estimation of AChE activity using the modified method of Ellman *et al*. (1976). Using a 96 well-plate containing 155µL of 0.1M phosphate buffer, 10µL of supernatant, and 10µL of DTNB (39.6mg of Dithiobisnitrobenzoic acid was dissolved in 10mL 0.1M phosphate buffer and 15 mg of sodium bicarbonate was added.) in each well was incubated at 30°C for 5 min. The reaction was initiated by adding 5µL of substrate (0.2, 0.1 and 0.08 mM Acetylcholine Iodide) and color development was recorded every minute for 10 minutes at 410nm in a microplate reader (Model 550, Bio-Rad, USA). AChE activity was calculated as nanomoles of acetylcholine hydrolyzed per minute per mg protein using molar extinction coefficient of 14,150 M^{-1} cm^{-1}. Each enzymatic assay was carried out in triplicate. Protein Content Assay was performed using Bio-Rad Protein Assay by Bradford (1956).

3. Results and Discussion

Adult Japanese Medaka used were 5 to 7 months old, body weights ranged from 239.8 – 550.1 mg and body lengths ranged from 32.22 – 41.58mm. The temperature of test water varies from 22.5 – 27.1°C and pH values ranged from 7.14 – 8.12mg/L. The dissolved oxygen ranged from 3.10 – 6.69mg/L during experiment period.

Spawning pairs were exposed to three different concentrations of profenofos and a solvent control spiked with acetone. The nominal concentrations used were 0.005ppm, 0.03ppm and 0.2ppm. The high concentration inhibits the acetylcholine esterase enzyme activity of Japanese Medaka on the 5th day of exposure. Under the assumption that inhibition of acetylcholinesterase activity alters the behavior of the fish, 0.2 ppm was chosen as the highest concentration for the exposure tanks to serve as a positive control since spawning of eggs and fertilization is greatly affected by fish mobility. In addition, 0.005ppm was used to possibly identify the No Effect Concentration (NOEC), while 0.03ppm is the geo-mean of the two concentrations.

Total egg production for the control ranges from 4 – 26 eggs, while the average lies around 15 eggs per day (Figure 1). For the low concentration group, there is a linear decrease in the egg production with the exposure days, the correlation coefficient is 0.9597. This correlation coefficient suggests that there is linear dependency in the decrease in egg production to that of exposure days at 0.005 ppm. In the middle concentration exposure group, this is a slight decrease from day 1 to 3, followed by a drastic drop on day 4 when the fishes already stopped spawning. At the high concentration exposure, a drastic drop in egg production was observed on day 2, while egg spawning totally stopped on day 3. The descriptive analysis using Two-

Way ANOVA without replication suggests that there are significant differences in the egg production in different exposure concentrations (P value < 0.0001) and a significant difference in the egg production between days (P value = 0.0145).

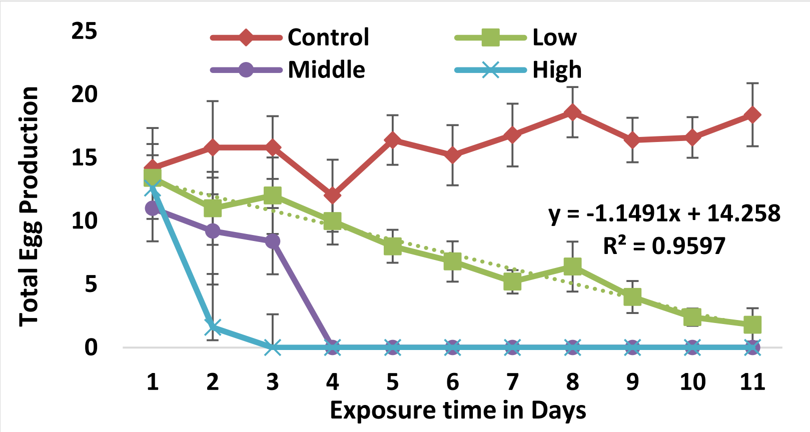

Figure 1. Total egg production during the 11-day exposure of the J. Medaka pairs to varying concentration of profenofos. Nominal concentrations of profenofos were 0.005 ppm, 0.03 ppm, and 0.2ppm for low, middle and high concentration respectively. Acetone levels were maintained below 0.01% in all exposure concentrations. Error bars represent the standard error of the five replicates.

Spontaneous swimming activity increased in the fish exposed to profenofos; the rate of speed and time spent in swimming increased with the increase in duration of exposure. Similar behavioral responses were observed in the catfish, *Mystus vittatus* (Arunachalam *et al.*, 1980) and *Channa punctatus* (Anees, 1975) when exposed to various concentrations of insecticides. Henry and Atchinson (1984) observed hyperactivity in bluegills exposed to methyl parathion. The hyperactivity was defined as an almost continuous swimming combined with numerous jerks, partial jerks, and flickering of fins.

McKim *et al*. (1987) indicated that fish poisoned with cholinesterase inhibitors lose equilibrium, swim in a spiral or cork screw pattern, over-react to stimuli, have increased amplitude of respiration, and may have terminal tetany and convulsions. Sheepshead minnow (*Cyprinodon variegatus*) poisoned with diazinon had abnormal forward extension of the pectoral fins and were excessively reactive when startled (Goodman *et al*., 1979). Similar signs were observed in the Asiatic catfish, *Heteropneustes fossilis* poisoned with malathion (Singh *et al*., 1984).

The average hatching rate is 8.81, 9.44, 9,52 and 10.86 days for control, low, middle and high exposure group respectively. The hatching rate in embryos exposed to profenofos decreased significantly (Figure 2) compared to control and is concentration dependent. The low hatchability could be attributed to the delayed development of embryos as one of the important sub-lethal effects of the toxicant. It may be due to the inhibition of Tetraspanin cd63 gene, which resulted in lack of secreted proteolytic enzymes required for chorion-softening (Michael *et al*., 2011). In contrast, some other OP insecticides like monocrotophos (Pamanji *et al*., 2015), malathion (Cook *et al*., 2005) and a pyrethroid, bifenthrin (Jin *et al*., 2009) induced hatching rate in zebrafish embryos at lower concentrations, it may be due to either weakening the chorionic membrane or inducing the activity of chorion's enzyme. Difference between hatching days is also significant (p <0.001).

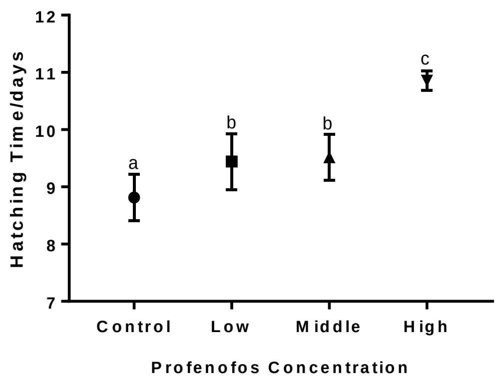

Figure 2. Average Hatching days of embryos exposed to different concentrations of profenofos. Error bars indicate standard error of the mean (control, n=814; low, n=309; middle, n=117; high, n=64).

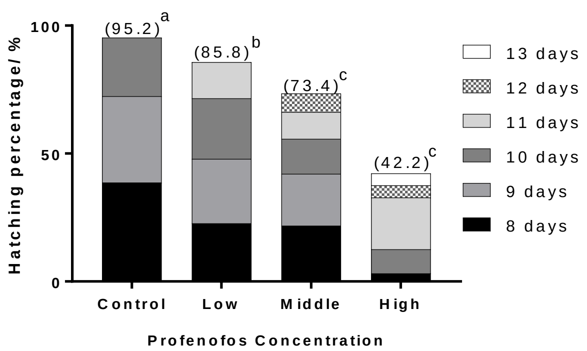

Figure 3. Percent hatchability of embryos exposed to different concentrations of profenofos in relation to 24h time interval (from 8 to 13 days). Figures in parenthesis indicate total percent hatchability. (control, n=814; low, n=309; middle, n=117; high, n=64).

Embryo survival exhibits a similar trend with hatching days (Figure 3). Survival rate is concentration dependent. Post Hoc analysis indicates that the exposure concentration is significantly different from the control, but the difference between the survival of the embryos in the middle and high concentration is not significant.

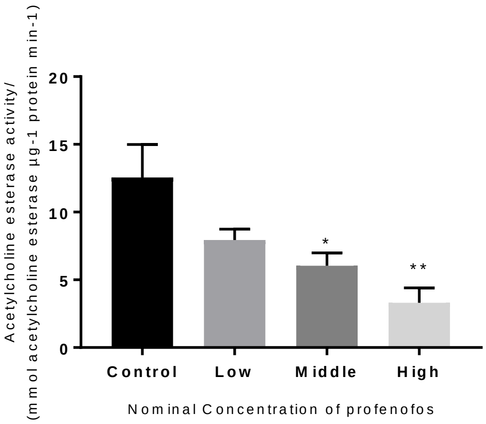

Figure 4. Acetylcholinesterase enzymatic activity in fish (*O. latipes*) brain exposed to different concentrations of profenofos. Error bars indicates normal error of the mean.

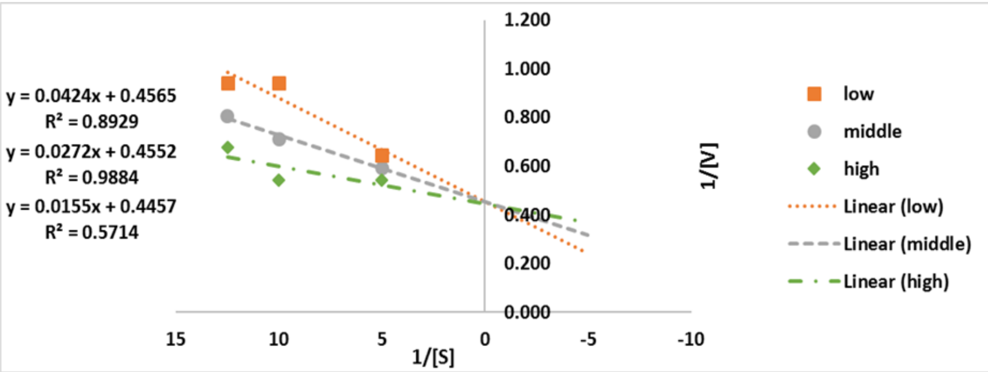

Figure 5. Line Weaver-Burk plots of fish brain acetylcholine esterase in the presence of different concentrations of profenofos. The graphs were plotted using reciprocals of the relative hydrolysis velocities versus reciprocal substrate concentrations of the inhibitor concentrations.

The AChE inhibition in Japanese medaka was greater at higher concentration of profenofos. The inhibition in the low concentration is not significantly different from the control, while at higher concentrations (middle and high) the difference from the control is significant. This accords with other studies in fish (Kumar and Chapman, 1998; Verna *et al*., 1979; Klaverkamp and Holden, 1980).

Figure 5 depicts typical kinetic plots (in vitro) for the inhibition of fish brain and gill AChE by profenofos. The graphs were plotted using reciprocals of the relative hydrolysis velocities versus reciprocal substrate concentrations of the inhibitor concentrations. The linearity of the kinetic plots is consistent with a first-order process with respect to inhibitor concentration. The reciprocal of regression lines of increasing slopes corresponds to increasing inhibition concentration. The common intersection of all the slopes at the ordinate and increase in the apparent Km indicates that the profenofos is competitive in nature.

The kinetic constants (V_{max} and K_m) describing the hydrolysis of acetylthiocholine substrate by AChE are presented in Table 1. This summarizes the apparent K_m in the presence of increasing concentrations of profenofos fish brain. Profenofos reflected a significant increase in Km percentage with an increase in inhibitor concentration. The inhibition constants were derived from double reciprocal plots of K_m/V_{max} regressed against inhibitor concentrations. This result coincides with the findings of Venkateswara *et al*. (2003) where profenofos exhibits competitive inhibition in both brain and gills of a euryhaline fish, *O. mossambicus*.

Table 1. Relative V_{max} and percentage increase in K_m of fish brain AChE with increase in the profenofos concentration.

Profenofos Concentration (ppm)	Y-intercept	Slope	V_{max} (1/intercept)	Apparent and relative K_m (–1/x-intercept)	
				K_m	% increase
Low (0.005)	0.46	0.04	2.19	10.77	27.33
Middle (0.03)	0.46	0.03	2.20	16.84	97.91
High (0.02)	0.45	0.02	2.24	28.75	240.06
Control	0.35	0.04	2.82	8.46	

4. Conclusion

The study showed that sub-lethal concentrations of profenofos can affect the reproduction of Japanese Medaka. Egg production is decreased relative to the dosage of profenofos in the water column, however, fertilization rate is not affected at a nominal concentration of 5ppb. Exposure to acetylcholinesterase inhibiting pollutants will restrict or hyperactivate the movements of fish. Egg production and fertilization of embryos is expected to lower since spawning and fertilization is greatly dependent on the mobility of the fish. Inhibition of the acetylcholinesterase activity is supported by manifestations of lost equilibrium, swimming in a spiral or cork screw pattern, over-reaction to stimuli, increased amplitude of respiration, and terminal tetany and convulsions.

Hatching days and survival rate were affected when embryos were incubated in sub-lethal profenofos concentration. An increase in the sub-lethal dosage of profenofos corresponds to lengthening of the hatching days and a decrease in embryo survival. It may be due to the inhibition of Tetraspanin cd63 gene, which resulted in lack of secreted proteolytic enzymes required for chorion-softening. Furthermore, AChE enzymatic activity can be inhibited by using sub-lethal profenofos. The mode of inhibition of profenofos in J. Medaka is competitive in nature and the inhibition follows a first-order inhibition with respect to inhibitor concentration.

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The Measurement of Nitrous Oxide Emission from Maize Cultivation

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Abstract

Field experiments were conducted during the 2014 and 2015 seasons to investigate the effect of inorganic nitrogen (N) fertilizer application on silt loam soils regarding nitrous oxide (N_2O) emissions, soil properties, biomass and maize yield. Daily N_2O emissions from three treatments: control with no fertilizer input (T1), 97 (T2) and 155 (T3) kg N ha^{-1} were studied using the static chamber method for maize (*Zea mays* L. var. Suwan 4452) cropping in a tropical savanna climate in Nakhon Ratchasima Province, Thailand during wet and dry seasons. Results indicated that the average N_2O fluxes in the T1, T2 and T3 treatments during the wet season were 0.33, 0.65 and 0.88 mg N_2O m^{-2} day^{-1}, and in the dry season 0.83, 1.11 and 1.29 mg N_2O m^{-2} day^{-1}, respectively. The highest N_2O fluxes were observed in the T3 treatment, corresponding to 18–32% of N_2O emissions. Values increased sharply after 5–7 days of N fertilization. The rates for N_2O emissions in the dry season were significantly higher than in the wet season ($P<0.05$) due to nitrification and denitrification processes and the different in maize cultivated condition such as, soil inorganic N, soil bulk density, and air temperature. With no different crop yields in the wet season, the T2 treatment had lower N_2O emissions than the T3 treatment and this fertilizer treatment could be applied for the sustainable maize farming.

Keywords**:** nitrous oxide flux; static chamber; maize cultivation

1. Introduction

Nitrous oxide (N_2O) is an important greenhouse gas (GHG) in the atmosphere. It also plays a significant role in ozone (O_3) depletion. With a global warming potential (GWP) 298 times greater than carbon dioxide (CO_2), N_2O is as powerful as GHG (Ravishankara *et al*., 2009). N_2O increased to 319 ppb by 2005 from a pre–industrial concentration of 270 ppb (IPCC, 2013). N_2O emissions from agriculture represent approximately 60% of the global and 67% of the agricultural soil derived from nitrogen (N) fertilization (U.S. EPA, 2012). Generally, it is estimated that around 10–50 kg of N will be lost from the soil as N_2O for every 1,000 kg of applied N fertilizers (Shcherbak *et al*., 2014). Agricultural soil is an important source of N_2O emission (Akiyama *et al*., 2010). Agricultural soil N_2O emissions are affected by environment factors (seasonal climate, soil texture and physical and chemical soil properties), and by management factors (synthetic N and fertilizer application rates and types) (Synder *et al*., 2009). N_2O is a by–product of soil nitrification and denitrification processes. Nitrification can occur under aerobic conditions. Ammonium (NH_4^+) is oxidized and converted into nitrite (NO_2^-) by *Nitrosomonas* sp. NO_2^- will be transformed into nitrate (NO_3^-) by *Nitrobactor* sp. In contrast, denitrifying bacteria will reduce NO_3^- to N_2O and nitrogen (N_2) due to lack of oxygen or without oxygen in soil (Metivier *et al*., 2009). Inorganic N application stimulates N_2O emissions by increasing substrate nitrification and denitrification. Modification of inorganic N fertilizer formulation, inorganic N fertilizer rate and/or the method of inorganic N fertilizer application have the potential to affect N_2O emission (Bijesh and Rodney, 2013).

Maize (*Zea mays* L.) is a crop that is vital to the economic development of the country. In general, maize production zones are in temperate regions with sub–tropical and tropical climates. Maize cultivation areas in Thailand comprise 1.14–1.18 million hectares (Office of Agricultural Economics, 2016). These maize production areas are mainly distributed in the northern, central and northeastern regions of Thailand. Maize cultivation in the croplands uses excess inorganic N fertilizers, which is the main source of N_2O emission from agricultural soil.

This study aims to verify the effect of rate of N fertilizer on N_2O emission using the static chamber method, soil properties, biomass, and crop yields with maize (*Zea mays* L. var. Suwan 4452) in agricultural soil under the tropical savanna climate in Thailand, in both the wet season and dry season. This study introduced maize cultivation practices to minimize N_2O emission and applied fertilizer treatment for the sustainable maize farming.

2. Materials and Methods

2.1. Site description

The field experiments were conducted in 2014 and 2015 at the National Corn and Sorghum Research Center and the Suwan Wajokkasikit Field Crops Research Station (14° 38' N, 101° 19' E) in Pak Chong District, Nakhon Ratchasima Province, Thailand. The soil at this site was classified using the Pak Chong (Pc) soil series described as follows: a reddish, (5YR3/3) silt loam with very fine soil texture and well–drained but low ability to absorb water and a high amount of iron (Fe) oxide nodules (classification by Land Development Department). Other soil characteristics are as follows: 25.0% sand, 55.0% silt and 20.0% clay, with pH 6.12, 1.09 g cm^{-3} bulk density and 3.84% organic matter (Soil Analysis by Department of Silviculture, Faculty of Forestry, Kasetsart University).

The local climate during the experimental periods was observed from the National Corn and Sorghum Research Center, Pak Chong Agrometeorological Station, which was located 800 m from the experimental site. Daily air temperatures and rainfall are shown in Figure 1. The means for daily air temperature in 2014 and 2015 were 26.0 ºC and 26.3 ºC, respectively. The means for daily maximum and minimum air temperatures were 31.6 ºC and 21.7 ºC in 2014, and 31.9 ºC and 22.0

ºC in 2015, respectively. The annual rainfall accumulation amounts were 775.6 mm in 2014 and 991.9 mm in 2015.

2.2. Field experiment designs

The experiments were conducted in a field with a randomized complete block design (RCBD). The site containing twelve rectangular plots, each with a size of 6m × 10m. In all plots, maize was grown all 2 crops on July to November, 2014 represent wet season and February to June, 2015 represent dry season. The treatment with four replications conducted of the following three treatments: T1 (control and no N fertilization, but with the same irrigation as the other treatments, T2 (traditional fertilization, fertilized by rate 97 kg N ha^{-1}) and T3 (excess fertilization, fertilized by rate 155 kg N ha^{-1}). Two fertilization events were conducted with NPK fertilizers formula 16–20–0 after planted maize seeding and urea is 46–0–0 about 30–40 days after planting maize seeding cultivated as the basal fertilizer and topdressing, respectively. The maize crop cultivar used in this study was Suwan 4452 (*Zea mays* L.). Maize was planted by direct seeding at a spacing of 75 cm × 20cm.

2.3. N_2O emission measurement

N_2O emissions were measured by using static chamber. Each gas sampling chamber consisted of an acrylic cover resting on a stainless steel base measuring 30cm × 30cm square open at the bottom, with sides 5cm above the ground and 10cm below the ground. The acrylic cover rested in a groove around the top of a square base filled with water as a gas seal. The acrylic cover was black to prevent photosynthesis in plants during the gas sampling and covered with white polystyrene foam sheeting for thermal insulation.

Gas samples were taken from the headspace once a week with a 20ml plastic syringe and transferred to evacuated vials. From the beginning of cropping to the end of harvest, gas samples were collected every other day for 5 days after the N fertilizer period. Samples were collected from 09:00 to 11:00 AM (local time) at time intervals of 0, 10, 20 and 30 min after chamber closure. Air temperature was monitored in each chamber simultaneously while gas samples were collected. The gas concentrations were analyzed by a gas chromatograph (Agilent model 6890, Agilent Technologies, USA) equipped with an electron capture detector for measuring N_2O emission. The net emission flux of N_2O was calculated using a linear fit to the gas concentration change inside the chamber over the sampling time (Nishimura *et al*., 2008). Gas fluxes (*F*) were then calculated using linear regression and ideal gas laws (Ussiri *et al*., 2009, Eq. 1) as:

$$\left(\frac{\Delta g}{\Delta t}\right)\left(\rho\frac{V}{A}\right)\left(\frac{273}{T+273}\right)k \quad F = \qquad (1)$$

Where $\Delta g/\Delta t$ is the average rate of change in gas concentration inside the chamber (mg m^{-2} min^{-1}), ρ is the gas density, *V* is the volume of the chamber (m^3), *A* is the surface area circumscribed by the chamber (m^2), *T* is the temperature in the chamber (ºC) and *k* is the time conversion factor.

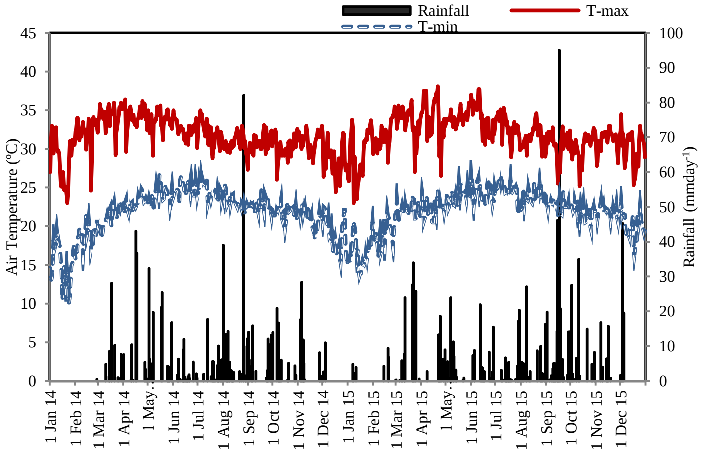

Figure 1. Dairy air temperature (maximum and minimum) and rainfall conditions during the experimental period (2014–2015) at the National Corn and Sorghum Research Center, Pak Chong Agrometeorological Station (Data observed by the National Corn and Sorghum Research Center, Pak Chong Agrometeorological Station).

A seasonal cumulative emission of N_2O was calculated by plotting the fluxes measured each week. The combined 100–year global warming potential (GWP) of N_2O in maize planted areas was calculated using a factor of 298 times for N_2O (IPCC, 2007; Nishimura *et al*., 2011).

2.4. Aboveground biomass sampling and crop yield analysis

In order to estimate the dry weight of the aboveground biomass of the crop harvest, 1m×1m areas in each plot were marked out and the crops collected at harvest time. These parts of biomass were dried in an oven at 80 ºC for 48 h to determine dry weight. Harvested maize was used to calculate the total crop yield.

2.5. Soil sample collection and soil properties

The bulk samples of surface (0–15cm) soils, about 1 kg from each horizon (0–15cm), were air dried, gently pulverized, and sieved to a particle size < 2000µm by a stainless steel sieve before analysis. Soil pH was measured in water (pH $_{H2O}$) (Peech, 1965). Organic carbon (OC) and organic matter (OM) determined by a wet oxidation procedure (Walkley and Black, 1934). The ammonium (NH_4^+) and nitrate (NO_3^-) concentrations were analyzed by colorimetric techniques (Li *et al*., 2014). Soil bulk density was measured in each field plot at soil depths of 0–15cm using stainless steel cylinders with a 5cm internal diameter and 5cm height. The soil cores were dried in an oven at 105 ºC for 48 h.

2.6. Statistical analysis

Statistical analyses were performed utilizing IBM SPSS Statistics 20 for Windows. One–way analysis of variance (ANOVA) calculations and Duncan's Multiple–Range Test (DMRT) (P<0.05) were conducted in order to categorize the effects of different N fertilizer rate treatments on seasonal N_2O emission, soil properties, biomass and crop yield.

3. Results and Discussion

3.1. Effects of N fertilizer on soil properties

3.1.1. Soil properties

The soil is classified as reddish with moderately high water permeability. Red soil develops on crystalline igneous rocks in regions with a tropical climate. Moreover, there is darker red in the top soil than the subsoil due to the accumulation of organic matter on the soil surface. Reddish soil types are typically found in tropical climate zones. The reddish tropical soil contains low activity clay and is rich in iron (Fe) and aluminum (Al) oxides. The highly–weathered reddish soil found in the northeast region of Thailand has a soil surface formed of crystalline Fe more than amorphous Fe, which is due to climate factors specific to these areas (Wisawapipat *et al*., 2010). Fe oxide in the surface soil allows aggregate soil particles to form granular soil structures that drain water well but have low water–holding capacity (Trakoonyingcharoen *et al*., 2012), resulting in dryness in the dry season.

Table 1. Soil properties and inorganic N in this experiment.

Parameters	**Unit**	**Wet season 2014**			**Dry season 2015**		
		T1	T2	T3	T1	T2	T3
Soil pH		6.48±0.15 a	6.52±0.17 a	6.55±0.16 a	6.50±0.18 a	6.60±0.19 a	6.62±0.16 a
Bulk density	g cm^{-3}	1.17±0.44 b	1.20±0.90 b	1.16±0.05 a	1.26±0.10 a	1.28±0.12 ab	1.30±0.99 b
Organic matter	%	1.08±0.19 a	1.07±0.15 a	1.04±0.20 a	1.01±0.23 a	1.01±0.13 a	0.93±0.12 a
Organic carbon	%	0.63±0.11 a	0.62±0.09 a	0.60±0.12 a	0.59±0.13 a	0.58±0.07 a	0.54±0.07 a
Ammonium	mg NH_4^+–N kg^{-1}	8.57±3.69 a	9.73±4.02 ab	10.42±3.34 b	7.10±3.14 a	8.42±3.09 b	10.69±2.86 c
Nitrate	mg NO_3^-–N kg^{-1}	29.38±10.87a	34.85±10.12b	39.28±11.17c	14.85±7.73 a	26.50±14.89b	30.45±13.67b

Means ± standard error of mean deviation with different letters in the columns of each treatment and cropping season are significantly different at the 0.05 level (*P<0.05*).

The pHvalue is within a neutral range (6.0–7.0). It is usually moderate and has rather low fertility. The soil tends to lose moisture and nutrients rapidly. The soil is less porous that is difficult to plow and lumpy when rainfall is scarce. The soil is suitable for the cultivation of field crops, yielding especially good maize crops in the rainy season. The NH_4^+ and urea are oxidized to nitrite (NO_2^-) and NO_3^- by the nitrification process and hydrogen ion (H^+) by–product, which make the soil acidic. However, the ability of soil to resist pH shifts, making fertilizer application impractical because of sharply decreasing soil pH due to soil pH buffering. Average soil bulk density in the dry season (1.28±0.11 g cm^{-1}) is higher than in the wet season (1.18±0.07 g cm^{-1}) because soil compaction does not absorb water in the dry season and there is no tillage of soil since initially preparing harrow soil for planting in the early period. Table 1 summarizes the soil properties and inorganic N in the three treatments by wet and dry seasons.

3.1.2. Organic matter and organic carbon

The amount of organic matter (OM) was low (0.5–1.0%) and moderately low (1.0–1.5%). OM ranged from 1.04–1.08% in the wet season and 0.93–1.01% in the dry season. The OM decreased due to the decomposition of biomass, organic materials, decayed plants, straw and animal materials that exist naturally. The organic agricultural residue and straw in the soil degrade rapidly in topsoil. As a result, the OM tends to drop after the N fertilization phase, lasting until harvest. Organic carbon (OC) has low values in top soil. Maize production has OC values ranging from 0.60–0.63% and 0.54–0.59% in the wet and dry seasons, respectively. Soil organic carbon is another soil parameter implicated in N_2O emissions (Giles *et al*., 2012). In synthetically–fertilized soils, the OC could be an indicator of the concentrations of C substrates accessible to nitrifying and denitrifying microorganisms that produce N_2O (Charles *et al*., 2017). Tropical climate soil is generally OC depleted due to environmental conditions favoring the decomposition and mineralization of OM and OC.

3.1.3. Inorganic nitrogen

The results of inorganic N in the soil of maize production can be detailed as ammonium (NH_4^+) and nitrate (NO_3^-) from mineralization process in N cycle by organic N and N fertilizer application in soil. The amount of NH_4^+ in treatments T2 and T3 was higher than treatment T1 (P<0.05) in both crops. The T3 treatment had the most NH_4^+ in the soil at 10.42±3.34 and 10.69±2.68 mg NH_4^+–N kg^{-1} in the wet and dry seasons, respectively. The amount of NH_4^+ in the soil was higher after added N fertilizer that contains N element and NH_4^+ decreased to the end of the maize cultivation. Concerning the amount of NO_3^- in the soil, the results showed that the T2 and T3 treatments were higher than treatment T1 and statistically significant (P<0.05). The T3 treatment added excess N fertilizer application and had the highest amount of NO_3^- at 39.28±11.17 and 30.45±13.67 mg NO_3^-–N kg^{-1} in wet and the dry seasons, respectively. Compared to the amount of NH_4^+ in the soil, it contains a reduced proportion to the amount of NO_3^- in the soil. Moreover, NO_3^- ion is a form of N that plants can uptake, likely because NO_3^- has an anion the same as the soil colloids. Thus, it has less–absorbing surface soil colloids, which cause plants to uptake and leach NO_3^- lost to an environment more easily than NH_4^+. OM and clay have anions that are easily attached to cations of NH_4^+ than NO_3^-.

The average of NH_4^+ in soil was less than NO_3^- due to NH_4^+ being oxidized to nitrite (NO_2^-) and quickly transformed to NO_3^- by the nitrification process in aerobic condition. The N fertilizer inputs to the maize crops (100–275 kg N ha^{-1}) at significant amounts of 70%, which can be accounted for in plant uptake, retention/accumulation in soils and ammonia volatilization (Borin and Tocchetto, 2007), whilst 25% was probably lost to ground water and 2–7% was lost in the denitrification process by N_2O (Zhao *et al*., 2011).

3.2. Effect of N fertilizer on N_2O emission

In general, the nitrification process contributes to N_2O emission during the oxidation of NH_4^+ to NO_3^- after the addition of N fertilizer to the crop soil (Hou and Tsuruta, 2003). For N_2O emission during the wet season, treatment T1 had the lowest average daily N_2O emission, which was significantly different ($P<0.05$) from other treatments. N_2O emission of the T1 was 0.33±0.17, while the T2 and T3 were 0.65±0.35 and 0.88±0.45 mg N_2O m^{-2} day^{-1}, respectively. Concerning maize production in the dry season, treatment T1 had the lowest average daily N_2O emission, which was significantly different ($P<0.05$) from other treatments. The T1 was 0.83±0.32, while the T2 and T3 were 1.11±0.53 and 1.29±0.55 mg N_2O m^{-2} day^{-1}, respectively, as shown in Table 2. Average N_2O emission from the dry season was significantly ($P<0.05$) higher (1.08±0.51 mg N_2O m^{-2} day^{-1}) than the wet season (0.63±0.41 mg N_2O m^{-2} day^{-1}).

The N fertilizer application increased N_2O emission by increasing the availability of substrate for the nitrification process. N_2O emission by the nitrification process was found in the early period of the wet season and most of the dry season. Rainfall and air temperature stimulate the conversion of organic N to inorganic N as NH_4^+. The results indicate that the denitrification process was the main contributor to N_2O emission in both the wet and dry seasons especially anaerobic condition in soils, while the nitrification process was responsible for the majority of N_2O emission in the dry season (Kachenchart *et al*., 2012). N_2O background emission was found in the T1 treatment because the biotic mechanisms involved in N_2O production share substrates and were driven by common variables in both the nitrification and denitrification processes (Lognoul *et al*., 2017).

Table 2. Seasonal N_2O emissions, combined dry weight aboveground biomass and crop yields.

Treatment	**Wet season 2014**			**Dry season 2015**		
	N_2O emission (mg N_2O m^{-2} day^{-1})	Above ground biomass (g)	Crop yield (kg ha^{-1})	N_2O emission (mg N_2O m^{-2} day^{-1})	Aboveground biomass (g)	Crop yield (kg ha^{-1})
T1	0.33 ±0.17 a	395.46 ±45.14 a	5,583.33 ±396.75 a	0.83 ±0.32 a	319.59 ±55.73 a	5,791.67 ±599.00 a
T2	0.65 ±0.35 b	402.74 ±38.58 a	8,666.67 ±490.65 b	1.11 ±0.53 b	327.83 ±47.19 b	5,958.33 ±478.71 a
T3	0.88 ±0.45 c	440.41 ±14.34 a	9,000.00 ±561.08 b	1.29 ±0.55 c	437.22 ±23.11 c	7,166.67 ±304.29 b

Means ± standard error of mean deviation with different letters in the columns of each treatment and cropping season are significantly different at the 0.05 level (*$P<0.05$*).

One distinct N_2O flux peak and the difference of emission between treatments were observed in wet and dry seasons, appearing after N fertilizer application. During this period, N_2O flux increased sharply in the basal fertilizer and topdressing over approximately 5–7 days of N fertilization, which contributed to 18–32% of N_2O emissions. Bouwman *et al*. (2002) and Huang *et al*. (2017) reported that N_2O emissions remain relatively static across a broad range of N fertilizer rates that approach crop demand levels, and then sharply increase with higher fertilizer rates. Our results showed a static range of N fertilizer rates after a sharp peak of basal fertilization and a sharp increase with the topdressing fertilization stage. N_2O flux from the topdressing fertilization released sharply trended emissions higher than the basal fertilization because the topdressing fertilization used N fertilizer as urea (46–0–0), which had 46% higher N element than the 16% of the NPK fertilizer formula 16–20–0 (Figure 2).

N_2O emissions will be evaluated for greenhouse gas emission as well as global warming potential (GWP). N_2O emission has a GWP of 298 over 100 years, equivalent to CO_2. In 2015, Thailand had maize–planting areas throughout the Kingdom and in Nakhon Ratchasima Province of 1,145,000 and 108,371 hectares, respectively. N_2O emission from these maize–planting areas throughout the Kingdom was 0.26 and 0.31 Tg CO_2 eq. at N fertilizer 97 kg N ha^{-1} and 155 kg N ha^{-1}, respectively. GWP from maize planted in the area of Nakhon Ratchasima Province was 0.02 and 0.03 Tg CO_2 eq. at N fertilizer 97 kg N ha^{-1} and 155 kg N ha^{-1}, respectively.

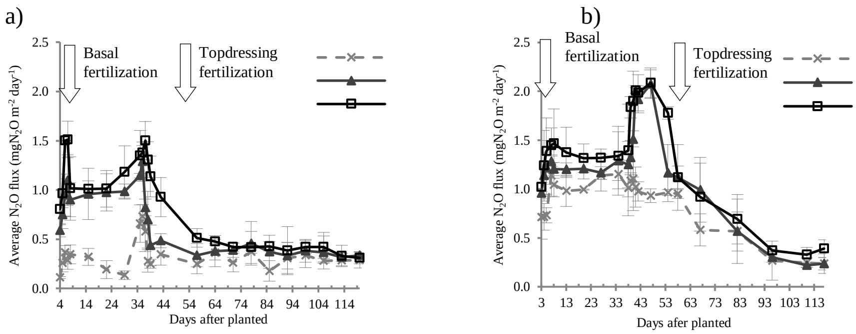

Figure 2. N_2O emission during different N fertilizer applications in wet season (a) and dry season (b).

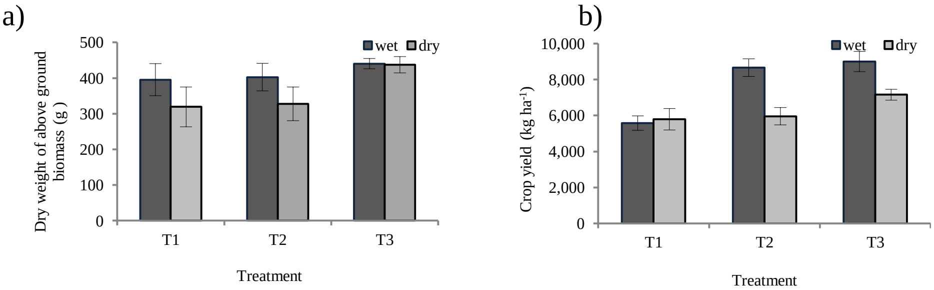

Figure 3. The Effect of N fertilizer on the dry weight of aboveground biomass (a) and crop yields (b).

3.3. Effect of N fertilizer on dry weight of aboveground biomass and crop yields

In the wet season, the average dry weight of above ground biomass in T1, T2, and T3 were 395.46±45.14, 402.74±38.58, and 440.41±14.34 g, respectively. For dry weight of above ground biomass in the dry season, the T1 was 319.59±55.73, while the T2 and T3 were 327.83±47.19, and 437.22±23.11 g, respectively (Table 2 and Figure 3). Statistical analysis found that the average dry weight of above ground biomass in all treatments during the wet season was not significantly different (P>0.05). However, it was significantly different in the dry season (P<0.05).

In the wet season, all treatments recorded high crop yield as a result of rate of inorganic N fertilizer and heavy rainfall. These factors resulted in high crop yields. The T1 treatment was 5,583.33±396.75 kg ha^{-1}, while T2 and T3 were 8,666.67±490.65 and 9,000±561.08 kg ha^{-1}. Statistical analysis found that the crop yields for T2 and T3 were significantly different (P<0.05) compared to the T1. In the dry season, T1 treatment had the lowest crop yield. The T1 treatment was 5,791.67±599.00 kg ha^{-1}, while the treatments for T2 and T3 were 5,958.33±478.71 and 7,166.67±304.29 kg ha^{-1}, respectively (Figure 3). Crop yield in the dry season was less productive than in the wet season (P<0.05). Statistical analysis found that crop yields for the T3 were significantly different (P<0.05) compared to other treatments. Moreover, the pod corn in T1 in the dry season usually seedless because of lack of rainfall during the fertility stage. The rate of inorganic N fertilizer application and seasonal condition especially rainfall affect crop yields in maize cultivation.

4. Conclusion

The rates of inorganic N fertilizer application affect N_2O emissions from maize cultivation, and the T3 treatment at 155 kg N ha^{-1} released higher N_2O fluxes compared with T1 and T2 treatments. Soil properties, especially inorganic N, soil bulk density and seasonal variations demonstrated high rates of N_2O emissions during the dry season. Fertilizer T2 treatment at 97 kg N ha^{-1} reduced N_2O emissions compared with the T3 treatment and recorded similar aboveground biomass and crop yields during the wet season.

Acknowledgements

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EnvironmentAsia
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The Effect of Steam and Glycerol Pretreatment on Chemical Contents of Oil Palm Empty Fruit Bunch (EFB)

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Abstract

This research aimed to evaluate the effect of the type of solvent, pH, substrate loading, and reaction time on the chemical components of palm Empty Fruit Bunches (EFB). Steam pretreatment was set up at 121°C temperature and 1.18bar pressure, using an autoclave with substrate loading of 5, 10, 15 and 20% w/v at reaction times of 15 and 60 min. Distilled water, waste glycerol, alkaline glycerol and acidic glycerol were used as solvents during steam pretreatment. The results showed that with distilled water, better pretreatment was achieved at 5% and 10% loading for 60 min. During the pretreatment with waste glycerol at 5% loading an increase on the reaction time from 15 to 60 min reaction resulted in a remarkable increase in reducing sugar in the liquid phase. Overall, the best condition of steam pretreatment was observed using alkaline glycerol at 5% w/v and 15 min reaction time, resulting in a cellulose increase to 66.20% and a lignin decrease to 9.17%. However, pretreatment with glycerol for 15 min was better than those for 60 min using either glycerol or distilled water. The results suggest that waste glycerol during steam pretreatment of EFB can be utilized effectively at short reaction times and at an increased pH to achieve a high output of cellulose and hemicellulose for sugar conversion in the bioethanol fermentation process.

Keywords: palm empty fruit bunch; steam pretreatment; waste glycerol; alkaline pretreatment

1. Introduction

Nowadays it is common to consider fossil fuels as finite and unsustainable resources; therefore, exploring the use of alternative renewable energy sources for bioethanol production is imperative. One such renewable source is lignocellulosic biomass from agricultural wastes. According to the Alternative Energy Development Plan (AEDP, 2015), fourteen million liters per day of biodiesel could be produced from oil palm fresh fruit brunch of about 30 million tons per annum, which in turn, could generate about 6 million tons per year of Empty Fruit Bunch (EFB).

The chemical composition of EFB includes cellulose, hemicellulose and lignin. Cellulose and hemicellulose can be converted to sugars (C-6 and C-5) through enzyme digestion and these sugars can be fermented to ethanol. However, cellulose and hemicellulose are densely packed by layers of lignin, which render them highly recalcitrant to enzyme accessibility (Trinh et al., 2016) Therefore, appropriate pretreatment of EFB is considered essential to accelerate the degradation process.

Many pretreatment technologies have been applied including physical, chemical, biological, or any combination of such methods. For example, degradation of the complex chemical structure can be accomplished by steam pretreatment (Shamsudin et al., 2012). Steam explosion exposes the lignocellulosic materials to high-pressure steam which increases the potential of enzyme hydrolysis (Duangwang et al., 2016). Additionally, chemicals like hydrochloric acid, sulfuric acid, sodium hydroxide, ammonia and glycerol have been used for the pretreatment of EFB (Baharuddin et al. 2013). However chemical pretreatment is expensive and has an impact on the environment. Crude glycerol is a by-product from biodiesel plants. For every 9 kg of biodiesel produced, 1 kg of crude glycerol is formed (Dasari et al., 2005). Previous studies have reported that glycerol is possible to work as delignification agent in the presence of alkaline substances (Ibrahim et al., 2012). Zhang et al. (2015) has reported that glycerol thermal processing can disrupt the cell wall without a noticeable change in chemical composition.

In this study, the effects of steam, waste glycerol, alkaline glycerol and acidic glycerol pretreatment were investigated at a laboratory scale. The objective of this research is to study the effect of steam and waste glycerol pretreatment as a function of reaction time, pH and substrate loading on the organic chemical composition of oil palm empty fruit bunch.

2. Materials and Methods

2.1. Raw Material

Palm empty fruit bunch (EFB) and waste glycerol were collected from Suksomboon's oil palm mill factory located in the Chonburi province, Thailand. The properties of waste glycerol were analyzed. To prepare the experimental samples, EFB was washed to remove particles and dried at 100-105°C for 5 hours. Subsequently, it was chopped to about 1-3mm size and stored in sealed plastic bags at room temperature until further use.

2.2. Experimental Approach

The pretreatment was carried out using steam in an autoclave at temperature and pressure of 121°C and 1.18 bars, respectively. The four different solvents used in pretreatment were distilled water, waste glycerol (pH=8.7), alkaline waste glycerol (pH=11.0) and acidic waste glycerol (pH=3.8). The alkaline waste glycerol was prepared with the addition of 1M NaOH while the acidic waste glycerol was prepared using concentrated H_2SO_4. Each liquid was added to EFB to formulate substrate loadings of 5, 10, 15 and 20%, respectively. Two reaction times of 15 and 60min were tested for each substrate loading. After the completion of pretreatment, solid samples were analyzed to determine the percentages of cellulose, hemicellulose and lignin following the forage fiber analytical method described in the Agriculture Handbook (Goering, 1970). The pretreated EFB was stored in plastic bags to be used for enzymatic hydrolysis in a future study.

The liquid phase from the pretreatment was analyzed for soluble chemical oxygen demand (SCOD) using the closed reflux, titrimetric method as outlined in the Standard Methods (APHA, AWMA & WEF, 2012) and for reducing sugar applying the DNS method (G.L. Miller, 1959).

3. Results and Discussion

3.1. Effect of pretreatment on the components of EFB

The EFB used as raw material contains cellulose, hemicellulose and lignin, typically expressed as percentages as shown in Table 1. The organic content of EFB, measured as volatile solids, is close to 90%. The experimental results show that with distilled water (DW), steam pretreatment of 5%EFB load needed a period of 60min to increase the %cellulose (%C) to 54.08%, %Hemicellulose (%H) to 32.32% and decrease %Lignin (%L) to 12.69%, while a 10% loading increased the %C to 53.03% and %H to 31.27%, and decreased %L to 13.20%. The other conditions studied show a higher up %C and a lower %H. The pretreatment with waste glycerol (WG), at 15min of 5%load was found to improve %C to 57.37% while %L was decreased to 12.41%, however it achieved a low %H. Although %C and %H at a 10% loading exhibited a similar trend, the %L was higher than that in the raw material. At a pretreatment time of 60min with waste glycerol, it was found that the %C and %H mainly decreased and were lower than the values obtained with distilled water. Such a decrease in cellulose and hemicellulose may indicate that these compounds have already been degraded to sugars.

It should be noted that the modification of pretreated EFB structure illustrates the effect of steam and waste glycerol on the biomass components. Baharuddin et al. (2013) studied the effects of high pressure steam pretreatment on EFB structure using Scanning Electron Microscope (SEM) observations which showed that the holes on the EFB surface were found to be swelling and the outer layers were disrupted along the structure. In addition, the previously-cited study reported that glycerolysis is a chemical method which can break the glycosidic bonds between carbohydrates and may also act as an aid to increase delignification selectivity. This process can be accelerated by the addition of small amount of sulfuric acid or sodium hydroxide (Ibrahim et al., 2012).

Table 1. Characteristics of the raw EFB.

Characteristics	Values
Cellulose	48.19
Hemicellulose	29.44
Holocellulose	77.63
Lignin	13.75
Moisture	6.57±0.06
Volatile solid	89.57±0.27
Ash	3.85±0.24

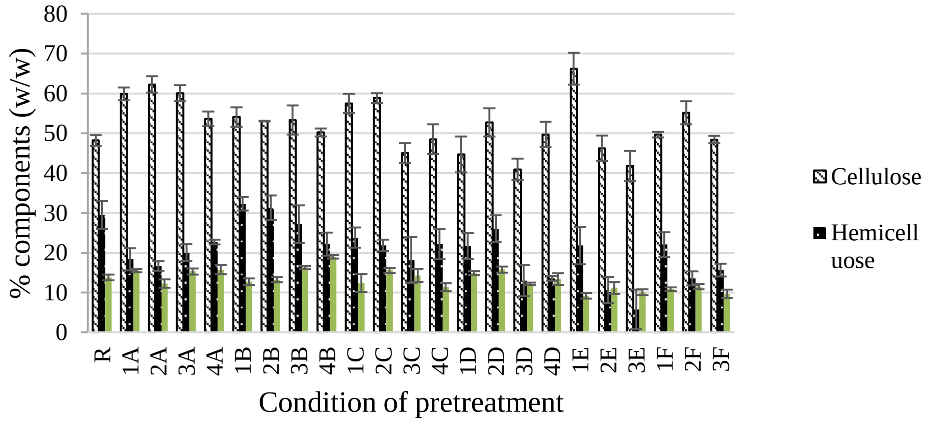

Figure 1. Components of pretreated EFB (percentage) Raw material(R); DW 15min(A); DW 60min(B); WG 15min(C); WG 60min(D); Alkaline waste glycerol, 15min(E); Acidic waste glycerol, 15min(F) Substrate Loading; 5%(1); 10%(2); 15%(3); 20%(4).

As shown in Figure 1, the maximum %C value of 66.20% and lowest %L one of 9.17% correspond to the pretreatment with alkaline waste glycerol at a 15min time period and 5% EFB loading, designated as 1E. Although the percentage of hemicellulose decreased in 1E in comparison to the raw (untreated) sample (R), the %holocellulose (%C plus %H) shows the highest percentage value. In addition, the percentage of lignin obtained from alkaline (E) and acidic waste glycerol (F) pretreatment for 15min was lower compared with the waste glycerol (C samples). However the effect of loading using alkaline and acidic waste glycerol on %C and %H release is also noticeable (Figure1). The above results indicate that alkalinity in waste glycerol appeared to enhance the effectiveness of steam pretreatment of EFB, resulting in higher output of holocellulose. The result in this study is relate to Choi et al., 2013 research, NaOH-catalyzed steam pretreatment for EFB can remove lignin efficiently and requires only a short reaction time. Besides, in previous research reported that glycerol as delignification solvent was more efficient in the presence of acid or alkaline (Ibraham et al., 2012). Although the percent increase in cellulose and the reduction in lignin during pretreatment, in general, appear to be modest compared to the raw sample (Figure 1), the changes in the EFB structure can be significant as illustrated above, which can facilitate further degradation of the EFB.

3.2. Parameters of liquid phase

Following pretreatment, the treated samples were filtrated and the filtrate was analyzed for soluble chemical oxygen demand (SCOD) and reducing sugar concentration. In general, as the EFB load increased the reducing sugar concentration also increased (Figure 2). The highest concentration was observed during pretreatment with waste glycerol at 60 min (D), regardless of the loading variation, suggesting that glycerol can release more reducing sugar at a longer reaction time. Whereas at 15min, both alkaline and acidic conditions encourage a higher reducing sugar generation from glycerol than that observed with waste glycerol without pH adjustment. The results of alkaline waste glycerol pretreatment relate to the composition of EFB, that is, a low initial percentage of cellulose and hemicellulose may increase the reducing sugar content. Overall, it is apparent that steam pretreatment can convert the components of EFB to reducing sugar.

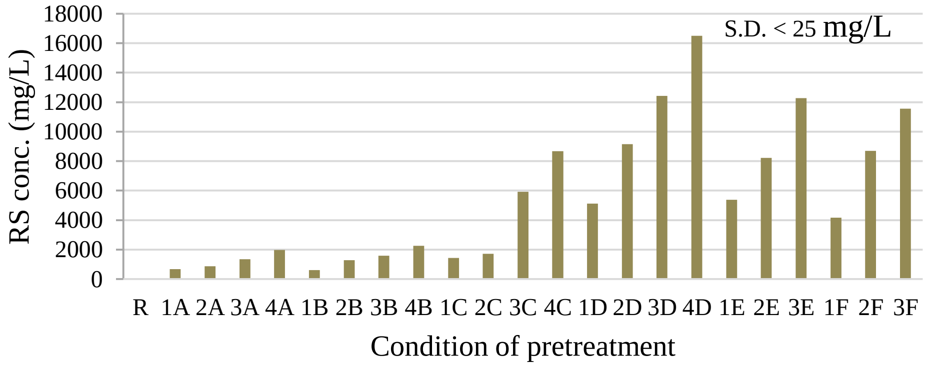

Figure 2. Concentration of reducing sugar in liquid phase (mg/L) Reducing sugar(RS); Raw material(R); DW 15min(A); DW 60min(B); WG 15min(C); WG 60min(D); Alkaline waste glycerol, 15min (E); Acidic waste glycerol, 15min (F) Substrate Loading; 5%(1); 10%(2); 15%(3); 20%(4).

Regarding the SCOD data, pretreatment with distilled water produced the lowest concentrations at both reaction times of 15 and 60min, designated as (A) and (B) (Figure 3). The values corresponding to distill water pretreatment are significantly lower than those obtained with glycerol as a solvent, because glycerol as an organic compound itself contributes to SCOD of the sample. An EFB loading of 5% achieved the highest SCOD in each pretreatment method, however, a reduction in SCOD was observed with an increase in the loading. This indicates that a low organic loading may favor the production of soluble organic compounds. Moreover, pretreatment with alkaline and acidic glycerol for a shorter time period (15 min) generated a moderately lower SCOD concentration than waste glycerol without pH adjustment, indicating that the pH of a sample may have an effect on the release of organic matter.

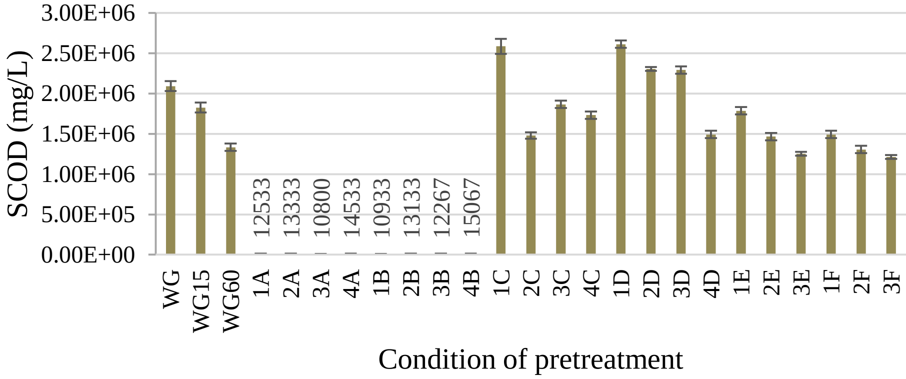

Figure 3. Soluble Chemical Oxygen Demand (SCOD) in liquid phase (mg/L) Glycerol 15min(1G); Glycerol 60min(2G); DW 15min(A); DW 60min(B); WG 15min(C); WG 60min(D); Alkaline waste glycerol, 15min (E); Acidic waste glycerol, 15min (F) Substrate Loading; 5%(1); 10%(2); 15%(3); 20%(4).

Overall, reducing sugar appears to be a minor component of the SCOD in the liquid phase. It is interesting to note that the use of distilled water as a solvent (conditions A and B) resulted in higher RS content in the liquid phase compared to the other solvents applied. When EFB was pretreated with crude glycerol, not only reducing sugar was produced but also other soluble organic compounds were present. The ratio of RS / SCOD signifies that most of the SCOD occurring in the liquid phase of the glycerol solvent did not originate from reducing sugar. Therefore, concerns about the treatment and disposal of the high organic-content wastewater generated should be also addressed during the pretreatment with glycerol. Moreover, it is apparent that regardless of the type of solvent used, an increase in the substrate loading caused a gradual increase in the RS content, which can be attributed to the higher initial organic content of the samples.

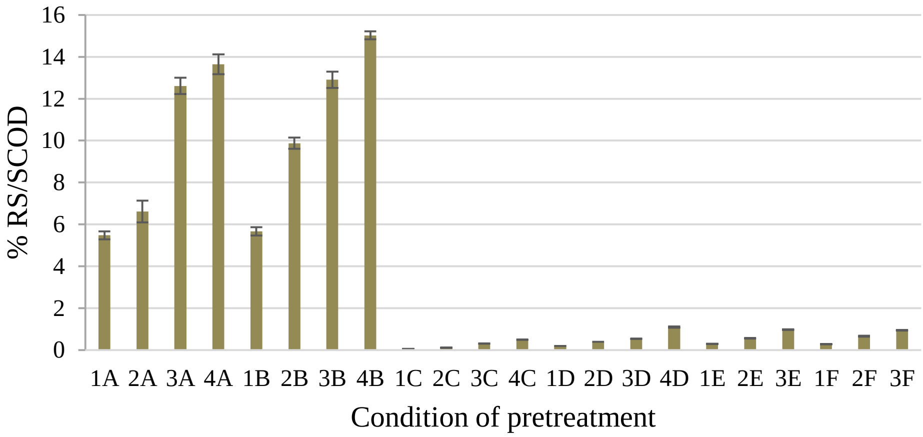

Figure 4. Ratio of reducing sugar (RS) to Soluble Chemical Oxygen Demand(SCOD) in liquid phase (percentage) DW 15min(A); DW 60min(B); WG 15min(C); WG 60min(D); Alkaline waste glycerol, 15min (E); Acidic waste glycerol, 15min (F) Substrate Loading; 5%(1); 10%(2); 15%(3); 20%(4)

4. Conclusions

The chemical composition of treated EFB during steam pretreatment was found to vary according to the type of solvent use, the pH of the liquid phase, and reaction time. The steam pretreatment with distilled water for 60min produced a higher content of holocellulose than that for 15min. However, steam pretreatment with distilled water for 60min achieved similar holocellulose concentrations when compared to pretreatment with waste glycerol for 15min. It is interesting to note that a shorter reaction time was needed when waste glycerol was used as a solvent in steam pretreatment process. Furthermore, the highest content of holocellulose and the lowest content of lignin were found during pretreatment with alkaline glycerol at low loading. The reducing sugar results also demonstrate that a limited degradation of the EFB components was achieved under such conditions. Overall, it can be concluded that alkaline pretreatment of EFB with waste glycerol can be achieved at a shorter reaction time, which could result, among other benefits, in lower energy requirements for the process.

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Emission Factors of Particulate Matter PM_{10} and $PM_{2.5}$ from Open Burning of Corn Stover in Thailand

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Abstract

PM_{10} and $PM_{2.5}$ from burning of corn stover residues were measured from a corn farm, control area. Then the related emission factors produced by open burning were calculated using Gaussian plume dispersion equation.Fine particulate matters were collected by low volume air pump and MiniVol air sampling. Automatic weather station was used to measure meteorological data in burning area. The concentrations of PM_{10} and $PM_{2.5}$in the corn farm before burning are 162 μg/m^3 and 97 μg/m^3 and the concentration during burning corn stubbles are 513 μg/m^3 and 347 μg/m^3, respectively. Emission rate of burning corn stover was calculated the fundamental air dispersion equation. Then emission factor of particulate matter (EFPMs) were calculated from total mass of burning crop and PM emission. The emission factor of PM_{10} from burning of the corn stover was 5.30±1.08 g/ kg and the emission factor of $PM_{2.5}$ was 3.69±0.765 g/ kg of corn stover.

Keywords: PM_{10}; $PM_{2.5}$; biomass burning; emission factor

1. Introduction

Crop residue burning is one of particulate matter emission source to the air environment (Andreae and Merlet, 2001, Reddy and Venkataraman, 2002). Corn stover consists of the leaves and stalks of maize (corn) plants left after harvest.The mass residues are from stalk; the leaf, husk, and cob remaining in the field. In Thailand, the agriculture area particularly in the northern part has been increasing dramatically from 2010 to 2015, report from LDD 2016. This induced wide spread of biomass burning for plantation field preparation. Therefore, the particulate matter emission factor from the agriculture wastes burning will be useful in inventory calculation and further air quality management.

Particulate matter emission factors (EFPM), which predict particulate emissions per biomass consumed, have a strong influence on event-based and regional PM emission estimates and inventories.There were many methods to estimate particulate matter (PM) emission factors (EF) from biomass burning such as by laboratory simulations using a self-designed dilution chamber system

(Sillapapiromsuk et al., 2015), calculation from mass balance of burning residue (Alves, et al. 2005 and Andreae and Merlet 2001) or model based prediction (Akagi et al., 2011and Agapol), However, EFPMs were influenced from many parameters in the fire areas and burning conditions therefore in this study, the emission factor were estimated from the combination of actual measurement at burning site following with the calculation from air pollution dispersion equation.

2. Materials and Methods

2.1 Site description and sample collection

The selected site, a corn farm in Kaeng Khoi, Saraburi was shown in Figure 1. After harvest, the dry farming areas with corn stovers were divided in to four sections with equal area, 10 x 10 meters. Section 1 was a control area for counting number of corn stovers and random sampling for weight calculation. Other three sections were actual crop burning sites which set up the measurement one site at a time. Automatic weather station was used to measure meteorological data in burning area. Meteorological parameters, PM_{10} and $PM_{2.5}$ level were measured before and after burning using the equipment set as shown in Figure 2 and 3. Mini-volume air sampler and low volume pump were used to collect fine particulate matter. The air sampling instruments were set up 50 and 30 meters away from burning area at downwind receptor site to represent the ambient air concentrations.

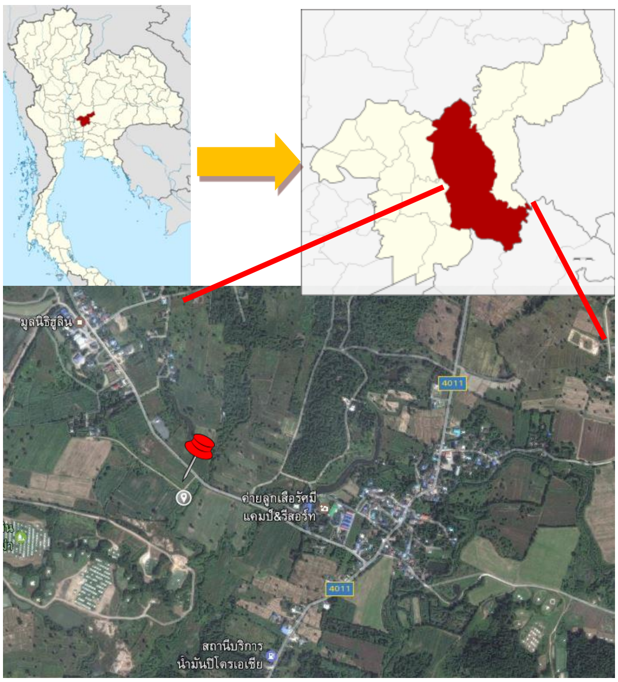

Figure 1. Site location of a corn farm in Kaeng Khoi District, Saraburi Province, Thailand.

Figure 2. MinVol air sampling collected particulate matter at 50 m and 30 m from sources.

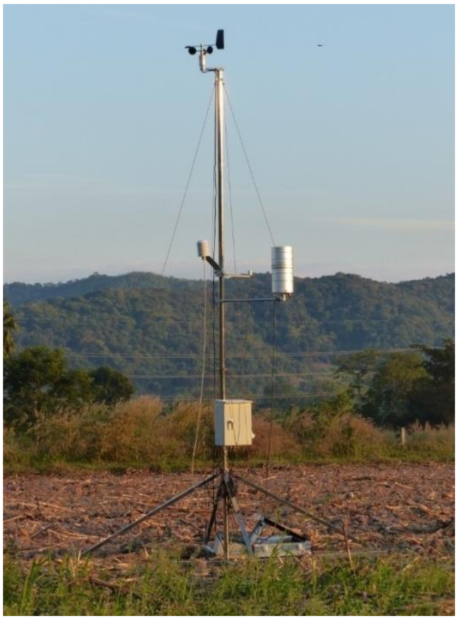

Figure 3. Meteorological equipment set up 100 m away from source, measured wind speed, wind direction, temperature, humid ity and solar radiation.

2.2 Emission Factors calculation

In this study, Concentrations at sites were measured at 50 m and 30m from sources. Emission rate Q, was calculated from the air pollution dispersion equation 1. Emission factor of burning corn stover was calculated from equation 2.

$$C = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left\{\exp\left[-\frac{(z-H)^2}{2\sigma_z^2}\right] + \exp\left[-\frac{(z+H)^2}{2\sigma_z^2}\right]\right\} \quad (1)$$

Where as C = Concentration of pollution at point (x,y,z) (µg/m3)

(x,y,z) = Interested point (m) (x = Downwind, y = Crosswind, z =Upwind)

Q = Source pollutant emission rate (g/s)

H = Height of emission plume centerline above ground level (m)

u = Wind speed (m/s)

σy = Vertical standard deviation of the emission distribution (m)

σz = Horizontal standard deviation of the emission distribution (m)

Emission Factor = Q (g/s) x burning time(s) / corn stover weight (kg) (2)

3. Results and Discussion

3.1 Air environment at the study site

Meteorological parameters in a corn farm in Kaeng Khoi, Saraburi were shown in Table 1. Three experiment conditions were in the same range. Major wind direction of three experiment sets was from south west wind as shown in Figure 4. The air sampling equipments were set up along south east and northwest directions.

Table 1. Temperature, Relative Humidity, Air pressure and Global radiation during performing the burning of corn stover.

Parameter	Test 1	Test 2	Test 3
Temperature ^{0}C	25.32	25.63	26.32
Relative Humidity **%**	47.72	47.51	46.85
Air pressure mmHg	755.06	755.05	754.33
Global radiation W/m^2	711.40	726.94	756.17

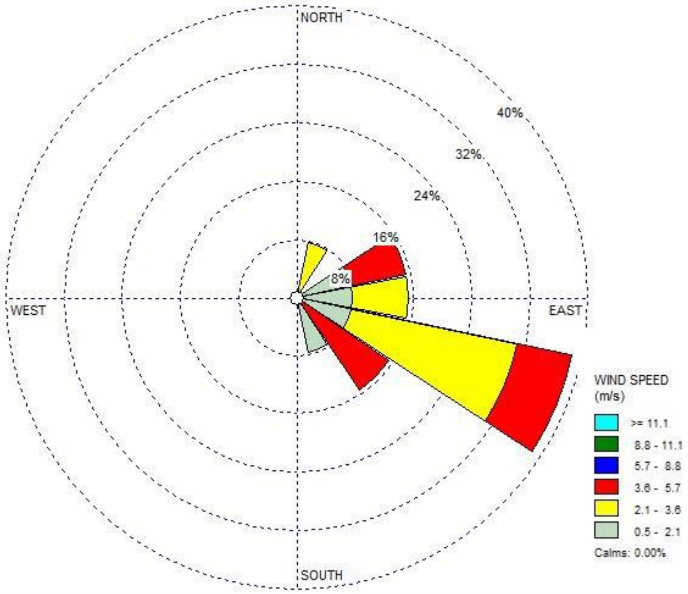

Figure 4. Wind rose at the study site.

3.2 PM_{10} and $PM_{2.5}$ Quantitative analysis

PM_{10} and $PM_{2.5}$ were sampling before burning as control values and during the burning at different distances from sources. The concentrations were shown in Table 2 and compared in Figure 5.

Table 2. PM_{10} and $PM_{2.5}$ concentrations

Sample (each n =3)	PM_{10} (μg/m^3) measured	PM_{10} (μg/m^3) Burn–control	$PM_{2.5}$ (μg/m^3) measured	$PM_{2.5}$(μg/m^3) Burn–control
Control 50 m	161.96	0	96.79	0
Burn 1 30 m	452.43	290.47	264.26	167.47
Burn 2 30 m	508.87	346.91	378.76	281.97
Burn 3 30 m	577.45	415.49	397.44	300.65

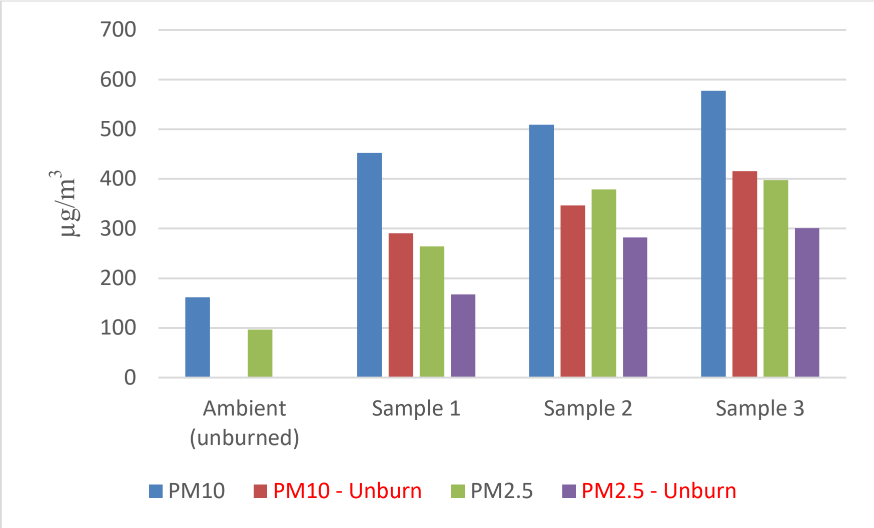

Figure 5. PM_{10} and $PM_{2.5}$ concentrations before and after burning.

3.3 PM_{10} and $PM_{2.5}$ Emission Factors

Emission Factors were calculated from equation 2. Where C is the concentration of burn PM_s subtracted its control value. Weight of corn stove in the test area 100 m^2 was 60 kg. The emission factors in this study were found close to the literature values which calculated from biomass burning experiment in the laboratory.

Table 3. PM_{10} and $PM_{2.5}$ Emission Factors (g/kg).

Emission factor	**PM_{10} (g/kg)**	**$PM_{2.5}$ (g/kg)**
Burn sample1	5.36	3.10
Burn sample2	3.94	3.20
Burn sample 3	6.59	4.77
Average	5.30± 1.08	3.69 ± 0.76

4. Conclusions

The emission factor of PM_{10} from burning of the corn stover was 5.30± 1.08 gram per kilogram of corn stover and the emission factor of $PM_{2.5}$ was 3.69 ± 0.76 gram per kilogram of corn stover. The EFPM could be further applied in PM inventories from biomass burning area in Thailand, particularly in the case of corn farm land development.

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Synthesis of Calcium Oxide from River Snail Shell to a Catalyst in the Production of Biodiesel

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Abstract

This research aim to study synthesis of calcium oxide from river snail shell by calcination at 700, 800 and 900 °C for 4 h and used as catalysts in the biodiesel production. Calcium oxide fraction in calcined river snail shell was analyzed by X-ray fluorescence (XRF), X-ray diffraction (XRD) and scanning electron microscopy (SEM). The XRF result showed the amount of calcium oxide that were 59.499%, 70.113% and 73.881%, when the calcination temperature were 700, 800 and 900 °C, respectively. It corresponded with the XRD pattern of 800 and 900 °C displayed the phase of calcium oxide. The SEM results exhibited that the particle was agglomerate, while the calcination temperature was increasing, the surface area of the river snail shell was porous, rough and fragile. The calcium oxide from each calcination temperature was utilized as a catalyst in the production of biodiesel. The biodiesel production from waste cooking oil and methanol in molar ratio of 6:1, reaction temperature 60-65˚C for 3 h with 1-3 wt% of catalysts were studied. From transesterification reaction using calcined river snail shell as catalyst in 3 range of temperature. They were found that the calcination temperature at 800 ºC, the catalyst amount 1% have maximum biodiesel yield. It was 95.91%. The properties of biodiesel, flash point, heat of combustion, acid value and methyl ester content were analyzed. The results found biodiesel from this research was qualified according to the standards of department of energy business. Therefore river snail shell was the natural waste material as source of calcium oxide. As a catalyst to produce biodiesel commercially in the future.

Keywords**:** calcination; calcium oxide; biodiesel; calcined river snail shell

1. Introduction

The increasing of population quantity and energy consumption are growing up and lead to the highly energy demand (I. Choedkiatsakul et al., 2013; Guanyi et al., 2014). At the same time, the quantity of oil reserves of the world are decreasing continuously (Achanai et al., 2014). Therefore, alternative energy technologies are interested at the present. Biodiesel is widely interesting alternative because of it could instead diesel fuel. Biodiesel are environmentally-friendly, helping to prevent global warming and air pollution (Jutika et al., 2014). Biodiesel can produced from vegetable oils, animal fats and waste cooking oils (Márcia Cardoso Manique et al., 2012). Transesterification is the most commonly popular method for the biodiesel production as using homogeneous catalysts such as sodium hydroxide (NaOH) and potassium hydroxide (KOH) (Suchada et al., 2015; Xin et al 2010). The advantage of this method are high yield providing, inexpensive and short reaction time but these catalysts have problems about wastewater from washing in the process and contaminate with methoxide that happen when methanol mix with NaOH or KOH and surely that it is not good for researcher or person who produce biodiesel (Achanai et al., 2014; Suchada et al., 2015; S. Niju et al., 2014). For solving this problem, the study of biodiesel catalyst have started. Heterogeneous catalysts from many animal shell are interested such as egg shell, river snail shell and crab shell because of they can easily separate from biodiesel product and reduce amount of wastewater (Suchada et al., 2015; N. Viriya-empikul et al., 2010; Wuttichai et al., 2016). Calcium oxide (CaO) is one of the heterogeneous catalysts that synthesis from river snail shell. Therefore this research studied the heterogeneous catalyst type calcium oxide from river snail shell for biodiesel production from waste cooking oil with the transesterification process.

2. Experimental

2.1 Catalyst preparation and analysis

The river snail shell, sometimes known as the viviparidae that was a family of large operculated freshwater snails. It was classified in the group of Architaenioglossa, adult specimen with operculum, height: 3.45 cm, alive in water source ditch according to nature as illustrated in Figure 1 (Viviparidae, 2015).

Figure 1. River snail shell.

The river snail shell with a mass of (1 kg) was cleaned by washing thoroughly with water several times and then dried heat by hot air oven at 105 º. The resulting material were calcined in a muffle furnace under static air conditions at designated temperatures (700, 800 and 900 ºC) for 4 h, then crushed of river snail shell to powder and filtered through a stainless steel sieve 60 mesh. The result of calcined river snail shell powder (CRSP) was 0.5 kg and stored in desiccator to avoid the reaction with air before used.

CRSP was analyzed the elemental chemical compositions by X-ray fluorescence (Philips, Netherlands) spectroscopy under vacuum condition for precise measurement. The characterization of the river snail shell-derived were analyzed by X-ray diffraction (XRD; Philips, Netherlands) coupled with Cu ka radiation (λ = 0.154 nm) generated at 40 kV and 30 mA, over a 2θ range from 5º to 90º with a step size of 0.05º at a scanning speed of 3º /min. The microstructures of CRSP was observed by scanning electron microscope (SEM). The SEM images and surface elemental analysis were recorded on a Quanta 400 (Czech Republic).

Waste cooking oil was filter and boiled for moisture removing at 105 ºC for 30 min. Then free fatty acid analysis (FFA) by titration with standard based-solution, weigh 5 g oil into a flask, add 2-propanol 25 ml and fill 3-5 drop of Phenolphthalein. Dissolve 0.1 N potassium hydroxide solution (KOH) in a flask and shake until the solution changes into pink. Record the volume of KOH used. Calculate the FFA for estimate the proper amount of catalyst.

2.2 Transesterification reaction

A 200 ml waste cooking oil in a 500 ml. The methanol/oil molar ratios was 6:1 and used calcium oxide from CRSP as catalysts at temperature of 700, 800 and 900 °C. The amount of catalyst were 1-3% and experimental temperature was 60-65˚C and stirred at 300 rpm for 3 h, using a hot plate controlled by a thermo regulator, the experiments were repeated 3 times. After the transesterification reaction finished, the catalysts or calcium oxide was separated from the mixture by centrifugation and the excessive amount of methanol was evaporated with heat at temperature 100 ºC. The percentage yield was calculated using the following equation (1) (Natarajan et al., 2013).

$$Yield\,(\%) = \frac{(\text{Weight of biodiesel})}{(\text{Weight of oil})} \times 100 \qquad (1)$$

2.3 Biodiesel production properties

The research studied properties of biodiesel. They were analyzed by acid value (ASTM D664), density (ASTM D1298), flash point (ASTM D93), heat of combustion (ASTM D4809) and fatty acid methyl ester (FAME) were performed in Gas Chromatograph (Agilent 7890A) by method (EN 14103), equipped with a flame ionization detector and a capillary column (DB-WAX, 30 m × 0.25 mm × 0.25 μm). Methyl heptadecanoate was used as an internal standard to quantify the content of biodiesel.

The FAME of biodiesel samples was identified and then the peak areas were utilized to quantify the FAME content, using the following equation (2) (Vanessa et al., 2015).

$$C = \frac{\left(\sum A\right) - A_{EI}}{A_{EI}} \times \frac{C_{EI} \times V_{EI}}{m} \times 100 \qquad (2)$$

Where C = fatty acid methyl content (%); ΣA = total peak area; A_{EI} = peak area corresponding to the methyl heptadecanoate; C_{EI} = concentration of methyl heptadecanoate solution in heptane (mg/ml); V_{EI} = volume of methyl heptadecanoate solution (ml); m = mass of biodiesel sample (mg).

3. Results and discussion

3.1 Catalyst characterization

XRF analysis

The study of chemical compositions with XRF technique in CRSP at 700, 800 and 900 °C for 4 h. It was found at 700 °C, calcium in the shells transform into active calcium oxide catalyst 59.49%. When the calcined temperature increased to 800 °C, the amounts of calcium oxide was 70.11%. The result showed when temperature increased, more calcium carbonate ($CaCO_3$) completely transform to CaO (Supakorn et al., 2015). When calcium carbonate (CaCO3) was heated, the reaction produced carbon dioxide and calcium carbonate changed to calcium oxide as illustrated in equation (3) (Supakorn et al., 2015).

$$CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2 \qquad (3)$$

It was found calcium oxide increased slightly from 70.11% to 73.88%. It refered to optimum of calcination temperature is 800 °C. The optimum temperature for the synthesis of calcium oxide from calcium carbonate in the CRSP. The XRF spectroscopy showed that CaO derived from $CaCO_3$ and was composed of CaO, *magnesium oxide* (MgO), aluminium oxide (Al_2O_3) and silicon dioxide (SiO_2) as shown in Table 1.

Table 1. Elemental chemical compositions of CRSP at 700-900 ºC for 4 h.

Element	Calcination 700 ºC	Calcination 800 ºC	Calcination 900 ºC
CaO (%)	59.499	70.113	73.881
MgO (%)	0.271	0.362	0.329
Al_2O_3 (%)	0.237	0.159	0.162
SiO_2 (%)	0.123	0.109	-

XRD analysis

The study of crystal structure with XRD technique at different calcination temperatures, XRD pattern of 700 °C, the calcium carbonate contained in the shell and converted to calcium oxide slightly. X-ray diffraction found that had many peaks of $CaCO_3$. The peaks at 2θ = 29.43 º 39.46 º 43.23 º, 47.46 º, and 48.53 º as illustrated in Figure 2, while calcination temperature at 800 and 900 ºC showed CaO as a major peaks. The peaks at 2θ = 32.23 º, 37.41 º, 53.93 º, 64.26 º, 67.48 º, 79.1 º and 88.56 º were the characteristic as similar to the standard XRD pattern of CaO. As a result, it was concluded that the high temperature over 800 ºC is required to completely convert calcium carbonate into calcium oxide. Thus calcium carbonate decomposition to change the calcium oxide when higher temperatures (Achanai et al., 2014; Supakorn et al., 2015).

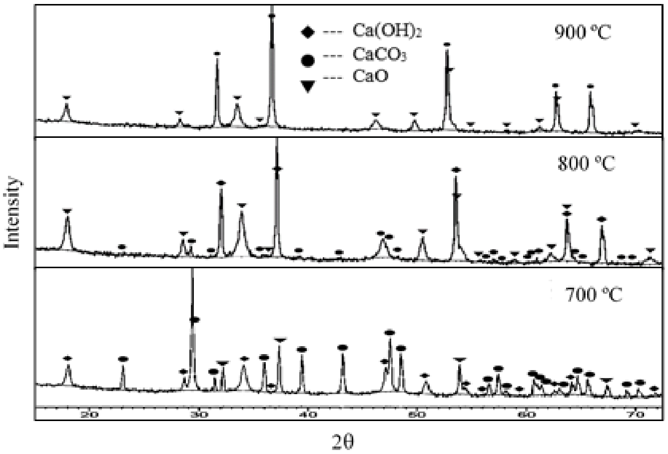

Figure 2. XRD patterns of the river snail shell catalysts calcined at 700-900 ºC for 4 h.

SEM analysis

In studying on external structure of the calcined river snail shell with a scanning electron microscope (SEM) as illustrated in Figure 3 (a-c). The catalysts particles of size 5 µm at 6000 imaginable found that porous diffuse on the surface and the particles of size 2 µm at 20,000 imaginable as shown in Figure 3 (d-f) the calcination temperature 700-800 ºC, the structure had more rough and many cracks on surface area. The increasing of calcination temperature at 900 ºC. The particle was small size and agglomerate. The particle was a small size will result in catalysis surfaces having more exposure (Achanai et al., 2014; Chakkrapong et al., 2013). Calcination at higher temperature thus fragile, easily brittle fractures and can be easily crushed to calcination at a lower temperature (Supakorn et al., 2015; Chakkrapong et al., 2013).

3.2 Transesterification reaction

The analysis of free fatty acids (FFA) of waste cooking oil was 0.49%. From transesterification reaction using CRSP as catalyst of designated temperature found that the calcination temperature at 800 ºC, catalyst amount 1% as catalyst for the theoretical methanol/oil ratio 6:1 have maximum biodiesel yield as shown in Fig.3. It was 95.91%. However, when the amount of catalyst was increased to 2%, the yield decreased to 94.67%, because of catalyst that had more solid contents it effect to incomplete distribution. This results effected to difficult for reaction (Hatthason et al., 2013). In addition, an excessive catalyst would increase biodiesel viscosity and reduced the mass transfer of reactant that might be reversible reaction and reduced biodiesel yield (Chakkrapong et al., 2013). Effect of each conditions of designated temperature catalyst (700-900 ºC) to the yield of biodiesel as shown in Figure 4

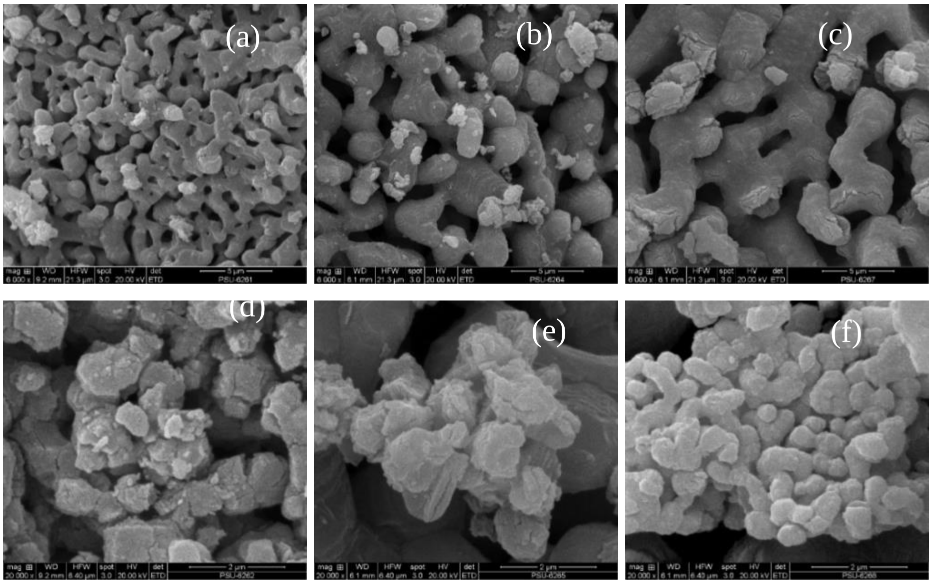

Figure 3 SEM images of the river snail shell catalysts calcined at 700-900 ºC for 4 h; (a-c) with diameter of approximately 5 µm, and (d-f) with diameter of approximately 2 µm.

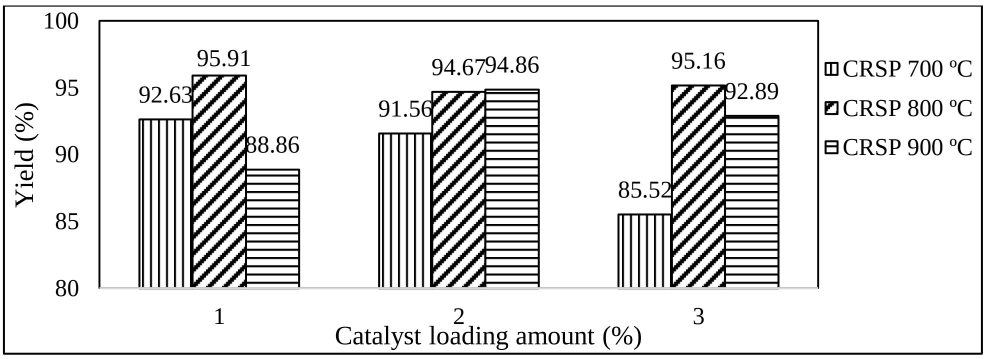

Figure 4 Effect of different designated temperature catalyst to biodiesel yield.

3.3 Biodiesel production properties

In studying biodiesel production by transesterification from waste cooking oil using CRSP at 700-900 ºC, yield of all experiment had more 85%. The properties of biodiesel were tested, flash point, acid value, density heat of combustion as shown in table 2.

From table 2, the density were in range of 880-910 kg/m^3 and acid value ranges were 0.33-0.88 mg KOH/g. The density of biodiesels ASTM D1298 standard should be 860-900 kg/m^3 and the acid value of the ASTM D664 standard should be lower than 0.5 mg KOH/g (Department of Energy Business, Ministry of Energy, 2016). The result showed when the amount of catalyst were increased, it effected to decreasing of biodiesel density whereas acid value would increase that effected to corrode engine.

The flash point of biodiesel followed to standard value. The standard ASTM D93 was not less than 120 °C (Department of Energy Business, Ministry of Energy, 2016). The flash point of biodiesel from all experiment were higher than 150. The heat of combustion values of biodiesel followed to ASTM D4809 should around 40,000 kJ/kg which was slightly lower than that of petroleum diesel fuel (Ertan et al., 2014). The heat of combustion properties of biodiesel from all experiments were 31,000-42,000 kJ/kg. So, the proper condition would chosen from properties of experiment that passed standard value of density, acidity, flash points and heat of combustion and were analyzed for the amount of methyl ester by Gas Chromatograph.

Table 2. Biodiesel properties from waste cooking oil by tranesterification using CRSP.

No.	Catalyst (%)	Yield (%)	Density (kg/m^3)	Acid value (mg KOH/g)	Flash points (ºC)	Heat of combustion (kJ/kg)
1.	CRSP 700 ºC (1%)	92.63	920	0.55	220	31760
2.	CRSP 700 ºC (2%)	91.56	910	0.33	> 230	32891
3.	CRSP 700 ºC (3%)	85.52	905	0.86	> 230	35627
4.	CRSP 800 ºC, (1%)	95.91	900	0.45	175	31170
5.	CRSP 800 ºC, (2%)	94.67	890	0.46	157	41430
6.	CRSP 800 ºC, (3%)	95.16	880	0.56	165	43022
7.	CRSP 900 ºC, (1%)	88.86	910	0.55	>230	35925
8.	CRSP 900 ºC, (2%)	94.86	880	0.88	169	36001
9.	CRSP 900 ºC, (3%)	92.89	880	0.77	158	31940

From the results in Table 2, biodiesel properties of experiments No.4 and No.5 passed all the standard properties of the Department of Energy Business. They were chosen to analyzed percent of methyl ester by Gas Chromatography technique as shown in Table 3.

Table. 3 Properties of biodiesel product from 2 conditions.

No.	Catalyst (%)	Yield (%)	Density (kg/m^3)	Acid value (mg KOH/g)	Flash points (ºC)	Heat of combustion (kJ/kg)	Methyl ester (%)
1	CRSP 800 ºC, (1%)	95.91	900	0.45	175	31,170	81.34
2	CRSP 800 ºC, (2%)	94.67	890	0.46	157	41,430	97.95

From Table.3, The experiment that using CRSP 800 ºC of 1% catalyst, methyl ester was 81.34%, but in the experiment that using CRSP 800 ºC of 2% catalyst, methyl ester was 97.95%, which was followed to the Department of Energy business standards determination value (more than 96.5%) (Department of Energy Business, Ministry of Energy, 2016) and their properties (density, acidity value, flash point, heat of combustion and methyl ester) followed to the Department of Energy's business standards too. The result showed using CRSP at 800 ºC of 2% catalyst t in biodiesel production was optimum condition in study of biodiesel production by tranesterification using calcined river snail shell powder.

4. Conclusions

This research studied the synthesis of calcium oxide from calcined river snail shell, it found that at the higher temperature of calcination, the results showed calcium carbonate transform to calcium oxide active catalyst while temperature of calcination at 800 ºC , it was not different for calcination of 900 ºC. Therefore, the catalyst from calcined river snail shell could be the high potential catalyst and lead to the development of using catalyst from natural waste material as source of calcium oxide to biodiesel production well in the future.

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Spatial and Temporal Variation of Seawater Qualities and Indigenous Benthos along the Northern Gulf of Thailand from Chonburi to North Pattaya

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Abstract

Marine ecology caused severe risk to degenerate from urbanization, industrialization, agriculture and tourism. The coast line was the vulnerable areas where directly receiving discharges from anthropogenic activities. The study areas were the nearby coast line along the Upper Gulf of Thailand from Chonburi to Pattaya (approximately 55 kms) in which the famous beaches, the aqua farms, deep sea as well as local fishery ports and industrial estates were located. Thus, the spatial and temporal variations of seawater qualities were determined in terms of marine resource usage, management and conservation. The physical parameters were determined at each half depth below the sea level. Water temperature ranged from 30.00 – 31.40 and 28.40 – 29.30 ºC; DO 4.93 – 7.60 and 5.10 – 6.54 mg/L; pH 7.97 – 8.36 and 7.98 – 8.10; salinity 32.05 – 32.77 and 32.35 – 32.70 psu in rainy season and winter, respectively. The sediment samples were collected by Ekman dredge and scuba diving with. 0 – 10 cm depth. The other seawater qualities were determined by modification from Standard Methods for Water and Wastewater. BOD in the two seasons (0.1 – 1.56 and 0.3 – 2 mg/L) were agreed with Standard values. The variation was affected by muddy pier at Fish dock, tourism activities at Bangsaen beach Bangpra and Banglamung community wastewater discharge. The organic contents in wastewater were clearly originated from anthropogenic activities. High contents of COD were found at sta. 3, 4, 6 and 7 where the population communities, shipping and local fishery ports were located. COD were ranged from 7.35 – 205.88 and 198.66 – 377.48 mg/L, respectively. FOG varied very wide range in winter (7.13 – 273.40 mg/L) and higher than in rainy season (0.09 – 35.60 mg/L). The higher amounts were found in Wastewater discharge, Bangpra, community and the local fishery port at Sri Racha pier. Low PO_4^{3-} and TKN were observed for all stations (0.01 – 0.09 and 0.16 – 0.59 mg/L). The higher contents were found in muddy and water discharge areas. Sulfide ion varied from 0.15 – 0.53 mg/L. Among heavy metals in sediment, the highest amounts of Fe (4.2 ± 0.18 and 8.3 ± 0.86 g/kg) were observed in the rainy and winter season, respectively. Mn was the component of anti-corrosion as coating agent, it was found for the second most metal in the sediment around Shipyard (Laem Chabang pier). Pb was the third probable found at the Sanctuary of Truth, Bang Lamung and Sri Racha pier with similar quantities (260.69 ± 8.42, 233.21 ± 7.13 and

205.74 ± 8.20 mg/kg, respectively) from spraying of primer containning lead oxide. In winter, Cr which was the coating for protection metal oxide formation was the second probably at Sri Racha shipping area, Laem Chabang pier and Wastewater discharge, Bangpra: (1.2 ± .13, 0.93 ± 0.32 and 0.69 ± 0.15 g/kg, respectively). Mn was found in the third amount at Fish dock and Sri Racha pier: (0.59 ±0.13 and 0.36 ± 0.01 g/kg). The higher contamination of heavy metals was found at the deep-sea port and industrial estate than the beach, aquaculture farms, communities and local fish dock. The amount metals were Pb > Hg > Cu > Cd > Ni > Zn > Cr. The highest was found at Sri Racha pier followed by Wastewater discharge, Bangpra. The former may be contaminated from the source itself. The later may be enhanced by adsorption of metals on high organic matter from wastewater. The same phenomenon was observed for Pb which was originated at Bang Lamung and accumulated at the Sanctuary of Truth. The polychaete *Nereis* sp. was the dominant species in rainy season at Wastewater discharge, Bangpra and the bivalve *Lucina* sp. was dominant species in winter and summer at Wornnapa beach and Wastewater discharge, Bangpra. Annually diversity index was highest at Sri Racha pier valued 1.0985 and lowest at Bang Lamung valued 0.35163. The relationship between marine water qualities, sediment characterization and benthic composition should be observed continuously to monitor and warning for pollution impact in marine ecosystem.

Keywords: spatial and temporal variation; seawater qualities; heavy metal accumulation; benthos; diversity index; Gulf of Thailand

1. Introduction

The northern Gulf of Thailand is situated at 5° 0′ 13″ N, 99° and 106° E; (Cheevaporn *et al*., 2003). It is a relatively narrow; the shape of the semi-enclosed gulf is similar to the first Thai alphabet “ก”; the lower tip opens to The South China Sea. The upper tip is the Bay of Bangkok the delta of four rivers from the central parts of Thailand; the Chao Phraya, Meklong, Tah-chin and Bangprakong resulting the deposition of sediments around 6.32 million ton/y and the depth of accumulation of 0.8 cm/y (Meksumpuna *et al.*, 2005). The sediment is characterized between soil, geological matters and soil water, it consists of sand, clay, organic matters, minerals leaching into water bodies, organism carcass *etc*. For ecology and environment, it is the important habitat and food supplier of benthos. Moreover, it can be used as index of environmental degeneration particularly accumulation of pollutants. This index is more reliable than water quality indices because it is the ultimate matter accumulation and the lesser varies with time than water (IAEA, 2003).

As the confluent delta area of land runoff, the anthropogenic inputs from both point- and non-point upstream pollution sources from industrial, agricultural and urbanized activities caused drastic impact to marine ecosystem (Lia *et al*. 2017). The mixing processes between water runoff and stream flow with seawater induced various chemical changes which affected biodiversity, productivities and abundance of marine organism species (Eyre and Ferguson, 2006). The complexes of biogeochemical responds were strongly influenced by the quantities and timing of freshwater discharges (Garel and Alimonte, 2017). The chemical and biochemical species could be used as basic water quality indices including BOD, nitrate, ammonium, phosphate *etc*. Beginning with organic carbon concentration, it potentially controlled physical, chemical and biological characters of water bodies including biochemical oxygen demand (BOD) resulted from oxygen consumption heterotrophic microbial activities (Kirk, 1994). BOD was a common widely parameter to indicate the quantity of oxygen consumption from the biodegradable of organic matters and nitrification of ammonia (Sullivan *et al*., 2010). It was globally reporting as organic carbon concentrations in both freshwater and seawater. Furthermore, deposition of inorganic nitrogen accumulated into water bodies caused adverse effect to aquatic ecosystem through nutrient enrichment (Bergström *et al*, 2005). It was also reported from Mishra *et al*. (2015), the parameters including pH, DO, BOD, NO_2^-, NO_3^- and PO_4^{3-} were the nutrient inputs from the point sources while total suspended solid (TSS), SiO_4^- and chlorophyll-*a* were independent in dry season. In wet season, these parameters proposed similarly with dry season except BOD, TSS and SiO_4^- resulted from runoff and sewage discharge during monsoon events.

Thus, the seawater qualities were vital in terms of marine resources usage, management and conservation, the spatial and temporal variation of seawater qualities that affect numbers and biodiversity of benthos will be determined.

2. Methods and materials

2.1 Sampling locations and sample collection

Water samples were collected along Chonburi coast line from Bansuan, Muang Chonburi to Bang Lamung district (part of the upper Gulf of Thailand; a semi-enclosed gulf) with totally about 55 kms. Each sample point was approximately located 1 km far from the seashore, the positions (coordinates) were determined using Geographical Position System GPS seen in Figure 1. Water samples were mainly collected in dry and wet seasons (2015 - 2016). Before collection, the physical parameters of seawater consisting of pH, temperature, electrical conductivity, salinity and dissolved oxygen were measured at each half depth below the sea level using YSI -60 Multimeter. The marine sediment samples were carried out by Ekman dredge sample and some samples were taken by scuba diving at a depth of sediment core between 0 – 50 cm. Some portions of sediment were divided for determination of benthos and heavy metals.

2.2 Analysis of seawater qualities

Seawater qualities were determined for biochemical, chemicals and biological parameters by methods modified from Sawyer (Sawyer, *et al*. 2003) and Standard Methods for Examination of Water and Wastewater (APHA, 2015). BOD: - wet oxidation of biological organic matter - iodometry. COD: - oxidation of organic matter with dichromate in acidic condition by open reflux and measurement of excess oxidizing agent by titration with standard ferrous ammonium sulfate using ferroin as indicator. Phosphate: - persulfate digestion and spectrophotometric determination for the blue color of potassium antimony tartrate, vanadium molybdate complex in ascorbic acid at 880 nm. TKN: - digestion for emission of ammonia and neutralization of ammonium hydroxide with standard sulfuric acid. Oil and grease: - acidified sample (pH 1) to release free fatty acid and filtered to remove oil and grease from aqueous phase and then hexane extraction by Soxhlet extractor. Sulfide: precipitation with zinc acetate in alkali solution followed by titration with sodium thiosulfate. Solid: gravimetry and characterized for total solid and total suspended solid.

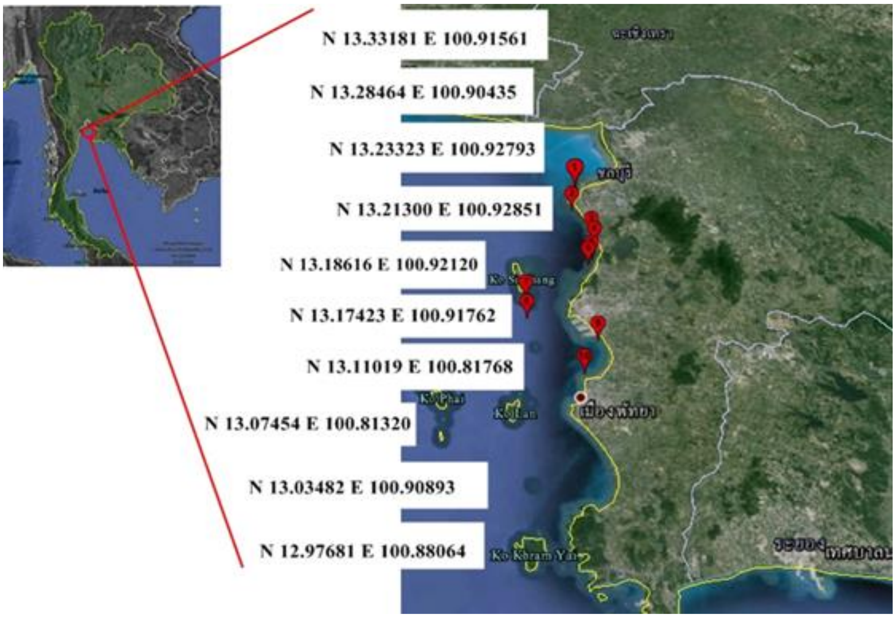

Figure 1. Sampling locations: (1) Fish dock, Chonburi, (2) Wornnapa beach, (3) Wastewater discharge, Bangpra (4) Bangpra, community, (5) Sri Racha Fishery Research Station, (6) Sri Racha pier, (7) Sri Racha Shipping area, (8) Laem Chabang pier, (9) Banglamung and (10) The Sanctuary of Truth

2.3 Analysis of heavy metals in sediment samples

After air drying, the dried sediment was ground and sieved through 2 millimeter-test sieve. Potions of sediment were determined for their texture and organic contents at the Department of Soil Science, Faculty of Agriculture, Kasetsart University. The sediment was then digested according to USEPA (USEPA, 2012). One gram of dried sediment was digested in 8 M nitric acid, 10 ml over hot plate at 92 – 95 ^{o}C for 10 min. After cooling, 5 ml of concentrated nitric acid was added with continuous heating for 30 min. Deionized water (2 ml) and hydrogen peroxide 30% (3 ml) were added, the digested sediment was then heated until the bubble was disappeared. Hydrochloric acid (6 M, 10 ml) and 2 ml of deionized water were then added and heat for 10 min, then left them cool and filtered through Whatman paper No. 42 to get rid of non-filtered part. The solution was adjusted to 100 ml with deionized water.

Concentrations of heavy metals; As, Cd, Cr, Cu, Hg, Ni, Pb and Zn were determined by the well calibrated ICP-AES (Jobin Yvon, JY 2000) with detection limit of 2.82, 0.32, 4.49, 0.002, 0.05, 0.12, 0.007 and 0.05 ppm, respectively. The precision and accuracy of measurement were determined using Spex Certiprep Standards and the recoveries of digestion were also performed (data not shown).

2.4 Characterization of benthos

Three grabs sampled by Ekman dredge were collected for benthic species composition in each station. The sediments were transferred into basin and then filtered through a 0.5 mm mesh sieve. The sieve was agitated to wash away sediments and leave organisms, detritus, sand particles and pebbles larger than 0.5 mm. The organisms were rinsed and transferred from the sieve into a plastic container and preserved with 10% formalin. The instrument used for identification was a dissecting stereomicroscope. Identificatio

3. Results and Discussion

3.1 Characterization of sampling stations

Due to the activity difference along the sampling coastline, the sampling site was started from local fish dock with muddy beach and distorted mangrove (site 1). The new road over the sea was already constructed from Chonburi Municipal Hall to Bangsaai. The various activities including local fish dock, fish market, roadside restaurant and transportation were performed. Wornnapa beach (2) was located next to Bangsaen. It was a famous sandy beach with plenty of tourism, beach activities and beach site restaurants. Bangpra community (3) was located closed to Bangpra beach with many seafood restaurant besides the sea. Bangpra wastewater discharge (4) collected water stream from upland and discharge to the sea. The water contents included rainwater runoff, agriculture and untreated municipal wastewater. Sri Racha Fishery Research Station (5) was one of the selected station because there were plenty of aqua culture farm majority in mussel. Si Racha Pier (6) was located nearby Koh Loy (the famous tourism attraction). It was also the port of local fish boat and passenger ship to Sichang Island. It was much closed to the other local fish ports, seaside community and Sri Racha market. The next station was close to Siam Seaport, the big commercial port that mainly delivered tapioca flour, coal and cement. Laem Chabang shipping pier (7) and Laem Chabang Port (8) were belonged to Port Authority of Thailand. It was important port in Chonburi. Since, it was a deep sea port, the fraction of sand and gravel were found in the seabed. Bang Lamung (9) was located at the end of wastewater discharge drainage. The Sanctuary of Truth (10) was located in North Pattaya, the most seaside tourism attraction in Chonburi.

3.2 Physical variations of seawater qualities

With the high specific heat of water (4.148 J/g), water temperature along the coast line was almost constant and slightly decrease in winter (Fig. 2), it provided potentially regulating of aquatic environment (Perlman, 2017). All parameters were measured at similarly depth (approximately 2- 6 m) except at Sri Racha Shipping area and Laem Chabang pier (up to 23 m depending on season, tidal current and naturally deep channel). Then infrared from solar radiation did not cause significantly effect to water temperature.

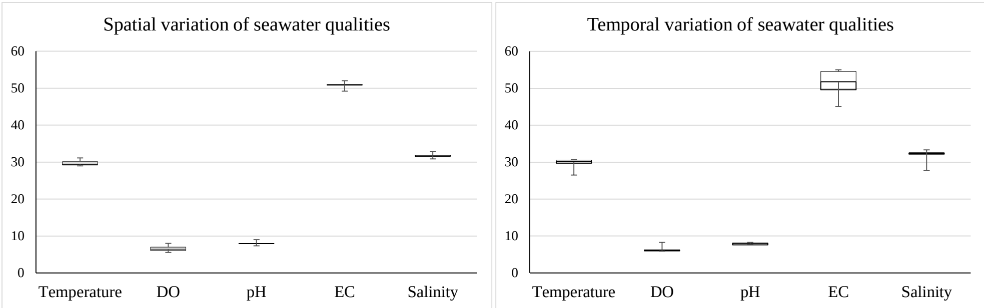

Figure 2. Spatial and temporal variations of water qualities

Note Sampling locations: (1) Fish dock, Chonburi, (2) Wornnapa beach, (3) Wastewater discharge, Bangpra (4) Bangpra, community, (5) Sri Racha Fishery Research Station, (6) Sri Racha pier, (7) Sri Racha Shipping area, (8) Laem Chabang pier, (9) Bang Lamung and (10) The Sanctuary of Truth.

Units: temperature (ºC), DO (mg/L), EC (mS/m), Salinity (PSU)

Anthropogenic activities caused seriously effect to DO rather than water temperature. However, DO was quite high, it might be because of high dissolution of atmospheric O_2 and the less water depth. The lower water temperature, the higher DO.

Although spatial variations of water pH were slightly basic (7.1 – 8.1), anthropogenic activities caused seriously effect to water pH. Lower pH was found in the community area (site 1 and 4) and higher pH was observed in the sandy beach and shipping area because of the equilibrium of carbon dioxide resulted the buffer capacity of seawater and alkali properties of the cluster ions (Ca^{2+}, Mg^{2+} and K^{+}) in sand particles and shipping materials (cement, ammonium fertilizer and so on). The lower pH was found in dry season due to high deposition of acid gases (mostly SO_2 and HCl) into the sea. Although the higher deposition of the two acid gases were observed in wet season but the highest deposition of ammonia was found (Khuntong *et al*., 2015 and 2016). The neutralization phenomena from ammonia corresponded with Marine Water Quality Standard for Natural Resource Reservation (Class I); pH 7.0 – 8.5 and DO not less than 4 mg/L (PCD, 1994).

Spatial and temporal variation of EC and salinity were almost exactly the same pattern. The lower EC and pH were found in September - October, 2016 because of dilution from high amount of rainwater (278 and 364 mm in September and October, respectively, Khuntong *et al*. 2016).).

Finally, it could not observe the spatial and temporal variations in field parameters of seawater. EC provided more variation than the others resulting from total dissolved solid in seawater.

3.3 BOD and COD of seawater

BOD and COD were the basic important parameters to indicate water qualities and anthropogenic activities. The greater variation of BOD was observed at wastewater discharge, Bangpra (3) and Laem Chabang pier (8) because of the high organic matter content in the two discharge sites as in Fig. 3. The high BOD values were generated from the cannel discharge containing high organic matter nearby the sampling sites. Almost 60% of BOD were less than 1.5 mg/L which were suitable for aquatic organisms (Songkla Lake Basin, 2016). The higher amounts of COD were observed at the discharge site and shipping areas. The former was originated from the same reason as BOD while the latter were generated from shipping materials such as tapioca flour, cement, fertiliser and so on. The temporal variation patterns of BOD and COD were similar. It could be clarified that the amounts of BOD and COD depended greatly on anthropogenic activities: community, tourism and industry.

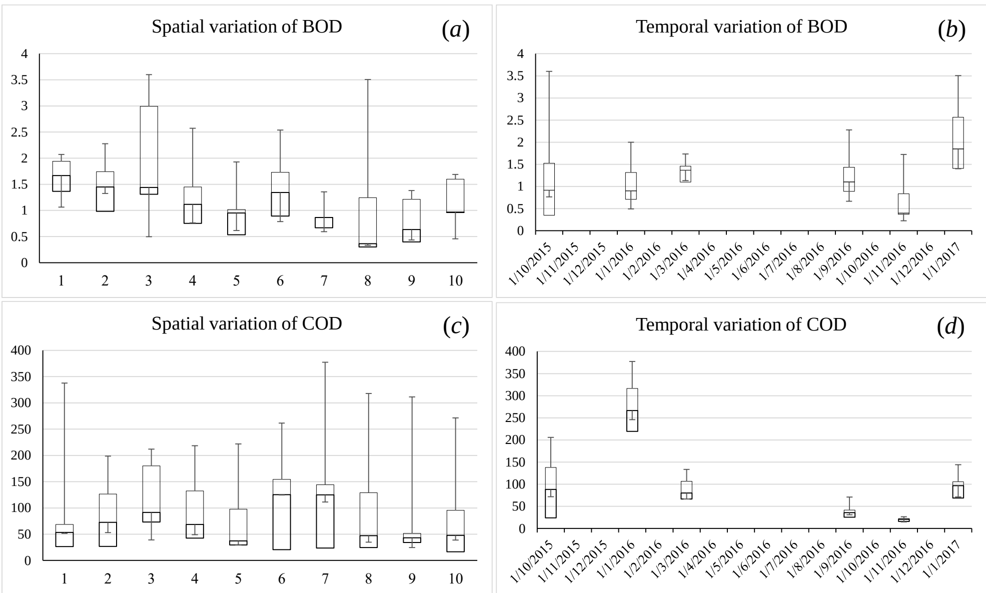

Figure 3. Spatial and temporal variations of BOD and COD in mg/L

3.4 Fat, oil and grease (FOG) in seawater

The tendency variation of FOG was slightly corresponded to BOD and COD. FOG is one of the major composition from sewage discharge. Difference from Bangpra wastewater discharge (3), the cannel discharge nearby Laem Chabang pier (8) passed through the mangrove area, the large amount of organic or inorganic compounds were found in the form of BOD and COD not for oil and grease. The difference in temporal variation indicated that FOG was not affected from season (Figure 4).

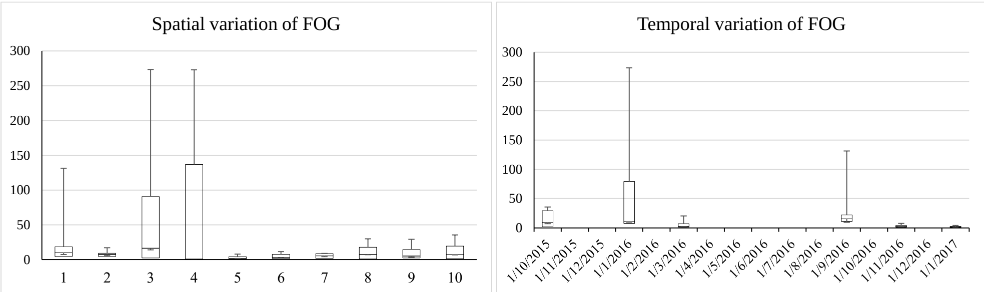

Figure 4. Spatial and temporal variations of FOG in mg/L

3.5 Transparency and total suspended solid (TSS) in seawater

Variations of TSS were corresponded with transparency for both temporal and spatial. The more transparence, the less TSS was observed. High amounts of TSS were strongly affected from the steam of wastewater discharge from Bangpra wastewater discharge (3) and Laem Chabang pier (8) which was corresponded with Mishra *et al*. (2015). TSS was also affected from high population densities and seawater activities at Bangsaen to Wornnapa beach as well as the high content of colloid particles from clay beach: Fish dock, Chonburi (1), Sri Racha Fishery Research Station (5), Bang Lamung (9) and The Sanctuary of Truth (10). The lower amounts were around the port; (6) Sri Racha pier (6) and Sri Racha Shipping area (7); because of the depth of the water channel supporting the port except at Laem Chabang pier (8). The variation of transparency and TSS were performed in Fig. 5.

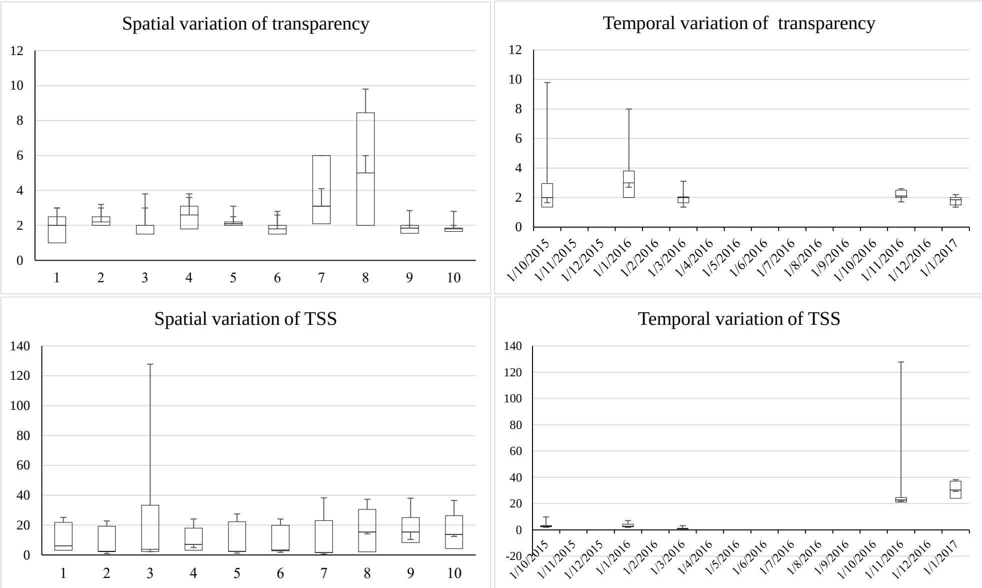

Figure 5. Spatial and temporal variations of transparency and TSS in mg/L

3.6 Nitrogen, phosphorus and sulfide in seawater

Nitrogen as ammonium and nitrate and phosphorus as phosphate played an important role in nutrient supply for phytoplankton, algae, *etc*. in seawater. Eutrophication followed by plankton bloom was the final phenomena in aquatic ecosystem. An enormous blooming of red tide from *Noctiluca scintillans* annually took place from Bangsaen beach to Ao Udom, Sri Racha. The high density of dark green symbiont of Pedinomonas noctilucae inside cell during daytime and spectacular bioluminescence during nighttime (Sirirattanachai *et al.* 1994 and Gunbua *et al*. 2015). From the annually critical phenomena, the contents of nutrient must be routinely determined. The variation of TKN and phosphorus in seawater (Fig. 6) were similar to BOD, COD, FOG and TSS as mention above. The average amounts of nitrogen and phosphorus were below PCD marine water quality standards (< 20 mg/L for nitrate and < 15 mg/L for phosphate). Occurrence of ammonium, nitrate and phosphate in seawater indicated the predominate inputs from wastewater discharge, agricultural runoff and some chemical based such as fertilizer industries.

Sulfide was not found for all sampling sites for three reasons; (1) the depth of sampling sites did not exceed 7 m with presence of dissolved oxygen (Lichtschlag *et al*. 2015). Sulfide was observed in anaerobic condition (lacking of oxygen) (2) water pH was ranged from neutral to slightly basic (7.3 – 8.1), sulfide was preferably dissociated in strong alkali condition and (3) DO increased from shallow-water wave, sulfur species might be found in oxidized form mostly sulfate.

Due to all parameters above, the seawater was classified as Class 1: Natural resource reservation from Permitted Value for Marine Water (PCD, 1994).

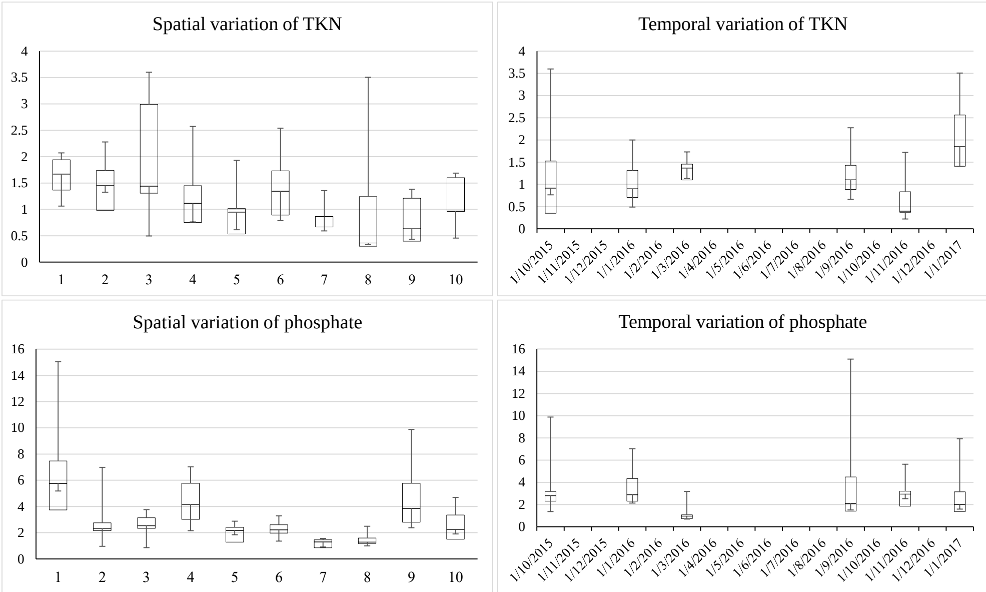

Figure 6. Spatial and temporal variations of TKN and phosphate in mg/L

3.7 Concentrations of heavy metals in marine sediment

The sand particles were major abundant particles in marine sediments (60 – 90%) followed by silt (10 – 40%), and clay particles (4 – 10%). The moderate to high organic contents (1.2 – 6.2%) were found at Fish dock, Chonburi and Sri Racha areas effecting accumulation of organic matter into the clay particles.

Heavy metals persisted in marine ecology because of their difficult degradation and easy accumulation in sediments. Besides coastal environment, sediments had been observed as carrier and sink of pollutants from agricultural and industrial emissions (Gan *et al*. 2013).

The highest amounts of Fe (4.2 ± 0.18 and 8.3 ± 0.86 g/kg) were observed in the rainy and winter season, respectively. The transportation and import/export goods containing Fe were the most important sources contaminating in marine sediment. Normally, the high concentration of metals should be found near the source *for example* the high amount of Zn (19.8 g/kg) was found near the Huludao Zinc Plant, largest zinc plants in Asia; (Zheng *et al*. 2008). Besides anti-corrosion for column of dock and jetty, Mn was used as coating agent (Parthiban *et al*. 2009). Then it was observed for the second most metal in the sediment around Laem Chabang pier (8) where the shipyard was located. Mn was sensitive for embryo of marine organisms (Columina *et al*. 1996). The third probable metal of Pb was found at the Sanctuary of Truth (10), Bang Lamung (9) and Sri Racha pier (8) with almost similar quantities (260.69 ± 8.42, 233.21 ± 7.13 and 205.74 ± 8.20 mg/kg, respectively). Spraying of primer containing lead oxide may be the source of lead, it was probably carried by wind or water stream from the shipyard area to the contaminated areas.

Chromium was the second probably metal at Sri Racha shipping area (7), Laem Chabang pier (8) and Wastewater discharge, Bangpra (3): (1.2 ± .13, 0.93 ± 0.32 and 0.69 ± 0.15 g/kg, respectively) in winter. Since chromium was also used for coating to protect metal oxide formation, component of vanish oil and primer in ship repairing processes. Mn was found in the third amount at Fish dock (1) and Sri Racha pier (6): (0.59 ±0.13 and 0.36 ± 0.01 g/kg).

In winter, the amount of individual metal was lower than in rainy season except Pb which was probably originated from shipyard and transported by southwest monsoon (seasonal rainy wind). However, the accumulation of metals in marine sediment was slightly low in rainy season due to turbulence of strong wave from rainwater.

The high amounts of heavy metals was observed around the deep-sea port and industrial estate than the beach, aquaculture farming, communities and local fish dock. The fine particle with high surface area and enormous negative exchangeable sites may cause high accumulation of metals to their surface. From Fish dock, Chonburi (1) to Sri Racha Fishery Research Station (5), the sand particle was dominated and the utilization of habitat and tourism provided low concentration of metals.

The amount metals were Pb > Hg > Cu > Cd > Ni > Zn > Cr. The highest was found at Sri Racha pier (6) followed by Wastewater discharge, Bangpra (3). The former may be contaminated from the source itself. The later may be enhanced by adsorption of metals on high organic matter from wastewater discharge with high amount of clay and silt. The same phenomenon was observed for Pb which was originated at Bang Lamung (9) and accumulated at the Sanctuary of Truth (10).

Finally, the pollution contaminated in sediment was the major source of aquatic organism health stress (Chapman and Wang, 2001). Moreover, the release of heavy metals into seawater depended on environmental conditions including pH, salinity, redox potential *etc* (Hill *et al*. 2003).

3.8 Benthos

The major components of benthic macro-invertebrates were Phylum Annelida, Arthropoda Echinodermata and Mollusca. In rainy season, macro-invertebrates were found 3 Phylums 10 Families and the polychaete *Nereis* sp. was dominant species at Wastewater discharge, Bangpra (3) with 149 ind./m^2. Diversity index was highest at The Sanctuary of Truth (10) valued 1.4681 and lowest at station Wornnapa beach (2), Sri Racha Fishery Research Station (5) and Sri Racha pier (6) with valued zero. In winter season, benthic organisms were found 4 Phylums 15 Families and the bivalves *Lucina* sp. was the dominant species with density 1,660 ind/m^2 at Wastewater discharge, Bangpra (3) followed by Bangpra, community (4) (326 ind/m^2). Diversity index was the highest at Laem Chabang pier (8) valued 2.0198 and lowest at station Bang Lamung (9) with valued zero. In summer, benthic organisms were found 3 Phylums 19 Families. *Lucina* sp. also was dominant species with density 830 ind/m^2 at Wornnapa beach (2). Diversity index was highest at Sri Racha pier (6) valued 1.6465 and lowest at Laem Chabang pier (8), Bang Lamung

(9) and The Sanctuary of Truth (10) with valued zero. The average diversity index in year round was highest at Sri Racha pier (6) valued 1.0985 and lowest at Bang Lamung (9) with valued 0.35163.

4. Conclusion

The coast line from Ampoer Muang Chonburi to Pattaya was part of the coastal areas with various anthropogenic activities covering aqua culture, tourism beaches, mangrove areas, local and deep sea ports and industrial estates. They were vulnerable and vital areas for good coastal managements. The results presented the direct anthropogenic impacts including fisheries, municipal and industrial wastewater discharges, shipping and beach activities caused the deterioration of marine ecosystem. Deposition of rainwater caused indirect impacts to some parameters such as pH, NO_3^-, salinity and TSS of seawater. Nevertheless, the nearby coastal water qualities were agreed with Permitted Value for Marine Water; Class I, Natural resources and preservation. Moreover, the sediments were contaminated with some heavy metals including Fe, Mn, Cr and Pb in the areas where the deep sea ports and industrial estates were located. Finally, benthic organisms composition varied during rainy and winter season especially the highest density of dominant species at Wastewater discharge, Bangpra that found *Nereis* sp. in rainy season and *Lucina* sp. in winter season. Marine water qualities and sediment characteristics including benthic organisms should be gather and monitor continuously to be use for environmental quality evaluation and ecological impact assessment in the future.

Acknowledgements

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Gastrointestinal Parasitic Species of Gaur (*Bos gaurus*) and Native Breed Cattle (*Bos taurus indicus*) between Transition Zones of Conservation Area in the Northeast, Thailand

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Abstract

The parasitic infections exhibit a significant factor on the population of the wildlife and it is a critical issued in the conservation of threatened species of wildlife. In this study, the potential risk of gastrointestinal parasitic prevalence and transmission between the vulnerable species of Gaur (*Bos gaurus*) and native breed cattle (*Bos taurus indicus*) in the transition zone between the Khao Pha Ma Non-hunting Area, Northeast of Thailand were determined. Fresh fecal samples were collected from both species and examined by carpological examinations. Total 34 fresh fecal samples from gaur and 9 fresh fecal samples from domestic cattle were examined. It was found 3 gastrointestinal parasitic species including 2 species of nematode and one species of trematodes. The overall results of gastrointestinal parasitic prevalence rates of strongylus, strongyloides and paramphistomum were 46.51%, 13.95%, and 4.65%, respectively and total gastrointestinal parasitic prevalence rate was 51.16%. The average parasitic egg per gram of feces was 110 (range: 50-550) eggs/gram. Single gastrointestinal parasitic infection rate was 72.72% and eggs/gram rate was 76 (range: 50-200), and multiple gastrointestinal parasitic infection rate was 27.27% and eggs/gram rate was 203 (range: 50-550). The study showed that the prevalence rate of gastrointestinal parasitic infection was higher at gaur due to lack of deworming and nutrition but more gastrointestinal parasitic species found in domestic native cattle due to ineffective management of cattle production system. Following activities will be recommend to control gastrointestinal parasitic infection in gaur: artificial salt lick with nutrient supplement, management of grassland, and barrier between forest and agricultural area.

Keywords: gaur; gastrointestinal parasite; strongylus; strongyloides; paramphistomum

1. Introduction

Animal health is an important issue for livestock production and wildlife conservation. Many diseases effect on population, production, and transmission between each group. Understanding the conditions between wildlife conservation and livestock production are needed to know both sides of the groups and their activities, behavior and ecology system. The transmission of diseases between wild and domestic livestock may occur in many ways and these ways are depended on the distance of both group and temporal elements (Bengis et al., 2002). The parasitic infections exhibit a significant factor on the population of wildlife (Watson, 2013) and it is a critical issued in conservation of threatened species of wildlife (Thompson et al., 2010).

Gastrointestinal parasites have been associated with the host condition in livestock (Gorsich et al., 2014) and wildlife (Stien et al., 2002; Gorsich et al., 2014). They were ubiquitous (Rose et al.,2014), taxonomically diverse, and caused mortality or reduced performance of livestock production, (Larsson et al., 2006; Larsson et al., 2011; Thumbi et al., 2014; Rose et al., 2015) and wildlife system (Pedersen & Greives, 2008; Gorsich et al., 2014). Gastrointestinal parasites effected on their host not only directly but also indirectly and host behavior (Gorsich et al., 2014). Parasitic infection in wildlife caused the potential to impede conversation efforts by restricting the range of species and threatening the persistence of species of conservation concern (Page, 2013; Rose et al., 2014).

In Thailand, gastrointestinal parasitic infection is one of the major constraints to ruminant livestock production and insidiously productivity losses decreased feed intake and low efficiency in feed utilization. This condition is associated with subclinical or chronic condition of parasitic infection and it leads to large economic losses of livestock production (Jittapalapong et al., 2011) and parasitism is a primary cause of production losses in most cattle production in the world including in Thailand (Kaewthamasorn & Wongsamee, 2006).

Gaur is the largest wild cattle and it is the tallest living oxen. Gaur is under the red list of threatened species categorizes as a vulnerable species and are found in 11 range countries. Gaur population in Thailand is estimated approximately 920 at 1994 in protected area and populations in other countries are declining. In Thailand, population of gaur is increasing yearly in some area (Duckworth et al., 2016; Ashokkumar et al., 2012). Bhumpakphan (1997) studied that livestock area is raising and it can be found in many protected area of Thailand. Domestic cattle and buffalo share and occupy feeding ground, salt lick, water sources and living space with gaur and other large herbivores.

Khao Yai National Park was established as the first national park of Thailand in 1962 and national park covers a total area of 2,165.55 km^2 in the four provinces of Nakhon Nayok, Prachin Buri, Nakhon Ratchasima and Saraburi. Consisting of large forested areas, scenic beauty and biological diversity, Khao Yai National Park, together with other protected areas within the Dong Phaya Yen mountain range, are listed as a UNESCO World Heritage Site. Khao Yai was a great diversity of flora and fauna and Khao Pha Ma Non-hunting Area was located southeast part of the Khao Yai National park. Before 1965, Khao Pha Ma Non-hunting Area was legal to cut the forest for agriculture area and around 1989-1990, wildlife fund Thailand was implemented a project for forest and wildlife conservation (Biatayabha, 2001). The total area of Khao Pha Ma Non-hunting Area was 8 km^2. Now, Khao Pha Ma Non-hunting Area was a successful area for wildlife conservation and the population gaur was increased yearly (Biatayabha, 2001; Bhumpakphan, 1997).

Khao Pha Ma Non-Hunting Area and Wang Nam Khiao district were located in Nakhon Ratchasima province, northeastern part of Thailand. Guar population in Khao Pha Ma Non-hunting Area was around 150 individuals. During October to December 1995, at least six gaur emigrated from Khao Yai Nation Park to Khao Pha Ma Non-Hunting Area. The population was increased year by year due to immigration and reproduction (Biatayabha, 2001).

2. Materials and Methods

2.1 Sampling location

The 34 fresh fecal samples were collected from gaur at Khao Pha Ma Non-hunting Area and divided into two groups. Groups 1 was adapted at Central of Khao Pha Ma Non-hunting Area and group 2 was adapted at border of Khao Pha Ma Non-hunting Area and Wang Nam Khiao district. 20 fresh fecal samples from group1 and 14 fresh fecal samples from group 2 during December, 2016. Total 9 fresh fecal samples were collected from native breed cattle at Wang Nam Khiao district at the same time. All the cattle were native breed and free range grazing system. All the fresh fecal samples were collected from the pasture of cattle and gaur.

2.2 Fecal examination

All the fresh fecal samples were obtained from the pasture and put with plastic bags, labeled, packed and dispatched in a cool box and send to biological laboratory at the Faculty of Environment and Resourced Studies, Mahidol University, Thailand. All samples were stored at 4°C until examined in the laboratory. The gastrointestinal parasitic examination was evaluated by using simple flotation method with normal saline solution to identify nematodes and cestodes eggs, and simple sedimentation method with methylene blue dye to isolate trematode eggs. Identification of parasitic eggs were depended on morphology, size, color, shape and structure (Theinpont et al., 1986).

2.3 McMaster method

The McMaster method was used for counting gastrointestinal parasitic eggs in fecal samples. This method is determining the number of nematode eggs per gram of feces in the sample and to estimate the parasitic infection burden in host animal of the samples. All positive nematode samples were used McMaster method to count nematode parasitic eggs per gram of feces. The result of gastrointestinal nematode parasitic count was calculated by the number of parasitic egg in two chambers of

McMaster slide multiplied by 50. McMaster method can be classified the level of gastrointestinal nematode parasitic infection according to result of eggs per gram of feces, in young cattle such as light infection (50-200 eggs/gram), medium infection (200-800 eggs/gram), and heavy infection (< 800 eggs/gram) (Hansen & Perry, 1994).

2.4 Data analysis

A sample was founded at least one gastrointestinal parasitic egg, it was also identified as a positive sample and overall prevalence rate of gastrointestinal rate was calculated and express as percentage by using following equation: (prevalence rate = number of positive sample / number of sample) × 100. Statistical analyses were conducted using one way ANOVA Descriptive test with SPSS 18 software to determine whether the different gastrointestinal parasitic prevalence rate among groups of gaur and native breed cattle was statistically significant and significant at the level $p < 0.05$.

3. Results and Discussion

3.1 Fecal examination

Out of the 43 fecal samples, 22 samples were positive at least one of the gastrointestinal parasitic infections and overall prevalence rate of gastrointestinal gastro intestinal parasitic infection rate was 51.16% (22/43). The result of gastrointestinal parasitic egg in all group of sample, nematodes infection was the highest prevalence rate 51.16% (22/43) and trematodes infection rate was 4.65% (2/43).

The following gastrointestinal parasitic eggs were identified according to morphology, shape, size, and color of parasitic egg as follow strongylus 46.51% (20/43), strongyloides 13.95% (6/43), and Paramphistomum 4.65% (2/43). According to present study indicated that the overall prevalence gastrointestinal parasitic infection was 51.16% and this result was similarly with a previous study of Thailand which had average gastrointestinal parasitic infection rate at 46.59% (Jittapalapong et al., 2011). The almost gastrointestinal parasite of cattle is not only in the worldwide but also in Thailand which was strongylus spp. This study result showed strongylus was the dominant parasitic infection both in gaur and native breed cattle (Figure 1).

Figure 1. Strongylus in gaur at Khao Pha Ma Non-hunting Area (left), Strongyloides in gaur at Khao Pha Ma Non-hunting Area (middle), and paraphistomum in native breed cattle at Wang Nan Khiao district (right) with 40X lens

The prevalence gastrointestinal parasitic infection between groups were gaur in the central Khao Pha Ma (50%), guar in the border between Khao Pha Ma Non-hunting Area and Wan Nan khiao district was 57.14% and cattle in the Wan Nan Khiao district was 44.44% (Figure 2). The prevalence between groups was not significant difference but the highest gastrointestinal parasitic infection prevalence rate was gaur in the border between Khao Pha Ma Non-Hunting Area and Wang Nan khiao district.

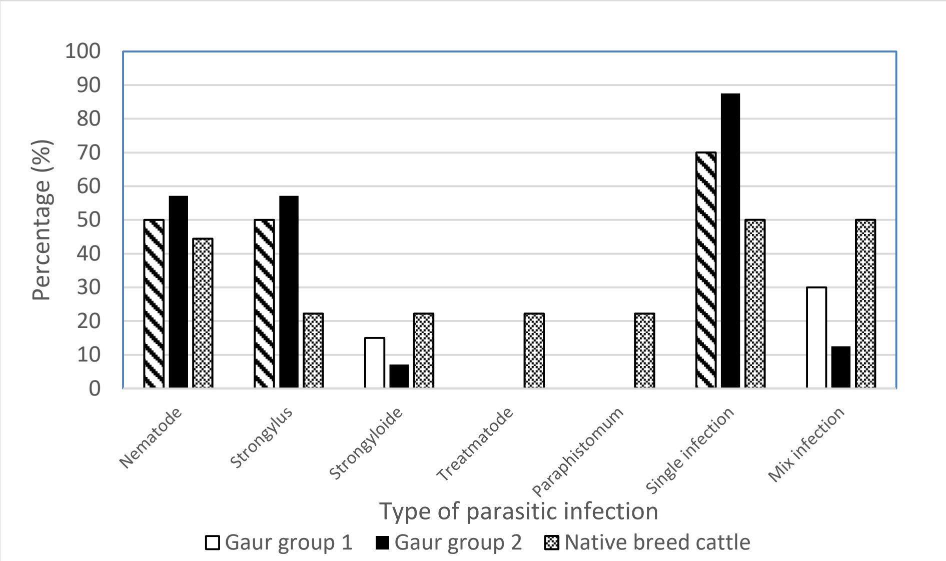

Figure 2. Prevalence rate of gastrointestinal parasitic infection in gaur and native breed cattle

Native breed cattle were got some nutrient supplements and deworming programs than gaur in the Khao Pha Ma Non-Hunting Area. Native breed cattle had lowest prevalence gastrointestinal parasitic infection rate than other two groups of gaur at Khao Pha Ma Non-Hunting Area. The parasitic infections might be increase sharing the same grazing pasture and the poor sanitation of the animal condition. Therefore, pasture management and good sanitation for gaur and domestic cattle were important factors to control gastrointestinal parasitic infections in both groups.

The result of fecal examination showed 90.9% of the positive samples were infected by strongylus parasite, 27.27% were strongyloides infection, and 9.09% was paramphistomum infection. Strongylus was dominant gastrointestinal parasitic in both gaur and native cattle in this area. All the mix gastrointestinal parasitic infections were strongylus mix with other gastrointestinal parasitic infections such as strongyloides and paramphistomum.

All positive samples from gaur were infected by strongylus parasitic infection and follow by strongyloides parasitic infection. The prevalence rate of strongylus parasitic infection were 50%, 57.14%, and 22.22% of gaur in the center of Khao Pha Ma Non-Hunting Area, gaur at border of Khao Pha Ma Non-Hunting Area and native breed cattle at Wang Nan Khiao district (Table 1). The result of previous studies in

Thailand, the prevalence rate of strongylus parasitic infection in cattle were 71.32% at Udonthani Province (Chuenpreeca et al., 2014), 27% at Nan province (Kaewthamasorn & Wongsamee, 2006), 76.97% at Maharsalakhan province (Aunpromma et al., 2006), and 63.56% at Kalasin province (Aunpromma and Papirom, 2005). This study showed the strongyl infection rate was within the range of previous studies (76.97%- 27%).

Treatmetode egg was not found in both of gaur fecal samples and there were only 2 positive samples (22.22%) from native breed cattle fecal samples. According to morphology of parasitic eggs by fecal sedimentation test, all the parasitic eggs were paramphistomum (rumen fluke). The prevalence rate of rumen fluke in native breed cattle was 22.22%. It was very similar to previous studies in Thailand which overall prevalence rate of rumen fluke was 28.41% (Jittapalapong et al., 2011).

The gastrointestinal parasitic infections were found two types, single gastrointestinal parasitic infection (70%) of total positive fecal sample and multiple gastrointestinal parasitic infections (30%) of total positive sample. All multiple gastrointestinal parasitic infections were infected by strongylus and other gastrointestinal parasite, strongyloides or paraphistomum. Gastrointestinal strongylus parasitic infection was main gastrointestinal parasitic infection at the studied area and over 90% of the positive samples were infected by strongylus parasitic infection.

3.2 McMaster method

The parasitic egg per gram of feces was useful method for to determine the level of parasitic infection of the host. The result of egg per gram in this study was highest 555 eggs per gram rate and most of the egg per gram was 50. In single gastrointestinal parasitic infection, the egg per gram rate was 76 (range: 50-200) and multiple gastrointestinal parasitic infection, the egg per gram rate was 203 (range: 50-550) (Table 1).

Table 1. The parasitic eggs per gram of feces result of positive sample in gaur and domestic breed cattle.

Group	Single infection		Multiple infection	
	Number	Eggs per gram (range)	Number	Eggs per gram (range)
Gaur group 1	7	71 (50-150)	3	333 (200-550)
Gaur group 2	7	107 (50-150)	1	200 (200)
Native breed cattle	2	50 (50)	2	75 (50-100)
Average total	16	76 (50-150)	6	203 (50-550)

According to eggs per gram results, multiple infections samples had more gastrointestinal parasitic infection burden than single infection samples. Eggs per gram result were showed high parasitic egg count in multiple infection samples at 203 eggs/gram (range: 50-550) and single infection samples was 76 eggs/gram (range: 50-150) (Table 2). Gaur with single and multiple parasitic infections had more average eggs per gram than native breed cattle in this study because they lack of deworming program and nutrient supply.

The gaur with multiple gastrointestinal parasitic infections, the eggs per gram rate was over 200 eggs/gram. Therefore, all multiple infection gaur had moderate gastrointestinal parasitic infection. The gaur with single gastrointestinal parasitic infection, eggs per gram was 50–150 eggs/gram and they had light parasitic infection. All native breed cattle, eggs per gram was 50-100 eggs/gram and they had light parasitic infection both single and multiple parasitic infection condition. We can be concluded that multiple infection gaurs had more burden of parasitic infection than single infection. Gaur and multiple infection hosts were get more serious effects than single infection host. But native breed cattle, single and multiple parasitic infection were not significant different on eggs per gram. In gaur, more parasitic species caused high level of parasitic infection to host. Host will be got serious parasitic infection in the future.

3.3 The prevalence rate of gastrointestinal parasitic infections between gaur and native breed cattle

The prevalence rate of gastrointestinal parasitic infections of each group of samples, the result of the test was as follow in Table 2.

Table 2. Statistical analysis of gastrointestinal parasitic infection rate between gaur groups and native breed cattles

Parasitic	Group	Number	Mean ± SE
Strongylus	Gaur group 1[a]	20	0.50 ± 0.12
	Gaur group 2[b]	14	0.57 ± 0.14
	Native breed cattle [c]	9	0.22 ± 0.15
	Total	43	0.47 ± 0.06
Strongyloides	Gaur group 1[a]	20	0.15 ± 0.08
	Gaur group 2[b]	14	0.07 ± 0.07
	Native breed cattle[c]	9	0.22 ± 0.15
	Total	43	0.14 ± 0.05
paramphistomum	Gaur group 1[a]	20	0
	Gaur group 2[b]	14	0
	Native breed cattle[c]	9	0.22 ± 0.15*
	Total	43	0.05 ± 0.05

a) Gaur at central Khao Pha Ma Non-Hunting Area
b) Gaur at border of Khao Pha Ma Non-Hunting Area and Wang Nan Khiao district
c) Native breed cattle at Wan Nan Khiao district
d) * $p < 0.05$

The result showed paramphistomum was significant different between gaur groups and native breed cattle group ($F = 4.52$, $df = 2$, $p < 0.05$) but other two parasitic infections, strongylus and strongyloides, were not significant difference ($p > 0.05$). The significant parasitic infection was threated to other groups and this parasitic infection had potential transmission to another group.

Parasitic and its associated diseases can cause high negative impacts on wildlife population. There are many example of parasitic and diseases were caused major thread to population of wildlife endangered species but the correlation between the prevalence rate of pathogen and population of specie does not establish causality. Gastrointestinal parasites were affected on to their host (Gorsich et al., 2014) and multiple infection hosts were gotting more serious effects than the single infection host. Parasitic infection in wildlife caused threatening the persistence of species of conservation concern (Page, 2013; Rose et al., 2014) as well as in livestock production. It leads to large economic losses of livestock production (Jittapalapong et al., 2011) and parasitism is a primary cause of production losses in most cattle production in the world including in Thailand (Kaewthamasorn & Wongsamee, 2006).

The present study showed the prevalence rate of gastrointestinal parasitic infection was not significant difference between the groups but the species of gastrointestinal parasites were different between gaur and native breed cattle. Native breed cattle in Wang Nan Khiao District had more parasitic species than gaur in Khao Pha Ma Non-hunting Area. Parasitic infections can also be transmitted by contaminated food and water. Ineffective management of cattle production caused high prevalence gastrointestinal parasitic infection rate.

4. Conclusion

Gaur was settled in secondary forest area and agricultural areas than primary forest because there was enough biomass of food plants for them than in the former place (Prayong & Srikosamatara, 2017; Conry, 1989). Khao Pha Ma Non-Hunting Area was suitable place for migration gaur from Khao Yai National Park and it was a natural resource value of ecotourism for this area. To maintain and increase gaur population is an important factor for gaur conservation at transition zone between primary forest and agriculture area. This study showed that the gastrointestinal parasitic infection was light to moderate threat to gaur. New gastrointestinal parasitic from native breed cattle will have a chance to transmit to gaur because each groups of animal is closed each other. Following activities will be recommend to control gastrointestinal parasitic infection in gaur: artificial salt lick with nutrient supplement, management of grassland, and barrier at forest and agricultural area.

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A Hybrid Input-Output Model for Analyzing: Agricultural Wastewater in Thailand

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Abstract

Thailand is considered one of the world's top agricultural countries since the land and the climate are suitable for agriculture. Agricultural activities including cultivation, livestock farming and fisheries require water as a main resource. The water used in agriculture causes large amounts of wastewater which is contaminated by cultivated fertilizer and farm waste. The wastewater has various impacts on environment; for instance, worsening water quality, reducing soil fertility as well as being harmful to users' and consumers' health. Using the study of Thailand's agricultural economy in 2010, we present a model for factors of production and hybrid production of the volume of agricultural wastewater in Thailand. This study aims to determine the volume of wastewater and the cost of wastewater occurring in the economic system in an agricultural sector. The table illustrating factors of production and hybrid production is the instrument which connects and explains the dimension of relationship between economy and environment. The result indicates that in one baht Gross Domestic Product (GDP), rice cultivation releases the highest wastewater volumes owing to the fact that rice plantation uses large amounts of water and fertilizers. Another reason is that rice is the major crop in Thailand and thus grown in significant quantity.

Keywords: hybrid input-output table; agricultural wastewater; Thailand

1. Introduction

Thailand is considered the country of agriculture comprising several types of geography with rich and abundant resources. Out of 512 billion sq.m. in Thailand, 208 billion sq.m. is used as the cultivation area. This demonstrates that Thailand has a stable agricultural foundation. Forty-two percent of Thai population works in agricultural sector. Therefore, agriculture in Thailand is the important activity. Agricultural activities include cultivation, livestock farming and fisheries. Thus, water is an indispensable resource. The more agricultural activities occur, the more water is used. Consequently, the more wastewater from agriculture is released. This agricultural wastewater can affect environment. For instance, it deteriorates soil quality and decreases soil fertility. The use of fertilizers and chemicals in cultivation may remain in plants and environment. Accordingly, can be harmful to both users' and consumers' health. A good wastewater management can contribute to the more effectiveness and efficiency of agriculture in Thailand. As a result of, it plausibly leads to the development of sustainable and environmentally friendly agriculture.

2. Methods and materials

2.1 Area of Study

This study focuses on water use in agricultural activities in Thailand. The total area of Thailand is 513,115 sq.km. Forty-six percent of which are agricultural areas. We used wastewater data from 2010-2016 obtained from the Pollution Control Department, data on production areas, produces, and prices of different agricultural activities from the Department of Agriculture and Cooperatives, Input-Output table data from the Office of the National Economic and Social Development Board, and livestock data from the Department of Livestock Development

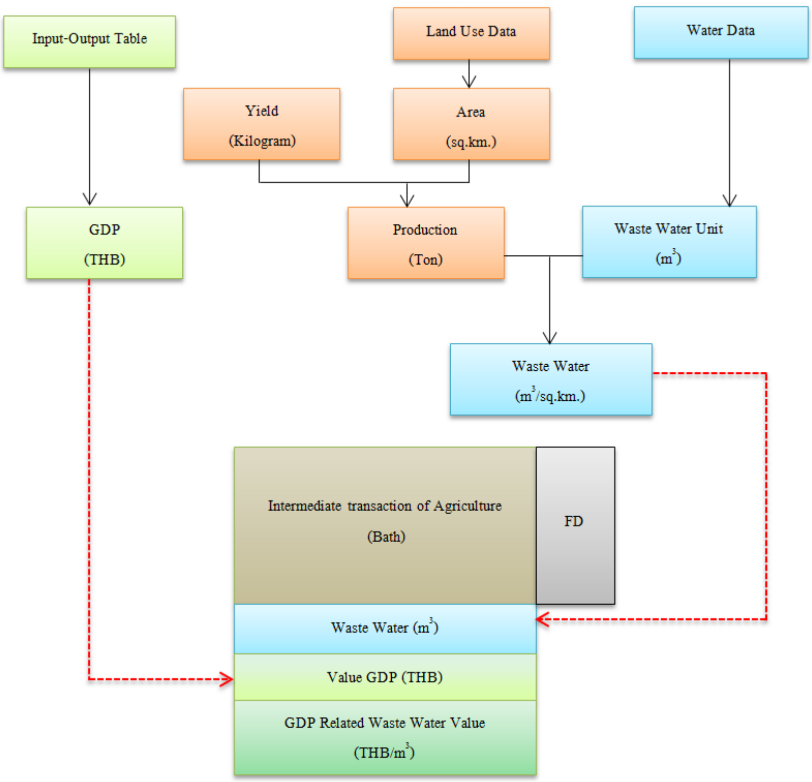


Figure1. Schematic diagram

2.2 Method of Study

Data from Input-Output activities of Office of the National Economic and Social Development Board, consist of 180 activities from three main sectors: 1) agricultural sector, 2) industrial sector, and 3) service sector. We selected only agricultural sector which consists of 29 activities and assigned numbers 1-29 to each activity. The agriculture sector data are divided into three categories: 1) agriculture, 2) livestock, and 3) fishery. The details are displayed on the following flowchart (Figure 1).

Agriculture

1. Gather and prepare the following data:

   - Wastewater – from the Pollution Control Department, The table below shows examples of waste water by types of crops.

Type of Crops	Waste Water Value(cu.m./sq.km.)
Rice (In-season rice field)	512,500
Rice (Double-crop field)	305,000

Source : The Pollution Control Department (2016)

   - Area, product, and yield – from the Office of Agricultural Information, Office of Agricultural Economics, Ministry of Agriculture and Cooperatives

2. Use the data to calculate waste water in the following equation.

Waste Water (cu.m./sq.km.) = Waste water value x Area

Livestock

1. Gather and prepare the data:

   - Animals' waste water – from the Department of Livestock Development; in case of unavailable data, waste water for similar animals are used instead as shown in the following table

Type	Waste Water Value (cu.m./animal)
Pig	0.02
Chicken	0.002
Cow	0.5

Source: Deparment of Livestock Development (2016)

- Number of animals and products – from the Office of Agricultural Information, Office of Agricultural Economics, Ministry of Agriculture and Cooperatives

2. Use the data to calculate waste water in the following equation.

Waste Water of Livestock (cu.m./animal) = Animal's Waste Water x Number of Animals

Fishery

1.Gather and prepare the following data:

- Products – from the Office of Agricultural Information, Office of Agricultural Economics, Ministry of Agriculture and Cooperatives
- Animals' waste water – from the Department of Fishery; Use the data to calculate waste water in the following equation.

Waste Water of Fishery (cu.m./animal) = Animal's Waste Water x Area of Fishery

Creation of Hybrid Input-Output Table in Agriculture

The original input-output form is used as the base to develop water demand input-output model for agriculture using the following formula:

$$X = AX + Y \tag{1}$$

where X is the vector of output, A is the matrix of input coefficient, and Y is the vector of final demand for products the equation (1) can be written in standard matrix as follows:

$$X = (I - A)^{-1}Y \tag{2}$$

Equation (2) shows the relationship between the value of final demand and the value of total demand produced by the economy system to support the scale of final demand where I is the identity matrix and $(I – A)^{-1}$ is the sum of scale of value of y and value of production factor in y production used in the production process.

The equation above when applied to water demand will result in the equation below.

$$W = wX(I - A)^{-1}Y \tag{3}$$

where w is the unit of water used per export in m^3/monetary unit (baht)

Data from i-o table by Office of the National Economic and Social Development Board are sorted in input-output table format. Then, the calculated data on water in agriculture are sorted into their respective 29 activities. In certain activities where no water is required in production, the set value is 0.

The cost of wastewater in the agricultural sector

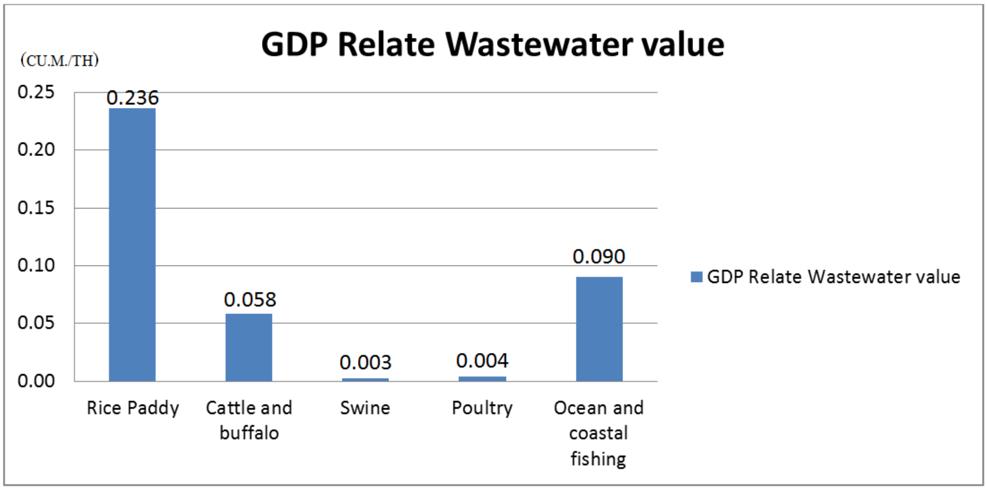
The cost of wastewater in the agricultural sector is calculated by finding the volume in cubic meters of wastewater per one baht. The equation is as follows:

$$\text{GDP Related Waste Water Value} = \frac{\text{The volume of wastewater}}{\text{GDP in each agricultural activity}} \tag{4}$$

3. Results and discussion

		Intermediate Transaction (Thousand THB฿)									
		Rice Paddy	Cattle and buffalo	Swine	Poultry	Ocean and coastal fishing	The Rest of AGR	MANF	SER	Final Demand	Total Output
Intermediate Transaction (Thousand THB฿)	Paddy	15,866,307	2,609,263	0	847,836	0	3,325,720	378,822,271	569,922	-35,949,113	366,092,206
	Cattle and buffalo	0	298,525	0	0	0	0	40,703,739	0	-4,732,879	36,269,385
	Swine	0	0	10,360,268	0	0	0	64,272,133	887	-3,933,253	70,700,035
	Poultry	0	0	0	8,339,174	0	344,777	88,026,930	313,877	11,595,391	108,620,149
	Ocean and coastal fishing	0	0	393	1,519,564	4,486,123	5,547,565	89,735,779	22,992,519	-16,762,334	107,519,609
	The Rest of AGR	9,524,007	88,480	2,297,375	2,616,688	28,053	99,439,382	534,106,800	143,757,396	306,299,581	1,098,157,762
	MANF	75,474,250	5,090,522	33,111,534	48,227,151	49,077,264	234,145,249	8,581,619,752	2,888,248,574	2,400,013,345	14,315,007,641
	SER	9,343,739	1,094,632	3,023,220	4,131,489	3,080,726	41,943,003	950,716,643	1,970,596,999	8,428,396,097	11,412,326,548
Value Added		255,883,903	27,087,963	21,907,245	42,938,247	50,847,443	713,412,066	3,587,003,594	6,385,846,374		
Total Input		366,092,206	36,269,385	70,700,035	108,620,149	107,519,609	1,098,157,762	14,315,007,641	11,412,326,548		
Waste Water		60,379,504,000	1577895000	55655200	181243670	4581354099					
GDP Related Waste Water Value		0.23596445	0.058250781	0.002540493	0.004221031	0.09009999					

It is found that the activity which releases the highest amount of wastewater is rice plantation. It accounts for 90% of all wastewater in the agricultural sector, in the view of the fact that rice cultivation needs high volumes of water. Furthermore, rice is the country's major crop of economic significance for both domestic consumption and export. Consequently, the farmers grow large quantities of rice. When the cost of wastewater, which represents the amount of wastewater released from each agricultural activity in one baht GDP, was calculated, the analysis indicates that rice cultivation is the activity which releases the highest amounts of wastewater. In one baht GDP, the volume of wastewater released from rice farming is equal to 236 cu.m.. For the reason that this activity needs high volumes of water and uses large amounts of fertilizers and chemicals. Not to mention a great deal of planting areas distributed throughout the region, it is nearly one third of country's total area. Accordingly, rice plantation is responsible for the highest amounts and costs of wastewater among the agricultural activities.



4. Conclusion

By implementing the model for factors of production and hybrid production of agricultural wastewater, one can indicate the relationship between the unit of money and the unit of water. The model is an instrument which enhances the understanding of relationship between the agricultural sector and wastewater in each related activity for both public and private institutions. The instrument can be used for analyzing environmental effects from wastewater which will benefit decision making and policy planning.

5. Recommendation

This study only studies the agricultural sector. The use of input-output table is capable of observing the relationship between a set of data and another. Therefore, other research can apply this table to other production sectors.

The future study should consider the water resources management measures for sustainable development such as real option and option game by using this hybrid IO table (Suttinon et.al., 2012, 2014).

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Distribution of Mercury in Water, Suspended Solid and Sediment in Chao-Phraya River Mouth Area

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Abstract

Mercury contamination in the Gulf of Thailand (GOT) has been monitored regularly by the Pollution Control Department of Thailand and the results have been published in the annual monitoring reports. Based on the reported data since 1999 until present, the total mercury level in the GOT never exceed Thailand's seawater quality standard. However, there were reports of episodic mercury contamination in certain locations that exceed the established environmental quality standard. In this study, water, suspended and bottom sediment samples from 25 sampling stations located in the delta of Chao Phraya River were collected twice during the high discharge period (January) and low discharge period (July) in 2016. The samples were analyzed for concentrations of mercury in water, suspended solid and sediment, and related water quality parameters. The results from this study indicated that in water samples, total mercury and dissolved mercury concentrations were almost at the same level, although much higher concentrations of mercury were found in the suspended solid, because water samples had relatively low suspended solid concentrations. Higher fraction of HgS (less bioavailable fraction) was found in the suspended solid in comparison to the sediment. Moreover, the results also indicated that although the average concentration of mercury was higher during the low flow period, the estimated total flux of mercury during the high and low flow periods were in the same order of magnitude.

Keywords: discharge; heavy metal; monitoring; pollution

1. Introduction

Mercury is one of the most toxic pollutants in the coastal environment. Mercury is released to the coastal environment due to human activities such as the used mercury in industrial and agricultural sectors. High mercury concentrations affect living organisms and human health due to accumulation of mercury in marine food chain. After being discharged into the coastal environment, mercury are deposited into bottom sediments (Thongra-ar et al., 2008).

The inner Gulf of Thailand has a coastline of 195 km from Phetchaburi province in the west to Chonburi province in the east. Four major rivers, namely Mae Klong, Tha Chin, Chao Phraya and Bang Pakong, discharge into the Gulf of Thailand. The water quality deterioration in the Gulf of Thailand in partly due to wastes from the rivers and the industries located along the coast (Menasveta, 1998; Thongra-ar et al., 2002).

In the Gulf of Thailand, mercury contamination has been monitored and published regularly in the annual monitoring reports by the Pollution Control Department of Thailand. Based on the reported data since 1999 until present, the overall situation of mercury concentrations in seawater is still within a safe level. However, mercury contamination in certain locations exceed the established environmental quality standard (PCD, 2000, 2006).

This study was carried out in order to investigate distributions of mercury and mercury sulfide in water, suspended solid and sediment from 25 sampling stations located in the delta of Chao Phraya River twice during the high and low discharge periods.

2. Materials and Methods

2.1 Sample Collection

Water, suspended solid and sediment samples were collected from 25 stations along the delta of Chao Phraya River, as shown in Fig. 1. The sampling stations were divided into 5 zones based on radius between Chao Phraya River Mouth and the Gulf of Thailand. Coordinates of each sampling station were recorded by Global Positioning System (GPS) to be a reference position for future sample collection.

At each station, water, suspended solid and sediment samples were collected during low tide in the high discharge period (January 2016) and the low discharge period (July 2016). A total 50 liters of water samples were collected at 30 cm below the surface of water using Kemmerer water sampler. Suspended solid samples were isolated from water samples collected by filtration. Approximately 500 grams of sediment samples were collected using sediment core sampler.

Mercury in water samples without filtration was reported as total mercury in water, while mercury in filtrate was reported as dissolved mercury in water. Mercury in suspended solid samples which were isolated from the water samples was reported as mercury in suspended solid, while mercury in sediment samples was reported as mercury in sediment.

Figure 1. Sampling point of water, suspended solid and sediment samples in Chao Phraya River Mouth

2.2 Water, Suspended Solid and Sediment Analysis

Mercury concentrations were determined by digestion method (USEPA). 1 g of each water, suspended solid and sediment sample was digested in 3 mL of 65% nitric acid, 0.8 mL of 37% hydrochloric acid and 1 mL of 40% hydrofluoric acid in 100 mL of TFM-Teflon microwave vessel on microwave (Anton Paar Multiwave 3000) during 26 minutes. The samples were filtered through 0.2 µm filter paper and analyzed for mercury concentration.

The related water quality parameters such as pH, suspended solid and dissolved organic carbon were analyzed. Analyses of water samples were performed as per standard methods of the examination of water and wastewater (APHA et al., 2005). The pH was measured by a pH meter. The dissolved organic carbon was analyzed by total organic carbon (TOC) analyzer. The mercury concentrations were analyzed by inductively coupled plasma - optical emission spectrometer (ICP-OES) and high performance liquid chromatography (HPLC).

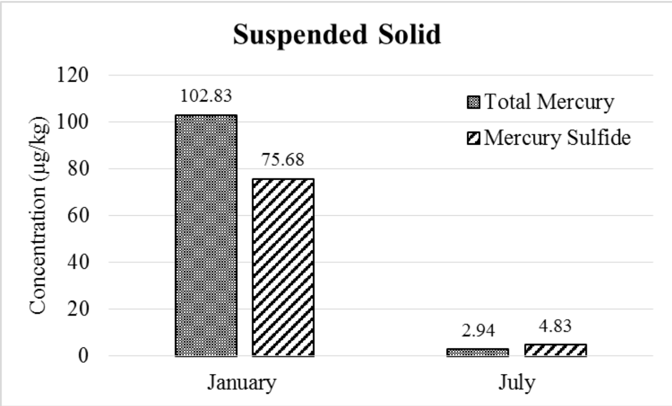
3. Results and Discussion

In high discharge period (January) in 2016, total mercury and dissolved mercury concentrations in water samples were almost at the same level, which ranged from 0.010 to 0.193 µg/L with average of 0.036 µg/L (coastal water mercury standard of 0.1 µg/L). On the other hand, much higher concentrations of mercury were found in suspended solid, which ranged from 13.48 to 293.00 µg/kg with average of 102.83 µg/kg. However, concentrations of suspended solid in water samples were relatively low, which ranged from 0.168 to 0.906 mg/L with average of 0.45 mg/L. As a result, the concentrations of total mercury in water samples without filtration were slightly different from the concentrations of dissolved mercury in filtrate.

The amounts of mercury in sediment ranged from 0.2 to 79.8 µg/kg with average of 29.1 µg/kg. The amounts of mercury in sediment were higher than total mercury in water samples. The results indicated that some mercury in sediment may be accumulated by suspended solid, which could be deposited into bottom of Chao Phraya River Mouth.

The amount of mercury sulfide in suspended solid ranged from 9.90 to 215.60 µg/kg with average of 75.68 µg/kg, and the amount of mercury sulfide in sediment ranged from 0.02 to 0.12 µg/kg with average of 0.08 µg/kg. The results showed that lower fraction of mercury sulfide was found in suspended solid in comparison to total mercury in suspended solid (average of 102.83 µg/kg), as shown in Fig. 2(a), and much lower fraction of mercury sulfide was also found in sediment in comparison to total mercury in sediment (average of 29.1 µg/kg), as shown in Fig. 2(b).

(a)



(b)

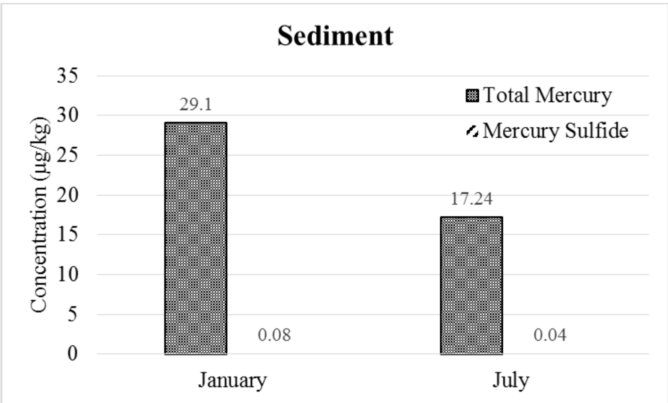


Figure 2. Mercury sulfide and total mercury in samples in both high and low discharge period (a) in suspended solid (b) in sediment

In low discharge period (July) in 2016, total mercury and dissolved mercury concentrations in water samples which were almost at the same level in high discharge period (January) in 2016 ranged from 0.001 to 0.181 µg/L with average of 0.059 µg/L. The average concentrations of total mercury and dissolved mercury in water samples were still within coastal water mercury standard of 0.1 µg/L. On the other hand, higher concentrations of mercury were found in suspended solid, which ranged from <0.01 to 10.21 µg/kg with average of 2.94 µg/kg, and concentrations of suspended solid in water samples were relatively low, which ranged from 0.10 to 0.29 mg/L with average of 0.21 mg/L. As a result, the concentrations of total mercury in water samples without filtration were slightly different from the concentrations of dissolved mercury in filtrate.

The amounts of mercury in sediment ranged from 6.01 to 55.21 µg/kg with average of 17.24 µg/kg. The amounts of mercury in sediment were higher than total mercury in water samples. The results indicated that some mercury in sediment may be accumulated by suspended solid, which can be deposited into bottom of Chao Phraya River Mouth.

The amount of mercury sulfide in suspended solid ranged from <0.01 to 11.83 µg/kg with average of 4.83 µg/kg, and the amount of mercury sulfide in sediment ranged from 0.02 to 0.07 µg/kg with average of 0.04 µg/kg. The results showed that higher fraction of mercury sulfide was found in suspended solid in comparison to total mercury in suspended solid (average of 2.94 µg/kg), as shown in Fig. 2(a), while much lower fraction of mercury sulfide was found in sediment in comparison to total mercury in sediment (average of 17.24 µg/kg), as show in Fig. 2(b).

In overall, the results showed that fraction of dissolved mercury in water samples was higher than mercury in suspended solid due to relatively low concentrations of suspended solid in water samples, although mercury could accumulate well in suspended solid and much higher concentrations of mercury were detected in suspended solid. Moreover, higher fraction of mercury sulfide (less bioavailable fraction) was found in the suspended solid in comparison to sediment, although higher amount of sulfide was generally detected in sediment.

Mercury sulfide is classified as mercury in stable form because solubility of mercury sulfide is less than other mercury compounds (UNEP, 2008). It may be mentioned that lower fraction of mercury sulfide found in sediment was higher bioavailable fraction so that higher fraction of organic carbon (average of 48.02 mg/kg) was also found in sediment. Solid/liquid partition coefficients, k_d are used to estimate the mobility and distribution of elements in the environment. The solid/liquid partition coefficient of mercury in the pH range of 6.5 to 7.0 is high (200 L/kg) (U.S. EPA, 1999). The data showed that mercury accumulated tends to sediment adequately, thus mercury in water is absorbed into suspended solids which settle out into sediment at bottom of a body of water. The results indicated that most mercury found in sediment was in less stable form and higher bioavailable fraction. Moreover, suspended solid plays an important role in mercury transport from land to environment in the sea. Seasonal variation of mercury in the Chao Phraya River Mouth tends to be similar to other areas such as the Sepetiba Bay in Brazil (Paraquetti et al., 2004) and the Gulf of Mexico in United States (Buck et al., 2015). The results suggested that the erosion and runoff are the major pathways of mercury transport to the river and eventually to the sea.

The data of flow of the Chao Phraya River during period of sample collection recorded by water watch and monitoring system for waring center reported that flow of Chao Phraya River during high and low flow periods was average of 8.8 and 6.1 million m^3/d, respectively. Total flux of mercury during high and low flow periods was estimated by multiplying total mercury concentration in water by flow of the water. The total flux of mercury during high and low flow periods were average of 327 and 362 g/d, respectively. Although the average concentration of total mercury in water was higher during the low flow period, the estimated total flux of mercury during high and low flow periods were in the same order of magnitude. The result showed that the total flux of mercury to the Gulf of Thailand by the Chao Phraya River were not seasonal variation. This may be an indicator that most sources of mercury come from natural decay and erosion.

4. Conclusion

The study results of distribution of mercury and mercury sulfide in water, suspended solid and sediment in Chao-Phraya River Mouth Area revealed that higher fraction of mercury sulfide (less bioavailable fraction) was found in the suspended solid with compared to the sediment. The total flux of mercury from land to the Gulf of Thailand by the Chao Phraya River were in the same order of magnitude during high (January) and low (July) flow periods, but the average concentrations of mercury were different.

Acknowledgements

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Seasonal and Land Use Effects on Amphibian Abundance and Species Richness in the Sakaerat Biosphere Reserve, Nakon Ratchasima

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Abstract

Protected areas cannot completely sustain biodiversity, thus understanding the role of human-disturbed areas in conserving the world's diversity is critical. Despite intensive deforestation, Southeast Asia is underrepresented in studies investigating faunal communities in human-modified landscapes. This project assessed the herpetofaunal community in dry dipterocarp forest, secondary disturbed forest, and *Eucalyptus* plantations in the Sakaerat Biosphere Reserve. In May, June, and September of 2015, we surveyed using 10 passive trapping arrays. Both the *Eucalyptus* plantations and secondary disturbed forest habitats (224 and 141 individuals, respectively) had higher amphibian abundance than the dry dipterocarp forest (57 individuals), but we observed significant seasonal variation in amphibian abundance. During the wetter month of September, we recorded higher numbers of amphibian individuals and species. In particular, we noted that distance to a streambed influenced amphibian abundance during the rainy season. The three most abundant species in May and June were *Microhyla fissipes*, *Fejervarya limnocharis*, and *Microhyla pulchra*. In September, the three most abundant species were *Microhyla fissipes*, *Glyphoglossus molossus*, and *Kaloula mediolineata*. Our findings suggest that seasonal resources should be considered when conducting monitoring programs and making conservation decisions for amphibians.

Keywords: amphibians; conservation; seasonal patterns; protected area management

1. Introduction

Protected areas alone cannot completely foster the world’s biodiversity (Rodrigues *et al*., 2004), thus understanding the role of human-disturbed areas in conserving the world's diversity is critical. The global protected area network protects 460 million ha (~12.5% of total forest area) (FAO, 2010) of forest cover from deforestation; however many reserves are becoming isolated from other large tracts of undisturbed landscapes (Sánchez-Azofeifa *et al*., 1999; DeFries and Hansen, 2005). Isolation could mean extinction for a multitude of species as global climate change puts additional pressure on populations by shifting suitable habitat ranges (Bickford *et al*., 2010).

Deforestation and other anthropogenic impacts such as urbanization and poaching are causing declines across all taxa; however, amphibians are the most threatened of all terrestrial vertebrates (Sodhi *et al*., 2010a). Several studies from Southeast Asia report that amphibian species richness decreases in response to habitat disturbance and increased fragmentation (Alcala *et al*., 2004; Wanger *et al*., 2010). Despite the high rate of deforestation (Sodhi *et al*., 2004; Stibig *et al*., 2014), Southeast Asia is generally underrepresented in studies on faunal community response to habitat loss and response to human-modified landscapes (Sodhi *et al*., 2010b; Trimble and Aarde, 2012).

Thailand is home to more than 142 species of amphibians and over 218 species of reptiles (IUCN, 2017). The herpetofaunal diversity and the level of human disruption make Thailand an ideal site to investigate the impacts of land-use change on tropical amphibian communities. To address the knowledge gap we assessed the amphibian community in dry dipterocarp forest, secondary disturbed forest, and eucalyptus plantations in the Sakaerat Biosphere Reserve, Thailand.

2. Materials and Methods

2.1 Study Site

Our study took place at the Sakaerat Biosphere Reserve (SBR), which is located in Nakhon Ratchasima Province, Thailand (14.44–14.55°N, 101.88–101.95°E). The reserve consists of an 80 km^2 core area (Fig. 1) along combined with making up the buffer and transitional zones 360 km^2, which consist mostly of agricultural and settlement areas. The core area of the reserve consists of primary growth dry evergreen forest, dry dipterocarp forest and secondary reforestation (Trisurat, 2010).

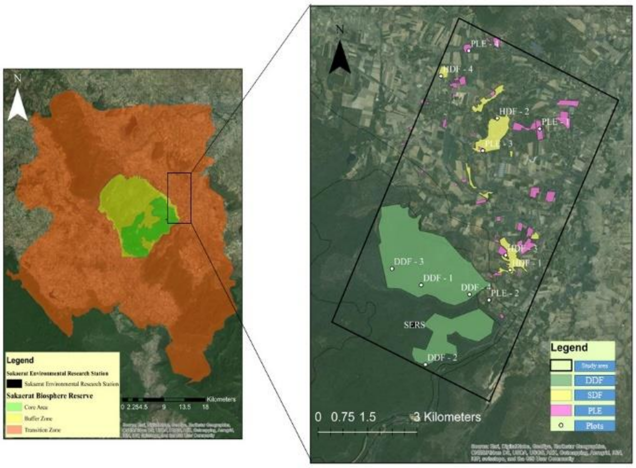

Figure 2. Map of the Sakaerat Biosphere Reserve delineating core, buffer, and transition areas (left) and the study site with the dry dipterocarp forest (DDF), secondary disturbed forest (SDF) and Eucalyptus plantations (PLE) shown (right)

2.2 Amphibian Sampling

We sampled amphibians in three habitats which were dry dipterocarp forest (DDF), secondary disturbed forest (SDF) and small scale *Eucalyptus* plantations (PLE). Both the SDF and the PLE sites occurred in the disturbed landscape of the transition zone of SBR, while the DDF sites were all located within the core area. We surveyed using 10 Y-shaped passive trapping arrays with each line measuring 15 m. Each array consisted of 12 double funnel traps and three 40 L pitfall traps (Fig. 2). We assessed habitat characteristics at each site collected from six 1 m x 1 m quadrats at each site, three set 7.5 m from the center away from each line, and three set 3 m away from the end of each line (Fig. 2). We measured several environmental variables at each plot including percent canopy cover, percent groundcover and leaf litter depth. To collect landscape variables such as elevation and patch size, we used ArcGIS mapping software. Elevation data was collected using a high resolution digital elevation model (Robinson et al., 2014), while patch size was using geometry tools in ArcGIS.

Both May and June had lower precipitation than September (Table 1). Despite the differences in precipitation of 2015, the average rainfall in May (107.8 mm) and June (90.8 mm) over the past 4 years are comparable. Due to differences in average temperature, relative humidity, and rainfall, May and June were categorized as dry season samples and September represented a single rainy season month. We sampled in May and June of 2015 to assess amphibians in the dry season, in September for a wet season sample. Within the study area, only two species are listed as Near Threatened (*Kaloula mediolineata* and *Glyphoglossus molossus*) on the IUCN Red-list. Over hunting may be a serious concern for these species, as one study noted that local villagers were removing roughly 6 kg per person per day (Kaesana *et al*., 2014).

Table 1. Monthly weather conditions for 2015 at the Sakaerat Biosphere Reserve showing the mean daily values for each month

Month	Mean Daily Maximum (˚C)	Mean Daily Minimum (˚C)	Mean Daily Average (˚C)	Humidity (%)	Rainfall (mm)
May	35.4	25.6	26.2	78	8.4
June	34.0	24.9	25.5	78	87.2
September	29.7	23.4	24.0	87	264.7

We elected to not sample in July or August as mortality rates were high in both May (16.4% of all captures) and June (15.5% of all captures) likely due to high temperature and low relative humidity. We recorded high mortality rates despite adding wet sponges and building shaded coverings over traps. Each site was sampled for three days in May, June, and September. We sampled half of the plots, representing an equal number for each forest type, for 3 days and then switched to the second set. We elected to not use mark and re-capture, as toe-clipping can have negative impacts on individuals and cause biased re-capture rates.

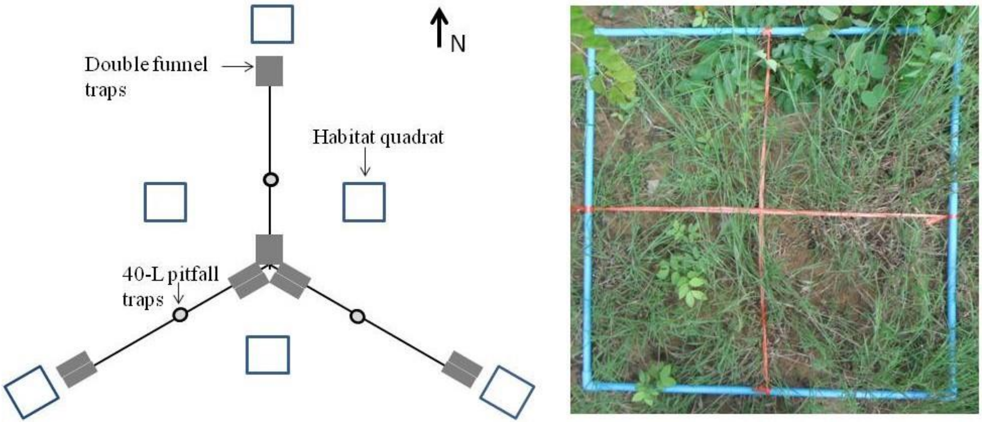

Figure 3. Plot layout showing the locations used to assess habitats (left) and an example quadrat used to estimate ground cover in the study (right)

2.3 Data Analysis

We assessed amphibian abundance between habitat types using an ANOVA test, after checking whether the data met the assumptions of normality and homoscedasticity. As the abundance data between months did not meet the assumptions for parametric analyses, we conducted a Friedman test with a Wilcoxon rank sum test to compare between months. We calculated diversity for each habitat type during each season using the Shannon-Wiener index which incorporates species richness and evenness to calculate diversity.

$$H' = -\sum_{i=1}^{s} p_i \ln(p_i) \quad (1)$$

3. Results and Discussion

Throughout the course of the study, we captured 422 individuals from 14 species across all habitat types (Table 2).

Table 1. Abundance of all amphibian species captured by habitat type sampled

Family	Species	DDF	SDF	PLE	Total
Bufonidae	*Duttaphrynus melanostictus*		1	5	6
Dicroglossidae	*Fejervarya limnocharis*	2	20	31	53
	Occidozyga lima			5	5
Microhylidae	*Calluella guttulata*		1	10	11
	Glyphoglossus molossus	18	2	28	48
	Kaloula mediolineata	20	27	11	58
	Kaloula pulchra	13	5	13	31
	Microhyla butleri	1	11	19	31
	Microhyla heymonsi	1	6	28	35
	Micryletta inornata			11	11
	Microhyla fissipes	1	37	51	89
	Microhyla pulchra	1	31	8	40
Ranidae	*Hylarana erythraea*			1	1
	Hylarana macrodactyla			3	3
Grand Total		57	141	224	422

Amphibian abundance did not vary significantly between habitat types when comparing the total number of captures at each site (ANOVA; df = 2, F = 2.545, p = 0.148). However, within each habitat type, there was a large amount of variation between sites (Table 3). The high variation within forest types could explain why we did not observe any significant difference between forest types.

Table 2. Descriptive abundance data on for amphibian abundance for each of the sampled habitats

Habitat type	Total abundance	Mean ± SD
DDF	57	14.25 ± 27.2
SDF	141	47 ± 27.7
PLE	224	74.7 ± 48.8

Amphibian abundance did vary significantly between each month that we sampled (Friedman test; $\chi^2 = 13.027$, df = 2, $p = 0.001$) (Fig. 3). In September, we captured 290 individuals compared to 18 in May and 114 in June. Amphibian abundance differed significantly between months with September ($V = 1$, $p = 0.035$) and June ($V = 0$, $p = 0.006$) having higher abundance than May. However, June and September did not show a significant difference in amphibian abundance ($V=12.5$, $p = 0.138$). However, as we did not employ mark and re-capture the observed abundances may be inflated as we cannot confirm that each capture was a unique individual. In the disturbed habitats, this could be an important factor as viable amphibian habitat is likely smaller than in the protected forest, which could lead to higher re-capture rate, as individuals cannot disperse away from the trapping array. Diversity and species richness was highest in the PLE forest across all months (Fig. 3). However, both species richness and diversity peaked in all habitat types during September. Our findings contrast with another study from Khao Yai National Park that found highest amphibian abundance during the dry season (Kongjaroen and Nabhitabhata, 2007). However, the study sampled along a stream and did not look at sites further away from a permanent water source, which could account for the conflicting results.

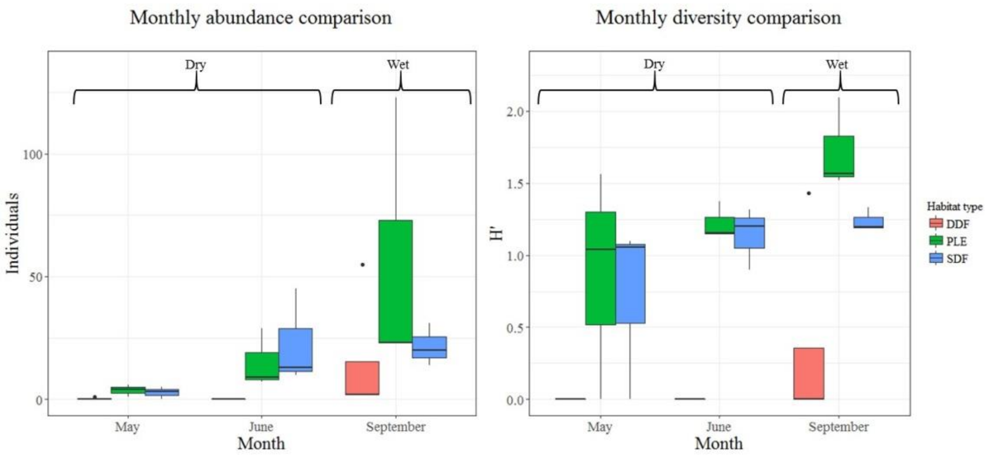

Figure 4. Boxplots of monthly amphibian abundance (left) and monthly Shannon-Wiener index (right) for each habitat type

Additionally, we observed higher species richness in September with 12 species compared to 9 in both May and June. While the rainy season yielded higher amphibian abundance and species richness, we noted that several species exhibited higher relative abundance in either May or June.

Table 3. Monthly abundance for each species captured along with percent of the total

Species	Common name	Abundance		
		Dry	Wet	Total
Microhyla fissipes	Ornate Chorus Frog	32	57	89
Kaloula mediolineata	Median-striped Bullfrog	19	39	58
Fejervarya limnocharis	Asian Grass Frog	37	16	53
Glyphoglossus molossus	Balloon Frog	0	48	48
Microhyla pulchra	Beautiful Pygmy Frog	24	16	40
Microhyla heymonsi	Dark-sided Chorus Frog	2	33	35
Kaloula pulchra	Asiatic Burrowing Frog	5	26	31
Microhyla butleri	Noisy Chorus Frog	2	29	31
Calluella guttulata	Stripe Spadefoot Frog	0	11	11
Micryletta inornata	Inornate Chorus Frog	1	10	11
Duttaphrynus melanostictus	Asian Toad	6	0	6
Occidozyga lima	Common Puddle Frog	1	4	5
Hylarana macrodactyla	Long-toed Frog	2	1	3
Hylarana erythraea	Dark-sided Frog	1	0	1
Total		132	290	422

As seen in Table 4 several species showed larger shifts in seasonal relative abundance**.** In the case of the two species within the genus *Kaloula*, each species showed a different tendency with *K. mediolineata* composing a large percentage of captures in June and September compared to the *K. Pulchra*, which peaked May. The trend shows possible seasonal partitioning between the two species. Identifying natural history differences between these two species may have conservation value as *K. mediolineata* is listed as Near Threatened on the IUCN Redlist while *K. pulchra* is classified as Least Concern.

The limited number of sampling sites restricted our ability to identify significant environmental factors in amphibian abundance; however, our results suggest several trends. The plantation ($\mu = 258$) and secondary disturbed forest ($\mu = 263$) sites occurred at lower elevation than the dry dipterocarp forest sites ($\mu = 361$), meaning increase water drainage. Additionally, as the landscape has been modified for agricultural practices, more water sources, such as ponds and irrigation canals, are available for amphibians when compared to the natural forest. Both factors may explain the much higher abundance of amphibians in the more disturbed habitats. Kaensa *et al*. (2014) found that in upper NE Thailand that unprotected forest habitats had lower abundance compared similar protected forest habitats, in opposition to our results. However, they also identified that woodland habitats sites in protected areas had the lowest amphibian captures, supporting our results that sites in the DDF showed lower amphibian abundance. Sampling in stream beds within the protected DDF forest may reveal higher species richness and abundance.

Water availability may have also influenced the differences in abundance and species richness between seasons. For instance, sites closer to streambeds showed increased amphibian abundance specifically in September. One site located within 150 m of a streambed captured no amphibians during May and June, but in September recorded 55 individuals. A second site located within 10 m of a streambed supported this trend as we recorded only 8 amphibians in May and June combined compared to 123 in September. One possible explanation for the dramatic increase in amphibian abundance is that within our study area streambeds typically remain dry for long periods of the year. During the rainy season starting around September, the streambeds fill for a brief period. The results indicate that seasonal water availability may be an important factor in predicting amphibian abundance. Phochayavanich (2007) found similar results with higher amphibian diversity in the wet season and in agricultural areas in the Num San Noi stream located in the Phuluang Wildlife Sanctuary. Our results suggest that amphibian diversity and abundance in agricultural areas can be high in small forest patches, in addition to the stream beds found as noted by Phochayavanich (2007).

4. Conclusion

As a preliminary study on the effects disturbance on amphibians, this study provides useful results for establishing continued study in the Sakaerat Biosphere Reserve. Particularly we documented that amphibian abundance changes over seasons. Our results also suggest that seasonal variation may not be based solely climatic factors, such as temperature and rain, but also on changing water availability overtime. We also noted the need to monitor how specific species respond to seasonal changes as not every species exhibits similar patterns. However, we did not assess amphibian developmental stage, which may be an important factor in both abundance and species richness patterns observed between seasons and land uses. All of these conclusions can aid in natural land management to maximize the effectiveness of protected areas.

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Contribution of Root Respiration to Soil Respiration during Rainy Season in Dry Dipterocarp Forest, Northern Thailand

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Abstract

Soil carbon dioxide (CO_2) from root respiration (R_r) was about 10-90% of soil respiration, depends on the spatial variation. Dry dipterocarp forest has clearly separate season. Rainy season is a period by higher root growth than dry season which affect to root respiration variability over the drought. The study of R_r in Thailand was less information because the separating root and microbial respiration from total soil respiration (R_s) is difficult. This study aims to estimate R_r and analyze environmental factors affect to R_r during rainy season in dry dipterocarp forest, northern Thailand. The results show that R_r ranged from 41.04-61.97 mgCO_2/m^2/hr and ratio of R_r to R_s was 23-48%. The response of R_r to environmental factor found that soil temperature has weak negative relation with R_r and soil moisture is a main driver for emitted soil CO_2 from root in rainy season. However, long period study and root biomass will improve accuracy and understanding for root respiration in the future.

Keywords: root respiration; soil respiration; dry dipterocarp forest

1. Introduction

Soil CO_2 emission includes respiration from root and soil microorganism which it is an important role for terrestrial carbon cycle (Wang et al., 2009; Schlesinger and Andrews, 2000). Root respiration (R_r) is a key source of CO_2 emission from soil wherefore it is a main factor affect to soil respiration contribution. (Raich and Tufekcioglu, 2000). CO_2 lost from R_r and rhizophere activity is implicate with consumption of organic compounds by plant's organ (Horwath et al., 1994). The separate of soil respiration components helps to improve our understanding about carbon dynamic to environmental change (Bond-Lamberty et al., 2004). The previous study reported root respiration may be 10-90% of soil respiration however it is depends on spatial, which forest ecosystem has R_r/R_s about 46% (Hanson et al., 2000).

The technique for estimate root respiration has many methods such as component integration, root exclusion, isotope method (Hanson et al., 2000). This study chosen root exclusion technique: trenching method which is installed the barrier for prevent growth of plant root in the future and this method has been widely used to separate soil respiration components (Bowden et al., 1993; Hanson et al., 2000; Bond-Lamberty et al., 2004; Hanpattanakit, 2013; Zhang, 2013). Trenching method is less disturbance to remaining tree than other methods and block carbon supply from tree to soil (Hanpattanakit, 2013). In addition, this method still treat the condition in study plot closely the original condition (soil temperature, soil moisture) and trenching plot are inexpensive and general method for partitioning R_s components (Bond-Lamberty et al., 2004). The study of root respiration in Thailand were less information to improve understanding about variation of R_r. Hanpattanakit (2015) reported average ratio of R_r to R_s was 29% for 4 year in rainy season at dry dipterocarp forest, Ratchaburi. He found that the growth of fine roots was strongly correlated with root respiration in rainy season. This study aims to estimate R_r and analyze environmental factors affect to R_r during rainy season in dry dipterocarp forest, northern Thailand.

2. Materials and Methods

2.1 Site descriptions

The study site located in Dry Dipterocarp Forest Flux Phayao Site Thailand (DPT) at University of Phayao (Latitude: 19° 02’ 14.38”N, Longitude: 99° 54’ 10.96”E, altitude 512 m). The forest type is dry dipterocarp forest. Topography is slope terrain. The dominant species were *Shorea obtusa, S. siamensis, Dipterocarpus tuberculatus* and *D. obtusifolius*. Tree density was ovserved that number of standing tree and sapling were 1,920 tree/ha and 600 tree/ha, respectively (Intanil et al., 2016) (Fig. 1a and 1b). The site has tropical monsoon climate, precipitation was 936 mm and mean air temperature was between 18.64 to 31.62 °C. While soil temperature and soil moisture were between 19.07-31.86 °C and 11.84-30.82 %WFPS (measured in 2013-2016 at DPT station). Main texture of top soil was sandy loam (0-10 cm depth) and sandy clay loam in lower layer. Soil bulk density ranged from 1.40 to 1.89 g/cm^3 which contained organic carbon between 0.67 to 3.89%. (Intanil et al., 2016).

2.2 Soil respiration (R_s) and Root respiration (R_r)

Soil respiration measured by closed chamber technique. The chamber made from Polyvinylchloride (PVC) with 21.5 cm of diameter and 22.0 cm of height (Fig 1c). Nine chambers were installed the chamber into soil at 7 cm depth. R_s was measured at 10 minutes in each chamber and analyzed by using Infrared gas analyzer

(Li-820, Licor Corporation, Lincoin, Nebraska, USA). The data stored with data logger (CR1000, Campbell Scientific, Logan, Utah, USA) (Fig 1d). For root respiration calculated from the difference between soil respiration and microbial respiration (Eq. 1). Microbial respiration measured by trenching method (Fig 1e). For this method, roots were defeated by digging a trench about 100 cm around the plots (100 cm x 100 cm) (Luo and Zhou, 2006; Hanpattanakit, 2013) and barrier (polycarbonate sheet) and chambers were installed (Fig 1f). Meanwhile, chamber's temperature was measured at 0, 5 and 10 minutes, respectively. R_s and its components were observed during June to October 2016. Moreover, air temperature and rainfall measured by WXT520 (Campbell Scientific, Logan, Utah, USA). Soil temperature and soil moisture measured by Thermocouple and CS616 model (Campbell, Scientific, Logan, Utah, USA) at 5 cm depth.

$$R_r = R_s - R_m \qquad (1)$$

where R_r, R_s and R_m are root respiration, soil respiration and microbial respiration, respectively.

2.3 Soil CO_2 flux calculation

Soil respiration rate were calculated using linear portion of gas concentration change during chamber closing time. The first, the mixing concentration obtained from the chamber is inverted to a mass by the ideal gas law. Therefore, it depends on temperature and pressure of the enclosed air followed (Eq. 2) (Hanpattanakit, 2013).

$$C_i = \frac{qiMP}{RT} \qquad (2)$$

where C_i is mass per volume concentration (gCO_2/m^3), *qi* is volume per volume concentration (m^3/m^3), *M* is molecular weight of CO_2 (44 g/mol), *P* is atmospheric pressure (1 atm), *R* is gas constant (8.2058 x 10^{-5} m^3.atm/K/mol), *T* is average temperature inside the chamber (K).

Then, soil CO_2 flux was calculated using linear portion of the gas concentration change over time (Eq. 3) (Hanpattanakit, 2013).

$$F = \frac{dC_iV}{dtA} \qquad (3)$$

where F is flux on the aerial basis (g/m^2/min), V is volume of the chamber's headspace (m^3), A is area of soil enclosed by the chamber (m^2) and dc_i/d_t is rate constants of CO_2 concentration increase with time (gCO_2/m^3/min)

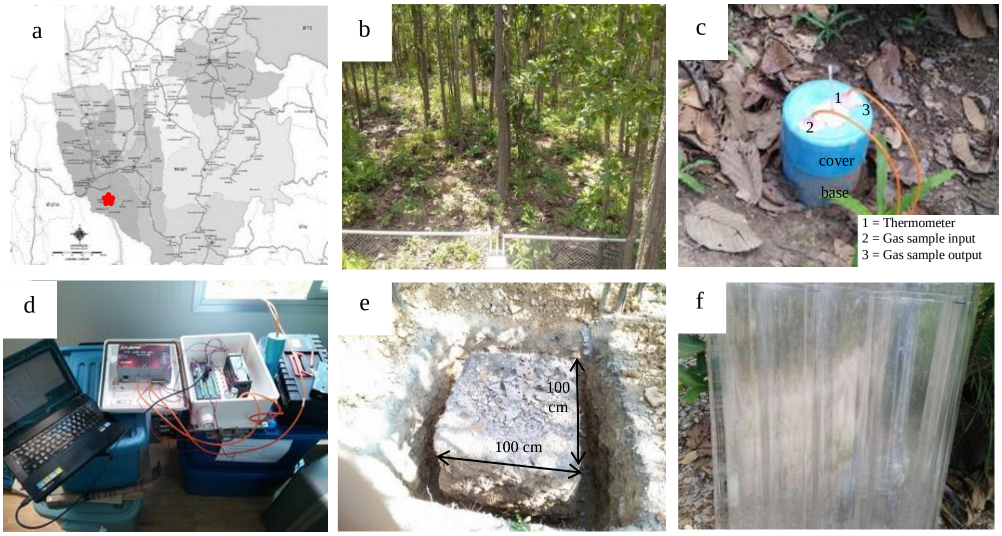

Figure 1. Dry Dipterocarp Forest Flux Phayao Site Thailand (a), dry dipterocarp forest (b), closed chamber (c), soil respiration system (d), trenching method (e) and polycarbonate sheet (f)

3. Results and Discussion

3.1 Meteorological data

Meteorological data during June to October 2016 includes air temperature, rainfall, soil temperature and soil moisture (%water-filled pore space; %WFPS). The results show that air temperature ranged 24.9–25.9 °C which June found the highest and October was lowest. Soil temperature ranged 25.4-26.4 °C which June was higher than others (Fig. 2a). Rainfall during study period was 733.3 mm: highest in September follow by June, August, October and July, respectively. While, the average soil moisture in each month were 24.67, 24.33, 25.34, 30.97 and 30.82 %WFPS, respectively (Fig. 2b).

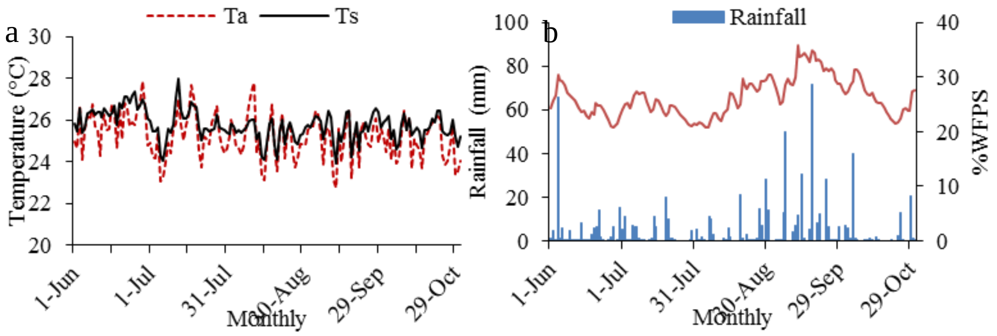

Figure 2. Air temperature and soil temperature (a), rainfall and soil moisture (b) during June to October 2016

(Ta and Ts represent air temperature and soil temperature, respectively).

3.2 Soil respiration (R_s) and Root respiration (R_r)

For R_s during June to October 2016, the results found that mean R_s in each month were 121.72±91.65 171.41±65.91 147.54±67.65 178.39±140.34 and 138.72±79.64 $mgCO_2/m^2/hr$, respectively. While, mean R_r were 58.40±56.06 52.86±14.69 61.97±45.63 41.04±29.78 and 45.74±31.90 $mgCO_2/m^2/hr$, respectively. The ratio of R_r/R_s during 23-48%, average as 35% (Fig. 3a and 3b). When compared with other studies in Thailand show that Hanpattanakit (2015) studied about root respiration at dry dipterocarp forest, Ratchaburi province during wet season in 2008-2011 which R_r ranged 112-205 $mgCO_2/m^2/hr$, and the ratio of R_r/R_s was 21-33%. It indicates that the previous study had R_r/R_s lower than this study due to the forest was invaded and may be adapted to actively transport the majority of fixed carbon to aboveground biomass instead the root (Hanpattanakit, 2013). Saiz et al. (2006) reported that R_r would inverse with age of tree which R_r/R_s in sapling (59%) were decrease when age of tree were increase (49%). Consistent with the forest in this study that the most trees are standing tree more than sapling. It makes the ratio higher than Ratchaburi site because the decreasing of root senescence activity. In addition, compared with other forest types show that R_r/R_s in this study was lower than which R_r/R_s of other forest types ranged from 50-93%, 62-89%, 33-50% and 35-62% in arctic tundra, boreal forests, broad-leaved forests and pines forests, respectively (Raich and Tufekcioglu, 2000). The difference of forest type and climate condition especially soil temperature and moisture affect to R_r. Because it is main controlling factor on microbial and root activity (Raich and Schlesinger, 1992). Moreover, photosynthetically active radiation (PAR) is a factor effect to increasing R_r value which consistent with our study was show positive relation (R^2=0.62). It affects to root growth and CO_2 emission from root activity (Lambers et al., 1998).

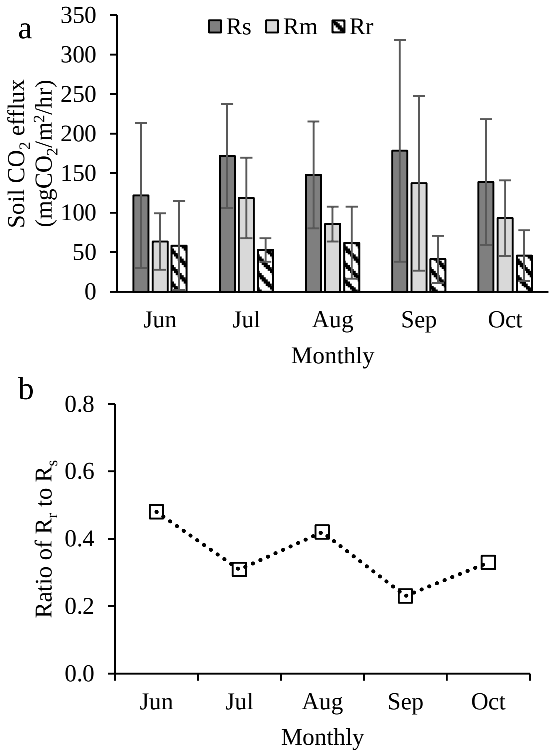

Figure 3. Soil, microbial and root respiration (a), the ratio of root respiration to soil respiration (b) during June to October 2016

3.3 Environmental factors affect to R_r

The environmental factors affect to root respiration found that R_r was exponential decrease if soil moisture was increase (R^2=0.77) but no statistically significant. While, relationship between soil temperature with R_r (R^2=0.05) were not significant. For Relationship of R_s and R_m with soil moisture were not significant although it had positive relationship. In contrast, both of them were negative relation with soil temperature (Fig. 4a and 4b).

Response of R_r depend environmental factors such soil temperature and soil moisture. R_r was sensitive to temperature which effect to enzyme catalyst of respiration process and root growth. The increasing of R_r to soil temperature was exponential but it only takes a short time (Luo and Zhou, 2006; Berry, 1949; Atkin et al., 2000). In this study indicated that R_r has weak positive relation with soil temperature due to the period for study was rainy which soil temperature was not varies (25.1-25.9 °C). While soil moisture in this study show negative relationship with R_r.

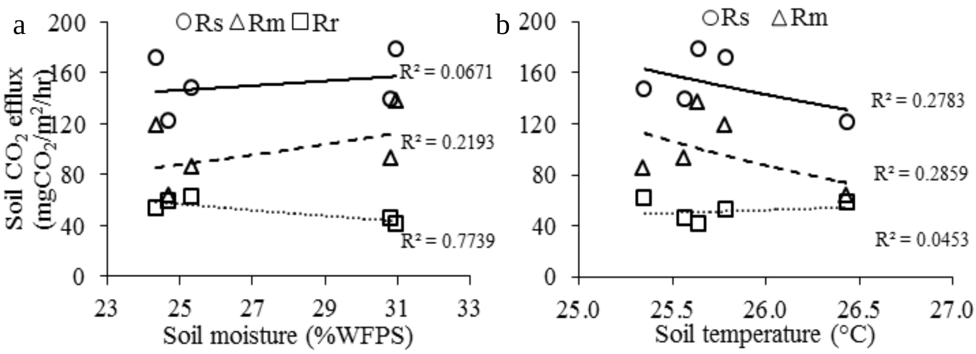

Figure 4. Relationship between soil moisture (a), soil temperature (b) with soil respiration and its components

High moisture affect to low respiration of root because high water in soil pores will make less aeration or anaerobic condition in soil which no gas exchange for respiration process. However, Bryla et al. (1997) reported R_r rate in high soil temperature and drought condition were lower than wet soil condition. In addition, other environmental factors indirectly control R_r such as salinity, water stress, nutrient supply and pH value (Lambers et al., 1998). Furthermore, photosynthesis is an important to root growth and synthesis of new tissue which affect to R_r. It is a strong controlling factor to respiration from root (Hanson et al., 1993; Lee et al., 2003). Therefore, further studies should be conducted root biomass.

4. Conclusion

Contribution of root respiration to soil respiration during rainy season in dry dipterocarp forest, northern Thailand was 41.04-61.97 $mgCO_2/m^2/hr$ or 23-48%. Soil moisture is a main driver for amount of root respiration. However, long period and root biomass study will improve accuracy and understanding for root respiration in the future.

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Pollution Status and Potential Ecological Risk Assessment of Heavy Metals in Soils from a Municipal Solid Waste Open Dumpsite in Thailand

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Abstract

The aims of this study were to determine the pollution status of heavy metals in soil taken from Nakhonluang district municipal solid waste open dumpsite of the Phra Nakhon Si Ayutthaya province in Thailand and to assess the potential ecological risk of the area. Contamination factor, geo-accumulation index and potential ecological risk index were used as analytic tools for the assessment of the pollution status and the potential risk of the heavy metals to environment. The concentrations of 8 heavy metals were determined by atomic absorption spectrophotometer (AAS). The average concentrations of each metal from soil inside the dumpsite area were higher than those in the outside area and they were in the following order: Fe >> Mn > Zn > Cu > Cr > Ni > Pb (Cd was not detected). Contamination factors and geo-accumulation indices of heavy metals were found in the following order: Zn > Cu > Ni > Cr > Pb (Background concentration values of Fe and Mn are not available). The values showed a strong contaminated level for Zn in soil inside the dumpsite area and uncontaminated level for Pb. The potential ecological risk index (RI) in the dumpsite area showed that it generated moderate risk degree to environment and the RI value obtained from inside the dumpsite area was higher than those in the outside area. The results indicated that the dumpsite contains toxic substances that cause adverse effects to the environment. The potential ecological risk obtained in the order of $E_r^{Cu} > E_r^{Ni} > E_r^{Zn} > E_r^{Cr} > E_r^{Pb}$ demonstrated that Cu is the most important factor leading to risk.

Keywords: heavy metal; open dumpsite; contamination factor; geo-accumulation index; potential ecological risk assessment; soil contamination

1. Introduction

Municipal solid waste (MSW) is one of the most important environmental issues in Thailand since its amount has been increasing year by year (23.93 million tons in 2008 to 26.77 million tons in 2013) (Pollution Control Department (PCD), 2014). Most of the MSW is generated from daily life activities. Waste disposal management in Thailand is varied. Proper disposal facilities that meet the standard can be found in only 466 sites while other 2,024 sites are found operating with the improper managements. One of the improper managements that is most used for waste disposal is an “Open dumping”, which is found in 1,955 sites all over the country.

Phra Nakhon Si Ayutthaya province is considered a crucial industrial hub as well as major tourist destination of Thailand, it has more than 6 million tourists visiting each year, since 2012 (National Statistical Office, 2016). The province generates about 300,000 tons of MSW per year. Although it has 26 disposal sites, but none of them is designed for proper disposal i.e. 18 open dumpsites, 1 control dump with the capacity of more than 50 tons/day and 7 incinerators without air pollution control system (PCD, 2014). Nearly 600,000 tons of MSW has been accumulated in these dumpsites and they have been deposited over the open grounds without liner system and leachate control. The leachate from these sites can flow into water supplies for agricultural use and contaminate surrounding soil and groundwater.

An open dumping is the oldest and the most common way to dispose the solid waste. It can be located wherever in any usable land space regardless of safety and health risk. The waste is often piled up as high as it can be on the dumpsite. Some of the refuses are ignited and allowed to burn while some are regularly leveled and compacted. Open dumpsites are known to be the releasing source for several toxic and carcinogenic compounds such as heavy metals, volatile organic compounds/semi volatile organic compounds (VOCs/SVOCs), brominated flame retardants and phthalate esters (Huang *et al*., 2015; Eguchi *et al*., 2013; Adeniyi *et al*., 2008). Among these, contamination with heavy metal has attracted more attention due to their wide sources, toxicity, non-biodegradable properties and accumulative behaviors in environment (Qing et al., 2015). Generally, heavy metals entered the environment through various routes and several studies showed that they caused harmful effects to the environment and human health (Huang et al., 2015; Tchounwou et al., 2012; Järup, 2003).

Despite 2,000 sites of improperly managed landfills and dumpsites in Thailand, a few have been extensively studied on heavy metal contamination from landfills and open dumpsites i.e. Uttaradit (Wachirawongsakorn and Sangyoka, 2013), Nonthaburi (Prechthai et al., 2008) and Khon Kaen (Chuangcham et al., 2008). Therefore, the aims of the present study were to determine the soil quality of Nakhonluang open dumpsite in terms of heavy metals by determining their concentrations from the samples taken in the area of the dumpsite and to assess their potential ecological risk. The results provide a comprehensive soil contamination status of heavy metals and can be useful for waste disposal control and risk management of heavy metals in similar areas.

2. Materials and Methods

2.1 Study area

Nakornluang district municipal solid waste open dumpsite is in Phra Nakhon Si Ayutthaya province which is located in the central part of Thailand (Figure 1). This dumpsite has been in operation since 2002 and now receives about 25 tons per day of MSW. The MSW is disposed into natural pits of hollows with no liner system, gas controls, leachate control and leachate treatments (Figure 2). This dumpsite has an accumulation of MSW of about 68,400 tons (PCD, 2014). It is surrounded by agricultural land mainly rice paddy field.

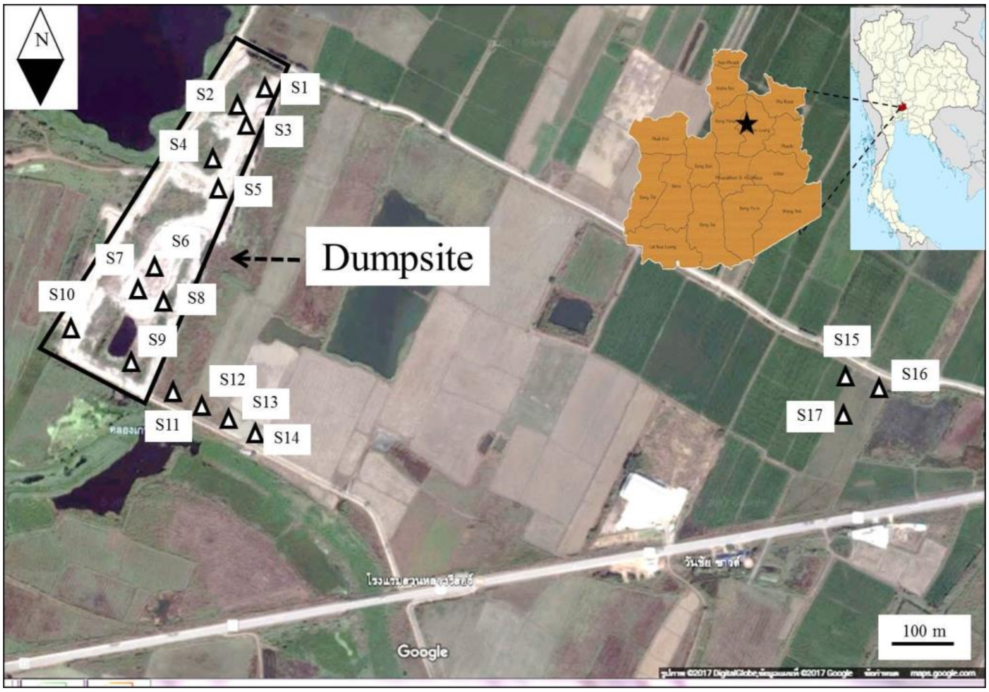

Figure 1. Map showing sampling sites in Nakhonluang district municipal solid waste open dumpsite of the Phra Nakhon Si Ayutthaya province in Thailand

2.2 Soil sampling

Ten soil samples were collected inside the dumpsite area (S1-S10) while seven soil samples were collected from its surrounding area outside the dumpsite (S11-S17) during March 2016 (Figure 1). Each soil sample was collected at about 30 cm depth for 1 kg, stored in a sealed polyethylene bag and transported to the laboratory for pre-treatment and analysis.

Figure 2. An overview of the dumpsite

2.3 Heavy metal analysis

The soil samples were air dried for 5-7 days, ground and sieved through a 0.5 mm sieve. Sieved soil (0.5 gram) was digested using a microwave digester (Milestone, Ethos one) method EPA3051 by adding 10 mL of 65% nitric acid and run under the following condition i.e. power 1,000 watt, ambient temperature to 175˚C in 5 minutes 30 seconds and maintained at 175˚C for 10 minutes. Heavy metals i.e. Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn were determined using atomic absorption spectrophotometer (AAS; Agilent, AA240). All glassware used in all heavy metal determination experiment was soaked in 0.1 M nitric acid for 24 hours and rinsed with deionized water. Three replicates were used for the analysis of soil samples.

2.4 Assessment of heavy metal contamination

Contamination factor (CF) and geo-accumulation index (Igeo) were adopted to use for the assessment and quantification of the level of contamination in sediments and soils (Nweke and Ukpai, 2016; Akobundu and Nwankwoala, 2013).

CF can be calculated using this equation:

$$CF = C_n / B_n \tag{1}$$

while Igeo can be calculated using this equation:

$$Igeo = \ln (C_n / 1.5 \times B_n) \tag{2}$$

Where C_n is the mean concentration of element in the soils (mg/kg) and B_n is the background concentration of element (mg/kg). For Igeo, factor 1.5 is used because of possible variations in background values for a given metal in the environment and very small anthropogenic influences. Igeo value can be classified into seven classes indicating different degree of contaminations as described in Table 1.

Table 1. Geoaccumulation class intensity and degree of contamination according Igeo value (modified from Gupta et al., 2014)

Igeo value	**Geoaccumulation class intensity**	**Degree of contamination**
5 < Igeo < 6	6	Very strong
4 < Igeo < 5	5	Strong to very strong
3 < Igeo < 4	4	Strong
2 < Igeo < 3	3	Moderate to strong
1 < Igeo < 2	2	Moderate
0 < Igeo < 1	1	Uncontaminated to moderate
Igeo < 0	0	Practically uncontaminated

2.5 Potential ecological risk assessment

Potential ecological risk index (PERI) was originally used as a diagnostic tool for water pollution control, but it was also successfully used for assessing the contamination of soils in the environment by heavy metals. PERI was originally introduced by Hakanson (1980) according to the toxicity of heavy metals and the response of the environment. It is formed by three basic modules: degree of contamination (C^i), toxic-response factor (T_r) and potential ecological risk factor (E_r). According to this method, the potential ecological risk index of a single element (E_r^i) and comprehensive potential ecological risk index (RI) can be calculated via the following equations:

$$C_f^i = C^i / C_n^i \qquad (3)$$

$$E_r^i = T_r^i \text{ x } C_f^i \qquad (4)$$

$$RI = \Sigma E_r^i \qquad (5)$$

Where C^i = the concentration of element in the soils (mg/kg)

C_n^i = the regional background value of elements (mg/kg)

C_f^i = the contamination factor of a single element

T_r^i = the toxic-response factor of a single element

i.e. Mn = Zn = 1, Cr = 2, Cu = Ni = Pb = 5 and Cd = 30 (Hakanson, 1980; Xu et al., 2008)

E_r^i = the potential ecological risk index of a single element

RI = the sum of all of the risk factors for elements in the soils

Risk assessment is a useful tool for prediction the environmental safety level of the contaminants. PERI was used for environmental risk determination, if the total risk of all contaminants is higher than 150 (See risk grading in Table 2), the samples could pose harmful effects to the environmental. In this study, the risk assessment was carried out in two groups to compare the risk derived from the soil inside the dumpsite area (S1–S10) and the soil outside the dumpsite area (S11-S17).

Table 2. Grading standard of potential ecological risk according to E_r^i and RI

E_r^i	Pollution degree	RI	Risk degree
$E_r^i < 40$	Low	RI < 150	Low
$40 \leq E_r^i < 80$	Moderate	150 ≤ RI < 300	Moderate
$80 \leq E_r^i < 160$	Considerable	300 ≤ RI <600	High
$160 \leq E_r^i < 320$	High	RI ≥ 600	Very high
$E_r^i \geq 320$	Very high		

2.6 Statistical analysis

All data were analyzed using Microsoft Excel and SPSS for windows (version 22). Arithmetical means ± standard deviation (SD; $n = 3$) were used to assess the contamination levels of heavy metals in all soil samples and T-test ($p<0.05$) was performed to determine the significance of differences between the pairs of means of the soils inside and outside the dumpsite area.

3. Results and Discussion

3.1 Heavy metals in soil

The average concentration of the heavy metals were detected with the order of abundance as Fe > Mn > Zn > Cu > Cr > Ni > Pb and Cd was below the detection limit. Among 8 heavy metals determined, 5 of them (Cr, Cu, Mn, Pb and Zn) were found in significantly ($p<0.05$) higher concentrations inside the dumpsite comparing to the outside area (Table 3 and Figure 3). However, the concentrations of Fe were not much higher than those of the surrounding sites. This results from the fact that in nature, it already contains high level of Fe.

Heavy metals such as Cr, Cu, Mn, Pb and Zn have been reported to contaminate soil in open dumpsites elsewhere in Thailand. These metals were reported to have mobility potential and contaminate surrounding area and underground water (Wachirawongsakorn and Sangyoka, 2013; Chuangcham et al., 2008; Prechthai et al., 2008). Results from this study confirm that the municipal waste release high amount of heavy metals into soil and may contaminate its surroundings.

The concentration of Cu inside the dumpsite area (mean 46.76 mg/kg, range 26.08-76.43 mg/kg) is significantly ($p<0.05$) higher than the surrounding area (mean 25.72 mg/kg, range 24.52-28.54 mg/kg). The source of Cu contamination in the dumpsite area could come from electrical wiring, alloys, cooking utensils, piping and agrochemicals. The average concentration of Cr inside and outside the dumpsite were 33.96 mg/kg and 24.37 mg/kg, respectively. The average concentration of Mn in the dumpsite and surrounding area were 432.46 mg/kg and 289.75 mg/kg, respectively. Zn concentration in the dumpsite (mean 123.56 mg/kg, range 18.11-512.67 mg/kg) is significantly ($p<0.05$) higher than that in the surrounding area (mean 39.30 mg/kg, range 27.70-55.60 mg/kg). Zn has been used in batteries, pigments, galvanizing steel and iron products. These results generate some concerns for ecological and human health, which can be adversely affected by the toxicity of these heavy metals.

Table 3. Comparison of heavy metal concentration (mg/kg) in the soils from this study to the uncontaminated or reference area

Soil sample		Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Inside Nakhonluang open dumpsite: This study	Average	ND	33.96	46.76	22,982.16	432.46	22.97	8.78	123.56
	Min	ND	18.73	26.08	8739.63	131.26	5.45	4.60	18.11
	Max	ND	74.95	76.43	30109.70	951.15	32.85	27.07	512.67
Outside Nakhonluang open dumpsite: This study	Average	ND	23.38	25.72	22179.72	289.75	17.94	5.28	39.30
	Min	ND	21.67	24.52	19806.34	87.32	5.05	4.21	27.70
	Max	ND	29.80	28.54	25772.80	536.41	26.30	5.97	55.60
Background Ultisols soil: Thailand[a]	Average	0.01	3.4	2.3	NA	NA	1.7	4.9	3.6

[a] Zarcinas et al., 2004
ND = not detected; NA = not available

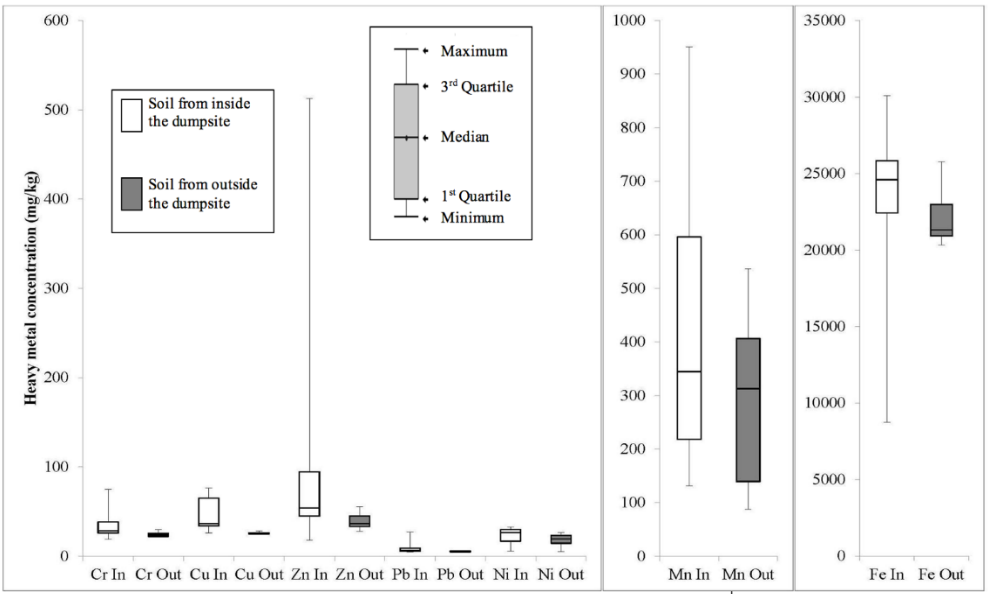

Figure 3. Box and whisker plots showing variation in heavy metal concentrations (mg/kg) in soils taken from inside (In) the dumpsite area compared to the outside (Out) area.

3.2 Contamination levels of the soil heavy metals

Background concentration (Bn) of heavy metal in the soil of Nakornluang district or Phra Nakhon Si Ayutthaya province has not been reported. Therefore, the Bn values in this study were referenced from soil survey in Thailand (Zarcinas et al., 2004). Because Bn values of Fe and Mn are not available, CF and Igeo were calculated without them. Fe and Mn are natural elements and usually found in high amount in nature.

The CF and Igeo were calculated and the results are presented in Table 4. CF and Igeo values of the soil from the outside area indicated that these paddy fields around the dumpsite area were contaminated with some heavy metals mostly in moderate level i.e. Igeo values range from -0.33 to 2.01. Agricultural activities such as applying fertilizers and pesticides to crops and soil, when overdoing, can lead to contamination of some heavy metals especially plant nutrients. However, the Igeo value of each heavy metal in the inside area was higher when compared to the outside area. Therefore, waste disposal increased the contamination of heavy metal to the soil. CF and Igeo values have been used to determine the environmental quality of soils from a dumpsite in Aba of Southeastern Nigeria. These values indicated that the dumpsite was moderately and slightly contaminated with cadmium and copper respectively (Akobundu and Nwankwoala, 2013). In current study, CF and Igeo of heavy metals in the dumpsite area were found in the following order: Zn > Cu > Ni > Cr > Pb. The values showed a strong contaminated level for Zn in soil within the dumpsite area and uncontaminated level for Pb. Excessive concentration of Zn in soil leads to phytotoxicity as it is a weed killer, therefore, these soils should have limited access from agricultural purposes.

3.3 Potential ecological risk assessment of heavy metal in soils

This study performs risk assessment by calculating RI of the dumpsite, the results are shown in Table 5. From the calculation, RIs of the dumpsite area were between 123.7-405.9 (low to high risk) with the average at 232.5 (moderate risk) while those of the surrounding sites were between 96.2-169.2 (low to moderate risk) with the average at 139.3 (low risk). The potential ecological risk obtained in the order of $E_r^{Cu} > E_r^{Ni} > E_r^{Zn} > E_r^{Cr} > E_r^{Pb}$ demonstrated that Cu is the most important factor leading to risk.

A dumpsite in Enugu of Nigeria generated high ecological risk. CF and Igeo values have been used to determine the environmental quality of soils from a dumpsite in Aba of Southeastern Nigeria. These values indicated that the dumpsite was moderately and slightly contaminated with cadmium and copper respectively (Akobundu and Nwankwoala, 2013).

4. Conclusion

In this study, municipal solid waste dumping has shown to have caused heavy metal contamination to the soil. The contamination factor and geo-accumulation index reflected the soil quality of the dumpsite as strongly contaminated by Zn. The potential ecological risk index (RI) demonstrated a moderate ecological risk to the dumpsite area. The potential ecological risk demonstrated that Cu is the most important factor leading to risk.

Table 4. Contamination factor (CF) and geo-accumulation index (Igeo) of heavy metals in soil from the dumpsite

	Heavy metal	**Cn**	**Bn**	**CF**	**Igeo**	**Contamination level**
Soil from inside the dumpsite (S1-S10): This study	Cr	33.96	3.40	9.99	1.90	Moderate
	Cu	46.76	2.30	20.33	2.61	Moderate to strong
	Ni	22.97	1.70	13.51	2.20	Moderate to strong
	Pb	8.78	4.90	1.79	0.18	Uncontaminated to moderate
	Zn	123.56	3.60	34.32	3.13	Strong
Soil from outside the dumpsite (S11-S17): This study	Cr	24.37	3.40	7.17	1.56	Moderate
	Cu	25.72	2.30	11.18	2.01	Moderate to strong
	Ni	17.94	1.70	10.55	1.95	Moderate
	Pb	5.28	4.90	1.08	-0.33	Uncontaminated
	Zn	39.30	3.60	10.92	1.98	Moderate
Soil from a dumpsite in Aba, Nigeria[a]	Cd	1.40	0.15	9.33	1.828	Moderately contaminated
	Mn	48.12	1000	0.048	-3.442	Uncontaminated
	Cu	12.86	70	0.184	1.098	Slightly contaminated
	Cr	1.34	122	0.011	-4.920	Uncontaminated
	Ni	2.94	80	0.037	-3.709	Uncontaminated
	Pb	1.08	16	0.068	-3.101	Uncontaminated
	As	0.05	5	0.010	- 3.007	Uncontaminated
	Zn	16.04	132	0.122	-2.513	Uncontaminated
	Co	10.58	23	0.460	- 1.181	Uncontaminated

[a] Akobundu and Nwankwoala, 2013
Cn = mean concentration of metal in the soil; Bn = background concentration of metal;
CF = Contamination factor; Igeo = Geo-accumulation index

Table 5. Concentration (C^i) and potential ecological risk (E_r^i, RI) of heavy metals in the soil samples

	Code	Cr		Cu		Ni		Pb		Zn		RI	Risk grade
		C^{Cr}	E_r^{Cr}	C^{Cu}	E_r^{CU}	C^{Ni}	E_r^{Ni}	C^{Pb}	E_r^{Pb}	C^{Zn}	E_r^{Zn}		
Soil from inside the dumpsite (S1-S10)	S1	27.10	15.9	33.91	73.7	10.08	29.6	4.71	4.8	58.60	16.3	140.4	Low
	S2	74.95	44.1	76.43	166.2	14.38	42.3	10.74	11.0	512.67	142.4	405.9	High
	S3	31.80	18.7	36.14	78.6	32.45	95.4	4.60	4.7	44.18	12.3	209.7	Moderate
	S4	40.60	23.9	74.53	162.0	27.53	81.0	7.52	7.7	296.45	82.3	356.9	High
	S5	25.63	15.1	52.47	114.1	32.85	96.6	5.25	5.4	68.03	18.9	250.0	Moderate
	S6	27.63	16.3	26.08	56.7	23.55	69.3	7.08	7.2	38.31	10.6	160.1	Moderate
	S7	40.67	23.9	69.02	150.0	30.63	90.1	9.39	9.6	103.29	28.7	302.3	High
	S8	29.35	17.3	27.45	59.7	25.45	74.9	5.63	5.7	49.61	13.8	171.3	Moderate
	S9	18.73	11.0	36.92	80.3	27.30	80.3	27.07	27.6	18.11	5.0	204.2	Moderate
	S10	23.17	13.6	34.61	75.2	5.45	16.0	5.81	5.9	46.31	12.9	123.7	Low
	Average	33.96	20.0	46.76	101.6	22.97	67.6	8.78	9.0	123.56	34.3	232.5	Moderate
	Range	18.73-74.95	11.0-44.1	26.08-76.43	56.7-166.2	5.45-31.85	16.0-95.4	4.60-27.07	4.7-27.6	18.11-512.67	5.0-142.4	123.7-405.9	
Soil from outside the dumpsite (S11-S17)	S11	24.10	14.2	24.70	53.7	5.05	14.9	5.69	5.8	27.70	7.7	96.2	Low
	S12	23.90	14.1	25.96	56.4	20.83	61.3	5.91	6.0	35.61	9.9	147.7	Low
	S13	27.07	15.9	28.54	62.1	25.50	75.0	5.97	6.1	36.60	10.2	169.2	Moderate
	S14	21.97	12.9	24.94	54.2	26.30	77.4	5.35	5.5	30.21	8.4	158.3	Moderate
	S15	29.80	17.5	26.42	57.4	9.86	29.0	4.21	4.3	55.60	15.4	123.7	Low
	S16	21.67	12.7	24.52	53.3	19.23	56.5	4.51	4.6	47.00	13.1	140.2	Low
	S17	22.12	13.0	24.94	54.2	18.8	55.3	5.31	5.4	42.42	11.8	139.7	Low
	Average	24.37	14.3	25.72	55.9	17.94	52.8	5.28	5.4	39.30	10.9	139.3	Low
	Range	21.67-29.80	12.7-17.5	24.52-28.54	53.3-62.1	5.05-26.30	14.9-77.4	4.21-5.97	4.3-6.1	27.70 - 55.60	7.7-15.4	96.2-169.2	

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The Use of Dredged Sediment from the Watsongpeenong Canal with Paper Mill Residue to Produce Facing Bricks

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Abstract

The potential to use dredged sediment from the Watsongpeenong Canal and paper mill residue as the primary raw materials for producing facing bricks was studied in the laboratory. Dredged sediment and paper mill residue were chemically, mineralogically, and thermally characterized using X-ray fluorescence (XRF) and X-ray diffraction (XRD). To evaluate the effects of the contents of the paper mill residue on pore-forming, large amounts of paper mill residue, ranging from 5 to 7% by mass, were blended with dredged sediments and fired at 700 °C. The physical-mechanical properties, including dimensions and tolerances, wryness, deviation of the right angle, water absorption, compressive strength, stain, hole, rails, and cracks, as well as the microstructural properties of the facing bricks, were investigated. In addition, the heavy metals (Mn, Pb, Cd, and Cr) in the facing bricks were identified. The obtained results show that facing bricks with dredged sediments and 5% paper mill residue fired at 700 °C exhibited beneficial characteristics. Therefore, dredged sediment and paper mill residue are suitable for use as primary raw materials in the production of facing bricks.

Keywords: dredged sediments; paper mill residues; facing bricks

1. Introduction

One of the main goals of sustainable solid waste management is to maximize the ability to recycle and reuse materials. In Thailand, due to the vast population growth and urbanization, the volume of bricks and sediment produced has increased dramatically in recent years. Approximately 100 million tons of dredged sediment is generated worldwide every year. River sediment is derived from soil erosion and human activities. These sediments are excavated and placed in designated disposal areas near canals or rivers, leading to visual pollution. Consequently, these sediments need to be disposed of in an environmentally safe manner. Preserving natural resources is a matter of sustainable development to ensure sufficient resources for future generations. The reuse of sediment as a partial replacement for other natural resources in construction activities results in reduced demand for the extraction of natural raw materials, and it saves energy and resources.

Mezencevova et al. (2012) found that the average clay particle content in dredged sediment is 47%, which is higher than that found in natural clay soil (40%). The composition and continuous availability of sediment shows the feasibility of using it as a major component in the production of bricks. Many studies have examined the use of river and marine sediment from lakes, dams, and sewage for brick-making (Casado-Martínez et al., 2006; Collins, 1980; Hamer and Karius, 2002; Karpuzcu et al., 1996; Lafhaj et al., 2008; Romero et al., 2008; Samara et al., 2009; Torres et al., 2009). Haner and Karivs (2002) showed that 50-wt% of dredged sediment from Bremen Harbor, in Germany, can be used to produce bricks with industrial-scale experiment without a hazardous impact on the environment.

Paper mill industrial works produce high amounts of residue, and these firms typically lack a management program to recycle the residue efficiently. Rich in silicon, with levels of approximately 60.57%, Raut et al. (2013) found that paper mill residue could be used as a raw material in brick production. These results indicate that paper mill residue-bricks obtained from a mixture of paper mill residue, rice husk ash, and cement are light and possess a compressive strength that falls within the requirements of Indian Standards.

Facing bricks are solid masonry units mostly used for indoor and outdoor decoration. Traditionally, facing bricks are made from clay or similar naturally occurring earthy substances and subjected to a heat treatment at elevated temperatures via the “sintering process.” These components normally contain 48–70% silica by weight, 8–25% alumina by weight, and 4.5–31% fluxing agents (K_2O, Na_2O, and CaO) by weight.

The main objective of this study was to investigate the appropriate mix proportions using Watsongpeenong Canal-dredged sediment and paper mill residue for the production of facing bricks. Physical-mechanical properties and the microstructures of facing bricks produced from Watsongpeenong Canal-dredged sediment and recycled paper mills residue are discussed.

2. Materials and Methods

2.1. Characterization of dredged sediment and paper mill residue

Dredged sediment was obtained from the Watsongpeenong Canal, which is located in the Sam Khok District of Thailand’s PathumThani Province (14º 5.278’N 100º 32.728’E). The canal has a length of 1.7 km and flows into the Chao Phraya River. Paper mill residue was obtained from the Thai Paper Co., Ltd. The collected dredged sediment had agglomerated, and was therefore ground into smaller sizes using a grinding machine (TBSN-330). The particle-size distribution test was carried out for the dredged sediment and paper mill residue using a sieve size analysis (Retsch, AS 200 digit).

The chemical characterizations of the dredged sediment and paper mill residue were determined by X-ray fluorescence analysis (XRF, Bruker model,S8 Tiger). Crystalline minerals were identified using X-ray diffraction (XRD, Bruker AXS Model,D8-Discover).

2.2. Preparation of sediment specimen and sintering operation procedure

In this study, to evaluate the effect of dredged sediment from the canal for the production of facing bricks, three different proportions of dredged sediment were added to paper mill residue bodies: 100% dredged sediment and 0% paper mill residue; 95% dredged sediment and 5% paper mill residue; and 93% dredged sediment and 7% paper mill residue (% by weight) on a dry basis using a mixer machine (T.M.C. HYDRAULIC PRESSES No.1009). The sieved sediments and paper mill residues were blended to produce homogenous mixtures by using attrition milling, and a water content of 20% by mass was added to the mixtures to achieve adequate plasticity. The moist mixtures were molded under 76 Kgf/cm^2 of pressure using a hydraulic press to produce square-shaped specimens (40 mm x 65 mm x 125 mm). The shaped specimens were dried naturally for 24 hours. Next, using a tunnel kiln, dried bricks were loaded onto a kiln car with dwell at 700 °C for 4–5 days, but variations occurred depending on production schedules. The sample preparation process is summarized in Figure 1.

2.3. Characterization of fired facing bricks

Dimension and tolerance, general appearance, wryness, deviation from the right angle, stain, hole, rail, and cracks were determined in terms of Thai Industrial Standard 168-2546 and 243-2520 test methods. For the water absorption test, the specimens were dried in a 110 °C oven for 24 hours and then allowed to cool in the air until their weight was constant (dry weight, W_d). Then, the specimens were immersed in water for 24 hours at room temperature (wet weight, W_w). The water absorption was calculated using the formula $[W_w – W_d / W_d]$ x 100. The compressive strength was determined using a compression machine (Amsler 20 ton) on test samples of full-brick size (6.5 x 12.5 x 4.0 cm^3). The micro-structures of the sintered specimens were examined using scanning electron microscopy (SEM, JSM-6400). The crystalline phases of the facing bricks were also identified via X-ray diffraction (XRD, Bruker D8) analysis.

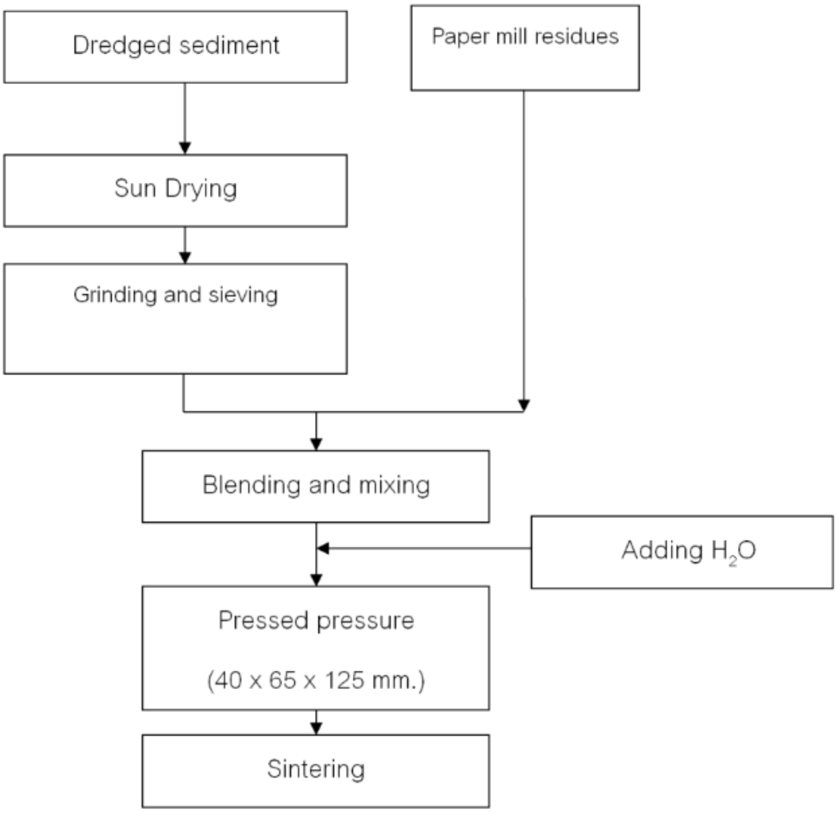

Figure 1. The process of facing brick production

3. Results and Discussion

3.1. Characterization of raw materials

The data on the chemical composition of the raw materials in oxide form is presented in Table 1. We can see that SiO_2 is the predominant oxide in the dredged sediment, followed by Al_2O_3, Fe_2O_3, K_2O,P_2O_5, MgO, and CaO. A significant amount of Fe_2O_3 (4.53%) in the clay contributes to the reddish color of the fired bricks. Paper mill residue exhibits a typical composition primarily constituted of CaO, followed by SiO_2, Al_2O_3, Fe_2O_3, K_2O, P_2O_5, and MgO.

The concentration of heavy metals in the dredged sediment and paper mill residue is shown in Table 1 and indicates that the amounts of heavy metals in the raw materials are below the thresholds prescribed by the Soil Quality Standard of Pollution Control Department (2004). Thus, dredged sediment and paper mill residue can be used as raw materials for producing facing bricks without worries of toxicity.

Table 1 Chemical compositions of dredged sediment and paper mill residue

Properties (%)	Dredged sediments	Paper mill residues	Heavy metals standard (%) (PCD,2004)
SiO_2	43.5	0.038	
Al_2O_3	15.5	0.01	
Fe_2O_3	4.53	>0.01	
P_2O_5	0.10	-	
CaO	0.98	0.12	
K_2O	-	-	
TiO_2	0.65	-	
MnO	0.06	-	0.18
Pb	-	-	0.04
Cd	-	-	>0.01
Cu	-	0.09	-

* Soil quality standards for residential and agricultural use (PCD, 2004)

Figures 2 (a) and (b) present the XRD patterns of dredged sediment and paper mill residue. The results show that quartz (SiO_2) is the main mineral phase of dredged sediment, followed by montmorillonite $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$ and greenalite ($Fe_3Si_2O_5(OH)_4$, respectively. X-ray diffraction analyses were also performed to identify the amorphous or crystalline phase of paper mill residue. As shown in Fig. 2 (b), the intense broad peak observed for paper mill residue samples indicates the amorphous nature of silica (Raut et al., 2013).

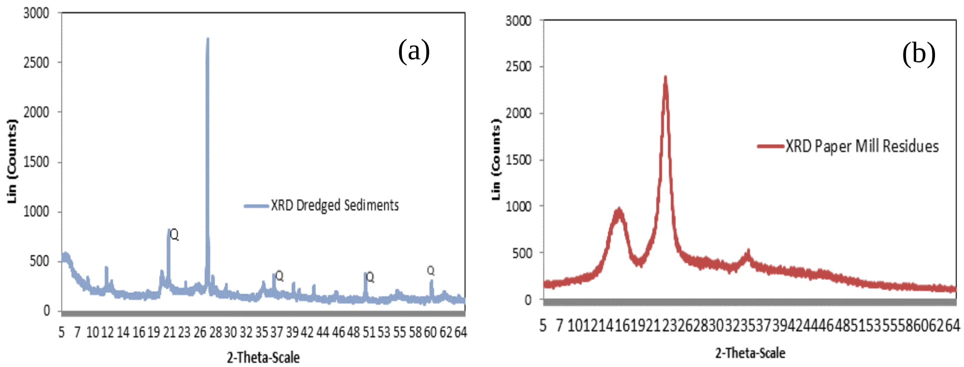

Figure2.X-ray diffraction patterns of (a) Dredged Sediment and (b) Paper Mill Residue

3.2. Characterization of fired facing bricks

3.2.1 Physical-mechanical properties

The dimensions and tolerance of fired bricks were analyzed using three approaches. First, the width of the fired bricks, compared with standard bricks, was 125±2.5 mm. Second, the length of the fired bricks, compared with standard bricks, was 65±2.5 mm. Finally, the height of the fired bricks, compared with standard bricks, was 40±2.5 mm. The standards of wryness and deviation from the right angle should be less than 2.5 mm and 3.0 mm, respectively. The results of dimension and tolerance, wryness, and deviation from the angle showed that fired facing bricks made from dredged sediment and paper mill residue satisfied the requirements of TIS168-2546.

The general appearance of the facing bricks is shown in Figure 3. The results indicate that all facing bricks with 0% paper mill residue (100% dredged sediment) were broken, but no cracks or broken pieces were found on facing bricks produced with 5% and 7% paper mill residue.

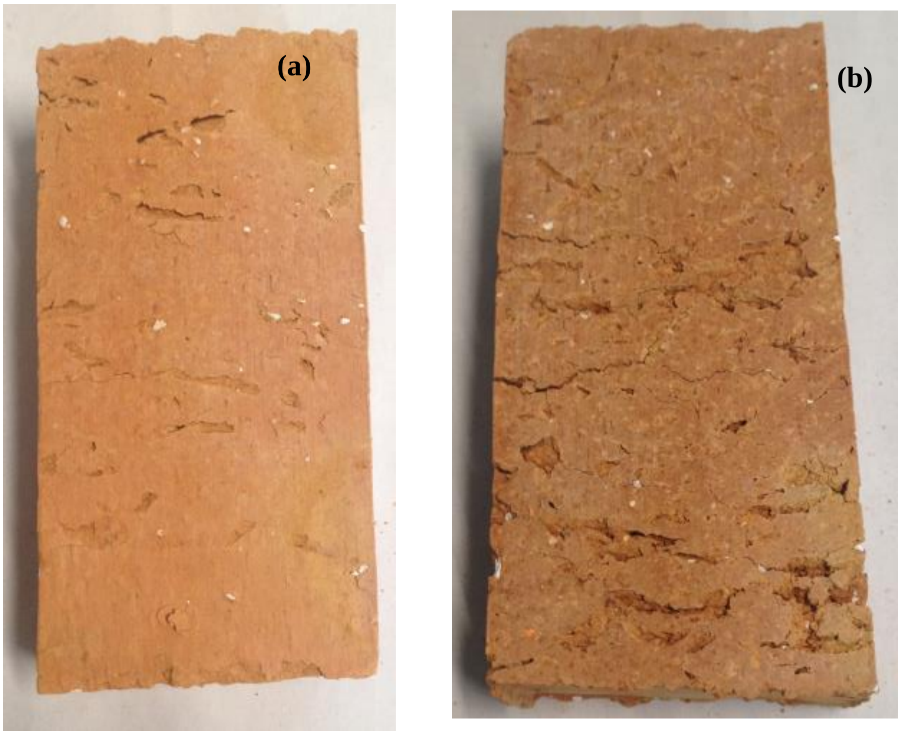

Figure 3.General appearance of facing bricks: (a) facing bricks with 5% paper mill residue and (b) facing bricks with 7% paper mill residue

Staining of the fired bricks was observed in both sample series, as shown in Figure 4. Staining was due to the ionic compound caused by the neutralization reaction of an acid and a base in the bricks when water was solvent. Water-soluble salts led to the formation of a white stain during the drying process. Stains could become permanently fixed during drying and adversely affect the aesthetic appearance of the bricks (Mezencevova et al., 2012); thus, fired facing bricks with 5% and 7% paper mill residue do not meet the stain requirements for good quality facing bricks

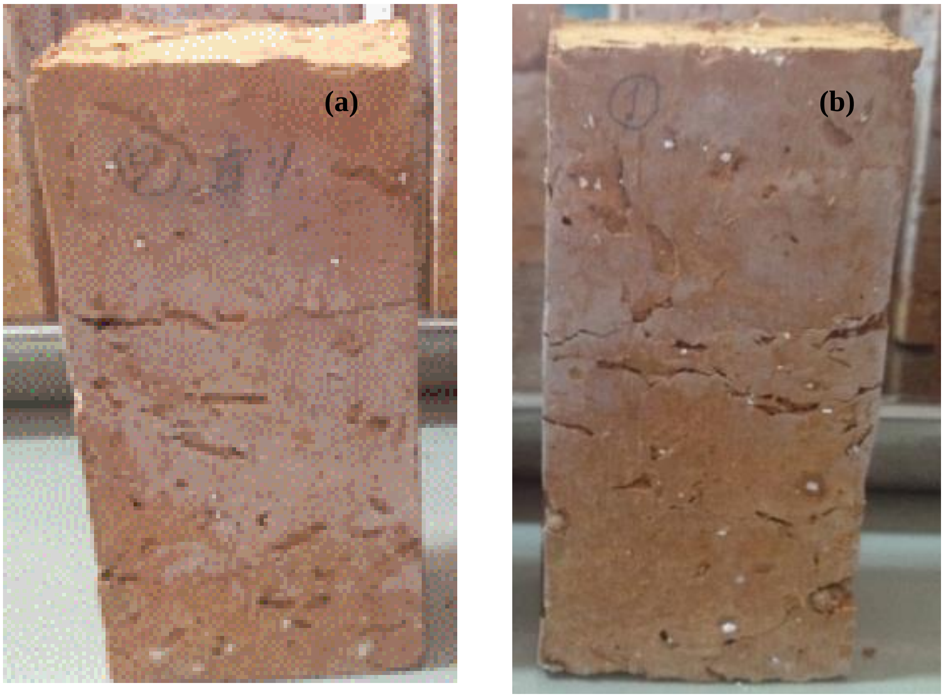

Figure 0.Stain on: (a) facing bricks with 5% paper mill residue and (b) facing bricks with 7% paper mill residue

Holes, rails, and cracks are crucial identity index elements of facing bricks. As shown in Figure 5, according to TIS168-2546, for good quality facing bricks, the fired bricks' net cross-section area must be greater than 75% of the gross cross-section area. In the present study, the net cross-section area of fired facing bricks with 5% and 7% paper mill residue were 98.30% and 94.56%, respectively. In addition, the rails and cracks in fired facing bricks did not exceed Thai standards. Thus, fired bricks with 5% and 7% paper mill residue meet the hole, rail, and crack requirements for good quality bricks.

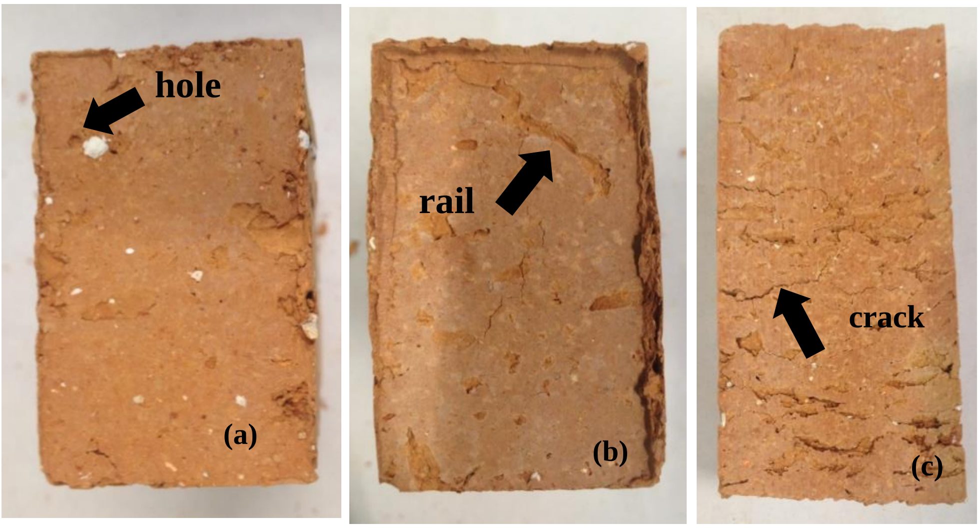

Figure 5. (a) Hole (b) Rail and (c) Crack

Water absorption is an effective index for evaluating the quality and density of building bricks. Water absorption is based on the amount of open pores in sintered specimens. As the results in Figure 6 show, the water absorption values of fired facing bricks with 5% and 7% paper mill residue were 17.25% and 19.33%, respectively, which is less than 22%, as required by TIS168-2546. Thus, both sample series of fired facing bricks satisfy the TIS standard.

Compressive strength is an important factor when using recycled products as construction material. According to TIS168-2546, the compressive strength of good quality bricks should be higher than 17 MPa. In Figure 7, the compressive strength of fired facing bricks with 5% and 7%paper mill residue is 21.84MPa and 23.66 MPa, respectively, which is compliant with Thai standards for facing brick products.

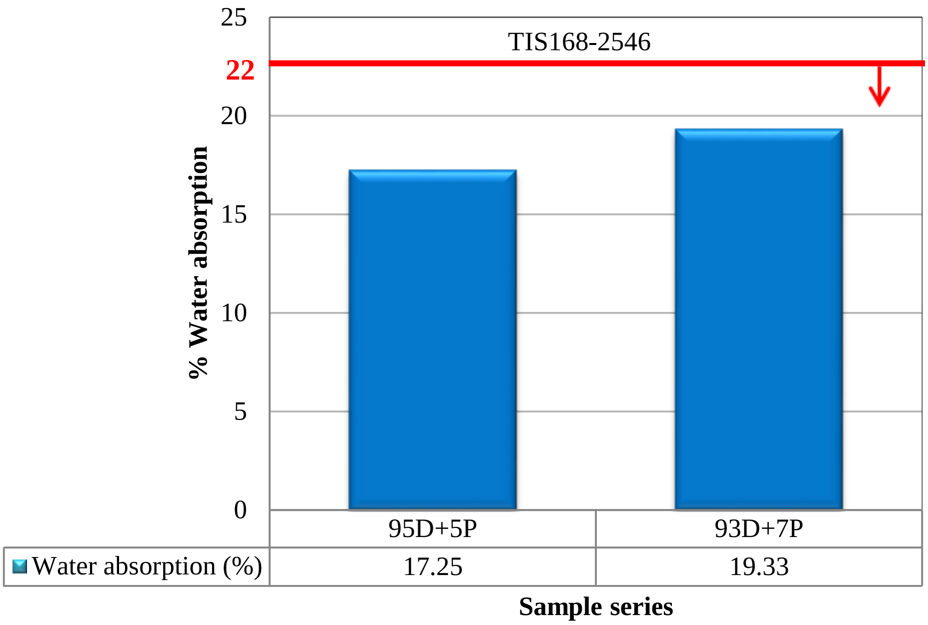

Figure 6.Water absorption of facing bricks with 5% and 7% paper mill residue D: Dredged sediment, P: Paper mill residue)

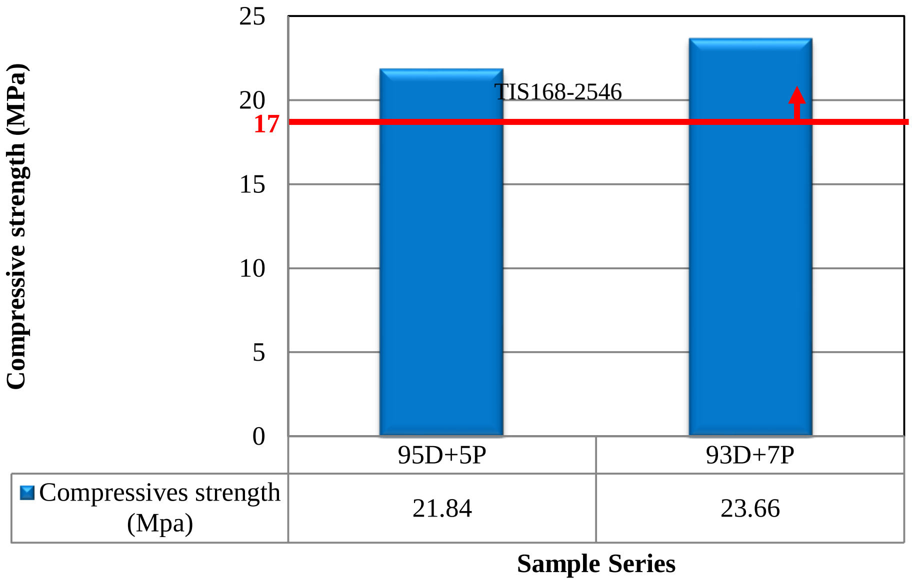

Figure 7.Compressive strength of facing bricks with 5% and 7% paper mill residue (D: Dredged sediment, P: Paper mill residue)

3.2.2Micro-structure and phase analysis

Figures 8 (a), (b), and (c) present the SEM micrographs of facing bricks with 0%, 5%, and 7% paper mill residue, respectively. As shown in Figure 8 (b), macro-pores and smaller particles were observed. Facing bricks with 7% paper mill residue showed the presence of a fibrous nature structure. With a decrease in the proportion of dredged sediment in facing bricks, the organic matter content dropped to a lower level. Therefore, as shown in Figure 8 (b), the macro-pores are changed into an arrangement of smaller particles. In addition, the porosity of facing bricks is related to water absorption and compressive strength. Greater levels of porosity lead to decreased compressive strength and increased water absorption (Raut et al., 2013).

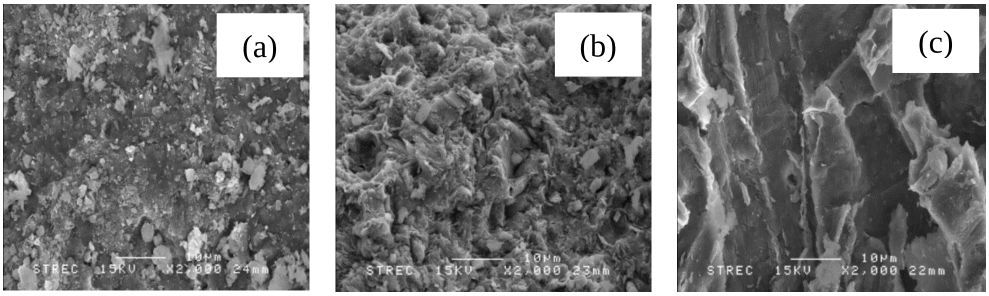

Figure 8.SEM micrographs of the fired bricks: (a) 0% paper mill residue, (b) 5% paper mill residue, and (c) 7% paper mill residue

The XRD patterns of fired bricks are presented in Figure 9; quartz (SiO2) is the main component, and traces of anhydrite ($Ca(SO_4)$),microcline maximum ($K(Si_3Al)O_8$), and muscovite 2M1($KAl_3Si_3O_{10}(OH)_2$) are also detected in fired facing bricks. Fired facing bricks with 5% and 7% paper mill residue revealed other peaks of magnetite (Fe_3O_4).

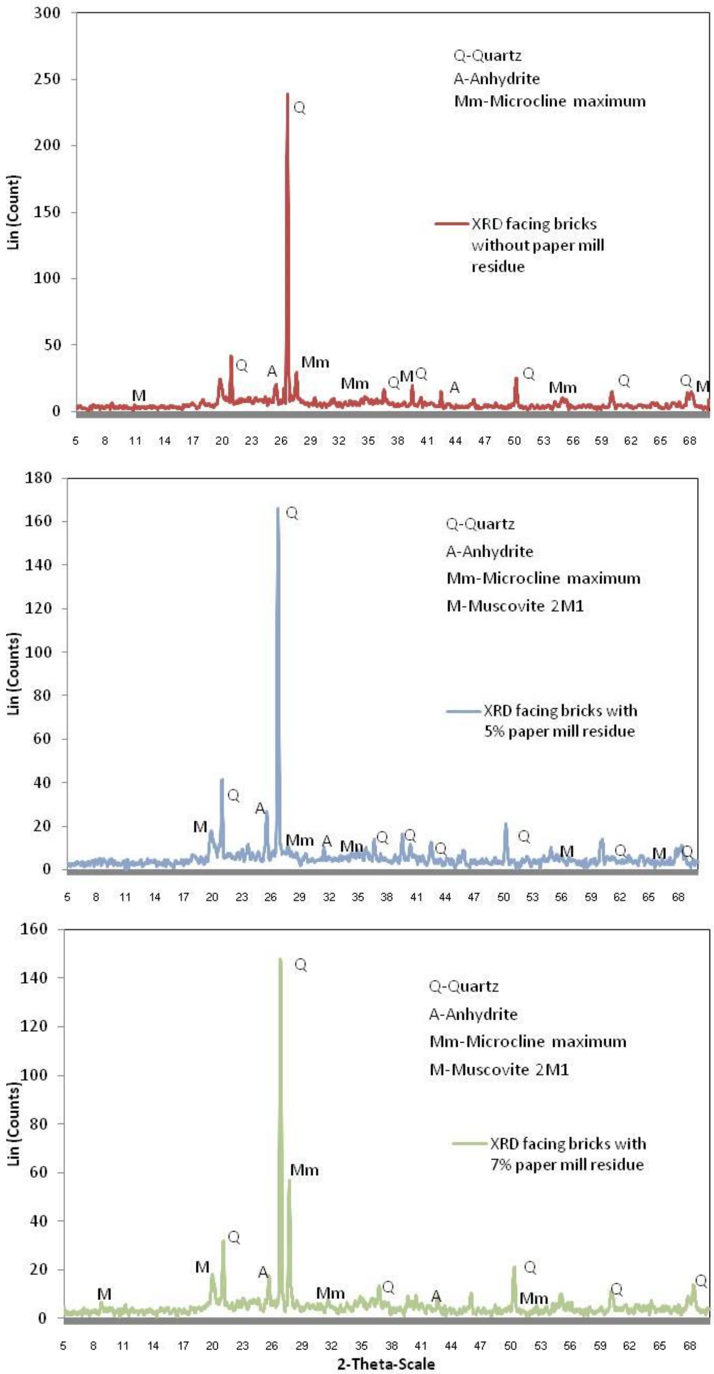

Figure 9.X-ray diffraction patterns of: (a) facing bricks without paper mill residue, (b) facing bricks with 5% paper mill residue, (c) facing bricks with 7% paper mill residue

3.2.3 Environmental impact

The leaching of heavy metals is the major negative environmental impact of fired bricks containing urban river sediment. Table 2 shows the presence of Mn, Pb, Cd, and Cr in specimens. The results indicate that the concentrations of these heavy metals were below the thresholds prescribed in PCD (2004) regulation limits (Mn 1800 ppm, Pb 400 ppm, Cd 37 ppm, and Cr 300 ppm).

Table 2 The concentrations of heavy metals in fired facing bricks

Properties	Facing bricks without paper mill residue	Facing bricks with 5% paper mill residue	Facing bricks with 7% paper mill residue	Heavy Metals standard (PCD,2004)*
MnO	913 PPM	934 PPM	901 PPM	Mn 1800 PPM
PbO		32.60 PPM	32.4 PPM	Pb 400 PPM
Cd		-	-	Cd 37 PPM
Cr_2O_3	128 PPM	132 PPM	107 PPM	Cr 300 PPM
CuO	68.30 PPM	69.70 PPM	69.10 PPM	
ZnO	152 PPM	157 PPM	155 PPM	

* Soil quality standards for residential and agricultural use (PCD, 2004)

4. Conclusion

This study investigated the properties of dredged sediment and paper mill residue used for the production of facing bricks. The obtained results indicate that dredged sediment from the Watsongpeenong Canal and paper mill residue can be used as raw materials to produce facing bricks that comply with the requirements of TIS168-2546. Therefore, using dredged sediment and paper mill residue could increase pore volumes in the structures of facing bricks and provide environmental benefits by reducing the use of natural soil. Even though staining, holes, rails, and cracks are found on the surface of the bricks, which could affect their aesthetic value, to make these facing bricks more attractive for decoration, more study is required to develop mitigating strategies, including stain removal, coloring, and decorative designs or patterns on the bricks.

Acknowledgements

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An Assessment of Climate Variability on Farmers' Livelihoods Vulnerability in Ayeyarwady Delta of Myanmar

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Abstract

This study identifies and locates the degree of farmers' household vulnerability in Ayeyarwady Region, Myanmar. Fifty-nine farmers' households were purposely selected for conducting questionnaire survey together with the secondary data conducted in 2016. In order to identify the variability of household vulnerability, the Livelihood Vulnerability Index (LVI), which was based on five capitals as identified in Sustainable Livelihoods Framework (SLF) was adopted and modified according to the context of the area. The vulnerable score ranged between 0 (low vulnerable) and 1(high vulnerable) and the overall LVI result obtained was 0.442, therefore, the study area was identified as the moderate vulnerability. In terms of capitals, the households were most vulnerable in terms of financial capital with the value of 0.530, followed by the natural capital (0.515), and the physical capital (0.418). The households were classified into three groups: low, moderate, and high vulnerable groups to understand where and who are likely to need special attention. The survey found that the vulnerability of each asset they suffered was different across the township. It is clearly seen that in order to reduce the vulnerability of farmers' livelihood, agricultural loan, divesifying livelihood activities, farm technology and inputs, infrastructure and enhancing their knowledge to crop failure should be provided.

Keywords: livelihoods; vulnerability assessment; capitals; climate variability; Ayeyarwady region

1. Introduction

The impact of climate variability is being an important issue worldwide in the 21st century. The global temperature will increase between 1.8°C and 4°C above the levels observed from 1980-1999 during the period of 2090-2099 (IPCC, 2007). Climate change is expected to have adverse effects on a various sectors especially the agricultural sector and smallholder farmers (Brown et al., 2012; Kurukulasuriya and Rosenthal, 2003; Hurvey et al., 2014).

Rice is central to the economy and food security of Myanmar (Denning et al., 2013). It is not only dependent on about 69 % of rural farmers but also one of the main economic activities that support 31% of GDP share in 2014 (FAO/WFP, 2016). The sown area of rice in Myanmar is about 7.17 million ha. However, 1.87 ha (26%) of the total rice area is under irrigation, while the rest is under rain harvesting system, making it vulnerable to climate change (CSO, 2016). The climate-induced extreme are being felt through the loss of agricultural productivity that hits the poor and smallholder farmers hardest. Due to the Cyclone Nargis in 2008 it damaged 4 million hectares of rice paddy field and the cost of damage was over US$ 4 billion (MOALI, 2015). The severe flooding in 2015, damaged 20% of the country's cultivated areas, and the estimated cost of damage was US$ 1.51 billion (World Bank, 2015).

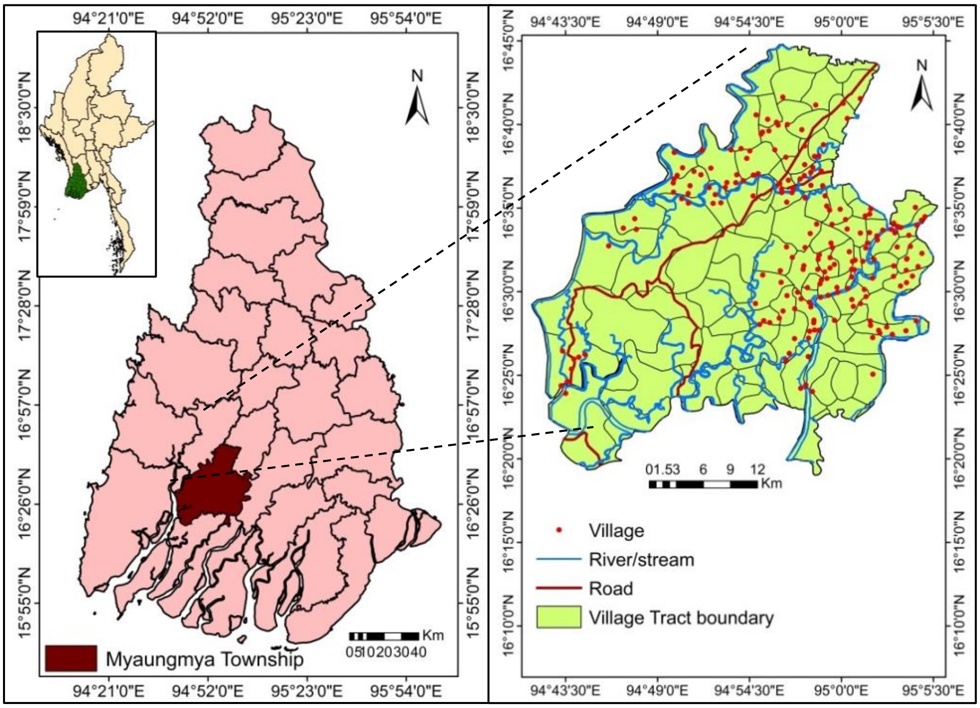
In recent year, climate change is being widely discussed and numerous researchers have used a variety of methods to assess vulnerability (Sullivan, 2004; Vincent, 2007; Hahn et al., 2009). In order to examine the climate change vulnerability, Livelihood Vulnerability Index (LVI) was first used by Hahn et al., (2009) in Mozambique and later it has applied in other countries. The LVI uses multiple indicators to assess exposure to natural disasters and climate variability, social and economic characteristics of households that affect their adaptive capacity, and current health, food, and water resource characteristics that determine their sensitivity to climate change impacts.

The objectives of the study are to identify the degree of farmer's livelihood and vulnerability in response to the impacts of climate change and variability and to locate the risk of household vulnerability map in Myaungmya Township, Ayeyarwady Region. Understanding these rural farmers vulnerability is to provide for development practitioners to understand in a way in contributing to response future climate change at the household level to the community level. The findings of the study can help to develop the effective adaptation measures to cope with climate change impacts on livelihoods of farmers and will contribute to policymakers and other stakeholders for effective management in response to future climate change.

2. Materials and Methods

2.1 Study area

This research work was carried out in Myaungmya Township, located on the eastern bank of Ngawun River, one of the townships of Ayeyarwady Region in Myanmar. It is located at 16°19´ and 16°44´ north and 94°40´ and 95°05´ east, covering an area of 1,152.23 sq.km, with a total population of 291,390 and 18,328 farmers households in 2014 (Census, 2015). Township is not only the major rain-fed rice area but also the highest irrigated rice area in Ayeyarwady Region, providing 69% of township's labour force (MOALI, 2015). Although the township has not been documented natural disaster since decades, it has recently experienced by the flood brought by climate extreme resulting in affecting agricultural area. The weather is tropical monsoon climate with annual mean temperature was 27.08°C, the hottest month in April with a mean temperature of 29.04°C and the coolest month in January with 22.89°C. The average annual rainfall was 2,844 mm (DMH, 2016). Most of the area is flat alluvial plain with the elevation of about 4 m above sea level (Figure 1).



Source: Myanmar Information and Management Unit.

Figure 1. Location of the Study Area: Myaungmya Township, Ayeyarwady Region

2.2 Data and Analytical Tools

Due to the limitations of the data, the population of each village and district and logistics. The study area was divided into a grid, each grid of 11 x 11 km. The grid that grows rice more than or equal to 50% is selected. Thus the samples area has 59 grids. Besides the authors want to study the properties of soil, but not shown in this study. In addition, farmers are in the same grid have similar farming pattern and environments. Therefore, farmer in the grid was selected for interviews. Structured questionnaires were used, which consisted of five sections; socio-economics, farm characteristics, institutional supports, farmer's knowledge on climate change, and adaptation options. The survey was carried out during February and May 2016. Data were proceded and processed in Excel 2007 and SPSS 18, and then outputs were displayed in tables and graphical forms.

2.3 Calculating the Livelihood Vulnerability Index

To identify the farmers' household vulnerability and to what levels they are vulnerable, Livelihood Vulnerability Index developed by Hahn et al., (2009) was applied incorporating with five capitals/assets as mentioned in Sustainable Livelihoods Framework (DFID, 1999). It can be used for assessing local vulnerability and adaptive capacity through analysing the level of five assets. The more assets the farmer possess, the less they are vulnerable.

The indicators used in this study were developed from literature (Sisay, 2016; Shah et al., 2013; Can et al., 2013; Vincent and Cull, 2010; Hahn et al., 2009). These were modified under five different assets of farmer's household in Sustainable Livelihood Framework, which are human, natural, physical, financial and social capital. Each capital is considered as an equal contribution. First, sub-components shown in table 1 were transformed into appropriate measurements such as ratios, percentages, and indices. Second, since all the indicators were measured in different scales, each of them was necessary to standardise as an index. To calculate the index, the equation used in the Human Development Index in equation (1) was applied. In the case of some indicators that reduce the vulnerability level, the inverse index was used eg. education. The maximum and minimum values were also transformed in equation (1).

$$Index_{S_t} = \frac{S_t - S_{\min}}{S_{\max} - S_{\min}} \tag{1}$$

Where S_t is the value of sub-component for township *t*, S_{min}, S_{max} are the minimum and maximum values respectively. Third, to estimate the indices for each livelihood asset, the average of the standardised index of each component was calculated by using equation (2).

$$M_{tj} = \frac{\sum_{i=1}^{n} index_{s_t i}}{n} \tag{2}$$

Where M_{tj} is the value of major component for township *t*, $index_{sti}$ represents the value of sub-component in major component *M*. Finally, the balanced weighted average of all components was generated for final LVI score for the community. The weights of the each component are determined by the number of indicators of such components equation (3).

$$LVI_t = \frac{\sum_{i=1}^{5} W_{Mj} M_{tj}}{\sum_{j=1}^{5} W_{Mj}} \text{ (OR) } LVI_t = \frac{W_H H_t + W_N N_t + W_P P_t + W_F F_t + W_S S_t}{W_H + W_N + W_P + W_F + W_S} \tag{3}$$

Where, LVI_t is the Livelihood Vulnerability Index of the township *t*, W_{Mj} is the weight value of major component *j*, $W_H + W_N + W_P + W_F + W_S$ are the weight value of asset *H, N, P, N,* and *S*. The LVI is scaled from 0 (least vulnerable) to 1.0 (most vulnerable).

Table 1. Contributing factors of major components and subcomponents of livelihood assets used in Livelihood Vulnerability Index

Capitals	**Major Components**	**Subcomponents**
Human capital	Health	Households with members suffering chronic illness, distance to health care
	Knowledge and skill	Education of household heads, farming experience of households heads, ownership of TV, radio, mobile phone, access to awareness raising
	Livelihood strategies	Crop diversification, households depending on agriculture as a major source of income
Natural capital	Natural Resources	Landholdings, barrier to access land, growing third crop, salt water intrusion, access to non-farm products, crop area affected by flood
	Climate variability and natural disaster	Households perception on climate variability
		Mean standard deviations of monthly mean maximum, minimum temperatures and precipitation
Social capital	Demography	Dependency ratio, age of household head, family members
	Social networks	Households participation in community, contribution in community, voting, membership in organisation
Financial capital	Finance and income	Income from rice sale, household expenditure, saving, credit loan, debt, and remittances
Physical capital	Transportation	Distance to agricultural market, ownership of motorbike,
	Production means	Water pump, trailer, farming equipment, application of fertiliser, extension service

Source: Hahn et al., (2009), Can et al., (2013) and Sisay (2016) but some indicators are modified to the context of the study area.

3. Results and Discussion

3.1 General Characteristics of the Sampled Households

The average age of the sampled farmer was 51 years old while the youngest farmer was 26 and the oldest one was 70 years old. Most of the sampled household heads (over 80%) were active working age group of 33-60 years. In the interviewees, 88.14% were male-headed households and 11.86% were female-headed households. The education level of sampled farmers was generally low whith the average schooling year of 5.92, which represents the middle school education. The average household size of farmer was 4.93 members, which was higher than the average household size of Myanmar (4.4). The members of the household, having 4-6 family members were the highest number (66.10%). The average dependency ratio of sampled households was 58.78%, which was higher than the country average (52.5%) and 37.29% of sampled households was highest dependency ratio (over 60). The landholding of respondents ranged from 0.40 to 38.45 ha and the average landholding size was 7.18 ha, which was higher than the country average of 2.4 ha (CSO, 2016). About 75% of sampled households had a farming experience over 20 years (Table 2).

3.2. Climate Hazard in Agriculture of Myaungmya Township

Myanmar is prone to multiple natural hazards such as cyclones, floods, drought, landslides and earthquakes. Previously, a cyclone occurs about once in every three years. However, cyclones have crossed the Myanmar coast every year since the year 2000. Since the profound flooding brought by Cyclone Komen in 2015, the MOAI reports that 80% of the cultivated area in Ayeyarwady Region was most affected one, resulting in 100,000 ha of cultivated land was away (MoAI, 2016).

Along with cyclone flood disaster occured at the end of July and August in 2015, when most of the rain-fed rice have already been sown or transplanted and are in the early growth stage. In fact, about 25% of sampled respondents reported that their cultivated area was affected by it in which about 14% of the sampled farm households affected 1% to 20% of their rice area and 10% of farmers responded 21% to 50% of rice area were damaged in Myaungmya Township. However, 98% of affected household replanted rice soon after the water receded and the rest could not grow rice again due to financial difficulties.

Table 2. Characteristics of sampled farmers' household in Myaungmya Township

Characteristics	Categories	**Frequency**	**Percent**	**Mean**	**Min**	**Max**
Gender	Female	7	11.86			
	Male	52	88.14			
	Total	59	100			
Age (year)	18-32	1	1.69	26.00	26	26
	33-46	18	30.51	40.50	35	46
	47-64	31	52.54	54.59	47	64
	>64	9	15.25	66.17	65	70
	Total	59	100	50.98	26	70
Education (year)	<5	19	32.2	3.84	3	4
	5-8	36	61.02	6.58	5	8
	9-10	4	6.78	9.75	9	10
	Total	59	100	5.92	3	10
Household size (person)	<4	9	15.25	2.67	2	3
	4-6	39	66.1	4.64	4	6
	7-9	10	16.95	7.60	7	9
	>9	1	1.69	10.00	10	10
	Total	59	100	4.93	2	10
Dependency ratio (%)	0	10	16.95	0.00	0	0
	1-30	15	25.42	21.29	13	25
	31-60	12	20.34	36.66	33	50
	> 60	22	37.29	123.11	67	500
	Total	59	100	58.78	0	500
Land holdings (hectare)	0.01-5.00	27	45.76	2.74	0	4
	5.01-0.00	20	33.9	6.87	5	10
	> 10.00	12	20.34	17.71	10	38
	Total	59	100	7.18	0	38
Farming experience (year)	1-10	7	11.9	7.71	2	10
	11-20	8	13.6	19.00	15	20
	> 20	44	74.6	35.05	22	50
	Total	59	100	29.63	2	50

Source: Field survey, 2016

3.3. The Farmers' Vulnerability Index: The Result of LVI

As single asset or capital generates multiple benefits (DFID, 1999), once deterioration of an asset can affect other assets. Although it is clear that those who depend most on natural capital are likely to be most affected by climate change, the level of vulnerability may differ, depending on the capitals which individual possess.

Since the overall result of LVI for the study area is 0.442, this result indicates the study area as a moderate vulnerability to the climate-related impacts. Figure 2 shows that financial capital has the largest contribution to the vulnerability of the farmers with a value of 0.530, followed by natural capital (0.515), physical capital (0. 418), human capital (0.389) and social capital (0.337).

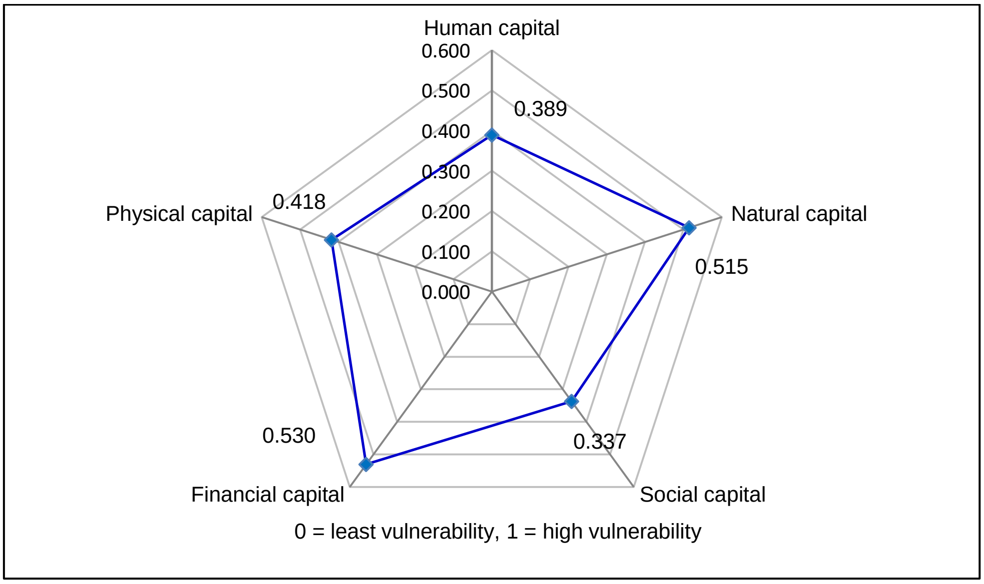


Figure 2. Spider graph showing the vulnerability of sampled farmers in terms of five capitals in 2016

3.3.1 Financial Capital Vulnerability

The financial capital is the most determinant to the vulnerability of sampled households with a value of 0.530. The result is in agrrement with the study of Vincent and Cull (2010). Among the factors having the highest effect on farmers' vulnerability is that 84.75% of the farmer households did not get remittances from any of family member since they did not work at another place (Appendix A). Other factors contributed to their vulnerability are an agricultural loan, the saving and the limited income. About 66% of the interview households had not been provided with enough credit from the Myanmar Agricultural Development Bank (MADB) for their investment in time. The loan plan is allocated for a famer household at the rate of

100,000 kyats/acre (214 USD/ha) for up to 10 acre (4.01 ha). The estimated cost of rice production was about 500 USD/ha in 2016. Adding the not enough income from rice sale for the household expenditures, 54.24% of participants earned with per capita rice income less than 1300 USD. Authough the annual per capita rice income of a farm household estimated about 2100 USD while the estimated per capita household expenditure was about 600 USD, the farmers with small holding did not have enough expenditure from rice sale. Moreover, the late provision of credit loan is one of most challenge of farmer facing and leads to late deliveries of farming inputs, which is supported by the study of Makondo et al., (2014). Hence, the limited institutional loan forces to use private lender (Tewari et al., 2014). A 59.30% of respondents had no saving last year while 37.29% of sampled farmers had not repaid money they borrowed. This can lead to a vicious cycle of debt for them, households having problems in response to the difficult situation. Therefore, the financial accessibility of a farmer is the most significant factor of the household's asset, suggesting that high access to credit have high possibility to reduce the vulnerablility. The finding is consistent with the studies conducted by Can et al., (2013) and Shewmake (2008).

3.3.2 Natural Capital Vulnerability

The second most affected asset of sampled households is the natural capital with the value of 0.515. Survey results show that the contributing sub-components for high vulnerability were farmers' opinion on climate variability, natural resources and access to non-farm products. According to interview, there has been a decrease in rainfall and changes in rainfall pattern in the last ten years, which alters the agricultural practices. About 86% of sampled households reported there has been an increase in temperature and 84.7% of respondents recounted that there has been a decrease in rainfall. About 73% of farm households also confirmed that untimely rain and flooding increased in the last 10 years. Their perception on climate change is consistent with observed data carried out by DMH. For example, flooding in 2015 which contributed to more vulnerable for some farmers (25.4 %) because they have replanted their rice field resulting in more vulnerable in terms of financial capitals. The second generating factor, the sampled households who did not grow the third crop (75.27%) due to lack of irrigation and saline intrution, suggesting that the adaptation like the irrigation facility and farm technology would reduce the vulnerable degree (Dechassa et al., 2016). Furthermore, collecting non-farm products such as fruits and vegetables, fishing, processing betel nuts etc. also play an important role in generating the degree of vulnerability. A majority of households (74.58%) have not collected such kind of natural resources, suggesting that diversification of income sources would be another adaptation option to reduce vulnerability (Urothody and Larsen, 2010; Lindenberg, 2002).

3.3.3 Physical Capital Vulnerability

The third affected component, the physical capital has the value of 0.418. The most affected factor that contributes to farmer vulnerability is not having the extension service from other organisation apart from Ministry of Agriculture Service (MAS). In addition, 83.10% of respondents did not own the small trailer, which is convenient for the transportation of commodities and people as the study area has limited infrastructure. Another factors contributed to vulnerability are fertiliser application and water pump owned, 38.89% of interview farmers applied less amount and misuse of chemical fertilisers than it is suggested by MAS. It proposes that providing extension service and quality fertiliser play a vital role to recover from the losses against flood. The finding is consistent with the studies of Makondo (2014) and Can et al., (2013). Since the study area is endowed with rivers and streams, the farmers also grow irrigated rice, hence the water pump is an important asset of the farmer households. However, 35.60% of households had not owned it and they have to pay charges for using others' owned. Additionally, the higher distance to the agricultural sale from the production area also creates the farmer more burden relating to transportation cost and time, which is also triggered by a shortage of road infrastructure. It also suggests that physical accessibility is important for the market access of produces (Makondo et al., 2014; Shah et al.,2013).

3.3.4 Human Capital Vulnerability

The human capital has the low effect on farmers' vulnerability with a value of 0.389. In the case of health problem, people have to go to the township hospital where is relatively far from their place of residence. This can be one of the factors that make the farmers' households vulnerablity with the value of 0.424. It describes that the health facilities should be more extended since the study area has poor infrastructure. Access to information and knowledge, although 77.97% of samples did not own radio, the vast majority of respondents knew the information from television. However, 79.66% of interviewees reported that they did not get the knowledge sharing or raising related to how to cope with climate-related hazards or agricultural related problems which were usually delivered by the extension specialist and some meteorologists. The mass media, therefore play an important role in public awareness (Manh et al., 2016; Nazari and Hassan, 2011). The livelihood strategies of the farm households mainly grow rice as double cropping; rain-fed rice and irrigated rice. The irrigated rice would contribute to reducing vulnerability than those who grow only rain-fed rice. However, majority of the sampled households mainly rely on rice cultivation that could be more vulnerable than those who have the various form of income-generating sources.

3.3.5 Social Capital Vulnerability

The least effect on household vulnerability are the social capital with a value of 0.337, due to the less proportion of female-headed household (11.90%) and housholds' contribution in community affair (27.10%) which compensate the vulnerable level. However, the age of the sampled household heads outweighed to the old age, making more vulnerable as the younger the age, the less vulnerable they are. The households with not participating in community affair (57.60 %) and one of the households' member not affiliating any organisation (52.54%), generate the relatively high vulnerability. However, they reported that household members are ready to participate or contribute some form of assistance such as labour exchange or cash aid that helps the recovery of a household in a needy situation. According to the Myanmar context, membership in the organisation is less popular because of over 50 decades' military rule and they are now becoming more participation in farmer's organisation under the new civilian government powered in 2016. It suggests that the farmers are needed to strengthen their knowledge on agriculture and climate through membership in the organisation. Additionally, the household family member had a relatively effect on their vulnerability (0.367). It is supported by the study of Senbeta and Olsson (2009), comfirming that large family size are mostly affected by the climate change event.

Table 3. LVI values by household capital and the vulnerable group of sampled farmers in Myaungmya Township in 2016

Household Assets	**Low Vulnerable Group (0-0.333)**		**Moderate Vulnerable Group (0.334-0.666)**		**High Vulnerable Group (>0.666)**	
	LVI Value	Affected Household (%)	LVI Value	Affected Household (%)	LVI Value	Affected Household (%)
Human capital	0.252	27.12	0.433	71.19	0.766	1.69
Natural capital	0.000	0.00	0.515	100.00	0.000	0.00
Physical capital	0.269	38.98	0.480	52.54	0.719	8.47
Social capital	0.258	52.54	0.424	47.46	0.000	0.00
Financial capital	0.229	5.08	0.404	55.93	0.751	38.98

3.4 Mapping Vulnerability

In order to prepare and provide basic amenities and access to resources to response for possibility of future climate risks at the household, the level of vulnerability would be classified into three categories. Since the vulnerability index of a sampled farmer is assigned between 0 and 1, the low vulnerability (0-0.333), the moderate vulnerability (0.334-0.666), the high vulnerability (>0.666) could be ranged (Table 3). However, only 5.08% of farmers' households are suffered low vulnerability, 94.92% in moderate vulnerability, and none of the respondents is high vulnerable (Figure 3 A). Although the high group was not affected by social capital vulnerability, all the assets are significantly different in affecting the vulnerability of all groups.

With respect to financial capital, 5.08% of farmer households were involved in the low vulnerability, 55.93% in the moderate vulnerability and 38.98% in the high vulnerability. The high vulnerable households settled in the western, northern and eastern part of the study area. The farmers in such areas had the barrier to access production because of salt-water intrusion and flooding from nearby rivers and streams, leading to low income, insufficient investment, unpaid debt and affecting other household assets (Figure 3 B).

In terms of natural capital, all of the sampled households were moderately affected by natural capital. In fact, the all moderate vulnerable farmers are found across the township (Figure 3 C).

Regarding physical capital, 38.98 % of sampled households were in the low vulnerability, 52.54% as the moderate vulnerability, and only 8.47% as the high vulnerability. Their production area of the high vulnerable group was mostly found in western and south central part where are relatively distant from the major agricultural sale and inputs market, facilities and services (Figure 3 D). Adding a poor road condition and relying on water transportation generate more physical vulnerability since the production means had the biggest effect on vulnerability to the high group.

On an average, 27.12% of sampled farm households were suffered as low vulnerability and 71.19% as moderate vulnerability and 1.69% as a high vulnerability in terms of human capitals. The moderately vulnerable households and their production area are located in the western, northern, eastern and central part of the township, which lies along the river banks of the rivers (Figure 3 E). These areas mostly rely on river transportation to get major agricultural market and public and private services.

In comparison, it was found that none of the sampled households highly affected by social capital. However, 47.46% of sampled household were suffered as moderate vulnerability and 52.54% as a low vulnerability. Their production area and the moderate vulnerable group was mostly found in north-western and central parts of the township (Figure 3 F).

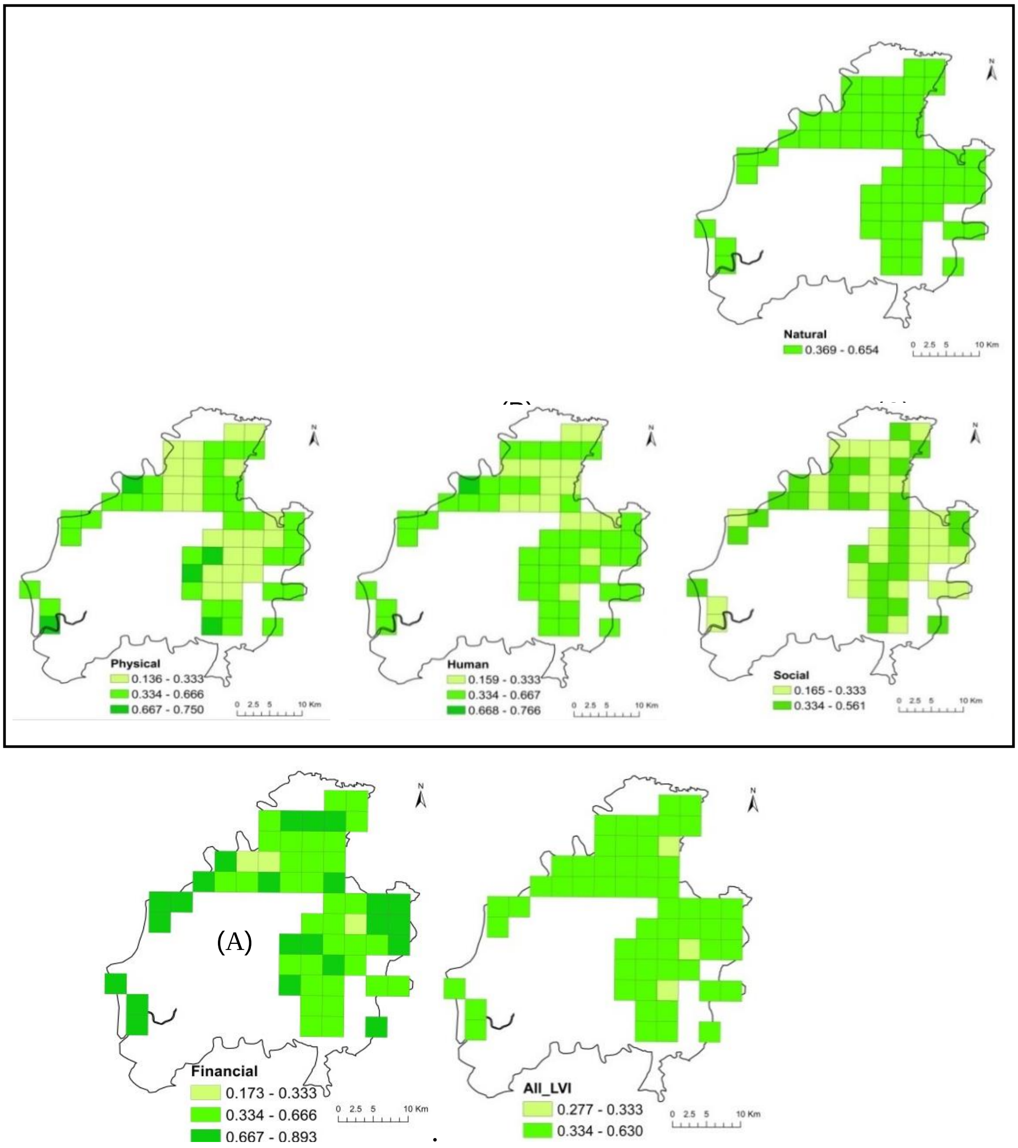


Figure 3. Distribution pattern of the livelihood vulnerability index of overall asset (A), financial capital (B), natural capital (C), physical capital (D), huma (F) al (E), and social capital (F) in Myaungmya Township

It is interesting to note that the production area of the high financial vulnerable group has been found on the flood area, which attributed their vulnerability. In addition, the moderate vulnerable group in terms of natural capital also settles in these area. It suggests that the development practitioners need to give priority in sensitive area to prevent from future climatic impacts.

4. Conclusions

This paper analyses the climate impact on the vulnerability of farmers' livelihood using the LVI method based on the assets defined by Sustainable Livelihood Framework (DfID, 1999) in Myaungmya Township, Ayeyarwady Region, Myanmar. As the overall result of LVI is 0.442, the study area can be assigned as moderate vulnerable to the response of impacts of climate change.

Based on the assets of sustainable livelihood framework, the application of livelihood vulnerability index contributes to the assessment of farmer's vulnerability to the climate variability and other stressors in the study area. When operationalization of theory, indicator selection needs to be modified according to the local context. However, data collection were based on the questionnaire incorporating interview, some data limitation comes into play, for example, income, saving, expenditure which are based on recall and be taken into account with care. The approach of this study should be further tested in the different locations over time in order to compare between and among communities within the local context. In doing so, such study will support more useful information for development practitioners and decision makers to evaluate the vulnerability of communities and to facilitate the effective development programs for the most vulnerable sector in the future.

Acknowledgements

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Appendix A. The LVI results of the each Sustainable Livelihood Capitals/Assets

Household Capitals	Component	Subcomponents	Unit	Observed value/Index	Maximum value	Minimum value	Value
Human capital	Health	Households with members suffering chronic illness	%	11.90	100	0	0.119
		Average distance to health care centre	Km	16.43	37	1.3	0.424
	Knowledge and skills	Average schooling years of household heads*	Year	0.19	0.333	0.1	0.374
		Average farming experience of households heads	Year	0.06	0.5	0.02	0.073
		Households who do not own TV at home	%	13.60	100	0	0.136
		Households who do not have mobile phone	%	3.40	100	0	0.034
		Households who do not have radio	%	77.97	100	0	0.780
		Households do not participate in awareness training	%	79.66	100	0	0.797
	Livelihood strategies	Average crop diversification index*		0.29	0.5	0.25	0.158
		Household depending on agriculture as a major source of income	%	100	100	0	1.000
Human capital vulnerability Index							**0.389**
Natural capital	Natural Resources	Household with small farm (<2.5 ha)	%	20.34	100	0	0.203
		Households who have barrier to access land	%	39.00	100	0	0.390
		Households who do not grow third crop	%	76.27	100	0	0.763
		Households who affected by salt water intrusion	%	13.559	100	0	0.136
		Households who do not collect non-farm product	%	74.58	100	0	0.746
	Climate variability	Households with crop area affected by flood	%	25.40	100	0	0.254

Household Capitals	Component	Subcomponents	Unit	Observed value/Index	Maximum value	Minimum value	Value
	and natural disaster	Households who reported rain decrease in the past 10 year	%	84.70	100	0	0.847
		Households who reported drought increase in the past 10 year	%	39.00	100	0	0.390
		Households who reported flood increase in the past 10 year	%	72.90	100	0	0.729
		Households who reported unusual rain in the past 10 year	%	72.90	100	0	0.729
		Households who reported temperature increase in the past 10 year	%	86.40	100	0	0.864
		Mean standard deviation of monthly mean maximum temperature	ºC	1.13	2.00	0.74	0.311
		Mean standard deviation of monthly mean minimum temperature	ºC	2.91	3.37	2.46	0.495
		Mean standard deviation of monthly mean precipitation	mm	87.28	238.81	3.61	0.356
Natural capital vulnerability Index							**0.515**
Social capital	Demography	Dependency ratio (<15+>64)/15-64)*100	Ratio	58.78	500	0	0.118
		Average age of household heads	Year	50.98	70	26	0.568
		Female-headed households	%	11.90	100	0	0.119
		Average household family member	Number	4.93	10	2	0.367
	Social networks	Households who did not participate in community affair last year	%	57.60	100	0	0.576
		Households who did not contribute in	%	27.10	100	0	0.271

Household Capitals	Component	Subcomponents	Unit	Observed value/Index	Maximum value	Minimum value	Value
		community affair last year					
		Households who did not vote in the last election	%	15.30	100	0	0.153
		Households with the least family member is affiliated with any institution	%	52.54	100	0	0.525
Social capital vulnerability Index							**0.337**
Financial capital	Finance and income	Inverse of rice sale*		0.022	0.127	0.002	0.164
		Households who earn per capita income less than 1300 USD	%	54.24	100.00	0.00	0.542
		Households who did not save money last year	%	59.30	100.00	0.00	0.593
		Households who got very limited credit loan	%	66.10	100.00	0.00	0.661
		Households who have unpaid debt	%	37.29	100.00	0.00	0.373
		Households with family member who do not work in another place	%	84.75	100.00	0.00	0.847
Financial capital vulnerability Index							**0.530**
Physical capital	Transportation	Distance to agricultural market	Km	16.97	37	2	0.428
		Households who do not own motorbike	%	25.40	100	0	0.254
	Production means	Households who do not own water pump	%	35.60	100	0	0.356
		Households who do not own trailer	%	83.10	100	0	0.831
		Households who do not own enough farming equipment	%	8.50	100	0	0.085
		Households who apply less than 50% of necessary fertiliser	%	38.98	100	0	0.390
		Households who do not get extension	%	0.00	100	0	0.000

Household Capitals	Component	Subcomponents	Unit	Observed value/Index	Maximum value	Minimum value	Value
		service from government					
		Households who do not get extension service from other organisation	%	100.00	100	0	1.000
Physical capital vulnerability Index							0.418
Livelihood Vulnerability Index (LVI)							**0.442**

Source: Authors’ own calculation

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PM_{10} and $PM_{2.5}$ from Haze Smog and Visibility Effect in Chiang Mai Thailand

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Abstract

Air pollution from haze smog in Chiang Mai Thailand becomes a serious problem, particularly fine particulate matter FPM, PM_{10} and $PM_{2.5}$. These issues have effects on health, transportation and tourism. Visibility reduction effect has impacts on transportation safety and environment aesthetic scenery. In this study, the visibility impact was monitored by a digital camera, video records and aerial photography. The visibility images were analyzed both qualitative and quantitative methods including in the comparison with related information during with and without haze. The visibility lengths were directly measured by GPS and Google earth mapping. Visibility reduction from haze events were also compared by photograph image analysis in unit of Deciview. Fine particulate matter concentrations and frequency of fire, in Chiang Mai were associated with visibility. During forest fire occurring, deciview number was increased. In dry season, the frequency of fire (times) were correlated with both PM_{10} and $PM_{2.5}$ with r = 0.9 (95, % CI, $p < 0.05$). The reverse correlation (-r) between visual length (km) and PM_{10} and $PM_{2.5}$ were 0.64 and 0.72 at altitude 444 m with 95% CI, $p < 0.05$. The correlation (–r), at altitude 313 m was 0.93 for PM_{10} and 0.96 for $PM_{2.5}$ with 95% CI, $p < 0.05$. The correlation (–r), at altitude 324 m was 0.86 for PM_{10} and 0.93 for $PM_{2.5}$ with 95% CI, $p < 0.05$. The association between Visibility and FPM at low altitude was found more significant than at high altitude.

Keywords: PM_{10}; $PM_{2.5}$; haze smog; visibility; Chiang Mai

1. Introduction

Chiang Mai is a big city with 1,735,762 population covered area 20,107 km^2])cited on 2017Feb13[, http//:stat.dopa.go.th. This province is one of tourist attraction place in north of Thailand) Kitirianglarp, 2015 .(The air environment of this area has been a problem from haze for a long time. The frequency and extensive of bushfires from 2013 to 2016 have been increased annually)FFCD 2017 .(Bushfire emission contained dust, smoke, fog, haze and air pollutants had various environmental and health effects)Viswanathan et al., 2006 .(Furthermore, emission pollutants could effect to the atmospheric visibility either or the visibility index can be used as an indicator of air quality in urban areas)Xiao et al., 2014.(In this study, we aim to identify the association betweenPM_{10},$PM_{2.5}$ and visibility during bush fire events . Recently in 2016, the fire occurred more than 1600 times covered the area more than 9000 acres, Table 1 .The highest impact area is in Chiang Mai.Recently in 2016, the fire occurred more than 1600 times covered the area more than 9000 acres, Table 1 . The highest impact area is in Chiang Mai.

Table1. The annual comparison between frequency of fire (time) and the impact area (acre) of 8 provinces in north Thailand

Provinces	2012		2013		2014		2015		2016	
	(time)	(acre)	(time)	(acre)	(time)	(acre)	(time)	(acre)	(time)	(acre)
Chiang Mai	865	2505	1,361	5,817	937	3,618	1,179	5,045	1,602	9,190
Mae HongSon	413	1000	506	1,177	429	1,168	140	1,536	378	1,888
Lampang	242	585	304	777	375	699	399	1,184	465	1,344
Lamphun	219	623	166	580	238	784	297	1,421	319	2,100
Chiang Rai	181	369	99	284	91	34	147	452	164	1,015
Phayao	76	127	38	78	36	66	62	172	122	525
Phrae	158	588	147	404	111	91	140	402	139	880
Nan	29	125	123	504	88	3	78	374	148	722
Total	**2,183**	**5,922**	**2,744**	**9,621**	**1,031**	**6,463**	**2,183**	**10,586**	**3,337**	**17,664**

Source: Forest Fire Control Division National Park, 2017

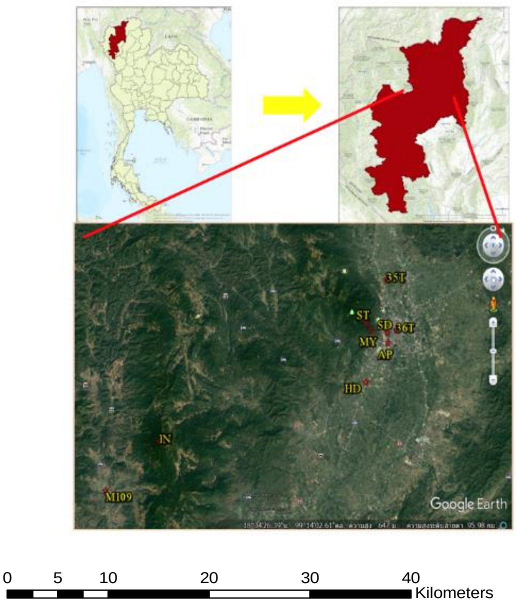

Figure 1. Sites location and air quality station (IN = Doi Inthanon, ST = Doi Suthep, AP = Airport, HD = Hangdong, SD = Suan Dok, MY = Maya Hall, ST35 = City Hall*, ST36 = Yupparaj*, M109 = Mae Chaem*)
*PCD monitoring station

2. Materials and Methods

2.1 Site description and sample collection

The studied sites in Chiang Mai were shown in Figure 1.The selected sites were Doi Inthanon, Doi Suthep, Maya and Chiang Mai International airport. The spot test daily $PM_{2.5}$ were measured between January 2017 and March 2017. The frequency of fire records were from Fire Control Department. Monthly average of PM_{10} and $PM_{2.5}$ data were obtained from Pollution Control Department.

2.2 Visibility measurement

Visibility data in 2013-2014 were obtained from Chiang Mai airport at altitude 444 m measured by automatic weather system and data in 2015-2016 were from Forest fire control division measured at altitude 324 m and data in 2013-2016 were from meteorological station in Chiang Mai at altitude 313 m. In this study, the visibility was measured by a digital camera and a video recorder. The photographs were taken at different altitude and data were compared between fire and without fire scenarios as relative visibility. The reference visibility point was selected and measured as the visual range (VR). Qualitative measurement was demonstrated from the photographs. Quatitative visibility was analyzed in comparison to the visual distance during fire and without fire. The visual range was directly measured by GPS and Google earth mapping. The changing in the of reduction distance visible photos were analyzed from Koschmeider's equation (1) followed Meyer et al.,1990 and deciview value calculated from equation (2),Willard, 1999.

Koschmeider's equation

$$VR = \frac{1200\ km.\mu g\ m^{-3}}{Particle\ Concentration} \qquad (1)$$

Deciview value (dv)

$$dv = 10In(\frac{391\ km}{VR}) \qquad (2)$$

2.3 PMs Measurement

PM_{10} and $PM_{2.5}$ data from 2014-2016 were measured from PCD monitoring stations at Yupparaj School (station 36T), using High volume air sampling and TEOM. $PM_{2.5}$. In this study, $PM_{2.5}$ 24 hrs. Averaged concentrations were measured from January 2017 – March 2017. Air samplings were conducted by personal air samplings attached $PM_{2.5}$ cascade impactor with PTFE membrane filter. Concentrations of $PM_{2.5}$ were analyzed by gravimetric method using 7 decimal points electric balance.

3. Results and Discussion

3.1 Qualitative analysis of the visibility

The Aerial photograph of Chiang Mai taken from Doi Suthep were shown in figure (2a) without bushfire and in figure)2b (during bush fire occurring .The image in figure 2a was found better visualized view than in figure 2b, indicated severe visibility effect from the highest frequency of fire.

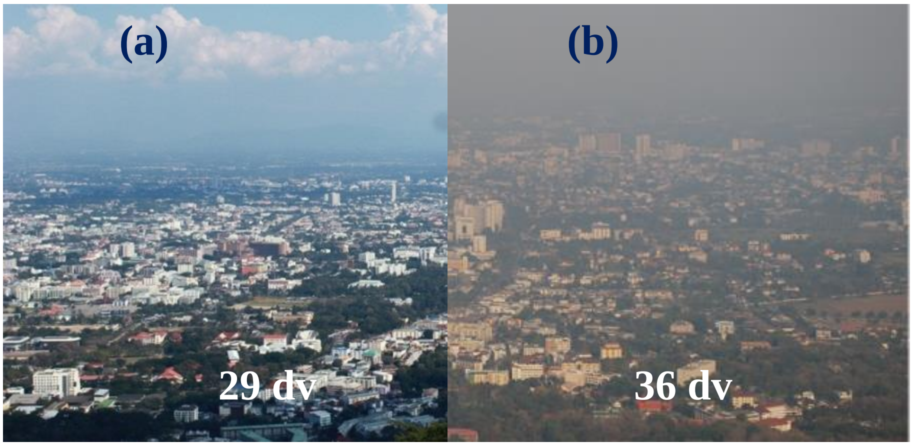

Figure 2. Photographs of Doi Suthep (ST) and deciview at N18.79138, E98.93330at 738 m

(a): 19 January 2017 at 2:49 pm, clean air (b): 9 March 2017at 5:42 pm, haze air

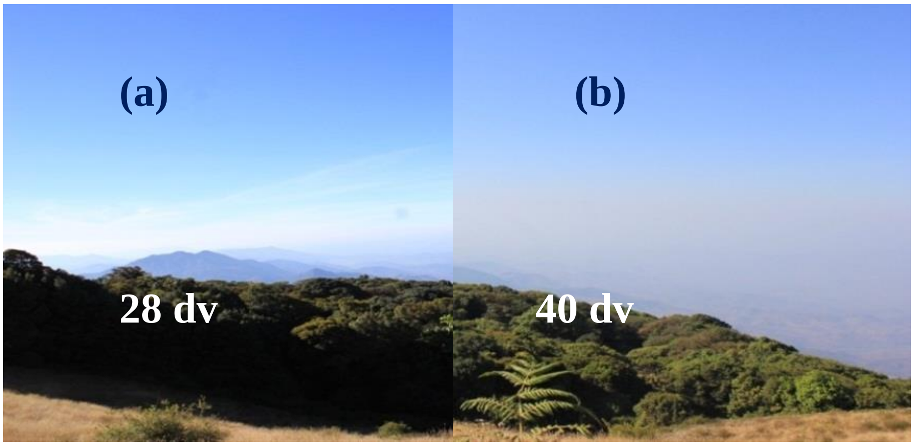

Figure 3. Photographs of Doi Inthanon(IN) and deciview at N18.56062, E98.47726at 2255 m (a): 17 January 2017 at 18.05 pm, clean air (b): 14 March 2017 at 17.42 pm, haze air

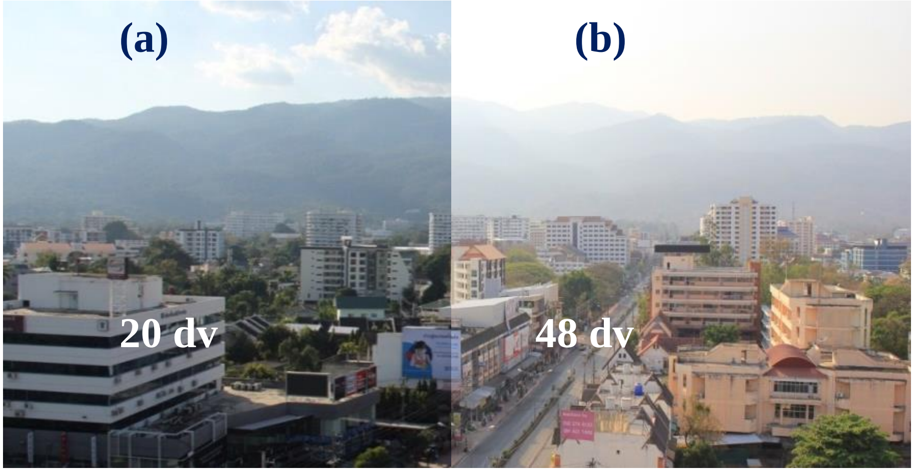

Figure 4. Photographs of MAYA (MY) and deciview at N18.802707, E98.967285 at 446 m (a): 20 January 2017 at 16.30 pm, clean air (b): 17 March 2017 at 16.25 pm, haze air

3.2 Quantitative analysis of the PM_{10}, $PM_{2.5}$ and visibility

PM_{10} Data were obtained from the monitoring station Yupparaj School (36T) in the city area. The average daily PM_{10} in January 2017 without fire was 35.7±14.8 µg/m^3 and March 2017 during the fire episode was 68.6±18.6µg/m^3. Spot test measurement data for $PM_{2.5}$ were shown in Table 2 in comparison to the monitoring station data. Measured daily $PM_{2.5}$ in January 2017 without fire was 19.5±5.5 µg/m^3 and in March 2017 with bushfire was 56.3±28.2 µg/m^3. PM_{10} and $PM_{2.5}$ concentrations were associated with the fire events and the relative visibility in deciview unit.

Table 2. Comparison of daily measurement and monitoring data of $PM_{2.5}$ and visibility in January 2017 (no fire) and in March 2017 (with Fire) : January 2017 (No fire)

Site	Date	$PM_{2.5}$ (µg/m^3)		Relative Visibility (dv)	Visibility (km)	Frequency of fire (time)
		PCD	Measure			
Doi Inthanon (IN) Mae Chaem (M109)	16/01/2017	- 19.0	14.0 -	28.0 -	22.7 -	0
Hangdong (HD) Yupparaj (36T)	17/01/2017	- 25.0	15.0 -	- -	- -	0
City 1 - Airport (AP) -MAYA (MY) -Yupparaj (36T)	18/01/2017	- - 24.0	25.0 - -	- 20.0 -	- 7.0 -	0
City 2 - Suan Dok (SD) -Doi Suthep (ST) -Yupparaj (36T)	19/01/2017	- - 32.0	24.0 - -	- 29.0 -	- 20.0 -	0
Average ± SD		25.0 ± 5.4	19.5 ± 5.5	25.7 ± 4.9	16.6 ± 8.4	0

: March 2017 (with fire)

Site	Date	$PM_{2.5}$ (µg/m^3)		Relative Visibility (dv)	Visibility (km)	Frequency of fire (time)
		PCD	Measure			
Doi Inthanon (IN) Mae Chaem(M109)	13/03/2017	- 37.0	16.0 -	40.0 -	11.4 -	37
Hangdong (HD) Yupparaj (36T)	14/03/2017	- 45.0	70.0 -	- -	- -	33
City 1 - Airport (AP) -MAYA (MY) -Yupparaj (36T)	16/03/2017	- - 38.0	59.0 - -	- 48.0 -	- 3.0 -	35
City 2 - Suan Dok (SD) -Doi Suthep (ST) -Yupparaj (36T)	17/03/2017	- - 43.0	80.0 - -	- 36.0 -	- 10.0 -	40
Average $\pm$ SD		40.8 ± 3.9	56.3 ± 28.2	41.3 ± 6.1	8.1 ± 4.5	37.0 ± 3

3.3 Visibility correlation with PM_{10}, $PM_{2.5}$ during Bushfire episode

The association between fine particulate matters and the visibility reduction was analyzed. PM_{10} and $PM_{2.5}$ data were obtained from Yupparaj station (36T) which was a nearest PCD station to the visibility length measurement sites. The analyzed data were shown in Figure 5, 6 and 7. The correlations between PM_{10}, $PM_{2.5}$ and visibility were R^2 = 0.93 and 0.96, respectively). This result was similar to Xia *et al.* (2017) which studied the impact of size distributions on light extinction of the small particulate matter (especially less than 2.5 µm). The aerosol optical properties and their impact on haze formation were associated with visibility in different altitude. In addition, Yu *et al*. (2017) studied air pollution dispersion around high-rise buildings had the results in high level the pollutant had better distribution than in low level.

3.3.1 Visibility correlation with PM_{10}, $PM_{2.5}$ in dry season, 6 months between December to May

The associations of PM_{10}, $PM_{2.5}$ and visibility during with and without fire scenarios were analyzed. Results were summarized in Table 2 and Figure 5-7. In the wet season, there were no fire and no correlation between PM concentrations and visibility. In the dry season, from December to May, the frequency of fire (times) were correlated with both PM_{10} and $PM_{2.5}$ with r = 0.9 (95, % CI, $p < 0.05$). The reverse correlation (-r) between visual range (m) and PM_{10} and $PM_{2.5}$ were 0.64 and 0.72 at altitude 444 m with 95% CI, $p < 0.05$. The correlation (–r) of PM_{10} and $PM_{2.5}$ at altitude 324 m were 0.86 and 0.93 with 95% CI, $p < 0.05$. The correlation (–r), at altitude 313 m was 0.93 for PM_{10} and 0.96 for $PM_{2.5}$ with 95% CI, $p < 0.05$. Visibility at low altitude was found significantly correlated to FPM. The visibility reduction was found during bushfire events. The relative visibility involved further digital imaging analysis and the development of standard visibility in the smoke fire areas.

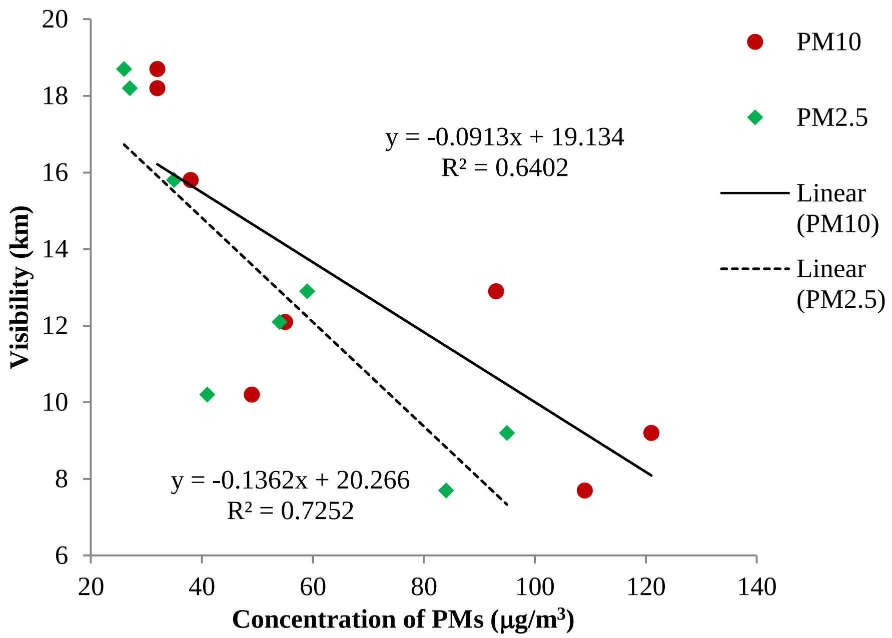

Figure 5. Visibility correlation with PM10 and PM2.5 data from Chiang Mai airport 2013-2014 (N18.96415, E99.22565) at altitude 444 m

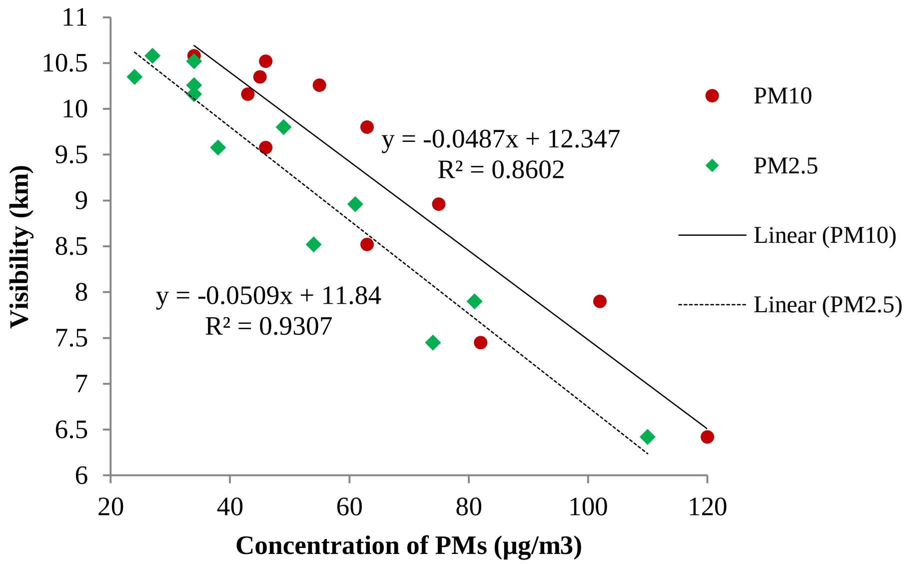

Figure 6. Visibility correlation with PM10 and PM2.5 data from forest fire control division 2015-2016 (N18.46590, E98.56630) at altitude 324 m

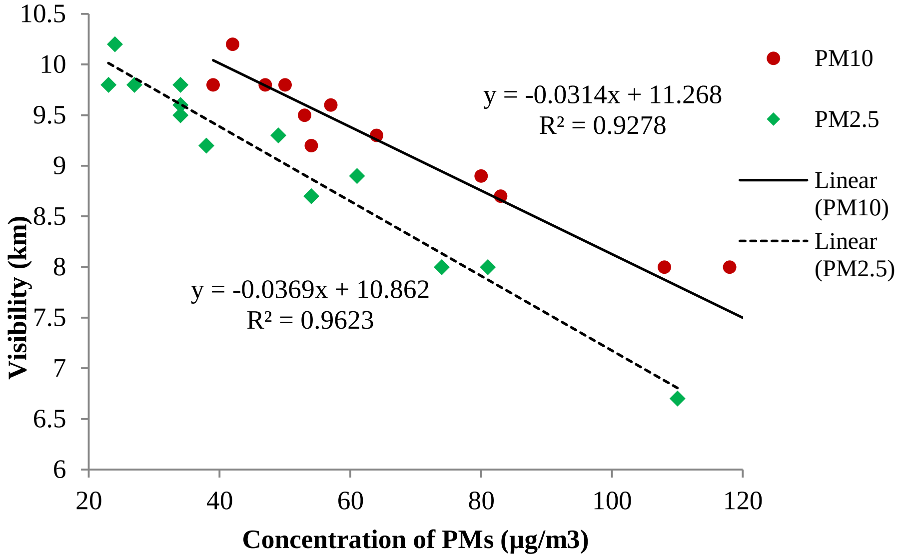

Figure 7. Visibility correlation with PM_{10} and $PM_{2.5}$ data from Meteorological station 2015-2016 (N18.47240, E98.58370) at altitude 313 m

4. Conclusions

Fine particulate matter, PM_{10} and $PM_{2.5}$ emission from forest fires were associated with visibility reduction in Chiang Mai, at low altitude was found more significant than at high altitude. . Visibility effects were detected in both by photograph analysis in deciview and in visibility distance length during haze events. In the future, the local visibility data could be a data for air pollution calculation in the remote places where there are not data from direct measurements either or from any monitoring station. However, the bush fires control program should be seriously concerned to reduce the visibility effect and the health impact in this area.

Acknowledgements

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Flash Flood Risk Estimation of Wadi Qena Watershed, Egypt Using GIS Based Morphometric Analysis

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Abstract

Flash flooding is one of the periodic geohazards in the eastern desert of Egypt where many parts of Upper Egypt, Sinai, and Red Sea areas were hit by severe flash floods for example in 1976, 1982, 1996 and January 2010. The hazard degree for each sub-basin was determined using the approach which developed by El-Shamy for assessing susceptibility of sub-basins to flash flooding risk. To determine the hazardous sub-basins, two different methods are applied. The first method is based on the relationship between the drainage density and bifurcation ratio, and the second one uses the relationship between drainage frequency and bifurcation ratio. The three morphometric parameters (the bifurcation ratio, drainage density, and stream frequency) were extracted and calculated for each sub-basin of the watershed. Based on the final hazard degree resulting from the two methods, a detailed hazard degree map is extracted for all sub-basins. The results illustrate that there are not any sub-basins with low possibility of floods. The sub-basins with the highest hazard degree are concentrated in the middle of the watershed although they have smaller areas comparing with the surrounding sub-basins. The sub-basins located at the boundary of the watershed have an intermediate possibility for floods and moderate potential for groundwater recharge. This constructed map can be used as a basic data for the assessment of flood mitigation and planning.

Keywords: morphometry; risk; flood hazard; groundwater recharge; Eastern Desert

1. Introduction

1.1. Literature Review

Torrential rain can be considered as the most dangerous event which cause flooding and often ends by a natural catastrophe which influences human beings and nature as well. Flash flood is one of the most dangerous natural disasters because it is highly unpredictable. Natural catastrophes happen frequently and their effect and frequency appear to have greatly increased in recent decades, mostly because of environmental degradation (Vincent, 1997), (Pradhan, 2010), (Pradhan and Lee, 2010a), (Pradhan and Lee, 2010b). There are many factors which are affecting to the flooding problem such as topography, climate, engineering structures, geomorphology and drainage climate. There are some other related factors in the desert regions which affect the severity flash floods. Some of these factors are involving environmental and human processes, drainage networks, drainage orders, drainage characteristics, water loss (evaporation and infiltration), and rainfall characteristics (Saleh, 1989). Morphometric analysis and studies include the evaluations of streams by the measurement of different network properties. Evaluation of morphometric parameters could be estimated from the analysis of different parameters of the drainage such as stream order, basin area, perimeter, stream frequency, drainage density, length of drainage channels, concentration, time and bifurcation ratio (Kumar, Kumar, Lohani, Nema, and Singh, 2000).

The human activities and highway in many areas in Gulf of Suez are affected seriously by the frequent flash floods (Hassan, 2000). Numerous other studies concentrated on the flood hazards in various areas of Egypt as the Red Sea drainage basins along the Qena–Safaga highway and the Red Sea basins between Latitudes 24° 41´ and 25° 26´ (El Shamy, 1992), (El-Etr and Ashmawy, 1993), (Ashmawy, 1994). To reduce the effect of flash floods, the study and analysis the morphometrical parameters of the drainage basins are required. Determination of drainage networks within watersheds or sub-watersheds can be carried out using traditional methods such as topographic maps and field observations or alternatively with advanced approaches using remote sensing and DEMs (Máčka and Hrvatin, 2001), (Maidment, 2002) In this respect, drainage networks and basins extents can be extracted by using DEMs (Ozdemir and Bird, 2009). Also, in the recent years, geographic information systems (GIS) and remote sensing have been established in the evaluation of the geo-environmental hazards. Remote sensing is employed as the primary information source in the hazards/disasters assessment. The remote sensing data and GIS tools had been used in many researches for risk mapping and flood hazard. Radar remote sensing data have been widely used for flood observation across globe (Hess, Melack, & Simonett, 1990), (Hess, Melack, Filoso, & Wang, 1995). GIS and neural network methods have been used for flood susceptibility mapping in many cases studies (Sanyal & Lu, 2004), (Sanyal & Lu, 2005), (Zerger, 2002).

1.2. Study area

Per the topography of the Red Sea Mountains nature, the rainfall makes the water rush in really quick, alternatively, a lot of rainfall comes in a short amount of time (flash flood). Flash Flood characterized by rapid occurrence and very limited opportunity for issuing warnings. Many parts of Upper Egypt, Sinai and Red Sea areas were hit by severe flash floods (Ex. In March 1976, April1983, April 1985, January 2010, and January 2013). According to the location of the study area as an arid zone, monitoring systems are lacked which lead to severe damage in the region. The study area is located at the eastern side of Qena meander in the Upper of Egypt.

Wadi Qena is located between Red Sea in the east and River Nile in the west within latitudes 26° 10′ to 28° 05′ N and longitudes 32° 20′ to 33° 36′ E as shown in Figure 1.

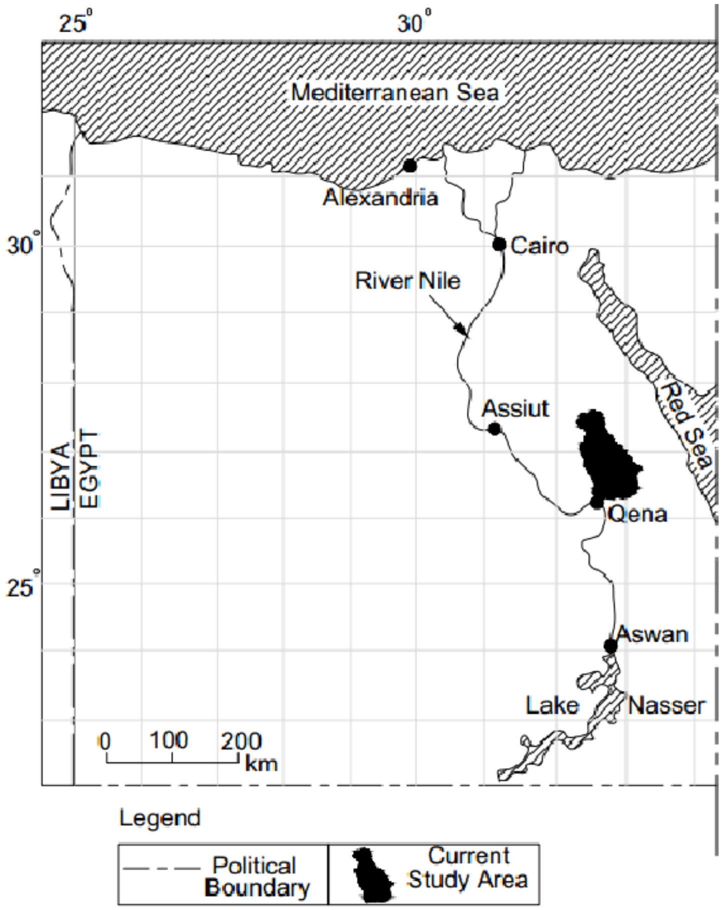

Figure 1. Egypt map and the location of study area (Mahmod and Watanabe, 2014)

The area of Wadi Qena watershed is approximately 15455 km^2 (Hussien et al., 2017). Based on Köppen climate classification (Geiger, 1954), the climate of the study area is classified as hot summers and cold winters as it is located in the dry desert. According to Egyptian meteorological Authority (EMA), the rainfall in the study area is scarce with an average value of 3.2 mm a year and in summers the highest recorded temperature reached to 41 degrees in July. For winter season, the lowest temperature reached to 7.5 degrees at night in January. The climatic data for Wadi Qena drainage basin are traditionally acquired from the closest weather station which is located at 26° 30′ N and 33° 06′ E in the south of the watershed. The mountainous area which located in the eastern boundary is varies in elevation by ranges from 77 m to 1866 m Above the Mean Sea Level (AMSL) as illustrated in Figure 2.

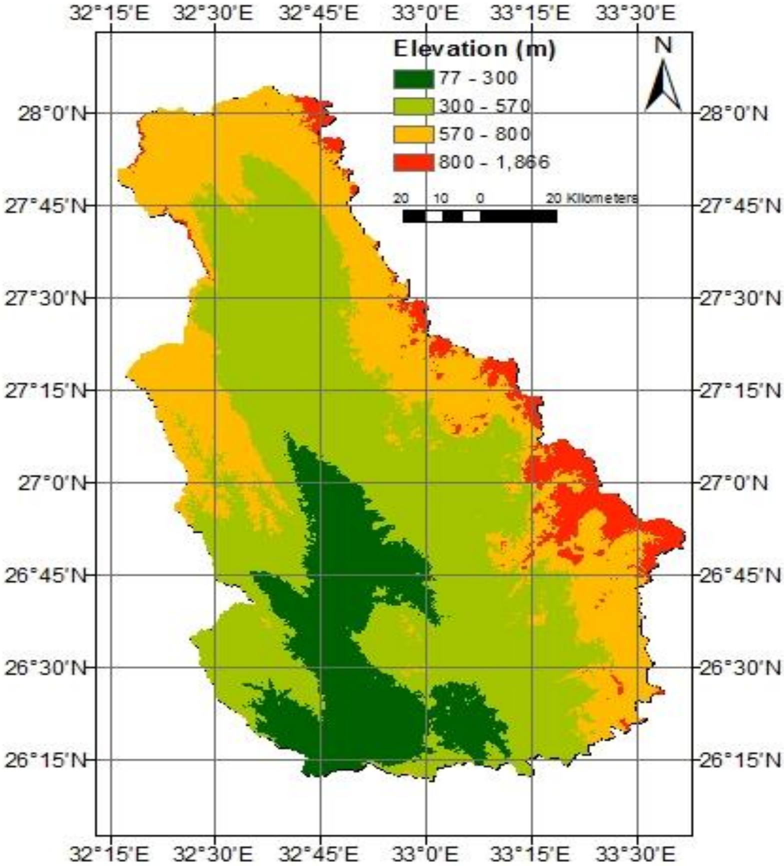

Figure 2. Topography of the study area

Flood hazard assessment studies are necessary to mitigate the probable damage. In the current study, the morphometric characteristics have been analyzed to estimate the flood risk of the sub-watersheds within Qena watershed using El-Shamy approach (El-Shamy, 1992). A detailed hazard degree map is presented based on the final hazard degree. This map can be used as basic data for the assessment of flood mitigation and planning.

2. Materials and Methods

There is terrain pre-processing has been utilized to create the watershed basin of the study area. This pre-processing used the digital elevation model (DEM) of Wadi Qena watershed which was obtained from Shuttle Radar Topography Mission (SRTM) data, with 90 m spatial resolution (Figure 3). These processes are clipping the boundary of the watershed to derive the drainage network of the study area in addition to create flow direction raster by using flow direction algorithms after remove small imperfections in the (Tarboton, Bras, & Rodriguez-Iturbe, 1991). After that, the flow accumulation could be created to get the watershed basin. The post-processing involved using the DEM in a GIS environment for estimation the morphometric parameters (area (A), stream order (u), stream number (Nu), stream length (Lu), drainage density (D), stream frequency (F) and the bifurcation ratio (Rb). The morphometric parameters were extracted and calculated for each sub-basin of the watershed.

Runoff is affected by the size and the area of watershed, where larger the watershed, larger runoff and storage of water in basin. Stream order is a method of assigning a numeric order to links in a stream network and the situation of a stream in the hierarchy tributaries. It is the essential parameter of analyses of any drainage basin. The stream order of the sub-watersheds has been achieved by using the method proposed by (Strahler, 1964) where the first order of the streams are the streams which have no tributaries. The second order is a number of the stream which has tributaries from the first order only. When two of second order streams join, the third order is formed. When two of third order streams join, the forth order stream is formed. http://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/how-stream-order-works.htm Also, stream number (Nu) and stream length (Lu) had been derived to calculate stream frequency (F) and Drainage density (D).

Drainage density (D) is the ratio between the total distances where the streams run in the sub-basin to total sub-basin area thus it has units of reciprocal of length. Drainage density points the nearness of spacing of streams. It is influenced by many factors such as resistance to weathering, relief, climatic changes, type and permeability of rocks and vegetation that controls the characteristic length of the stream (Moglen, Eltahir, and Bras, 1998), (Ozdemir and Bird, 2009). Also, it is worth mentioning that the higher value of drainage density with large amount of rainfall resulted in runoff where high density of streams and rapid stream response. The stream frequency (F) of a drainage basin is the total number of streams of all orders per square kilometer where it reflects the texture of the drainage network. The bifurcation ratio (Rb) is a dimensionless property and considered as the index of relief and distortion. The Rb of one order is observed that it differs from its next order; these irregularities are determined by the geological and lithological development of the drainage basin (Strahler, 1964). Bifurcation ratios show a small range of variation for different areas or for different environment except where the powerful geological control dominates (Strahler, 1957). According to (Strahler, 1964), the lower value of (Rb) is a representative of the watersheds, which have less structural turbulences and drainage pattern has been deformed (Nag, 1998). Higher value of (Rb) indicates high effect of structural control on the drainage pattern.

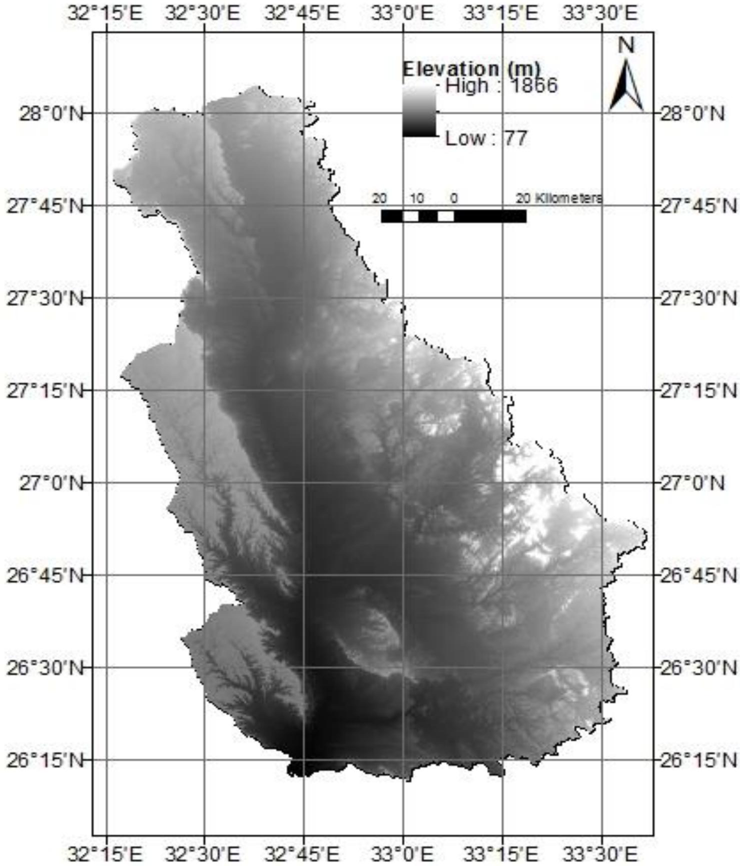

Figure 3. Digital Elevation Map (DEM) of Wadi Qena watershed

The hazard degree for each sub-basin was determined using the approach which developed by (El-Shamy, 1992) for evaluating susceptibility of sub-watersheds to flash flooding risk. To determine the hazardous sub-watersheds, two different methods were applied. The relationship between the drainage density and bifurcation ratio is used in the first method, and the second one is based on the relationship between the drainage frequency and bifurcation ratio. Each approach uses a figure which is divided into three zones; zone (A) refers to high potential for groundwater recharge and low possibility for floods, zone (B) refers to high possibility for floods and low potential for groundwater recharge and zone (C) represents sub-basins with intermediate possibility for floods and moderate potential for groundwater recharge. A detailed hazard degree map is extracted for all sub-basins and presented based on the final hazard degree resulting from the two methods. The final hazard degree for each sub-basin was estimated where if a basin has two different fields, then the most conservative situation has been selected.

3. Results and Discussion

The watershed consists from 70 sub-basins as shown in Figure 4. Based on Horton's methodology (Horton, 1932), the sub-basins were classified by size into three categories small (0-50 km^2), medium basins (50-100 km^2) and large basins (>100 km^2). The area of sub-basins was ranged from 28 km^2 to 1465 km^2 where the total area of the watershed was equal to 15488 km^2.

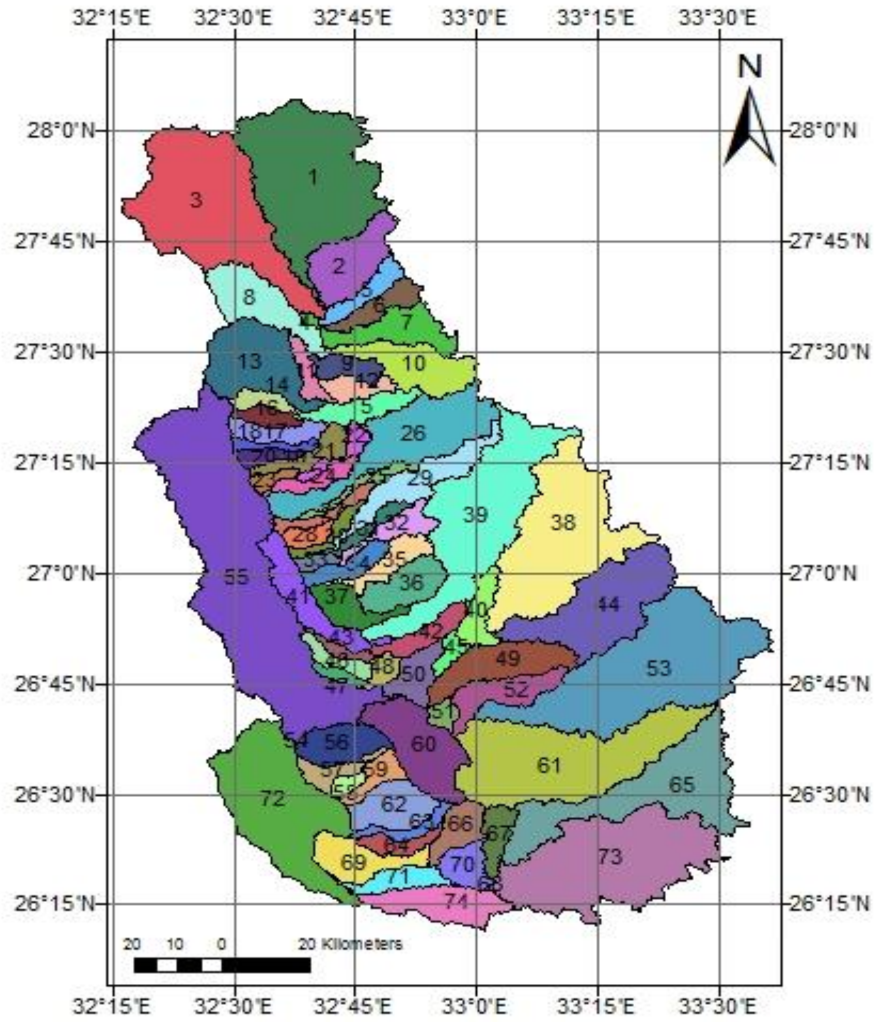

Figure 4. Sub-basins of the study area

As shown in Figure 5, about (84%) of sub-basins were classified by size into the category of large areas while the medium and small areas represent 12.51% and 3.19% respectively.

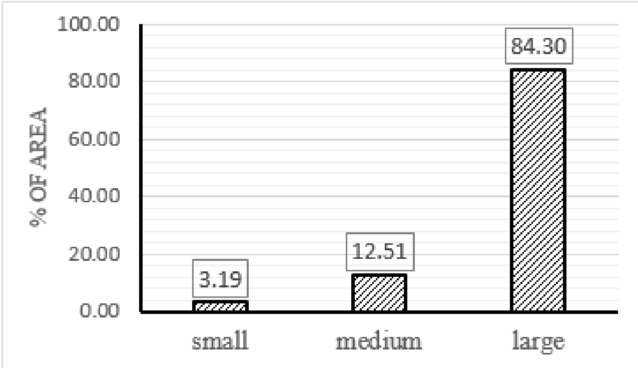

Figure 5. Classification of sub-watersheds

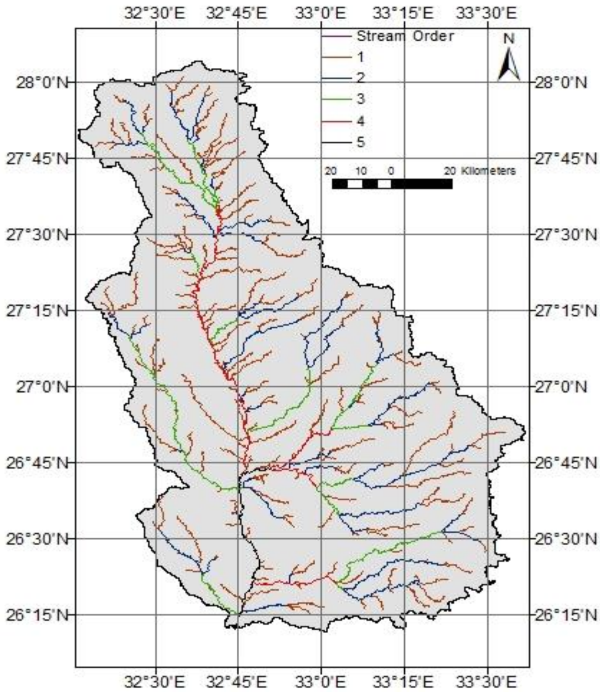

Figure 6. Stream order of the watershed.

The stream order of the watershed related to 5th order is illustrated in Figure 6. The watershed has altogether 273 streams linked with 5 orders of streams. The total number of stream is the maximum in the first order (210 streams) and gradually decreases with the increase of stream order. The total length of streams in the watershed is 3073.81 km. the minimum length is with the fifth-order stream which equals to 81.4 km where the first order shows the maximum length and equals to

1631.88 km. Drainage density (D) which indicates the landscape dissection, infiltration capacity of the land, runoff potential, climatic conditions, and vegetation cover of the basin is in the range from 0.176 km-1 to 4.85 km-1. On the other hand, the values of bifurcation ratio reached to 2.667. Moreover, the values of stream frequency of the sub-basins have a range varies from 0.11 km-2 to 0.71 km-2. The low values of stream frequency of the sub-basins point to the fact that the watershed includes scarce plant cover. Stream frequencies of the sub-basins have a small variation which comes from the similarity in lithology of the sub-basins. The lower values of drainage density and stream frequency of the sub-basins declared that the runoff is slower and flooding is less likely to occur. To determine the hazardous sub-basins, two different methods were carried out as shown in Table 1. For the first method, there are not any sub-basins in the zone (A) and the sub-basins spread in the high and moderate zone (Figure 7) but for the second method, there are not any sub-basins in the high or low zone and all sub-basins concentrate in the intermediate zone (Figure 8).

Table 1. The classification of the sub-basins based on El-Sahmy's approaches and the final assessment based on the final results.

Rb vs F		Rb vs D		Final Assessment	
sub-basin ID	Degree	sub-basin ID	Degree	sub-basin ID	Degree
There are not any sub-basins in the zone (A)	L	There are not any sub-basins in the zone (A)	L	There are not any sub-basins in the low zone	L
All sub-basins are in zone (C)	M	1-2-3-6-7-9-12-24-27-34-35-36-37-38-39-42-47-48-50-51-52-53-54-56-57-58-59-61-62-63-64-65-66-67-68-69-70	M	1-2-3-6-7-9-12-24-27-34-35-36-37-38-39-42-47-48-50-51-52-53-54-56-57-58-59-61-62-63-64-65-66-67-68-69-70	M
There are not any sub-basins in zone (B)	H	4-5-8-10-11-13-14-15-16-17-18-19-20-21-22-23-25-26-28-29-30-31-32-33-40-41-43-44-45-46-49-54-55-60	H	4-5-8-10-11-13-14-15-16-17-18-19-20-21-22-23-25-26-28-29-30-31-32-33-40-41-43-44-45-46-49-54-55-60	H

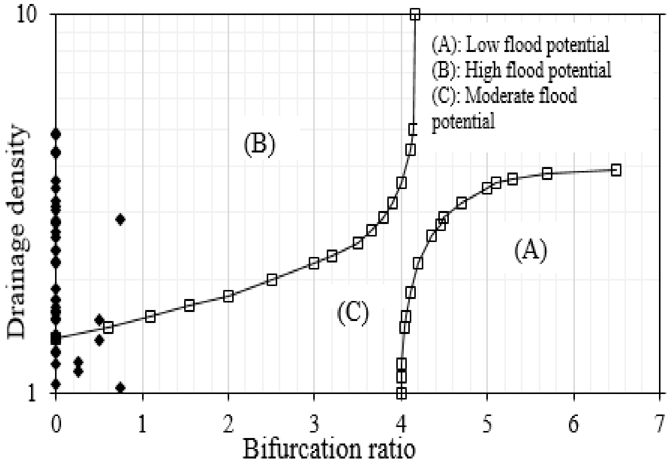

Figure 7. Flooding susceptibility: El-Shamy's approach (The Bifurcation ratio vs. Drainage density)

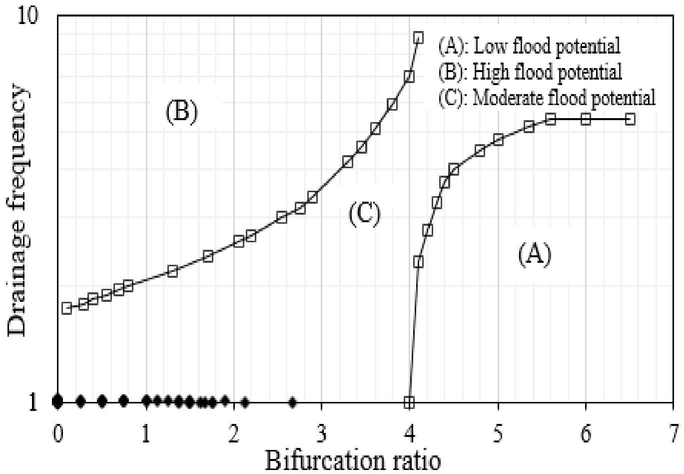

Figure 8. Flooding susceptibility: El-Shamy's approach (The Bifurcation ratio vs. Drainage frequency)

A detailed hazard degree map is extracted for all sub-basins using the two methods as shown in Figure 9. The sub-basins with the highest hazard degree are concentrated in the middle of the watershed although their smaller areas comparing with the sub-basins with an intermediate possibility for floods and moderate potential for groundwater recharge which are at the boundary of the watershed.

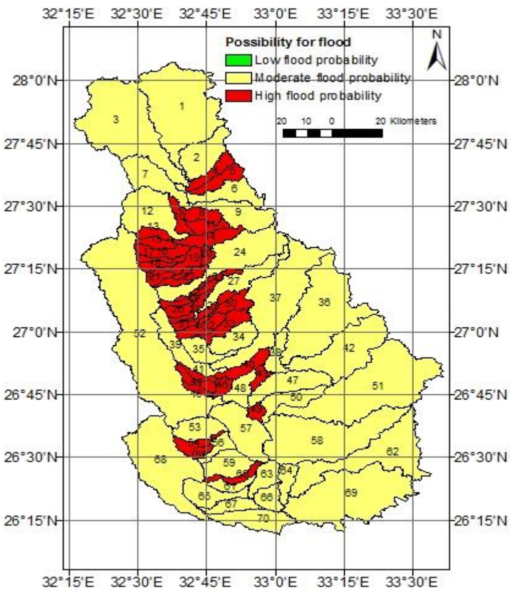

Figure 9. The hazard degree map for all sub-basins

4. Conclusion

In the present study, GIS based morphometry and remote sensing data were used for the flash flood risk mapping for Wadi Qena watershed, Eastern Desert, Egypt. Morphometry approach is used to determine the flash flood prone areas using flood risk analysis was performed based on El-Shamy's approach. Flood hazard map was prepared to delineate flood-prone areas and it is found that the sub-basins with the highest hazard degree are concentrated in the middle of the watershed. Such map helps the decision makers to evaluate the potential impacts of natural risks quickly and assist further to initiate appropriate measures for impact reduction. It also helps them during post-disaster activities for the assessment of damages and losses occur due to flooding. Moreover, GIS can aid in identifying flood prone areas or forecasting areas likely to be flooded based on the analysis of the drainage basins. The results shown in this research can help the developers, planners and engineers for effective planning and developments and also to minimize the harmful effects of flash floods.

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Age and Evolution of Beach Ridge Plain from Chaiya Coast of the Gulf of Thailand

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Abstract

The main objective of this research was to study coastal evolution from Lam Pho, Chaiya District, Surat Thani Province, Southern Thailand. This research methodology started from satellite image interpretation for planning landform, field survey and locating sample collection for Optically Stimulated Luminescence (OSL) dating. As a result, beach ridges in this area were prograded continuously and formed as beach ridge plain alongshore. Oldest ridge is formed at 7,170 ± 460 years BP and youngest is formed at 570 ± 20 years BP. This result indicates that Chaiya coastal area including ridges and swales was formed as beach ridge plain and progradation in eastward direction during the regression from middle to late Holocene. Orientation of sand spit shows southeast direction indicating southeast longshore current.

Keywords: beach ridge; optically stimulated luminescence dating; sand spit; sea level change

1. Introduction

The history of sea level change since late Pleistocene to middle Holocene in Southeast Asia reflects a significant relation to climate change. In a global scale, physical factors such as wave, wind, tide and local long shore current are the key to explain the evolution of the coast. In Thailand, coastal change around the southern part of the Gulf of Thailand (GoT) can be observed by geological and environmental evidences and also could be related to a global sea level change (e.g., Sinsakul et al., 2002; Nimnate et al., 2015). At the Andaman coast, age determination of beach-ridge plains from Phrathong Island wasidentified (Brill et al., 2015) providing the island evolution occurred from in the last 6,000 years before present.

Chaiya coast is the coastal area that has been affected from global sea level changesince the late Pleistocene. This coastal zone has been prograded due to the sea level dropped after reaching high stand in the middle Holocene (Chaimanee, 2001). Laem Pho, the study area, is selected because the area owns dominant depositional features of coastal landforms. Laem Pho is located in Chaiya district, Surat Thani province, Southern Thailand. The area consists of large lagoon, swamp, beach ridge plain (beach ridge and swale). Depositional landforms show their progradation from westward to eastward direction responded to sea level change. Sand spit is especially dominant depositional feature found in southeastward part of the area. These coastal landforms evolution may reflect local sea level change in the Holocene. Therefore, this study hypothesize that the evolution of beach ridge plain here is related to history of sea level change.

2. Materials and Methods

The methodology is divided into 3 steps. Firstly, the identification of coastal geomorphology within the study area from remote sensing data (satellite image and aerial photograph) was carried out (Figure 1). Secondly, after geomorphological map was made, detail field survey included topographic survey by digital topographic survey camera (Total Station SOKKIA SET 630R) was performed (Fig. 2a). Beach ridge sediment and stratigraphical profile description were done. Sediments were sampled at depth 0.5 m from beach ridge surface for age dating (Figure 2b and 2c) along a transect perpendicular to the present shoreline (Figure 3). Lastly, OpticallyStimulated Luminescence dating method (OSL) was made in order to determine an absolute age of beach sediments (Pailoplee, 2004).

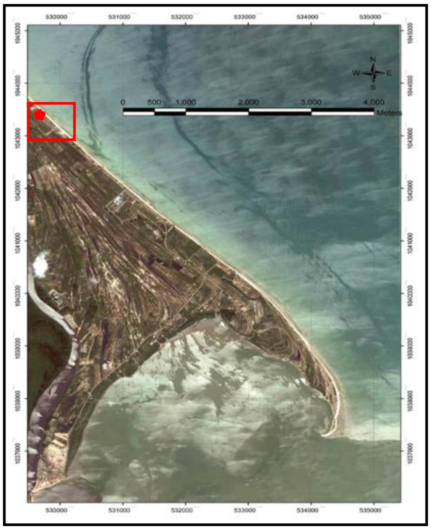

Figure 1. Satellite image showing the study area (red square) and transect line (red star)

Figure 2. Collecting data in study area. a) Topographic survey measuring by Total station survey camera (SOKKIA SET 630R), b)

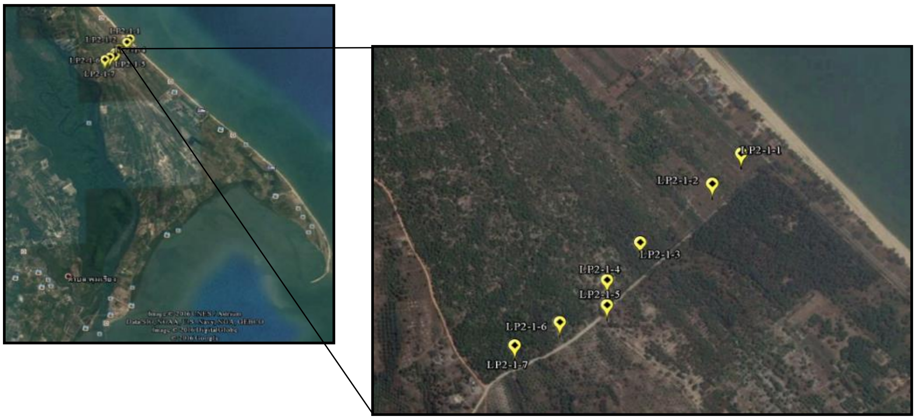

Figure 3. These satellite images showing where sediment was sampling

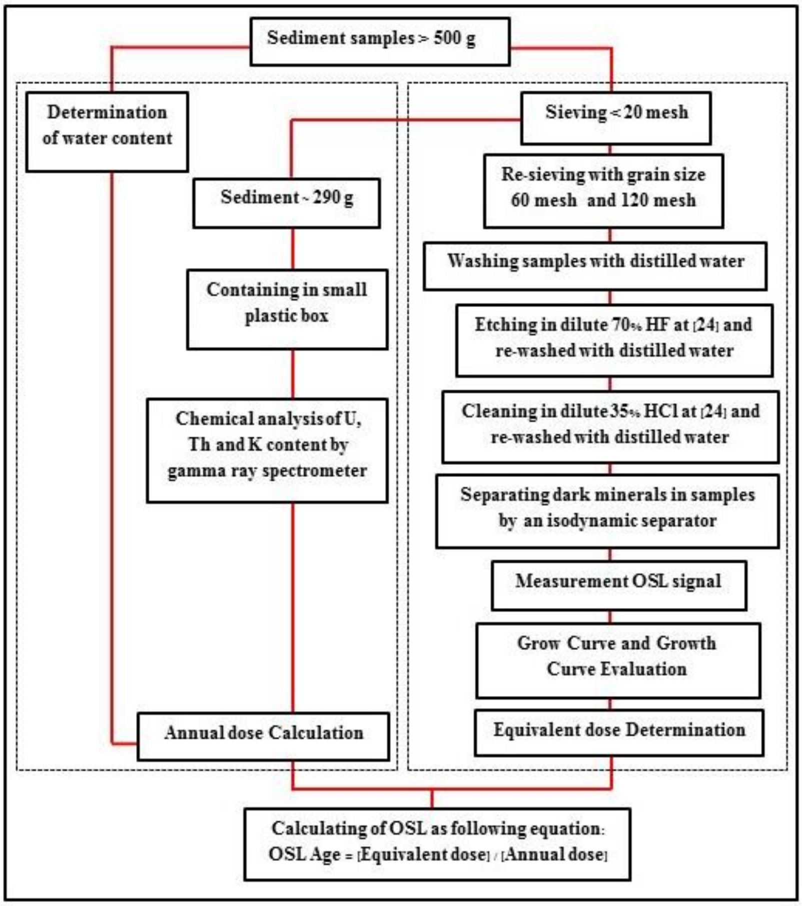

Figure 4. The age dating in laboratory by OSL method is illustrated by simplified flow chart. (modified after Pailoplee, 2004)

Detail of age determination method was described as a flow chart in Figure 4. The sediment samples were separated into 2 parts for further analysis. The first part was used for the equivalent dose determination. This part was light sensitive but red light can be safely used with no effect for sediment sampling. PVC tubes were used to collect the sediments to prevent the sunlight in the field work. The end-cap PVC tubes were taken into the pit at 0.5 m depth and then sampling the sediments. After that, PVC tube was pulled out and closed tightly with duct tape. The sediment second part was for annual dose calculation, the sediment was sampling at the same depth approximately 400 grams in the zip lock plastic bags which the light exposure was not concerned for this part. Then, both sediment samples were taken to identify age determination by Optically Stimulated Luminescence dating (OSL) by specification of Equivalent dose and Annual dose which have the radiation per years of significant radioactive elements such as Potassium (K), Uranium (U), and Thorium (Th). Then the ages of the sediment samples are calculated by dividing the equivalent dose by the dose rate of the environment surrounding the sediment sample:

Age (kyr) = Equivalent Dose (Gy) / Dose Rate (Gy/kyr)

3. Results and Discussion

As a result of remote sensing interpretation, geomorphological landforms in this area from the west to the east include tidal channel, former beach ridge plain (beach ridge and vegetated swale) and modern sand spit. The topography survey indicated that maximum elevation of beach ridge plainis about 4 m above present mean sea level. The elevation relief of beach ridge and swale on beach ridge plain is less than 1 m (Figure 5). It indicates the continuation of progradation in eastward direction. OSL dating of beach ridge sand provided the absolute age of beach ridges from west to east direction as 7,170 ± 460 to 570 ± 20 years BP (Table 1). All these results indicate that beach ridge plain at Chaiya coastal area show continuous eastward pro gradation that correspond well with the record of sea level regression during the middle to late Holocene (Nimnate et al., 2015). Orientation of beach ridges and modern sand spit shows their depositional feature as formed by southeast longshore current direction. Beach ridge plain in this area is extensively formed with large amount of sand. Therefore, source of sediment supply to the coast is expected to have come from Phumriang canal locating between former and recent beach ridge plain of Lam Pho.

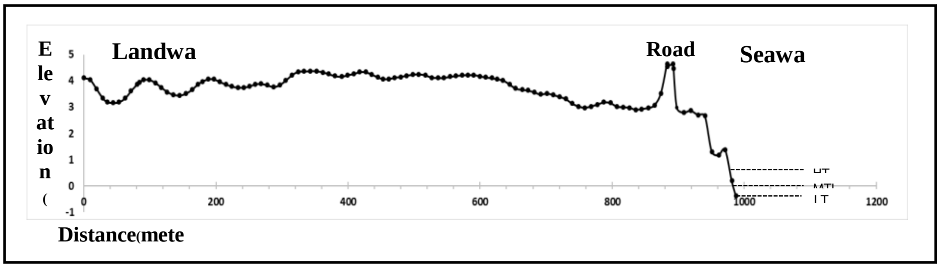

Figure 5. This linear graph showing topographic profile of the study area from topographic survey measuring

Table 1. The table showing results of age dating by OSL method

No.	U (ppm)	Th (ppm)	K (%)	W (%)	AD (Gy/ka)	AD (Error)	ED (Gy)	ED (Error)	Age (Yr)	Error (Yr)
LP2-1-1	0.39	4.86	2.70	4.87	2.93	0.07	1.67	0.04	570	20
LP2-1-2	0.20	4.68	1.14	4.31	1.51	0.07	2.96	0.21	1,960	160
LP2-1-3	0.00	4.23	1.98	4.39	2.15	0.07	5.93	0.17	2,750	110
LP2-1-4	0.07	5.03	1.11	3.89	1.47	0.07	6.80	0.26	4,620	280
LP2-1-5	0.07	6.54	1.62	3.50	2.03	0.07	9.50	0.38	4,680	240
LP2-1-6	0.27	4.68	1.33	4.04	1.69	0.07	10.59	0.63	6,280	450
LP2-1-7	0.33	2.61	1.42	4.16	1.63	0.07	11.68	0.56	7,170	460

4. Conclusion

The results of OSL dating beach ridge sediment from Chaiya coastal area in this study correspond well with the history of sea level change during the Holocene. Geomorphological landforms dominated in the area are beach ridge plain and sand spit. Both are among well indicator of depositional environment. The elevation of inner beach ridges (4 m above the present sea level) can also be related to level of the Holocene high stand in Thailand and adjacent areas in Southeast Asia.Therefore, age determination together with geomorphological landforms in this area can be used to determine not only the evolution of the area itself, but also the relation with the history of sea level change and environmental change during the Holocene.

Acknowledgements

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Morphometric Temporal Change Analysis for the River Nile Forced Bends using RS/GIS Techniques: Case Study of Damietta Branch of the Nile River, Egypt

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Abstract

The river Nile is one of the longest rivers all over the world. Damietta branch, Egypt, is important as a major source of irrigation and navigational path from Cairo to the Mediterranean Sea. The morphological changes of Damietta branch have been occurred after Aswan High Dam construction which affected the sedimentation and erosion power of the flow especially on bends locations. In this study, morphometric temporal changes are investigated for the forced bends using Remote Sensing (RS) and Geographical Information System (GIS) techniques for a study period between 1987 and 2015. In addition, a comparative study was performed among three image classification techniques; onscreen digitizing, maximum likelihood classification and histogram thresholding technique. Field map for the river banks for the year 2000 was used to verify morphometric behavior of the forced bends extracted from the satellite images. The comparative study showed that the maximum likelihood classification technique has a good performance at shoreline detection with percentage error of 0.42 % compared with the observed data. Results show significant morphometric changes of the bank status for the studied forced bends. The forced bend named Sherpas was found to have the highest average annual rate of erosion with value of 1.62 m/year. The maximum average annual rate of sedimentation was located in the inner bank of Sawalem forced bend with a value of 1.0 m/year and that the maximum erosion and sedimentation rate achieved the greatest values within the period between 1987 and 1998.

Keywords: morphometric changes; forced bends; remote sensing; geographical information system; damietta branch.

1. Introduction

The flow of fluids through channels, especially in bends, causes secondary currents which in turn is one of the most important causes of the erosion incidence at the outer curve of the bends and sedimentation at the inner curve. This phenomenon is evident and escalated in the case of severe sharp curves which are named "forced bends". Damietta branch is comprised of ten forced bends from its origin downstream delta barrage (south of Cairo governerate) to the Mediterranean Sea in the north.

The river channel changes from straight phase to meandering and then to braiding. Up until late 1970s, it was thought that the secondary flow at the bend consisted of a single skew-induced cell. However, close to the eroding outer bank, there is often a smaller cell of reverse rotation. The skew- induced secondary cell does not extend to the inner bank either. Flow over the upper point-bar is directed radially outward throughout the whole water column because the outwards acting centrifugal force on the curved flow overcomes the inward pressure gradient force. The secondary circulation pattern at a river bend cross section shows that the main circulation cell is limited to the deepest part of the section and it was suggested that this outward flow has a significant effect on the point-bar growth as shown in Figure 1 (Markham and Thorne, 1992; Smith, 1983). The primary longitudinal currents is disturbed by the secondary ones causing more deposition by the meaning of decreasing phase shift angle which leading to the braiding (Njenga, Kioko, and Wanjiru 2013). On a smaller scale, the process of bending in channels results from the process of sediment transfer (Fagherazzi, Gabet, and Furbish, 2004; Leopold, 1964). On the other hand, cross-stream circulation is imposed on the downstream motion, is a characteristic phenomenon for the channel bends (Graf and Blanckaert, 2002). Also, a near balance in the centrifugal force and cross-stream pressure gradient are responsible for the cross-stream velocity field through the bend, which are consisted of the outward velocity near the surface and inward velocity near the bed across the entire channel width. In addition, development of a point bar in a curved channel greatly modifies the pattern of flow and the downstream and cross stream force balances (Smith, 1983). Sadek, Salama, and Kamal, 2015 studied the physical characteristics of bends using hydrographic survey maps such as wave length, radius of curvature, and stream length. On the other hand, (Negm, Abdel-Aziz, Salem and Yousef, 2011) illustrated that the outer curve of Damietta branch will suffer from erosion with an expected erosion volume of 12921.90 m^3. (Ahmed and Fawzi, 2011) used the Landsat imaginary and field observation to study the meandering and bank erosion of the River Nile and its environmental impact on the area between Sohag and El-Minia, Egypt. In their study, onscreen digitizing method was verified to be used to obtain the shoreline of the study reach. The histogram thresholding technique showed an accurate result for separating the waterbody and none waterbody compared with the ground truth observations by using Band 5. Band 5 exhibits strong contrast between land and water features due to the high degree of absorption of mid-infrared energy by water (even turbid water) and strong reflectance of mid- infrared by vegetation and natural features in this range (Alesheikh, Ghorbanali and Nouri, 2007). On the other hand, the maximum likelihood classification was used to differentiate between several classes in one image (Masria, Negm, and Iskander, 2016). River bank erosion is a complex phenomenon in which many factors affect the erosion process such as flow, sediment transport, bank properties and water qualities. The bank properties induce the bank materials weight and texture, shear strength and cohesive strength, physicochemical properties, bank height and cross- sectional shape, ground water level and permeability, stratigraphy, tension cracks, as well as vegetation and constructions (Mosselman, 1989).

This study aimes to investigate the morphometric temporal changes for Dammitta branch forced bends. Three techniques for image classification which mentioned in the letrature above to extarct the Damiitta branch shoreline for a study period 1987-2015 are evaluated and the best technique was used.

2. Materials and Methods

2.1 Study area

The geographical location for Damietta branch lies between Latitude: 30° 10' 26" N, Longitude: 031° 08' 22" E and Latitude: 31° 31' 37" N, Longitude: 031° 50' 41" E. Sex forced bends of Damietta branch was studied in this research as identified on the map in Figure 2.

The Land used around the studied bends is varied including agriculture and urbanization. The agriculture represents the dominant Land used classes as shown in the composite Landsat image for year 2015 as shown in Figure 3.

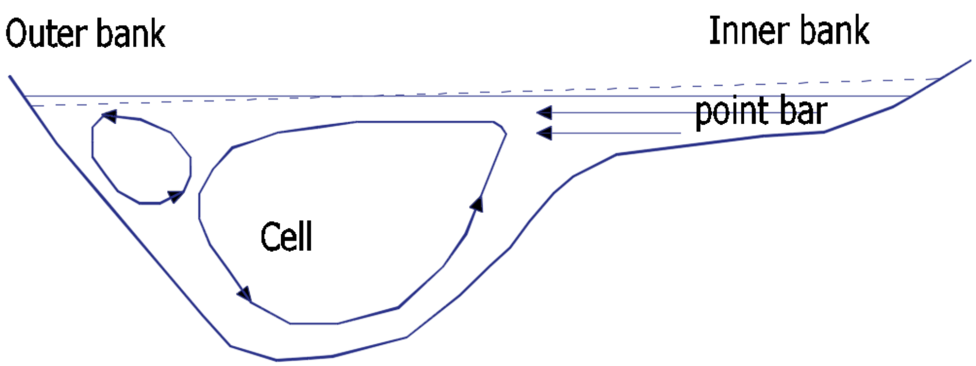


Figure 1. Balance between centrifugal force and pressure gradient

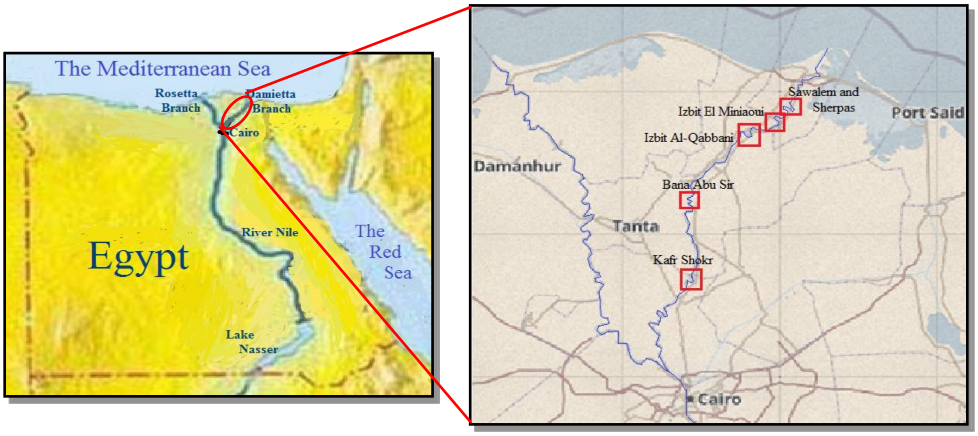
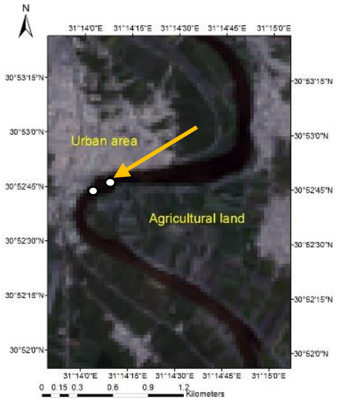


Figure 2. The geographical location for Damietta branch and the studied forced bends

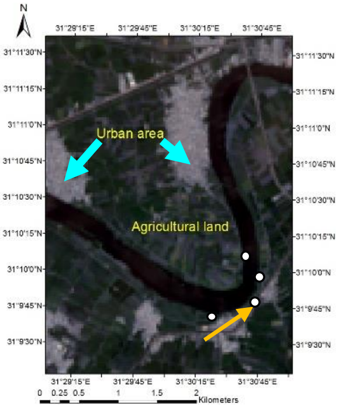
2.2 Data set

Ten satellite images were used for Damietta branch downloaded from the United States Geological Survey (USGS) server to cover Damietta branch between period of 1987 and 2015. Eight images were Landsat _5/TM acquired in 1987, 1998, 2000 and 2003. The remaining two images were Landsat_8/ETM acquired in 2015 as shown in Table 1 and Figure 3. These images were taken for the summer season, from May to August, to avoid climate change effects. As the nature of the climate in Egypt in winter is characterized by the presence of clouds and rain, which leads to the difficulty of using images in this period and a large proportion of errors during the image pre-processing (Li et al., 2014). In addition, to avoid the change of seasonal water levels; as in Egypt in the winter, from November to March, the chances of rainfall are increasing. Therefore, the Egyptian government, represented by the Ministry of Water Resources and Irrigation (MWRI), does not pump water to the waterways depending on the rain water in irrigation (http://www.mwri.gov.eg/irrigationlaw/1984-d.aspx). Therefore, in this period the water levels in the river are smaller than the rest of the year.

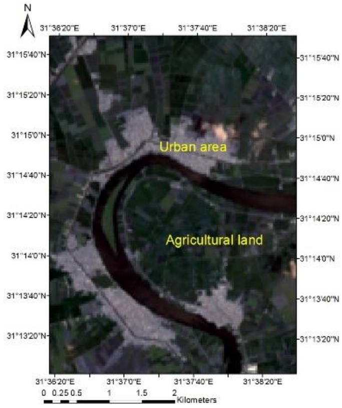
a) Kafr Shokr



b) Bana Abu Sir



c) Izbit Al-Qabbani



d) Izbit El Miniaoui

e) Sawalem and Sherpas

Figure 3. Landsat image for the studied forced bends along Damietta branch for year 2015 (Landsat_8/ETM, Path/Row 176/39 and 176/38)

Table 1. Characteristics of the images used in this study

Acquired Date	SpaceraftID/Sensor	Path/Row	Pixel Size (m)	Coordinate System/Datum	Zone
Jul 27, 1987	Landsat_5/TM	176/39	60	UTM/WG84	36 North
Jun 07, 1998	Landsat_5/TM	176/39	30	UTM/WG84	36 North
May 11, 2000	Landsat_5/TM	176/39	30	UTM/WG84	36 North
Jul 07, 2003	Landsat_5/TM	176/39	30	UTM/WG84	36 North
Jul 08, 2015	Landsat_8/ETM	176/39	30	UTM/WG84	36 North
Jul 27, 1987	Landsat_5/TM	176/38	60	UTM/WG84	36 North
Jun 07, 1998	Landsat_5/TM	176/38	30	UTM/WG84	36 North
May 11, 2000	Landsat_5/TM	176/38	30	UTM/WG84	36 North
Jul 07, 2003	Landsat_5/TM	176/38	30	UTM/WG84	36 North
Jul 08, 2015	Landsat_8/ETM	176/38	30	UTM/WG84	36 North

Field map for the river banks for year 2000 was used in the present study for verification process. This map was obtained from the Hydraulic Research Institute (HRI).

2.3 Image Preprocessing

Erdas Imagine 9.1 are used for checking images against defects as shadow and gaps. Also, all images were corrected radiometrically and geometrically. Then a composite image for every image were obtained using the RGB bands. For Landsat_8/ETM, Band 2 – blue, Band 3 – green and Band 4 – red. But for Landsat_5/TM, Band 1 – blue, Band 2 – green and Band 3 – red.

ArcGIS 10.2 was used for analysis of data and results visualization. In addition, field observations for Damietta branch are also considered for verification process.

2.4 Image Post-processing

Three remote sensing techniques were used to extract data from satellite images, including onscreen digitizing, maximum likelihood classification and histogram thresholding technique method as shown in Figure 4.

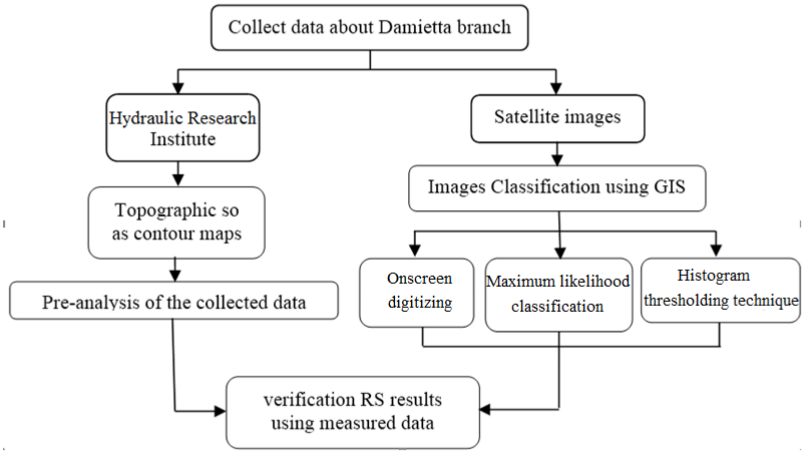


Figure 4. Flow chart for research methodology

Onscreen digitizing

The shoreline for Damietta branch, Nile river was be obtained by drawing the borders onscreen on the image according to the vision in the differentiation between the waterbody and land (Ahmed and Fawzi, 2011). For more accurate results, we selected pixel digital number equal 50 was selected to separate the borders of the river from the land.

Maximum likelihood classification

The classification process was used to separate the land-cover units in order to change the detection for each type (Masria, Negm, and Iskander, 2016). Considering Bayes' theorem, the maximum likelihood classifier was obtained by (Canty 2014) as illustrated in the following equation.

$$dk(g) \geq dj(g) \quad \text{for all j=1,….K} \qquad (1)$$

Where $dk(g)$ is a class-specific probability density function.

For suitable classification, a composite image conducted for all images was then used to make the classification process. The Maximum likelihood classification by support vector machine algorithm was made for the classification of the ten images into four land-cover classes which are recognized as follows: Nile river, seawater, agricultural land and urban. Then obtain the shore line of Damietta branch, Nile River, Egypt.

Histogram thresholding technique

Shoreline can be extracted from a single-band image, band 5, since the reflectance of water is nearly equal to zero in reflective infrared bands. This can be achieved, for example, by histogram threshold on one of the infrared bands of Thematic Mapper (TM) or Enhanced Thematic Mapper plus (ETM+) imagery (Alesheikh, Ghorbanali, and Nouri, 2007).

2.5 Sinuosity calculation

The channel sinuosity of a reach, here called the sinuosity index (S.I.), is defined by the ratio of length of channel to length of meander-belt axis (Brice, 1964) informed that the sinuosity index value, the channel can be divided in to three categories: i) straight ($SI > 1.05$), ii) sinuous ($1.05 > SI > 1.5$) and meander ($SI > 1.5$).

3. Results and Discussion

3.1 Comparative study

Observed field data were used to verify the results of the three remote sensing techniques (onscreen digitizing, maximum likelihood classification and histogram thresholding technique) to obtain the banks of the river in the forced bend location. The surface water area for the length of each bend was calculated with the three techniques for year 2000, then compared with the measured surface water area for the same year as shown in Figure 5.

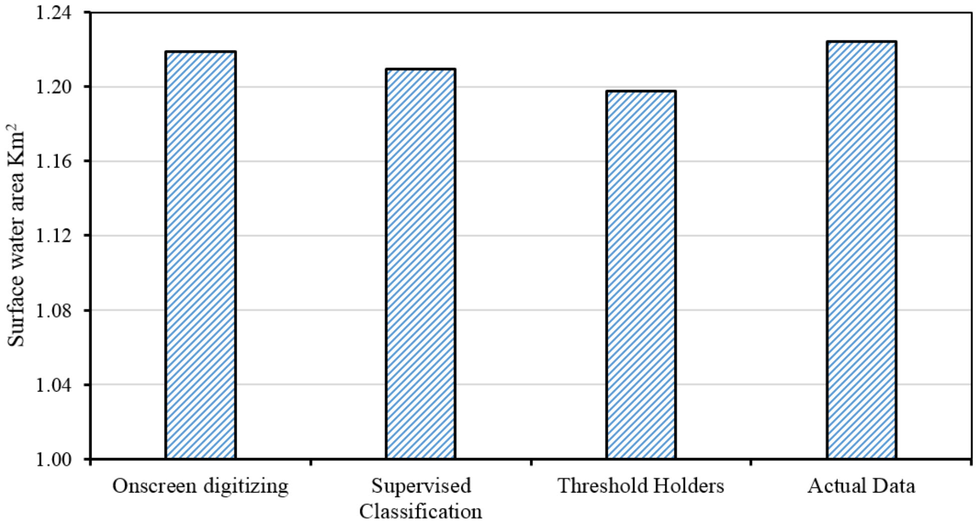


Figure 5. Surface water area Km^2 for year 2000

The percentage of error between the actual area for year 2000 and the calculated area obtained from the three remote sensing techniques was calculated as declared in Table 2 using equation 2 as follows:

$$Error\% = \frac{\text{Actual area - calculated area}}{\text{Actual area}} \qquad (2)$$

Table 2. The percentage of error for the three techniques

Method	Surface water area for year 2000	Error %
Actual area	1.2241174	0
Onscreen digitizing	1.218961	0.421234107
maximum likelihood classification	1.209634	1.18317083
histogram thresholding method	1.197803	2.149663096

It is concluded that the onscreen digitizing method has the lowest error rate. Accordingly, on screen digitizing method has been used for completion the morphometric temporal changes for the studied forced bends.

3.2 Morphometric changes for the studied forced bends

The morphometric analysis for the studied forced bend shows that the bend is subjected to erosion on the outer curve and sedimentation on the inner curve as shown in Figure 6 to Figure 10. These changes are mainly due to secondary currents occurred in the bends. Also, the sedimentation and erosion processes due to the stone heads in the bending sites (See Figure 3b, and 3c), dating back to before the establishment of the Aswan High Dam causes significant morphological changes in these locations and have influence on deposition and erosion rates such in Bana Abu Sir forced bend and Izbit Al-Qabbani forced bend as shown in Figure 7 and Figure 8 respectively. On the other hand, Izbit El Miniaoui forced bend and Sawalem forced bend have islands as shown in Figure 9 and Figure 10 respectively. These Islands were affected by the secondary currents which lead to changes in their shapes and areas. For Sherpas forced bends, it is worth mentioning that the roads along the banks will be a risk because of deterioration of the river bank, which negatively affects the safety of the road from collapse as shown in Figure 10 which deals with (Hemphill and Bramley, 1989).

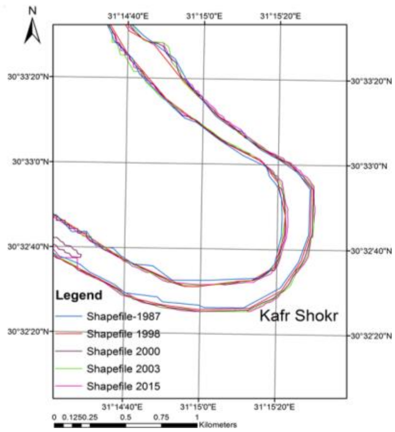


Figure 6. Temporal changes for Kafr Shokr forced bend

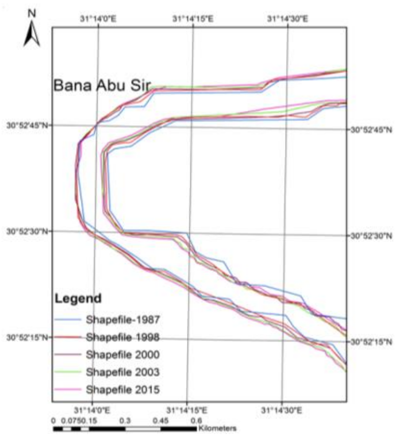


Figure 7. Temporal changes for Bana Abu Sir forced bend

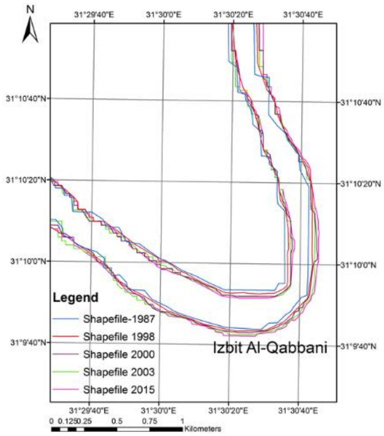


Figure 8. Temporal changes for Izbit Al-Qabbani forced bend

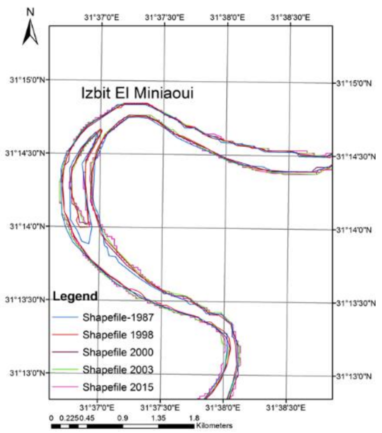


Figure 9. Temporal changes for Izbit El Miniaoui forced bend

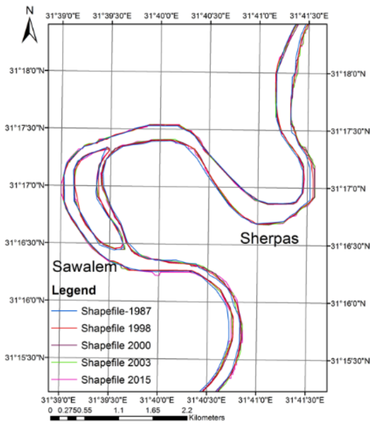


Figure 10. Temporal changes for Sawalem and Sherpas forced bends

3.3 Meander parameters investigation

The meander parameters of the forced bends of Damietta branch are calculated as shown in Table 2 according to the meander parameters stated by (Leopold, 1964) and (Sadek, Salama, and Kamal, 2015).

The sinuosity index was calculated for the studied six bends of Damietta branch then compared with (Sadek, Salama, and Kamal, 2015) published values who calculate the S.I. with the helping of field observation maps. Percentage of errors for the two values of S.I was obtained using equation 3 as shown in Table 3.

$$Error\% = \frac{\text{calculated S.I. - S.I. (Sadek, Salama, and Kamal 2015)}}{\text{calculated S.I.}} \quad (3)$$

Table 3. Meander Parameters of studied forced bends

Name	KM	Bend Length	meander belt axis	calculated S.I.	S.I. (Sadek, Salama, and Kamal 2015)	Error %
Kafr Shokr	95.00	7302	2881.08	2.271935	2.44	-0.07397
Bana Abu Sir	139.50	3621	3214	2.152794	1.88	0.126716
Izbit Al-Qabbani	194.50	7535	1682	1.770026	1.91	-0.07908
Izbit El Miniaoui	214.50	7734	4257	2.2687	2.05	0.096399
Sawalem	222.00	8023	3409	3.645161	1.96	0.462301
Sherpas	227.50	6128	2201	2.02311	2.6	-0.28515

One can conclude from the comparison between the calculated S.I. and the previous one that the percentage error did not exceed 0.46 % as shown in Table 3. Also, all studied forced bends are classified to be meander according to (Ahmed and Fawzi, 2011) as the sinuosity index for all of them exceeds 1.5.

3.4 Forced bends characteristics

The surface water area of the studied forced bends were calculated as shown in Table 4 and Figure 11 for the study period between 1987 and 2015.

Table 4. The surface water area of the studied forced bends

Name	Area Km^2				
	1987	1998	2000	2003	2015
Kafr Shokr	0.120979	0.114352	0.121493	0.13593	0.126515
Bana Abu Sir	0.394019	0.42071	0.428355	0.453809	0.456154
Izbit Al-Qabbani	0.173159	0.175426	0.183011	0.178905	0.177257
Izbit El Miniaoui	0.175217	0.175537	0.17842	0.187521	0.195895
Sawalem	0.314154	0.299038	0.307682	0.317043	0.321841
Sherpas	0.1256616	0.1196152	0.1230728	0.1268172	0.1287364

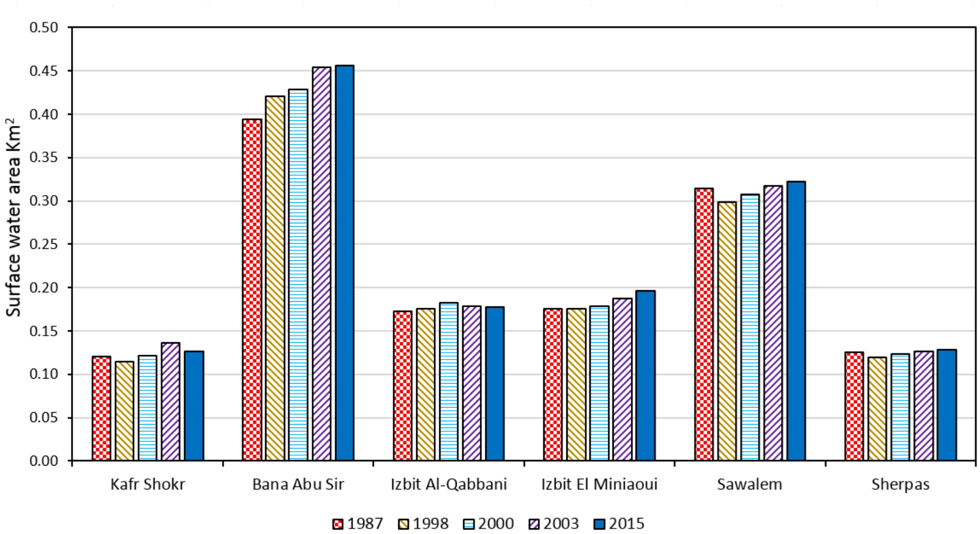


Figure 11. The surface water area of the studied forced bends in Km^2

It is clear from Figure 11 that the surface water area changing over the years is due to the erosion and sedimentation rates. Also, one can say that the surface water area of the studied forced bends in continuous increasing. This means that the erosion rates were higher than the sedimentation rates in this study. The results show also that Bana Abu Sir forced bend has the maximum surface water area which increased from 0.394 Km^2 to be 0.456 Km^2 in 1987 and 2015 respectively. On the other hand, Kafr Shokr forced bend has the minimum surface water area with a value of 0.12 Km^2 at 1987 and a value of 0.126 Km^2 at 2015.

The Annual erosion rate (m) and the Annual sedimentation rate (m) were calculated during the study as shown in Table 5, Figure 12 and Figure 13 for all bends. Also, the average annual erosion and average annual sedimentation were obtained. The results show that the annual erosion rate in the first period, from 1987 to 2003, is increasing in most forced bends. Therefore, in the period from 2003 to 2015 this rate started to decrease due to the protection processes done by the Ministry of Water Resources and Irrigation (MWRI) and the Nile Research Institute (NRI). From Figure 12 and Figure 13 it is clear that Sherpas forced bend has the greatest average annual erosion rate with value of 1.62 m/year but the minimum is for Bana Abu Sir with rate value of 0.56 m/year. For the average annual sedimentation rate, the greatest value is for Sawalem forced bend with a value of 1.0 m/year and Sherpas has the minimum value which equal to 0.66 m/year.

Table 5. The annual erosion and sedimentation rates for the studied forced bends

Name	**Annual erosion rate (m/year)**				**Average annual erosion rate (m)**	**Annual sedimentation rate (m/year)**				**Average annual sedimentation rate (m/year)**
	1987-1998	**1998-2000**	**2000-2003**	**2003-2015**		**1987-1998**	**1998-2000**	**2000-2003**	**2003-2015**	
Kafr Shok	1.27	3	2	0.67	1.2765	1.09	2	2	0.67	0.6856
Bana Abu Sir	0.9	0.5	0.67	0.167	0.56	0.9	3.5	2.67	0.25	0.9356
Izbit Al-Qabbani	2.36	3.5	1	1.08	1.4753	2	2.5	1	0.58	0.964
Izbit El Miniaoui	0.54	2	2	0.75	1.0322	0.63	3	2.3	0.67	0.7
Sawalem	0.9	1	1	0.5	0.8522	1	1.5	1.33	0.67	1
Sherpas	2.09	3.5	2	1.25	1.6268	0.72	1.5	0.67	0.25	0.66

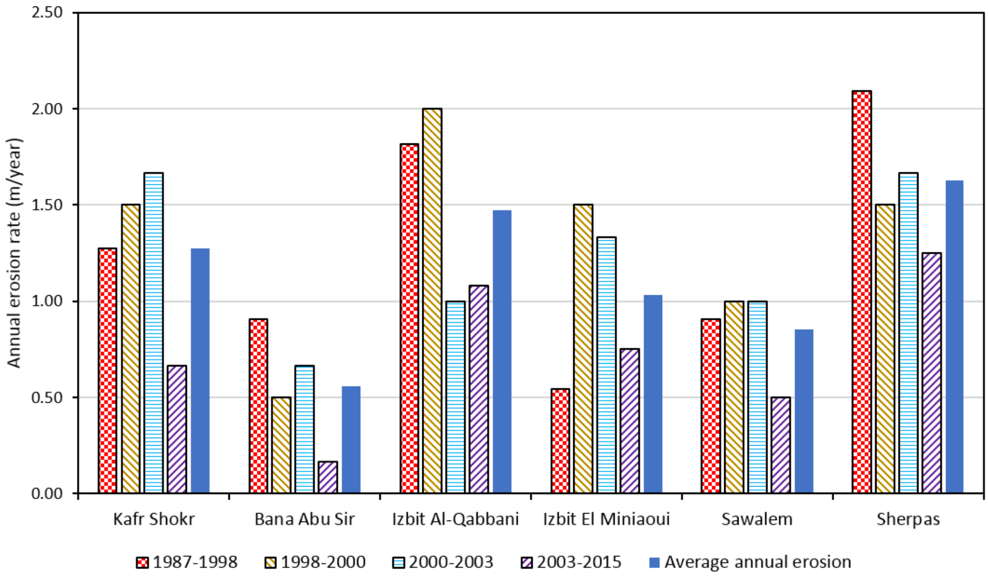


Figure 12. The Annual erosion rate (m/year)

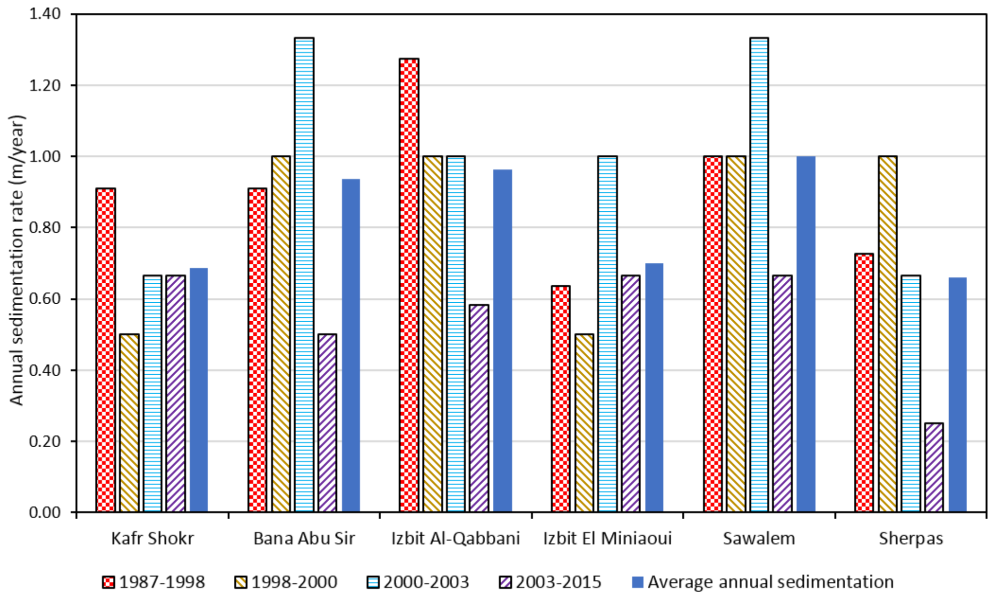


Figure 13. The Annual sedimentation rate (m/year)

4. Conclusion

A Satellite images are used to record the temporal changes occurred to the forced bends exists along Damietta branch, Nile River, Egypt. GIS and RS techniques are used to carry out this work. Onscreen digitizing, maximum likelihood classification and histogram thresholding technique are used to delineate the banks of the river forced bends over the study period. Comparative analysis was performed for the image classification techniques and the field maps for the year 2000 which led to select the onscreen digitizing method for the morphometric analysis. The surface water area of Bana Abu Sir forced bend shows the maximum surface area compared with the studied forced bends. The area temporal change of this bend was found to be 0.394 Km^2 in 1987 and increased to a value of 0.456 Km^2 by 2015. The annual erosion rate and annual sedimentation rate was calculated for all forced bends. It was found that Sherpas forced bend has the maximum average annual erosion rate of 1.62 m/year but the greatest value of the average annual sedimentation rate was for Sawalem forced bend with a value of 1.0 m/year. The secondary flow causes the occurrence of deposition for the concave curve and erosion for the convex curve, which negatively influenced the stream course and the surrounding areas along the river. This study to shed the light to the forced bends locations. Urged decision makers should, therefore pay attention to make the necessary protection to avoid adverse effects resulting from morphometric changes on these sites.

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Investigating reef contact rates of snorkel visitors at Koh Sak, Pattaya on guided and non-guided coral reef tours

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Abstract

Recreational snorkelling is a popular activity at Koh Sak, Pattaya Bay and although most snorkel visitors to the island arrive by speedboat on guided tours many visitors come on tours that do not provide a guide. Because there is widespread agreement that reef-based tourism negatively impacts coral reefs it is important to understand the potential role guides play in reducing visitor impacts. From February to November 2015 and 2016 the author observed 421 snorkelers 35% of whom came on non-guided tours. For 10 minutes I recorded the snorkelers' distance from their guide (if they had one), the number of people in their snorkelling group, and the number of contacts with the reef to calculate a per person reef-contact rate. There was no difference in contact rate between males (0.09 contacts min^{-1}) and females (0.11 contacts min^{-1}) nor was there any difference based on the group size (2-7 people). However, contact rates for snorkelers on tours with no guide (0.09 contacts min^{-1}) and snorkelers far from their guide (0.08 contacts min^{-1}) were significantly lower than visitors who snorkelled near their guide (0.18 contacts min^{-1}; $P<0.001$).The contact rate of guides (0.36 contacts min^{-1}) was significantly greater than the snorkelers they were looking after (0.17 contacts min^{-1}) in part due to the lack of knowledge and experience of snorkelers and guides alike. To reduce negative impacts to the coral reefs of Koh Sak guides need to reduce their destructive behaviour and improve their knowledge of reef biology and ecology.

Keywords: Koh Sak; coral reefs; recreational snorkelling impacts

1. Introduction

Coral reefs are particularly susceptible to the effects of global climate change including bleaching and ocean-acidification (Hoegh-Guldberg *et al*., 2007) and their global decline is well documented in the literature (Wilkinson, 2008; Eakin *et al*., 2010, Hughes *et al*., 2017). Local anthropogenic stressors such as fishing and tourism undermine the reef's structural complexity and challenge the balance between corals and macroalgae (Graham *et al*., 2014; Pratchett *et al*., 2014). After bleaching events, however, reefs that experience more intense tourism show slower growth rates (Carilli *et al*., 2009) implying that reefs facing local chronic negative impacts are less likely to survive global climate change.

Tourism, including nature-based tourism *(*Balmford *et al., 2009*), is increasingly important to Thailand’s economy; in 2016 the total contribution was 20.6% of GDP and this is set to rise to 31.7% of GDP by 2027 (WTTC, 2017). The islands and coral reefs in Pattaya Bay (see Figure 1A) are under increasing pressure from fishing and tourism. The near islands (Koh Sak and Koh Larn) are only 15 minutes by speedboat from Pattaya and host the majority of tours providing an island and reef experience for visitors. Because marine tourism is vital to the local economy and negative impacts to the local reefs could drive visitors to other destinations in search of a better reef experience, it would be particularly prudent to minimize the negative impacts of tourism on coral reefs and other natural areas.

Most snorkel visitors to Pattaya’s reefs go by speedboat on guided tours of 10-30 people but many come on speedboat tours of 5-20 people that do not provide a guide. Intervention by guides is known to decrease damage to reefs by reducing rates of contact with the coral reef substratum (Barker and Roberts, 2004; Roche *et al*., 2016) and here I assessed reef contact rate of visitors (and guides) on guided and non-guided tours to the North Reef of Koh Sak (see Figure 1B) to determine any difference.

2. Materials and Methods

2.1 Study site

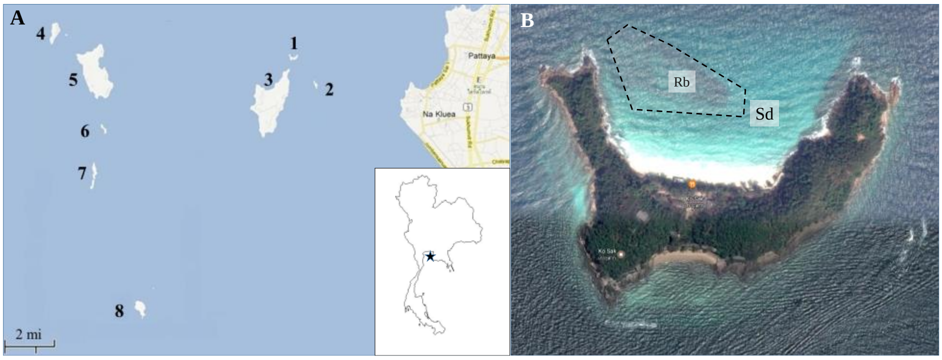

Figure 1, (A) Location (inset) of the Near Islands (1-Koh Sak, 2-Koh Krok, 3-Koh Larn) and the Far Islands (4-Koh Luam, 5-Koh Phai, 6-Koh Klung Bedan, 7-Koh Man Wichai, 8-Koh Rin) with respect to Pattaya. (B) Koh Sak’s North Bay; the reef is indicated by the stippled outline showing the rubble area (Rb) and sandy area (Sd) where most snorkel speedboat tours anchor.

Koh Sak (12°56'36.36"N, 100°47'30.29"E) is the nearest accessible island to Pattaya and experiences 1-3000 morning visitors depending on season. During the south monsoon (February to November) most visitors arrive at the North Beach by speedboat and all water-based activities (jetski and banana-boat rides) take place in the North Bay over the coral reef (Phillips, 2015). Because there are no proper moorings at the island, anchor use is prevalent and there is much evidence of broken colonies especially in the Rubble Zone (Fig 1B) and 49% of all hard corals show some sort of damage. *Porites* is the dominant coral at the island and 50% of the colonies show evidence of footprints on them and 70% of delicate foliose corals like *Pavona* are damaged (Phillips, 2015 and see Figure 2).

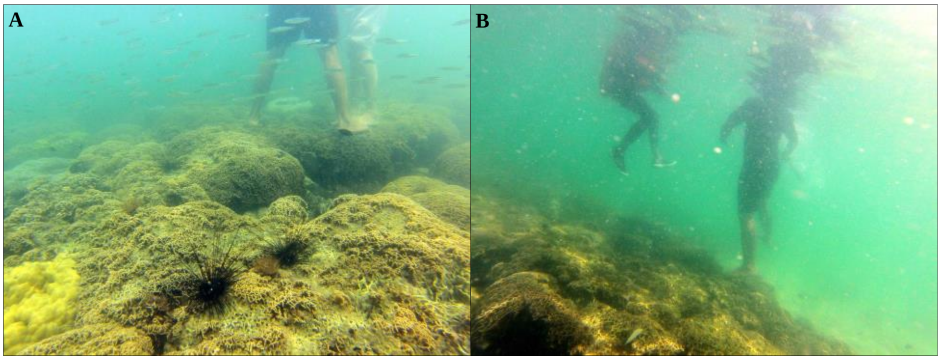

Figure 2. (A) A reef-tour guide (dark shorts) helps a visitor adjust the straps of their mask and snorkel; in order to do so, they stand on the reef. In this instance the snorkelers remained in location (but changed foot position numerous times) for about five minutes. Note the footstep-sized and shaped areas of damaged coral in the foreground. (B) A tour guide (right) stands on the reef while talking to a visitor (left). Note the guide is holding his mask and snorkel in his left hand and the visitor is in an upright position because she is wearing a personal flotation device (PFD). The photos were not taken during observation periods (sampling).

2.2 Methods

Sampling was conducted between February and November in 2015 and 2016. At each sampling event the author was in the water when snorkel tours began to arrive at the reef in the early afternoon and stayed in the water for about 2-3 hours. The author made 5-8 observations at each sampling event (described below) and sampled on 40 days over the 2 year period (20d each year). Sampling days were randomised as much as possible but did tend to fall on weekends for convenience and were constrained to those days and times in which the level of the tide would “allow” people to contact the reef – sampling was not done, for example, during high tide on days when the reef is too deep to contact. There was roughly equal number of days that had a rising tide as a falling tide. The author did not interact with the visitors or guides and although preliminary investigations showed that >95% of contacts at Koh Sak were made with the feet, in this study although a contact was recorded if any body part touched the reef, almost all contacts were made with the feet.

Random-number tables (printed on waterproof paper) were used to select snorkelers and when visitors entered the water they were given a couple minutes to orient to the reef and then they were followed for 10 minutes at a discrete distance to ensure they were not aware they were being observed which could alter their behaviour. The following information was recorded about the visitor: (i) gender; (ii) whether they wore a personal flotation device (PFD); (iii) if present, distance from the reef-tour guide (<3m or >5m); (iv) whether they snorkelled with friends; (v) the number of times the snorkeler contacted the reef and (vi) the number of times the accompanying guide contacted the reef (recorded as (0) 0, (1) 1, (2) 2-3 or (3) 3+ times). If the snorkeler swam in a group the number of people in the group and the total number of contacts with the reef made by the group (but not the guide) was recorded. No attempt was made to count the number of contacts of snorkelers outside of the immediate group being followed nor did the author differentiate between contacts made by males or females in the group, only the total number of contacts made by the visitor group being followed.

Independent of observations of visitors, tour guides were also followed for 10 minutes as soon as they entered the water and the following information recorded: (i) whether the guide contacted the reef or handled marine organisms (usually sea urchins or sea cucumbers) within the first two minutes; (ii) the total number of contacts with marine organisms and the reef and (iii) the number of visitors snorkelling with the guide during the observation and the total number of contacts made by the group.

In this study, once an observation was completed the author waited for the next arriving speedboat and using random number tables selected the next visitor to follow. Only one person (visitor or guide) was observed from each speedboat reef-tour. If the subject stood on or touched a coral with one foot it was counted as one contact; if the subject stood or touched with both feet it was counted as two contacts.

The average per person contact rate was calculated from the total number of contacts made by the visitor (group) and/or guide and all data were square root transformed before analyses. Factorial ANOVA was conducted to compare the main effects of guide (presence/absence and proximity), group size and the interaction of the main effects on snorkelers' rate of contact with the coral reef. An independent-sample t-test was conducted to compare the rate of contact for guides and the snorkelers under their immediate care and to compare contact rates between males and females when snorkelling alone (regardless of presence/proximity of guide). Group wise odds ratio of proportions of visitors that wore a PFD and proportion of visitors that did not contact the reef was conducted to assess likelihood of contact in the presence of the tour guide.

3. Results and discussion

In total 87% of the speedboat tours used anchors: 51% anchored in the sandy area adjacent to the reef, 36% anchored in the rubble area that was once healthy reef (see Figure 1B) and 13% tied-off to other speedboats that were already anchored. There is much evidence of anchor damage at Koh Sak and the use of anchors has long been known to cause problems for coral reefs (Davis, 1977) with lasting effects (Rogers and Garrison, 2001). Continued anchor use at Koh Sak is likely to further reduce reef complexity and prevent the growth and survival of coral fragments in the rubble area and reduce the chance of expansion of the reef. It is clear that proper moorings are needed at the island to prevent further damage and loss of habitat.

Table 1. Tour guide behaviour at Koh Sak during 10 minutes of observation (n=20).

	Handled[1] marine organism in the first two minutes	Total # contacts with wildlife in 10 minutes			Contacted the reef in the first two minutes	Total # contacts with reef substrate in 10 minutes		
		0	1	2		0	1	>2
% of guides	45	10	80	10	60	5	15	80

[1] Tour guides pick up an organism to show visitors, who may then subsequently also handle the organism. The organism is often brought out of the water.

Of the 20 tour guides directly observed in this study 45% handled a marine organism within the first two minutes of being in the water (Table 1). Only two of the guides made no contact with marine organisms at all and 90% intentionally contacted at least one, usually the long-spined sea urchin (*Diadema antillarum*) which is abundant at the reef and easier to find than the sea cucumbers handled by two of the guides (Table 1). Handling reef organisms is known to cause them stress (Shannon and Mustafa, 2015; Tan *et al*., 2015) and given that so many guides harassed marine organisms within minutes of being in the water, there is the potential for visitors to imitate such behaviour which the author observed on at least seven independent occasions but not in visitors from non-guided tours. Given that the observation period was only 10 minutes and most visitors stay at least 30 minutes, the true incidence of marine organism harassment by visitors may be much higher. 60% of the guides contacted the reef within the first two minutes of being in the water; 80% of them contacted the reef at least two times (one tour guide contacted the reef 18 times in 10 minutes) and only one guide did not contact the reef at all. No guides were ever seen or heard to intervene when visitors contacted the reef even though such interventions, coupled with pre-snorkel briefings about proper reef etiquette and behaviour are known to reduce contact rates, at least with SCUBA divers (Camp and Fraser, 2012; Krieger and Chadwick, 2013). On the three occasions the author challenged guides standing on a *Porites* colony (at the end of the observation period) they insisted they were standing on rock and pointed at other *Porites* colonies as an example of a coral - indicating a general lack of knowledge about coral reefs.

60 of the 180 visitors randomly selected snorkelled alone and 120 swam with one or more friends from the same tour leading to the author observing 421 visitors making 587 contacts with the coral reef (Table 2). Visitors in snorkel groups near their guide (<3m) on average made 2.0 contacts with the reef in the 10 minute

observation period whereas groups far from their guide (>5m) and groups with no guide made 1.1 contacts in the same time period. The 20 tour guides and the 65 visitors in their care made, on average, 4.4 and 1.7 contacts, respectively, in 10 minutes (Table 2).

Although the severity of contact with the reef was not recorded in this study, most contacts were intentional; visitors and guides stood on the reef (see Figure 2). The contact rate of tour guides was significantly higher (M=0.36, SD=0.063) than the snorkelers under their immediate care (M=0.17, SD=0.012); t(26)=2.68, p=0.01 (see Figure 3A *Guide* vs *Guided group*). The guides are as naïve as visitors concerning the proper use of mask and snorkel equipment and were observed standing on coral to adjust straps and to empty water-flooded masks as frequently as visitors. When visitors had the same problems the guide stood on the reef to help the visitor probably explaining why guide contact rates are two times higher than visitor contact rates. Contact rates of visitors observed near their guide (M=0.18, SD=0.032) did not differ from contact rates of the guided group (M=0.17, SD=0.012) but visitors with guides that contacted the reef more often had higher contact rates (see Figure 3B). No interaction was made with visitors or guides to establish their level of reef experience so it is difficult to determine, under the present study, if the visitors contacted the reef more often because they saw their (naïve) guide contact the reef often or because, as the author heard on numerous occasions, the guide encouraged visitors to stand on the reef so he could more easily help.

Table 2. The total number of guides and visitorsand the number of contacts made with the reef in 10 minutes on guided and non-guided coral reef tours.

	Group size near guide				Group size far from guide				Group size with no guide			
	1	2	≥ 3	Total	1	2	≥ 3	Total	1	2	≥ 3	Total
# observed	20	40	67	127	20	40	86	146	20	40	88	148
# contacts	54	79	125	258	18	55	86	159	20	48	102	170
Avg # contacts				2.0				1.1				1.1

	Tour guides	Visitors with tour guide[1]
# observed	20	65
# of contacts	87	113
Avg # contacts	4.4	1.7

[1] visitors snorkelled near the guide; modal group size = 3

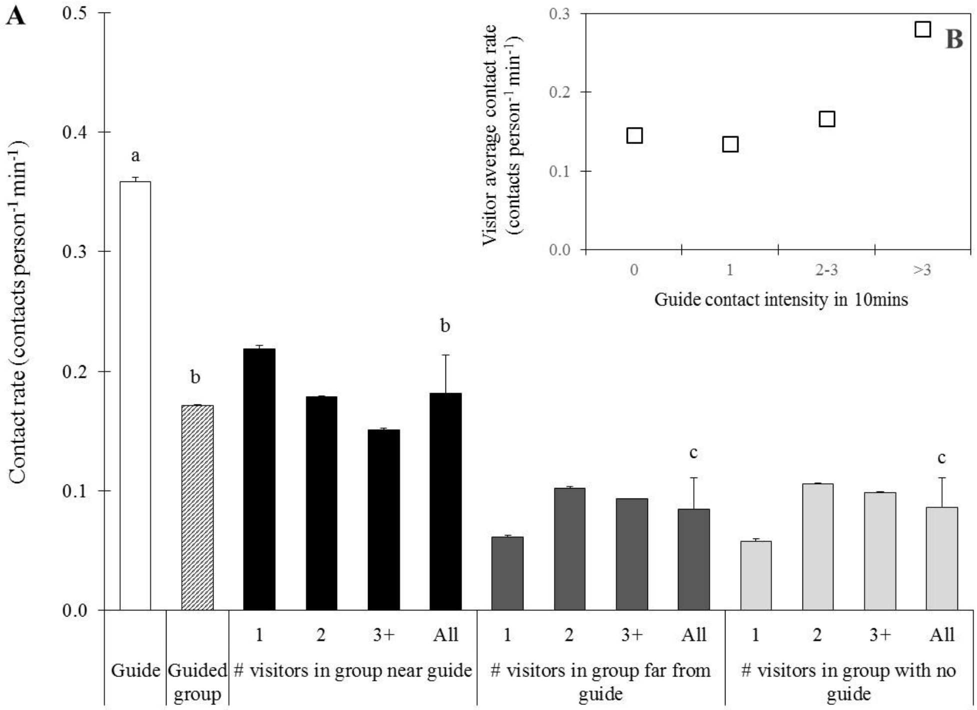

Figure 3. (A) Mean contact rates for guides and the visitors under their immediate care (“Guided group), and for visitors snorkelling alone, in pairs or larger groups near their guide (black bars), far from their guide (dark grey bars) and for visitors on tours with no guide (light grey bars). Error bars indicate standard error of the mean and letter symbols indicate rates that are statistically significantly different, with the same letters showing no difference in contact rate. (B) Guide contact intensity vs visitor average contact rate independent of guide proximity or group size.

There was no significant difference between the contact rates for males (M=0.09 contacts min^{-1}, SD=0.04) and females (M=0.11 contacts min^{-1}, SD=0.03). Although factorial ANOVA showed no effect of group size on contact rate, an F-ratio of $F(2, 171) = 13.01$, $p < 0.001$ indicates a significant difference in the contact rate of snorkelers who stayed near the guide (M=0.18, SD=0.032) and snorkelers who stayed far from the guide (M=0.07, SD=0.027) or who had no guide at all (M=0.09, SD=0.025) - see Figure 3A. There was no interaction between presence/proximity of the guide with group size on contact rate.

The proportion of visitors who made no contact with the reef was significantly higher in groups far from their guide and in groups with no guide (Figure 4A) and this was true for both males and females (Figure 4B). Whether this is because visitors far from their guide or who come on non-guided tours have more snorkelling experience or because they are beyond the influence of their guides who may encourage them to stand on the reef is difficult to determine given the objectives.

Visitors with no guides and visitors far from their guides were also significantly less likely to wear a PFD (Figure 5) and when comparing contact rates of visitors that snorkelled alone the contact rate for visitors that wore a PFD (M=0.12 contacts min^{-1}, SD=0.243) was two times higher than the contact rate for visitors without a PFD (M=0.06 contacts min^{-1}, SD=0.167) although the difference was not significant.

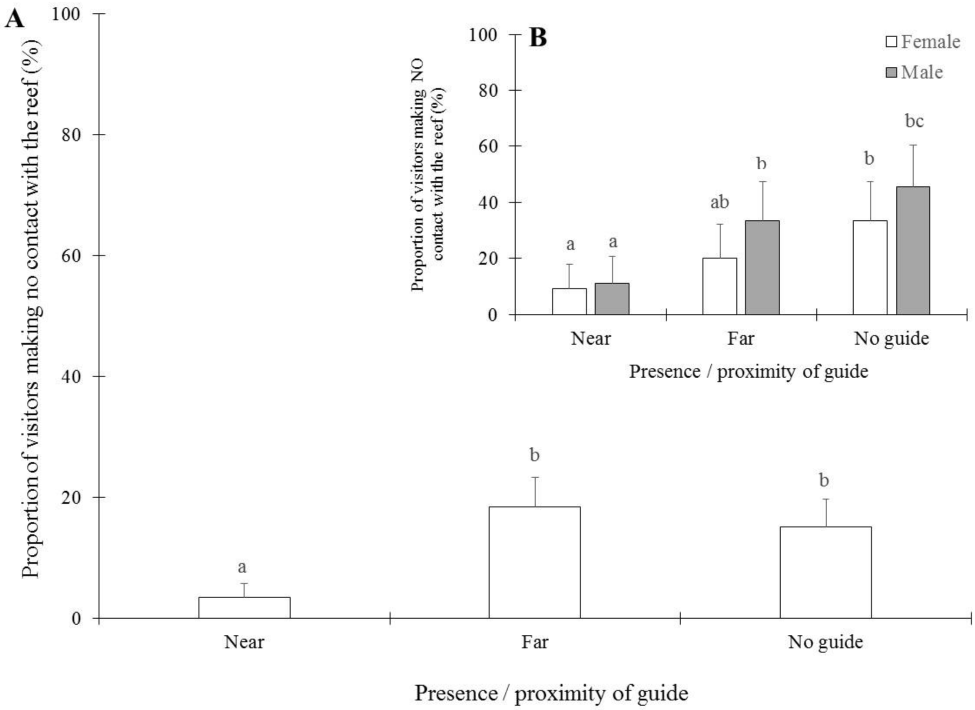

Figure 4. (A) The proportion of visitors (observed near their guide, far from their guide or with no guide) that made no contact with the reef. (B) The proportion of males and females that snorkel alone near their guide, far from their guide or with no guide who made no contact with the reef. Error bars indicate standard error of the mean and letter symbols indicate proportions that are statistically significantly different (P≤ 0.05), with the same letters showing no difference.

The visitor contact rates in this study are lower than rates measured for snorkelers in other studies. Snorkelers in Puerto Rico for example contacted the reef at a rate of 0.26 min^{-1} (Webler and Jakubowski, 2016) but at Koh Sak visitors do not wear fins as they do in the reefs of Puerto Rico explaining the lower rates. In that study the use of a PFD had no effect on contact rate but the type of PFD in use at Koh

Sak (high-visibility lifejackets) pushes wearers into an upright position (see Fig 2B) making it more likely that contact with the reef will occur. Visitors far from their guide or who had no guide were (i) less likely to wear PFDs, (ii) less likely to contact the reef and (iii) had contact rates lower than snorkelers near their guide; whether this is because they have previous snorkelling experience or because of the lack of the negative influence of guides remains to be seen and is the subject of further investigation.

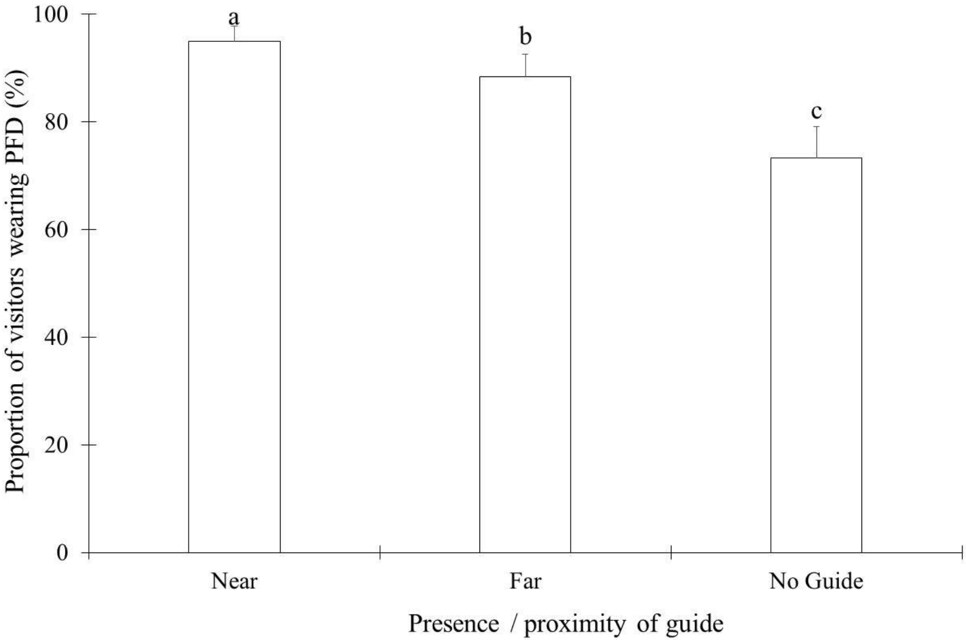

Figure 5. The proportion of visitors that wore a personal flotation device (PFD) at Koh Sak. The different letter symbols indicate proportions that are statistically significantly different.

Visitors are not shown how to properly fit and wear a mask before getting in the water and masks often flood potentially reducing the visitors' enjoyment of the reef experience. Because they do not know any different, and because visitors observe their guides doing the same thing, visitors often stand on the corals to rearrange their masks and snorkels and/or the straps of their PFD. Visitors are not given even rudimentary information about coral reefs nor advice on how to behave on the reef. Guides at Koh Sak play the role of "pathfinder" (Cohen, 1985) and lead people on the reef who "lack orientation"; however, because (i) a high proportion of guides contacted the reef and handled reef organisms within minutes of being in the water, (ii) only three guides did not contact the reef during observations, and (iii) visitors are less likely to contact the reef if they are far away from their guide or do not have one, one must question the role that guides play at Koh Sak. Tour guides contact the reef at a greater rate than visitors and it is evident that guides need training on proper reef etiquette and environmentally responsible behaviour. Programmes, such as Green Fins (Hunt *et al*., 2013) which has a code of conduct that tour providers agree to abide by, are known to reduce contact rates (Roche *et al*., 2016). Such an approach is needed at Koh Sak to establish a group of professional, well trained and knowledgeable guides that have the skills and motivation to exhibit reef friendly behaviour and pass on reef related knowledge to visitors.

4. Conclusion

Guides had the highest rate of contact with the coral reef compared to visitors and had a negative influence on nearby snorkelers. Visitors who snorkelled far from their guide or who had no guide at all had lower contact rates. To decrease contact rates and prevent further damage to the reef and potential loss of tourism revenue if tourists visit other destinations it is essential to re-design PFDs and train guides on proper reef etiquette and behaviour.

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Assessing the Sustainability of Ghanaian Cities: the case study of Accra Metropolitan Area

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Abstract

Cities have become integral in the quest to achieving universal sustainable development. For example, the United Nations in 2015 as part of the 17 Sustainable Development Goals called for cities and human settlements to be inclusive, safe, resilient and sustainable (Goal 11). Achieving a sustainable city requires continuous assessment of its development in line with the goals of sustainability. The aim of this study was to comprehensively evaluate the sustainability status of Ghanaian cities. As a case study the sustainability of Accra, the capital city of Ghana, was assessed using sustainable development indicators. Forty-one Accra sustainability indicators (ASI) were defined and classified into Economic, Environment, Social and Institutional dimensions. The evaluation was over the period of 4 years, from 2012 to 2015 during which the 2012 Urban Policy and its action plan were being implemented. The results show Accra's economic and social dimensions are approaching sustainability while environmental and institutional dimensions are performing poorly. Overall sustainability score of Accra however showed a progression towards sustainability over the last 4years, rising from 0.48 in 2012 to 0.51 in 2015. The findings of this study are helpful to local authorities for sustainable city planning and management.

Keywords: sustainable city; sustainable development indicators; city sustainability assessment; Accra

1. Introduction

With 54%urbanization, Ghana has witnessed an unprecedented urban growth in the past 20 years (Fuseini & Kemp, 2016). This rapid urbanization is associated with: 5.7 annual contributions to Gross Domestic Product from 1984 to 2013; structural transformation; and poverty reduction with Accra alone experiencing 20 percent drop in its poverty index from 1991 to 2012 (World Bank, 2015). However, Ghana's urbanization has been characterized with problems such as land use disorder, pollution, stressed urban services such as water and electricity, growth of slums, poor transport infrastructure and traffic management, amongst other negative aspects.

In an attempt to find a solution to these problems, the government of Ghana has implemented a number of policies, such as the 2012 National Urban Policy and the Accra Millennium City Project with the aim of promoting more sustainable cities. After years of implementing urban policies and projects, and five years into the 2012 National Urban Policy and its action plan, what is the sustainability status of Accra?

1.1 Sustainable City

A sustainable city is an urban area that satisfies the needs (in terms of infrastructure, education, safety, health and medical care, housing, utilities, greenery and good governance) of both current and future generations. It is capable of addressing environmental challenges associated with urban growth, middle-income status and population increases (Global Environment Facility, 2015), thereby promoting the health and wellbeing of residents at lower per capita environmental degradation. Due to the importance of cities in human development, the United Nations, as part of the 2030 Agenda for Sustainable Development Goal (UNSDG 11), called on governments to make cities and human settlements inclusive, safe, resilient and sustainable (United Nations, 2015). The targets of this goal aim to address issues regarding the provision of houses and essential needs, transport, participatory human settlement development, protection of cultural and natural heritages, disaster reduction and decreasing the per capita environmental impact of a city (United Nations, 2015). Development of sustainable cities depends on a governments' ability to significantly decouple economic growth from inefficient use of natural resource and environmental degradation**.**

1.2 City Sustainability Assessment

Sustainability assessment is essential to implementing and evaluating the sustainability development agenda. The two most recognized methods of assessing the sustainability of an industry, state or a nation are monetary aggregation methods and the use of physical indicators (Singh et al., 2009). The monetary aggregation method, normally adopted by economists, includes the use of monetary units and economic methods, such as Cost Benefit Analysis, Green Domestic Product, and Resource Accounting. This method however has its limitations, including the difficulty in placing monetary values on natural capital and intangible resources, such as air (Goodland, 1995). In light of these challenges, the use of physical indicators have become a widely-used approach to assessing sustainability, especially since 1992, when the United Nations approved such indicators as key aspects of sustainable development.

1.3 Sustainable Development Indicators

The use of these indicators can provide a good measure of a city's sustainable development (Ibrahim et al., 2015). In sustainability evaluation, indicators assess current sustainability conditions and trends, and anticipate future conditions. They are also useful tools for communicating performance, problem identification, urban planning, monitoring goals and objectives and for important decision-making (Searcy, 2009; Ibrahim et al., 2015). Many indicators have been developed and defined by governments and researchers for assessing the sustainability of societies. Some known sustainable development indices include: United Nations Council for Sustainable Development Indicators (UN, 2007); Sustainable Cities Index 2015 (Arcadis, 2015) and local Sustainable Development Indices (Shaker & Sirodoev, 2016).

2. Materials and Methods

2.1 Case Study Area

Accra (Figure 1), the capital of the Republic of Ghana and the Greater Accra region, is geographically located on longitude 05 35' and latitude 00 06' and shares boundaries with La-Dadekotopon Municipality to the east, the Gulf of Guinea to the south, Ga South and Central Municipalities to the west, and Ga West and La-Nkwatanang Municipalities to the north with a total land area of 139.674 Km^2 (GSS, 2014),Accra is the largest populated city in Ghana and the 6th in West Africa (UN Habitat, 2014) and has a 2015 population of 2,277,000 which is expected to grow to 2,870,000 by 2025 (UN-Habitat, 2016). Accra, a major contributor to the economic growth of Ghana, contributes about one-third of Ghana's total manufacturing output and 10 %of national Gross Domestic Product (UN Habitat, 2014).It is noted for major economic, institutional and social activities, such as manufacturing, marketing, banking and finance, entertainment, learning institutions, transport and governance. Major challenges of the city include the destruction of wetlands, inadequate supply of urban service (including water and electricity), poor management of municipal waste and increasing housing deficits which have resulted in the development of over 29 squats and slums (Accra Municipal Assembly, 2014).

Figure 1. Map of Accra Metropolis (Google, 2017)

2.2 Methods

Selection of Sustainable Development Indicators

This study defined 41 sustainable development indicators known as Accra Sustainability Indicators (ASI) based on the following criteria defined by Arcadis (2015) and Shaker & Sirodoev (2016).

- data availability
- usefulness for local decision making
- relevance to national policy
- consideration of very basic needs of the people
- simplicity

The indicators selected from UNSDG 11, Sustainable Cities Index, Local Sustainable Development index and the Ghana Shared Growth and Development Agenda II (2014 – 2017) were classified under economic, environment, social and institutional criteria (Table 1).

Table 1. Accra Sustainability Indicators (ASI)

Economic	**Social**	**Environment**	**Institution**
1. Incidence of Poverty 2. Incidence of extreme poverty 3. Income Inequality (Gini Index) 4. Unemployment 5. Access to energy 6. Transport/Mobility	1. Urban population living in Slums 2. Water Access 3. Infant mortality rate 4. Under 5 mortality rate 5. Maternal mortality rate 6. Prevalence of HIV 7. Prevalence of cholera 8. Net school enrolment in Kindergarten 9. Net school enrolment in Primary	1. concentration of PM10 in mg/ms at roadside 2. concentration of PM10 in mg/ms in residential area 3. concentration of PM10 in mg/ms in commercial area 4. concentration of PM10 in mg/ms in industrial area 5. Sanitation 6. Waste collection	1. Women participation in local governance 2. Sanitation management 3. Disaster Risk Reduction 4. Natural Resource conservation

Economic	Social	Environment	Institution
	10. Net school enrolment in JHS 11. Net school enrolment in Senior High School 12. Special education for People With Disabilities 13. Adult literacy 14. Crime Rate 15. Domestic Violence 16. Child abuse	7. municipal waste recycled, reused and composed (plastic) 8. metal wastes recycled and reused 9. Waste water treatment 10. Water efficiency 11. Land under agriculture cultivation 12. Land classified as built environment 13. Land covered by vegetation	5. Revenue Performance 6. Financial Management

Data collection

Statistical data on these indicators were collected over the period of four years (2012-2015). The data sources included the Accra Metropolitan Assembly and other relevant central government institutions, such as the Environmental Protection Agency and Ghana Statistical Service, as well as government and international reports and publications.

Standardization and Normalization of Indicator Values

a) In order to normalize all indicators to the same units and scale, standardized values were calculated over the period of 4 years using the standard deviation formula:

$$\textbf{Standard Value Z} = (\boldsymbol{Xi} - \mu)/\boldsymbol{\sigma} \quad (1)$$

Where Z = standardized value,

Xi = Indicator value,

μ = mean value and

σ = standard deviation.

b) The next step was to normalize the standardized indicator values such that the values fell within 0 to 1 in order to facilitate the weighting of the indicators. The normalized standardized value is defined as:

$$\mathbf{Y} = (\boldsymbol{Zi} - \boldsymbol{a})/(\boldsymbol{e} - \boldsymbol{a}) \qquad (2)$$

Where Zi lies between a to e, and Zi = standard score

a = minimum value

e = maximum value

Y ranges from 0 and 1.

c) Reverse indicators, such as incidence of crime were further standardized using the formula (1 - Y) so that all values nearer or equal to 1 are those approaching sustainability, while those approaching zero (0) means unsustainable development.

Weighting and calculating aggregate and overall scores

In this study, equal weight was assigned to each indicator based on the premise that they all posses equal significance to the sustainability of the city. Aggregate scores for each sustainability dimension, defined as Dimension Sustainability Score, were calculated using the formula:

$$\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}(\boldsymbol{YixWi})\,/(\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}\boldsymbol{wi}) \qquad (3)$$

Where, W = weighting of each indicator

Y = normalized value of each indicator

n = number of indicator

i = year of assessment

Finally, the overall Accra Sustainability Index was calculated by summing the sustainability of each dimension score in each year. Again, equal weight (1/4) was assigned each dimension of Economic (ES), Social (SS), Environment (EnS) and Institutional (IS) as shown in the formula.

$$\text{Accra Sustainability Index} = \frac{\sum_{i=1}^{n}(\boldsymbol{ESxW})(\boldsymbol{SSxW})(\boldsymbol{EnSxW})(\boldsymbol{ISxW})}{\Sigma W} \qquad (4)$$

3. Results and discussion

3.1 Economic sustainability performance

The economic dimension is the greatest contributor to the city's sustainability performance (Figure 2) with scores ranging from 0.84 in 2012 to 0.874 in 2015. The data show that Accra has the lowest poverty indicators (3.5 % of its total population) in the whole country, as compared to the national urban average of 8.4 % (GSS, 2014). It also experienced a decrease in its income inequality index from 0.5 in 2012 to 0.346 in 2015, while recording decreasing unemployment rates. The high sustainability scores affirmed Accra as a city with vibrant economic activities and a centre offering opportunities to both formal and informal sector workers, residents and other Ghanaians to enhance their economic and social welfare levels (Tufuor et al., 2015).

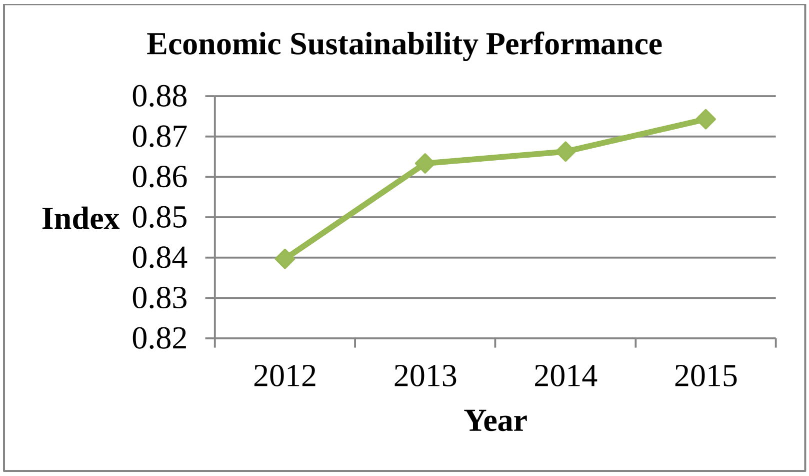

Figure 2. Economic sustainability performance of Accra

3.2 Social sustainability performance

The social dimension of Accra showed an average sustainability scores. This is the second strongest performing sustainability dimension of the city. Its sustainability scores rose from 0.50 in 2012 to 0.52 in year 2015 (Figure 3). There was, however, a decrease in the scores in 2013. This was because the highest incidences of maternal death (338 per 100,000 live births) and populations living in slum condition were recorded in 2013. However, government interventions, such as decongestion of the slums by the city authority (McTernan, 2014; Gadugah, 2015) improved these measures in 2014 and 2015. The high scores in this category came mainly from health indicators, such as low cases of child mortality and decreased incidence of other diseases, such cholera and HIV/AIDS. For example, child mortality decreased from 25 per 1000 live births in 2012 to 15 per 1000 live births in 2014, meaning the city has achieved the United Nations SDG 3 target (World Health Organization, 2017).

The low scores in the social dimension score of Accra are attributed to difficulty of the Accra Municipal Assembly (AMA) to significantly provide social services and infrastructure for the increasing population. The city still struggles with inadequate supply of quality piped water to the extent that some communities have access to pipe water only once a week (MWRWH, 2007). There is an annual backlog of provision of over 300,000 housing units, resulting in the growth of over 29 squatter zones and slums (Accra Municipal Assembly, 2014). Some educational indicators of the city also showed poor scores. Despite the existence of many public and private schools at all levels, coupled with the Free Compulsory Universal Basic Education (FCUBE) program by the government, net school enrolment is low. The National Development Planning Commission (2012) confirmed that the Accra region as a whole records the lowest net enrolment in primary schooling in the country, even though it has the lowest poverty incidence.

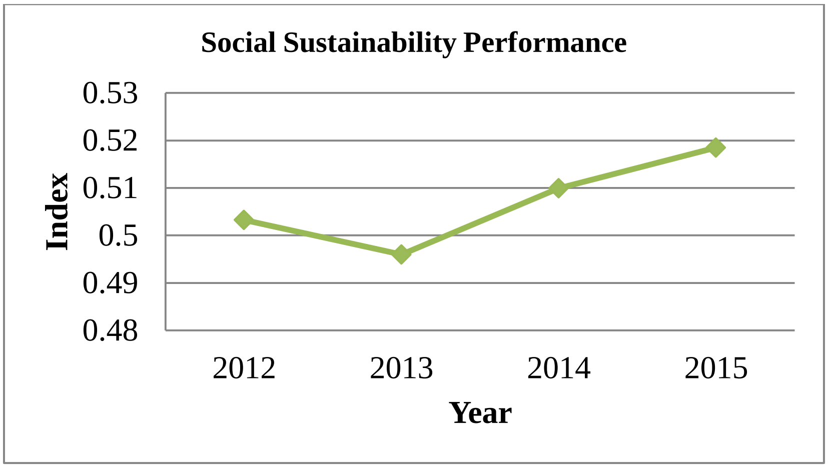

Figure 3. Social sustainability performance of Accra

3.3 Environmental sustainability performance

This is the worst performing dimension of the city. The environmental sustainability performance (Figure 4) of Accra showed very low scores decreasing from 0.23 in 2012 to 0.21 in 2013. This measure increased in 2014 to 0.25 but decreased again in 2015. The 2015 decrease may be attributed to the major flood that occurred on June, 2015 which increased the amount of municipal wastes left uncollected and destroyed agricultural and vegetative lands. The overall poor performance of the environment dimension is also negatively affected by poor waste management, air pollution and inadequate access to approved toilet facilities (Grant & Yankson, 2003; Arguello et al., 2013; UN-Habitat, 2014). For example, the mean annual concentrations of particulate matter (PM10) recorded over the 4 years were higher than the standard Air Quality Index (AQI) of Ghana's Environmental Protection Agency (EPA, 2014), posing a serious health risk for people with lung diseases, children and the very old.

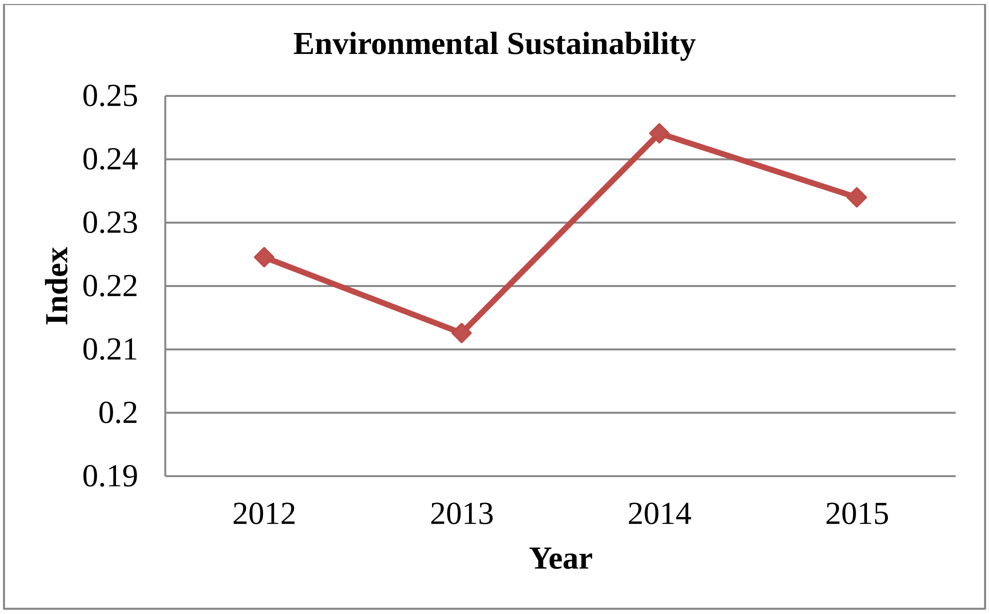

Figure 4. Environmental sustainability performance of Accra

3.4 Institutional sustainability performance

Accra's weak governance resulted in the poor institutional sustainability performance of the city. Figure 5 shows the institutional sustainability performance of the study area over the four assessment years. Its scores range 0.35 in 2012and rose to 0.4 by 2015.

Figure 5. Institutional sustainability performance of Accra

This dimension showed that Accra has relatively effective revenue generation and efficient financial expenditure management. The weak indicators in this category, which far outweigh the strong indicators, include poor management of wastes, disaster risk reduction, resource conservation and weak implementation of planning schemes, as highlighted by Fobil et al. (2008) and Oteng-Ababio et al. (2015). There are low budget allocations to these sensitive areas of the city by the metropolitan authority.

3.5 Overall sustainability performance

The composite of all four dimensions in each year of assessment produced overall sustainability scores of Accra (Figure 6). The results indicate economic and social dimensions approaching sustainability, while the environmental dimension and institutional dimensions are performing poorly. It is noteworthy however that some indicators have shown positive changes over the period of assessment. Overall sustainability index of Accra showed a slight progression to sustainability over the last four years rising from 0.48 in 2012 to 0.51 in 2015.

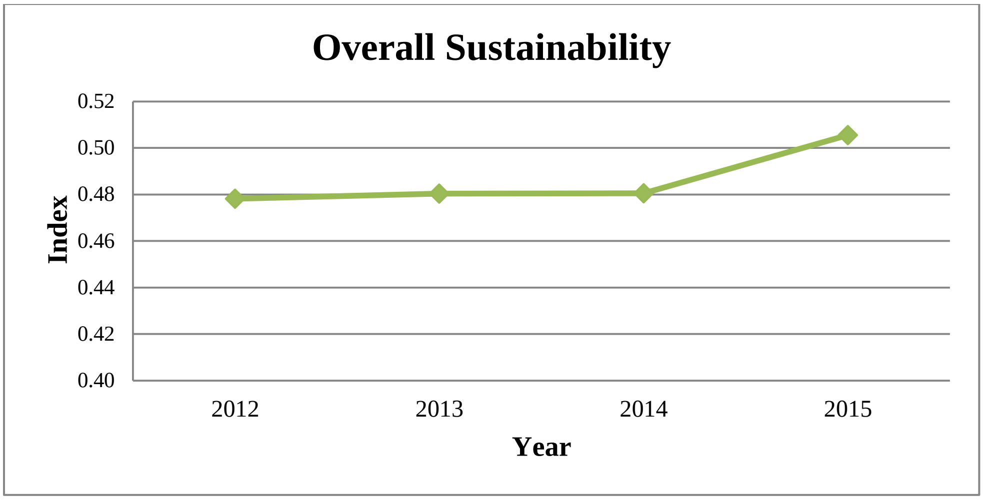

Figure 6. Overall Sustainability Performance

As shown in Figure 6, the rise in 2015 except environment dimension, the economic, social and institutional scores appreciated in 2015 and that was the main reason for the 2015 overall index. The previous years 2012 and 2013 maintained the score of ~0.48 because of the performance score of social and institutional dimensions which had their lowest scores of 0.496 and 0.301 respectively in 2013 and 2014. A study conducted by Tamanini et al. (2014) produced a sustainability score of 44.5 % (0.45) for Ghana (Accra), which is closer to the 2014 results (0.49) of this study, and also confirmed this research's findings on the economy and the worrying environmental performance of Accra.

3.6 Comparison between dimensions

Figure 7 shows that the economic dimension becomes closer to sustainability while environmental dimension moves closer to zero. This suggests a reverse relationship, whereby an increase in the economic performance worsens the environmental dimensions of the city. For instance, more economic opportunities attract rural-to-urban migration from other parts of the country into the city's major slums, including Old Fadama and Nima (Awumbila et al., 2014) resulting in increased population and consumption. The increased demand for goods and services, such as housing, leads to encroachment on wetlands, as well as building on water ways, which sometimes lead to flooding (the June 9, 2015 flood, as example). The high population's consumption also worsens the city's sanitation as evident in Makola, Kantamanto and Agbogbloshie markets and major Accra slums.

Social sustainability is also linked to the environment and economics of the city. Sanitation-and pollution-related diseases, such as malaria, is common annual phenomena in Accra. However, improvements in economic conditions can enable average residents to afford some decent social services which together with improvements in health infrastructure and services, and increasing health education have led to the city's social sustainability score showing a reasonably good performance. Unfortunately, the institutional results and the available literature (Fobil et al., 2008; Oteng-Ababio et al., 2015) have signaled weak urban governance, which is not providing a balanced socio-economic development in an environmentally-sustainable direction. It is expected that with a boost in the environmental and institutional dimensions, the city may attain high sustainability in the near future.

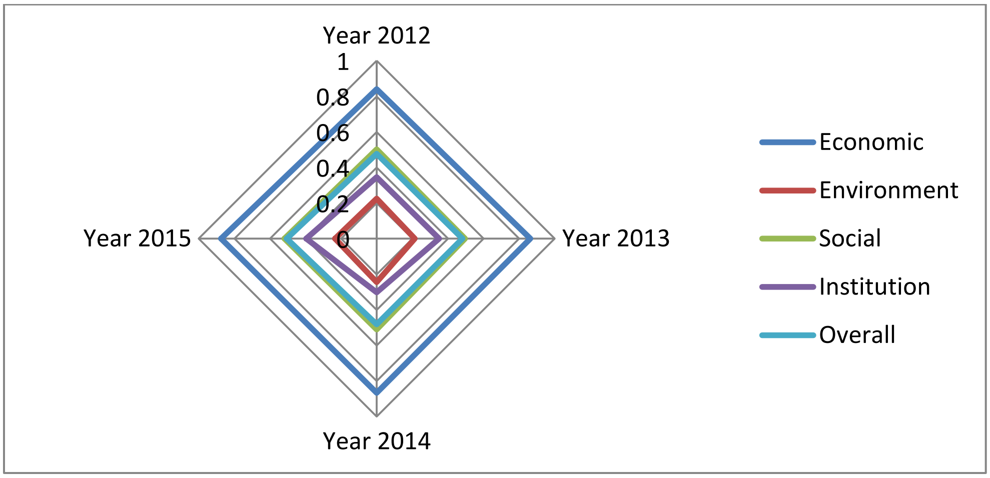

Figure 7. Radar analysis showing sustainability dimensions of Accra

4. Conclusion

For strong sustainability, Accra Metropolitan Assembly needs to direct its fast-growing economy to a "greener" growth path by addressing the city's environmental challenges, including air pollution, municipal waste management and conservation of ecosystems. Improving social indicators requires the provision of uninterrupted urban services, such as water, electricity and housing. There is also the need for sustainable and inclusive urban governance. Finally, a further study is recommended to analyze the sustainability performance of other major Ghanaian cities, including Kumasi, Tamale, Takoradi and Cape Coast. This would provide a better understanding of the sustainability status of Ghanaian urban areas.

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Health Survey of Primary-School Children in the Vicinity of a Sanitary Landfill in Nonthaburi Thailand

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Abstract

Recently, communities in the vicinity of a sanitary landfill in Nonthaburi have complained for bad landfill odor. This exposure to landfill odor and air pollutants may affect surrounding sensitive population like school children. In Thailand, there is no study on the excess risk of landfill-related symptoms in children. We then surveyed prevalence of the related symptoms among school children and investigated an association between the landfill-school distance and 8 adverse health effects. There were 2,362 students participating from a total population of 3,606 students (65.5%) of 12 kindergarten and primary schools. Participants were categorized into 3 landfill-school distances; Distance 1 (0-<4 km), Distance 2 (4-<7 km) as for exposed groups, and Distance 3 (7-<11 km) as for a reference group. A questionnaire asked their parents for odor exposure at school, children and family characteristics and children's recent related symptoms. Most children and family characteristics among Distances 1-3 were fairly similar thus to help control confounder effects. For odor exposure, they reported the odor exposure frequency as "sometimes" for 58%, 40%, and 29% in Distances 1-3 respectively. We found high prevalence for runny nose (82%), cough/sneeze (no fever) (78%), and headache (61%). Crude odds ratios as health risks were positively associated with all symptoms, were highest in Distance 1 and were decreasing over Distances 2 and 3 respectively. The risks in Distance-1 children were statistically significant (OR, 95% CI) in 3 symptoms, wheeze (1.278, 1.032-1.583), irritated eyes (1.296, 1.046-1.606), and fatigue (1.587, 1.282-1.965). For odor report, the risks were increased in all symptoms for those self-reporting odor exposure. With the odor exposure, all symptoms showed the statistically significant association except headache. They were runny nose (1.312, 1.056-1.631), wheeze (1.306, 1.106-1.542), cough (1.423, 1.165-1.737), vomit (1.202, 1.012, 1.427), diarrhea (1.272, 1.012, 1.427), irritated eyes (1.357, 1.151-1.601) and fatigue (1.521, 1.289-1.796). These findings are consistent with other works reporting that students and community surrounding landfills had statistically significant excess risks. This work confirmed the landfill odor-symptom relationship. It also agreed the closer school was located to landfills, the greater health risk was. However, it lacked of quantitative monitoring data of fugitive landfill emission and did not adjust for other confounders.

Keywords: landfill; children health; landfill health effects; solid waste

1. Introduction

The problem of pollution from municipal solid waste (MSW) is likely to be more aggravating because the generation MSW is increasing rapidly and the composition of waste is difficult to characterize and eliminate. If such a situation continues to be abandoned, it may lead to environmental health threat. To protect community health, some correct waste disposal methods such as sanitary landfill, incineration, and waste utilization are recommended. The landfill plays an important role in waste management systems for sustainable waste management. Nevertheless, incorrectly landfilled waste may create harmful effects to air, water, and soil environment and adverse impacts on human health. Currently, many landfills in Bangkok's vicinity are sources of air pollution that may affect health and quality of life of their neighboring communities. Landfill gas and hazardous fugitive air pollutants mainly cause most of the landfill-related human health problems. Nowadays more than 60 million Thai people generate MSW up to 14 million tons per year but an ability to manage and dispose the waste is less than 70% of which occurred (Pollution Control Department, 2012). Such the inefficient ability makes waste residues and results in adverse effects on the environment, wildlife and human health (Han et al., 2014).

Related to adverse community health, MSW landfills are sources of many toxic and carcinogenic organic compounds. As a result of waste disposal, hazardous constituents are released into the environment through landfill gasses and leachate. Communities living close to landfills are directly exposed to chemicals through inhalation of landfill gas. Odor pollution is significant for a downwind community nearby the landfill appearing to be a significant risk factor of environment and health (Palmiotto et al., 2014). Methane non-methanic hydrocarbons and CO_2 are main gasses emitted. (Penza et al., 2015). In addition, children living in proximity to landfill could be exposed to heavy metals such as Cadmium (Norkhadijah et al., 2015). Diarrhea is one of the important causes of death in Indonesian young children living in the landfill slum (Shibata et al., 2015). The risks of headache, fatigue, irritated eyes, vomiting and diarrhea were also significantly greater in households located near the hazardous waste disposal sites in Italy (Rosa, 2015). Others found a shorter distance of schools from the municipal waste site in Japan was independently associated with more prevalence of wheeze, headache, stomach ache, and fatigue (Miyake et al., 2005). Also living within 2 km from the landfill site in United Kingdom showed relatively a small increased risk of tiredness, sleepiness, and headaches and children living within 1 km from the landfill can potentially be exposed to the chemicals that can decrease their immune system function (Norkhadijah et al., 2015).

For past decades, Nonthaburi province has had many new developments. Its land use for commercial consumption, transportation, and housing has been increasing leading to more people moving in to the area. Material use and food consumption have been increased and some left contributing to waste at the end. Although Nonthaburi has its own sanitary landfill, it still may affect community health in its vicinity due to high volume of MSW load. Previously mentioned, there are many studies in other countries, finding significant increased risks in irritation, respiratory, nervous and digestive symptoms in people living near landfills. However, there is no such study conducted in Thailand and so there is a need to fill a landfill-health effect knowledge gap especially in a sensitive children population. This study mainly focused school children by surveying symptom prevalence and investigating the relationship between landfill-school distance and adverse health effects.

2. Methods and materials

2.1 Study area

This work was a cross-sectional study in primary school children population of 12 schools located in 5 Tambons (subdistricts) of Amphoe Sainoi (a district) in Nonthaburi province including Tambon Klongkwang, Tambon Khunsi, Tambon Ratniyom, Tambon Sainoi, and Tambon Taweewattana. The studied sanitary landfill operated by the Nonthaburi provincial administrative organization is located in Tambon Klongkwang (Figure 1). A whole solid waste disposal site has a total area of 472 acres divided into administration area, landfill site, and wastewater treatment facility. The landfill itself has an area of 110 acres coordinated at 14.004210 N and 100.190258 E. It has started operating since 1997 and was overhauled in 2005. Its ability to keep accumulating wastes is estimated up to 2019. The landfill has an average of waste load 1,200 tons per day. The composition of the waste is mostly community organic waste. This selected study area is a rapid growing town having many schools with a tremendous load of MSW daily from town's activities so there might be a chance that students' health may be affected by the landfill through environmental media air, water, and soil. As children are more sensitive to fugitive pollutants emitted from the landfill than adults because of staying at their schools for the 1/3 of a day for years, they could be more vulnerable to landfill pollutants.

Figure 1. The studied landfill of the Nonthaburi provincial administrative organization

2.2 Children population

All 12 kindergarten-primary schools of Amphoe Sainoi were included in this study. These schools had a total population of 3,606 students. In March 2016, the number of 3,500 questionnaires were distributed to their students in each class through a class advisory teacher as many as possible (97% of a total population). Exposed student population to the landfill pollutants were expressed as those children whose schools were located close to the studied landfill and reference population were described as those whose schools were located at a longer distance from the studied landfill. Each participant was then assigned into one of three groups according to his/her school location relative to the landfill location. The school-landfill distances were categorized as Distances 1-3 as following:

- Distance 1, 0-<4 km for exposed population
- Distance 2, 4-<7 km for exposed population
- Distance 3, 7-<11 km for reference population

To yield student's recent adverse health effects and personal data, these were self-reported by parents through a 2-page questionnaire. The questionnaire did not ask for names of students, parents, or any other info related to their identities. The students were asked to pass questionnaires to their parents to respond their personal and their family bio data, personal hygiene and related recent symptoms of respiratory, gastrointestinal tract and nervous systems and returned them to the class advisory teacher in a couple days. The questionnaire asked parents whether their children were exposed to landfill-ordor at the school recently. Other questions asked about eight recent related symptoms (runny nose, wheeze, cough/sneeze (no fever), headache, vomit, diarrhea, irritated eyes, and fatigue) and other related information such as sex, education level, personal hygiene, knowledge about the landfill by school training, and medical care mode. A study proposal along with the questionnaire was submitted to each school's management board and an ethics review committee of authors' affiliated institution.

2.3 Measurement of the school-landfill distance

The distance of each primary school from the landfill was measured by the Google Earth Pro using the Geographic Information Systems (GIS) function as shown in Figure 2. The software can find the coordinates of the landfill and each school from its search function. Distance measurement in a kilometer unit was determined using a ruler function by dragging the ruler from a center of the landfill to each school center. The Google Earth Pro has a high resolution and a high accuracy because it does not just display satellite images but can also display any terrain, house building as well as roads and various objects on the surface of the Earth in 3D to confirm an exact location of each school.

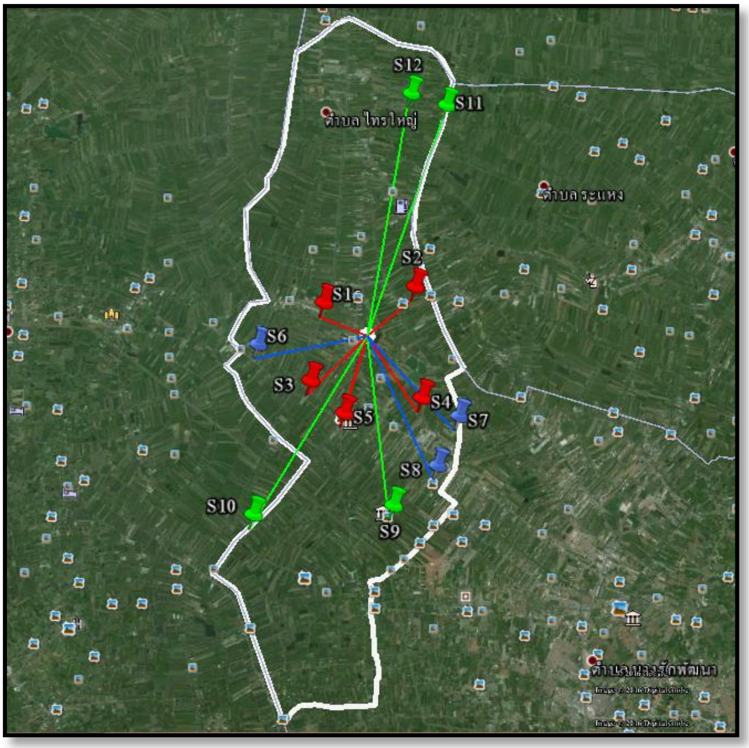

Figure 2. Measuring the distance from a center, the studied landfill to 12 schools (S1-12)

2.4 Statistical analysis

All returned questionnaire responses were read and coded using the Statistical Package for Social Science (SPSS) version 22.0 and were then analyzed using SAS® University Edition for descriptive statistics for symptom prevalence and inferential statistics for a crude odds ratio (OR) and its confident interval (CI). ORs with 95% CIs were computed for the association between the prevalence of 8 symptoms and the distance of schools from the landfill for each Distances 1, 2 (exposed) and 3 (reference) and for a landfill odor exposure frequency as “always”, “sometime” (exposed) or “never” (reference). The crude odds ratio is given by equation (1) with the standard error of the log odds ratio being shown in equation (2) and 95% CI in equation (3).

Table 1. Table 2×2 showing a number of students with and without symptom and in exposed and reference population

Population	Symptom	
	Yes	No
Exposed	(a)	(b)
Reference	(c)	(d)

Where a = number of exposed children with a symptom

b = number of exposed children without a symptom

c = number of reference children with a symptom

d = number of reference children without a symptom

$$\text{Crude odds ratio (OR)} = \frac{a/b}{c/d} = \frac{ad}{bc} \quad (1)$$

$$SE\{\ln(OR)\} = \sqrt{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}} \quad (2)$$

$$95\%\ \text{CI} = \exp(\ln(OR) \pm 1.96 \times SE\{\ln(OR)\}) \quad (3)$$

For an association interpolation of the landfill pollution and children's adverse health impacts, one can determine from the crude OR. If the crude OR is less than or equal to one that means no association between the symptom prevalence and the landfill-school distance or between the prevalence and the odor exposure while an OR is greater than one that indicates a greater risk among exposed school children. If a lower bound of the 95% CI is greater than a value of 1 meaning that the children are at an increased risk at statistically significant level (p-value < 0.05).

3. Results and discussion

This work covered more than a half of the school-children population in Amphoe Sainoi. There were 2,362 students participating from a total population of 3,606 students (65.5%). About 3,500 students were given questionnaires. However, 2,513 sets were responded and returned, yielding a return rate of 71.8%. Of 2,513 sets, there were 2,362 sets whose questions were responded valid and completed while other 151 sets responded uncompleted as no response to some symptom questions (43 sets) and responded more than 1 choice for a symptom frequency (108 sets). The number of exposed students grouped in the landfill-school Distances 1 and 2 and the number of reference students in the Distance 3 are shown in Table 2. Almost 50% of participants whose landfill-school distance were at a distance less than 4 km and about 30% and 20% of them were at a distance of 4 to less than 7 km and 7 to less than 11 km respectively.

Table 2. Distribution of participating students according to the landfill-school distance

Distance (km)	Number of students (%)
1. 0-<4	1165 (49.32)
2. 4-<7	708 (29.97)
3. 7-<11	489 (20.70)

Table 3. Symptom prevalence by the landfill-school distance

Symptom	Prevalence	
	n	%
1. Runny nose		
0-<4 km	955	83.48
4-<7 km	577	81.73
7-<11 km	386	80.58
2. Wheeze		
0-<4 km	657	57.53
4-<7 km	394	56.05
7-<11 km	248	51.45
3. Cough/sneeze (no fever)		
0-<4 km	912	78.28
4-<7 km	550	77.68
7-<11 km	380	77.71
4. Headache		
0-<4 km	707	61.64
4-<7 km	433	61.68
7-<11 km	278	58.28
5. Vomit		
0-<4 km	420	36.65
4-<7 km	247	34.99
7-<11 km	163	33.82
6. Diarrhea		
0-<4 km	544	47.47
4-<7 km	323	45.82
7-<11 km	217	45.21
7. Irritated eyes		
0-<4 km	567	49.35
4-<7 km	318	45.11
7-<11 km	206	42.92
8. Fatigue		
0-<4 km	669	58.07
4-<7 km	380	53.90
7-<11 km	226	46.60

The parameters of odor exposure, sex, education, personal hygiene, knowledge about the landfill from school training, and medical care mode were descriptively explored (results not shown). Except the odor exposure, we found nearly all parameters, sex, parental smoking, income, exercise, knowledge about the landfill, nail cutting, all hand washing parameters (before eating, after using toilet, and after activity) and medical care mode showed a similar proportion of each among the Distances 1-3. It can be concluded that children studying in 3 landfill-school distances have approximately similar characteristics, hygiene and family environment. This similarity could help control confounder effects related to children and family characteristics in the OR analysis. The landfill odor exposure was quite unequally distributed from distance to distance. Parents reported the landfill odor exposure frequency at school as “sometimes” for 58%, 40%, and 29% in the Distances 1, 2, and 3 respectively and as “never” for 40%, 58% and 70% respectively. So it was observed that the shorter landfill-school distance, the more frequent odor exposure. It was likely that the children’s health was vulnerable to fugitive landfill pollutants. For educational level, we found slightly more old children or healthier ones were studying in Distance 1 (grades 3-6) while more young children were in Distances 2 and 3 (grades 1-2). Thus, an age and immunity may slightly be different for each distance group of children.

Table 3 shows the prevalence of 8 related symptoms among school children around the studied landfill by distance category. High observed prevalence of all distance groups was runny nose (82%), cough/sneeze (no fever) (78%), headache (61%), and wheeze (55%) which were common in young school children. Runny nose and cough/sneeze (no fever) are symptoms related to the respiratory system which are common in young children with more sensitive to infectious agents and ambient air pollutants. When there are dust and VOCs in the ambient air in the vicinity of the landfill, they can cause irritation to respiratory system or can aggravate their allergy resulting in runny nose, cough, sneeze and wheeze. These landfill fugitive air pollutants can also induce adverse symptom of nervous system for example headache. If children were not healthy with low immunity, they may get weak, were prone for infectious agents and were infected. These symptoms may spread among children at their schools. This finding is consistent with other 2 works by Zeng at al., 2016 who found that prevalence of cough, phlegm, dyspnea, and wheeze was higher in children who lived in areas that exposed the chemical in e-waste community and Ray et al., 2005 who found that prevalence of running/stuffy nose, fever, sneezing, headache, cough, and wheeze were significantly higher in landfill community.

The symptom prevalence of students in 3 landfill-school distances are tabulated in Table 3 and graphed in Figure 3. The prevalence of six symptoms (runny nose, wheeze, vomit, diarrhea, irritated eyes and fatigue) were slightly higher in the Distance 1 following by the Distances 2 and 3 respectively. For other 2 symptoms, cough/sneeze and headache, their prevalence in the Distance 1 were as same as that in the Distance 2. For 3 symptoms of wheeze, irritated eyes, and fatigue, their prevalence showed obvious decreasing percentages from the Distance 1 tothe Distances 2 and 3 respectively (see figure 3). For examples, fatigue prevalence decreased from 58% to 54% and to 47% when the landfill-school distance increased from the Distance 1 to 2 and to 3 respectively and also 49%, 45%, and 43% for irritated eyes.

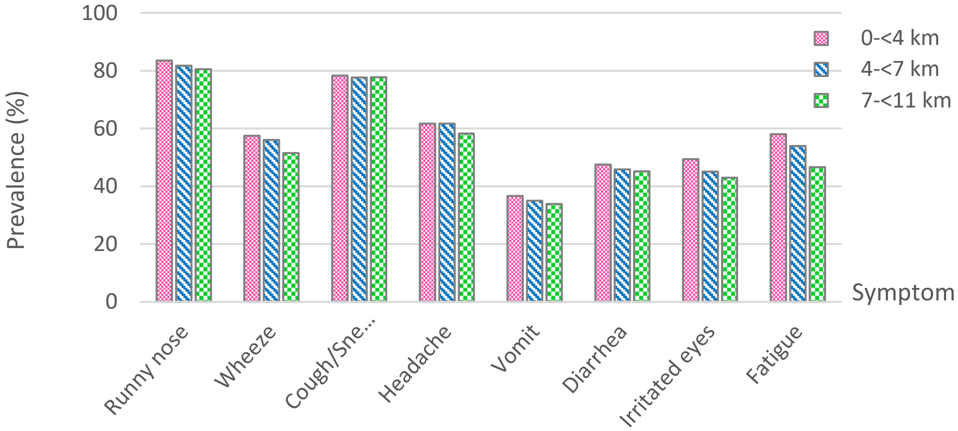

Figure 3. Symptom prevalence by the landfill-school distance

The result of the association between the landfill-school distance and the related symptoms can be seen in Table 4 in terms of crude odds ratio (OR) for each related symptom and 95% Cl. The ORs of all 8 symptoms were highest in Distance-1 students and were decreasing over the Distance-2 and Distance-3 students respectively. We found all positive associations (ORs greater than 1) in all symptoms in Distance-1 students. This also showed that the distance of the school from the landfill really affected children by causing various symptoms. The statistically significant risks, OR lower bounds greater than 1, were observed and pronounced in the Distance-1 children for wheeze (OR = 1.278, 95% CI: 1.032-1.583), irritated eyes (OR = 1.296, 95% CI: 1.046-1.606), and fatigue (OR = 1.587, 95% CI: 1.282-1.965). And this statistically significant risk was also observed again in the Distance-2 children for fatigue (OR = 1.340, 95% CI: 1.063-1.690). It was clearly seen that fatigue showed the most excess risk and statistically significant risk in both Distances 1 and 2, following by wheeze and irritated eyes showing their OR lower bounds above the null value.

For the association between the landfill odor exposure and the related symptoms, the ORs in the students reporting the odor exposure vs. those not reporting were estimated in Table 5. We noticed that all 8 symptoms showed positive relationships with odor exposure as their ORs greater than 1. It also showed that all symptoms except headache had statistically associated with self-reported odor exposure regardless of the landfill-school distance as their OR lower bounds greater than 1. The greatest risk was observed for fatigue (OR = 1.521, 95% CI: 1.289-1.790) following by cough/sneeze (no fever) (OR = 1.423, 95% CI: 1.165-1.737) and irritated eyes (OR = 1.357, 95% CI: 1.151-1.601). Such significant findings implied that children’s health was vulnerable not only to land fill odor but other landfill fugitive pollutants.

Table 4. Crude odds ratios of symptoms by the landfill-school distance

	Crude ORs	95% CI	
		lower	upper
1. Runny nose			
0-<4 km	1.217	0.925	1.603
4-<7 km	1.078	0.801	1.449
7-<11 km	1.000		
2. Wheeze			
0-<4 km	1.278**	1.032	1.583
4-<7 km	1.203	0.953	1.518
7-<11 km	1.000		
3. Cough/sneeze (no fever)			
0-<4 km	1.034	0.802	1.334
4-<7 km	0.998	0.757	1.317
7-<11 km	1.000		
4. Headache			
0-<4 km	1.150	0.925	1.430
4-<7 km	1.147	0.912	1.420
7-<11km	1.000		
5. Vomit			
0-<4 km	1.132	0.905	1.416
4-<7 km	1.053	0.825	1.344
7-<11 km	1.000		
6. Diarrhea			
0-<4 km	1.095	0.884	1.356
4-<7 km	1.025	0.812	1.293
7-<11 km	1.000		
7. Irritated eyes			
0-<4 km	1.296**	1.046	1.606
4-<7 km	1.093	0.865	1.381
7-<11 km	1.000		
8. Fatigue			
0-<4 km	1.587**	1.282	1.965
4-<7 km	1.340**	1.063	1.690
7-<11 km	1.000		

**Statistically significant increased risk at p-value = 0.05

Both OR analyses by the landfill-distance and the odor exposure confirmed that there was an increased significant risk of children studying close to the landfill for various adverse effects. We may say that the higher risk, the closer school is located to the landfill. These findings were in agreement with other studies by Miyake et al., 2005 who found that increased ORs of wheeze, and fatigue in children as reported increased ORs were independently associated with the shorter distance of schools from the nearest municipal waste site after adjusted for grade, socioeconomic status, and access to health care. Shy et al., 1995 found that adjusted ORs of chronic cough, wheeze and sinus trouble were significantly greater in those living near the hazardous waste site comparing with control communities. Another study in Indonesia reported that diarrhea was a major cause of death in young children living in the landfill slum (Shibata et al., 2015).

Table 5. Crude odds ratios of symptoms by the odor exposure

Symptom	Crude ORs	95% CI	
		lower	upper
Runny nose	1.312**	1.056	1.631
Wheeze	1.306**	1.106	1.542
Cough or sneeze (no fever)	1.423**	1.165	1.737
Headache	1.049	0.886	1.242
Vomit	1.202**	1.012	1.427
Diarrhea	1.272**	1.078	1.500
Irritated eyes	1.357**	1.151	1.601
Fatigue	1.521**	1.289	1.796

**Statistically significant increased risk at p-value = 0.05

From prevalence and OR findings, this work could imply that children studying in the vicinity of the studied landfill had various symptoms occurred at the greater risks. Schools located close to the landfill had more chance to be exposed to more pollutants emitted from the landfill. Increased risks of children in school proximity of landfill were seen and associated with related symptoms. The risks of all symptoms were higher than those in schools located far away from the landfill. The estimated prevalence and ORs were consistent with other findings. Miyake et al., 2005 found that the shorter distance of schools from the nearest municipal waste plant was independently associated with an increased prevalence of wheeze, headache, stomach ache, and fatigue. Zeng at al., 2016 found that children living in e-waste exposed area had a higher prevalence of cough, phlegm, dyspnea, and wheeze. Deloraine et al., 1995 found the association between reported exposure to residual landfill emission and frequency of respiratory illnesses in case patients when compared with control patients. Hertzman et al., 1987 reported that landfill workers had higher respiratory, skin, narcotic, and mood disorders than controls. Ray et al., 2005 also found that landfill workers had significantly higher prevalence of running/stuffy nose, fever, sneezing, headache, cough, wheeze, and they suffered more often from diarrhea when compared with matched controls. De Rosa et al., 2015 reported that headache, fatigue or tired, irritated eyes and vomiting were significant for persons in households located near the hazardous waste disposal sites. Hall et al., 1995 found most frequently reported disorders were respiratory symptoms and eye irritation in waste disposal employees. Shy et al., 1995 observed that symptoms of respiratory illness, such as chronic cough, wheeze and sinus trouble, were significantly greater in those living near the hazardous waste incinerator than those in their control community. From all these consistent works, we believed that this study is reliable and its results can be further used for school and municipality health care planning. However, this study did not cover all schools around the landfill as only schools in Amphoe Sainoi were participated. Furthermore, odor and air pollutant monitoring data were not available which could help improve the study results. Although children and family characteristics were fairly similar, an adjusted OR controlling confounding effects of the children and family characteristics that may also cause the symptoms in children should be further analyzed.

4. Conclusion

This work concluded that the studied landfill in Amphoe Sainoi in Nonthaburi with daily tremendous load of MSW likely affected students' health. Almost 50% of 2,362 participants were studying at a distance less than 4 kilometers from landfill. The most prevalence of symptoms was runny nose, cough/sneeze (no fever), and headache, respectively. However, children whose schools were located in a shorter distance from landfill had higher prevalence in all symptoms more than other groups. For odds ratios as excess health risks, we found the positive association between the landfill-school distances and all 8 symptoms; runny nose, wheeze, cough/sneeze (no fever), headache, vomit, diarrhea, irritated eyes, and fatigue. Decreases in the landfill-school distance were statistically associated with an increased prevalence of wheeze, irritated and fatigue. In addition, all symptoms showed the positive association with self-reported odor exposure. Seven of them were statistically significantly associated with the odor exposure. This work confirms that primary school children whose schools located surrounding the studied landfill were at the greater risk of related adverse health outcomes. The further confounding analysis of children and family characteristics are needed to confirm the reported increased risks although those characteristics were proportionally similar among the Distances 1-3.

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Model of Sustainable Wellbeing Integrated with Environmental Education for Agriculturist

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Abstract

This research was survey research. The objective of this study was to develop a causal relationship model of social justice, economic justice, and environmental education variables influencing sustainable wellbeing of agriculturist via inspiration of public mind. The questionnaire was used as a tool for data collection from population of 155,534 agriculturists in Maha Sarakham Province in Northeastern region of Thailand. The samples of 400 agriculturists were collected by using Multi-stage Random Sampling technique. Model verification was computerized with Structural Equation model (SEM) by considering on Chi-Square value differs from zero with no statistical significant at 0.05 level or Chi-Square/df value with lesser or equal to 5, RMSEA (Root Mean Square Error Approximation) value with lesser than 0.05, index level of model congruent value with GFI (Goodness of Fit Index) and AGFI (Adjust Goodness of Fit Index) between 0.90-1.00. The finding revealed that the structural model confirmatory factors of component analysis of Social Justice (SoJ), Economic Justice (EcJ), Environmental Education (EE) and Inspiration of Public Mind (PM) were able to elucidate the variation of endogenous latent variable of Sustainable Wellbeing (SW) with 95.00%. In addition, the exogenous variable of SoJ has the highest effect to PM with 0.51. The EE and EcJ were subsequent effect to PM with 0.34 and 0.30. Therefore, SoJ, EE and EcJ were able to clarify the variation of PM with 86.00%.

Keywords: social justice; economic justice; environmental education; inspiration of public mind; sustainable wellbeing; agriculturist

1. Introduction

Thailand located at the centre of the Indochina peninsula in Southeast Asia and it enriches of flora and fauna. Therefore, for subjectively conserving its biodiversity, Thailand has become a Contracting Party to the Convention on Biological Diversity on January 29, 2004. With suitable circumstances for cultivating a wide range of agricultural products, the farmers are able to grow various strains of plants such as teak, rubber tree, rice grains, fruits, vegetables and herbs (Ministry of Natural Resource and Environment, 2012; Office of the National Economic and

Social Development Board, 2016). However, the farming is still the major part of economic employment of country by 2006 representing with 65% of labor force in this sectors, therefore principal people has been habituated in rustic areas with about 68% and urban areas with 32% (Tirado *et al.*, 2008). There are about 50 percent of Thailand's population or 30 million-strong work-force in agricultural sector. There 4 apex exports are rice, canned fish, frozen or chilled shrimp, and rubber. These supplies are establishment of flourishing industrialized business enterprises of food processing. Processed foods like as canned fruits, vegetables, seafood, and ready-to-eat meals, also benefit from a vigorous local market, together with sugar and flour. For a century, Thailand's growth has depended on agricultural sector as a key driver for a long time. Thai agricultural segment became a most important comparative benefit in the international trade (Siamwalla, 1996; Office of Agricultural Economics, 2010). Additionally, Thailand is well recognized as a main agricultural exporter in the world with the order of fifteenth. The milled rice was the first rank and natural dry rubber was subsequently in the world. Thereby agriculture turns to be a key source of export earning and rural income (Suphannachart and Warr, 2010; Office of Agricultural Economics, 2010).

Not surprising, in 2016 Thailand also launched 12th economic and social plan based on the six primary strategies seek to enhance and develop the potential of human capital; ensure justice and reduce social disparities; strengthen the economy and enhance competitiveness on a sustainable basis; promote green growth for sustainable development; bring about national stability for national development toward prosperity and sustainability; and enhance the efficiency of public sector management and promote good governance (Office of the National Economic and Social Development Board, 2016). This plan tries to create social and economic justices to promote wellbeing of Thai citizen. The social justices includes public heath equality, public education, social welfare, equal opportunity, social security and social integrity. The economic justice covers distribution of wealth, income distribution, taxation equality and legal equality (Office of Agricultural Economics, 2010; Office of the National Economic and Social Development Board, 2016; Thai Health Promotion Foundation, 2016; The 2016 ISPAH International Congress on Physical Activity and Health, 2016).

Environmental education concepts includes knowledge and understanding of the environment and environmental challenges, awareness and sensitivity to the environment and environmental challenges, attitudes of concern for the environment and motivation to improve or maintain environmental quality with skills to identify and help resolve environmental challenges and participation in activities that lead to the resolution of environmental challenges with responsibility. These need to provide and cultivate through the learning approaches of formal, informal, non-formal and lifelong education. Moreover, environmental education is also a learning process that increases public mind of environmental conservation by performing the appropriate behavior to accomplish sustainable development. It teaches and motivates the individuals critical-thinking and enhances individuals' problem-solving and decision-making skills (Palmer, 2002; Thiengkamol, 2011; Bakshi and Naveh, 2013, United State Environmental Protection Agency, 2016). Therefore, environmental education is an essential variable that should take notice to integrate in the sustainable wellbeing consideration for more understanding to enhance the human quality of life.

There are a numerous papers were conducted on inspiration of public mind of environmental conservation for this decades by Thiengkamol and her colleague via wide rang researches of environmental issues whether about water, forest, ecosystem, biodiversity conservations and Life Cycle Assessment (LCA) (Donkonchum *et al.*, 2012; Saisunantharom *et al.*, 2013; Suebsing *et al.*, 2013; Maporn *et al.*, 2015). All of these articles indicate that the inspiration of public mind of environmental conservation is an intermediate variable that has influence to environmental conservation behavior or pro-environmental behavior. Consistence considering on inspiration of public mind of environmental conservation, it is recognized that is dissimilar to motivation since it necessitates any incentive or complement to perform environmentally friendly behaviors. It might be occurred from insight of people or might be stimulated by impressive person, environment, event and media reception including movies watching, book and magazine reading, and internet using (Thiengkamol, 2013; Saisunantharom *et al.*, 2013; Maporn *et al.*, 2015; Wongsueb *et al.*, 2015). In addition, the several researches were carried out by her colleagues, these have also proved that inspiration of public consciousness or public mind are critical factor for environmental conservation in diverse environmental management with combination of environmental education concept (Donkonchum *et al.*, 2012; Saisunantharom *et al.*, 2013; Suebsing *et al.*, 2013; Thiengkamol, 2013; Maporn *et al.*, 2015; Wongsueb *et al.*, 2015).

Sustainable wellbeing is considered on social wellbeing, economic wellbeing physical wellbeing, psychological wellbeing, environment wellbeing, and political wellbeing. However, wellbeing is a condition of being happy, healthy, successful, and welfare. Furthermore, it also regards on career, social, financial, physical and community or environment wellbeing and psychological wellbeing or subjective wellbeing or hedonic wellbeing is should be paid attention (Collins English Dictionary, 2014; Rath, and Harter, 2010; Ryff, 1989). Currently, a variety of policy makers of governments and official bodies in the UK, France, the European Union, the United Nations and the OECD are interested in wellbeing utilization for formulating policy in place of economic growth because wellbeing is the result that will make a genuine distinction to people's lives. Besides, a successful society is making living standards of people to accomplish well-being with prolong period. Consequently, the sustainable development accomplishment, it may be determine involved three global solutions include 1) goals of universally high levels of wellbeing, 2) resources with sustainable use of environmental resources, and 3) human systems with activities that achieve transitional objectives such as a firm and productive economy, an attached society, good shelter, and so on (Eurostat, 2010; Marks *et al.*, 2006; Abdallah, 2009; Marks *et al.*, 2006). Previously, the study was conducted on wellbeing in Thai society that is not careful on individual but it was paid attention to the relationship of required accomplishment; freedoms of action, and achieving the satisfaction goals (McGregor, 2008).

Clarification on sustainable wellbeing of agriculturists in Maha Sarakham Province, the social justice and economic justice integrated with environmental education through inspiration of public mind must be carefully consideration. These variables will facilitate us the deeply understand to develop and improve wellbeing of agriculturist for accelerating sustainable development (Office of the National Economic and Social Development Board, 2016). All referred latent variables above are used to create the causal relationship model of social justice, economic justice, and environmental education variables influencing sustainable wellbeing of agriculturist via inspiration of public mind. Therefore, the results of this study would initiate the policy planner to formulate the policy and plan by concerning on these important variables to assist to solve quality of life of agriculturist to meet their better life in the near future.

2. Methodology

2.1. Population and Sample

Population was 155,543 agriculturists who lived in Maha Sarakham Province of Northeastern region of Thailand. The sample of 400 agriculturists was collected by using Multi-stage random sampling technique. The Yamane formula was used to calculate the sample size with confident interval at 0.05 (Yamane, 1973).

2.2. Research Tool

The content and structural validity of questionnaire were proved with Item Objective Congruent (IOC) by 5 experts in the disciplines of economy, social science, environmental education and social research methodology. The reliability was tried out by handling with the 45 agriculturist lived adjacent province. The Cronbach's Alpha formula was used to determine the reliability of Social Justice (SoJ) with 30 items, Economic Justice (EcJ) with 20 items, Environmental Education (EE) with 30 items, Inspiration of Public Mind (PM) with 20 items, and sustainable wellbeing with 30 items with 5 rating scales (Likert’s Rating Scale with 5 = Strongly Agree, 4 = Agree, 3 = Neither Agree nor Disagree, 2 = Disagree, and 1 =Strongly Disagree). The constructs and variables are shown in Table 1. The reliabilities of Soj, EcJ, EE, PM, SW, and whole items were 0.874, 0.878, 0.923, 0.945, 0.951 and 0.977 respectively.

2.3. Data Collection

The Multi-stage random sampling technique was used for gathering the sample group of 400 agriculturists who lived in Maha Sarakham Province. The questionnaire was used as research instrument for data gathering.

2.4. Data Collection

The frequency, percentage, mean and standard deviation were used as descriptive statistics. Model verification was computerized with Structural Equation model (SEM) by considering on Chi-Square value differs from zero with no statistical significant at 0.05 level or Chi-Square/df value with lesser or equal to 5, and RMSEA (Root Mean Square Error Approximation) value with lesser than 0.05 including index level of model congruent value, GFI (Goodness of Fit Index) and index level of model congruent value, AGFI (Adjust Goodness of Fit Index) between 0.9-1.00.

Table 1. Constructs, Variables and Number of Items

Constructs	**Variables**	**Number of Items**
Social Justice (SoJ)	X1 Public Heath Equality	30
	X2 Public Education	
	X3 Social Welfare	
	X4 Equal Opportunity	
	X5 Social Security	
Economic Justice (EcJ)	X6 Social Integrity	20
	X7 Distribution of Wealth	
	X8 Income Distribution	
	X9 Taxation Equality	
Environmental Education (EE)	X10 Legal Equality	30
	X11 Environmental Knowledge	
	X12 Environmental Awareness	
	X13 Environmental Attitude	
	X14 Environmental Responsibility	
Inspiration of Public Mind (PM)	X15 Environmental Participation	20
	X16 Environmental Skill	
	Y7 Person as Role Model	
	Y8 Impressive Environment	
	Y9 Impressive Event	
Sustainable Wellbeing (SW)	Y10 Media Receiving	30
	Y1 Social Wellbeing	
	Y2 Economic Wellbeing	

3. Results and Discussion

3.1 Results of Effect among Variables in Model in Terms of Direct and Indirect Effect

Social Justice (SoJ), Economic Justice (EcJ), Environmental Education (EE), and Inspiration of Public Mind (PM) had direct and indirect effects to Sustainable Wellbeing (SW) as the followings.

3.1.1 Confirmatory factors of SoJ had direct effect PM with statistically significant at level of 0.01 with effect of 0.51. SoJ had direct effect to SW with statistically significant at level of 0.01 with effect of 0.24 and indirect effect SW with statistically significant at level of 0.05 with effect of 0.29.

3.1.2 Confirmatory factors of EcJ had direct effect PM with statistically significant at level of 0.01 with effect of 0.30. EcJ had direct effect to SW with statistically significant at level of 0.01 with effect of 0.32 and indirect effect SW with statistically significant at level of 0.05 with effect of 0.17.

3.1.3 Confirmatory factors of EE had direct effect PM with statistically significant at level of 0.01 with effect of 0.34. EE had direct effect to SW with statistically significant at level of 0.01 with effect of 0.44 and indirect effect SW with statistically significant at level of 0.01 with effect of 0.19.

3.1.4 Confirmatory factors of PM had direct effect to SW with statistically significant at level of 0.01 with effect of 0.57.

The structural model confirmatory factors of component analysis of SoJ, EcJ, EE and PM were able to elucidate the variation of endogenous latent variable of SW with 95.00%. The structural equation is able to demonstrate as the following in equation (1).

$$SW = 0.57*PM + 0.24*SoJ + 0.32*EcJ + 0.44*EE \qquad (1)$$

$$R^2 = 0.95$$

Equation (1) the endogenous variable of PM was the most effect to SW with 0.57 and subsequences were EE, EcJ, and SoJ with 0.44, 0.32, and 0.24 respectively. These were able to elucidate the variation of SW with 95.00 percent

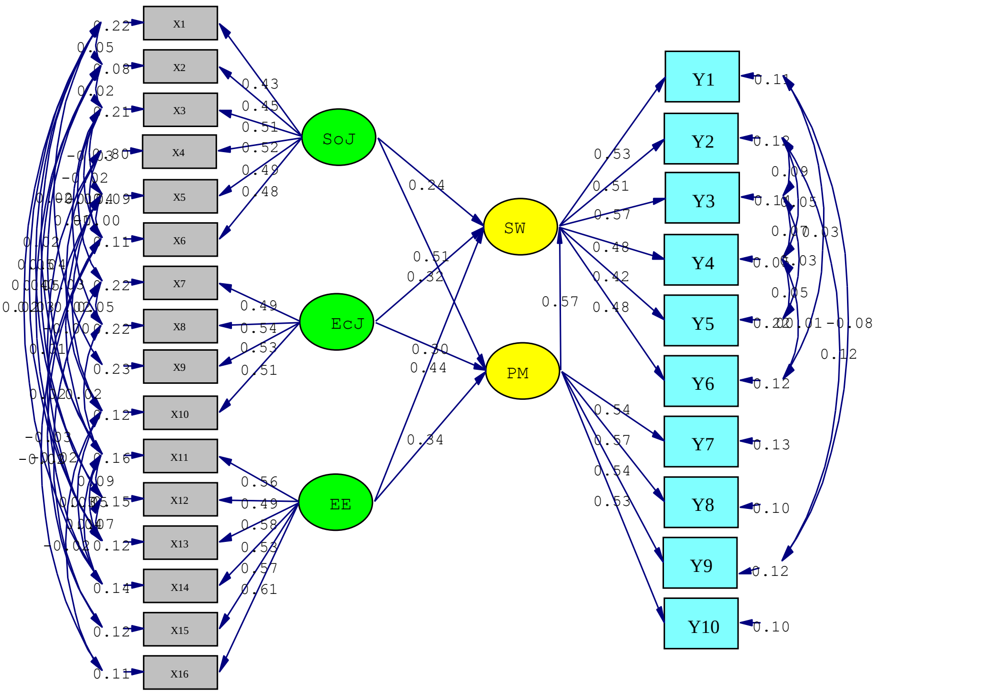
The exogenous variable of SoJ has the highest effect to PM with 0.51. The EE and EcJ had effect to PM with 0.34 and 0.30. Therefore, SoJ, EE and EcJ were able to explain the variation of PM with 86.00%. The structural equation is able to demonstrate as the following in equation.

$$PM = 0.51*SoJ + 0.34*EE + 0.30*EcJ \qquad (2)$$

$$R^2 = 0.86$$

Equation (2), the exogenous variable of Soj had the highest effect to PM with 0.51. The others variables of EE and EcJ were subsequently predictable PM with effect of 0.34 and 0.30. These were able to explain the variation of PM with 86.00 percent.

The demonstration of exogenous variables were predictable the endogenous variables with direct and indirect effects in Fig. 1 and Table 2.



Chi-Square=355.54, df=229, P-value=0.10254, RMSEA=0.043

Figure 1. Model of Social, Economic and Environment Education for Sustainable Wellbeing of Agriculturist

3.2 Discussion

The results showed that Environmental Education (EE), had direct effect to Sustainable Wellbeing (SW) with effect of 0.44. While considering on prediction of correlation of observed variables Environmental Skill (X16), Environmental Attitude (X13), of Environmental Participation (X15), Environmental Knowledge (X11), Environmental Responsibility (X14), and Environmental Awareness (X12) can predict the Environmental Education (EE), with weights of 0.61, 0.58, 0.57, 0.56, 0.53 and 0.49 respectively. This explicates that the exogenous latent variable is essential factor to forecast the sustainable wellbeing of agriculturist because they realize that the environmental quality will rely on their responsibility to properly solve the environmental problem based on their skill, attitude and participation in environmental conservation. The results are relevant to diverse studies of Thiengkamol and her colleagues (Thiengkamol, 2013k; Saisunantharom et al., 2013a; Maporn et al., 2015; Wongsueb et al., 2015). It is evidently proved that the environmental education is critical factor to accelerate the agriculturists’ sustainable well-being.

Table 2 Direct and Indirect Effect of SoJ, EcJ and EE Affecting SW via PM

Causal variables	**Result variables**					
	PM			SW		
	TE	IE	DE	TE	IE	DE
SoJ	0.51** (0.045)	-	0.51** (0.045)	0.53** (0.025)	0.29** (0.033)	0.24* (0.022)
EcJ	0.30** (0.032)	-	0.30** (0.032)	0.49** (0.012)	0.17* (0.013)	0.32** (0.014)
EE	0.34** (0.024)	-	0.34** (0.024)	0.63** (0.023)	0.19** (0.23)	0.44** (0.032)
PM	-	-	-	0.57** (0.024)	-	0.57** (0.024)
χ^2 = 355.54; df = 229			CN = 268.99		χ^2/df = 1.553	
GFI = 0.94; AGFI = 0.91			RMSEA = 0.043		RMR = 0.035	

TE=Total Effect; IE=Indirect Effect; DE=Direct Effect

Furthermore, considering to confirmatory factor of Social Justice (SoJ) had direct effect to PM with effect of 0.51. SoJ had direct effect to SW with effect of 0.24 and indirect effect to SW with 0.29. The SoJ was predicted by public heath equality, public education, social welfare, equal opportunity, x5 social security and social integrity while confirmatory factor of Economic Justice (EcJ) is also related sustainable wellbeing of agriculturists since this variable. EcJ was able to predict by Distribution of Wealth, Income Distribution, Taxation Equality and with Legal Equality and equally threat (OAE, 2010; Office of the National Economic and Social Development Board, 2016; Thai Health Promotion Foundation, 2016; The 2016 ISPAH International Congress on Physical Activity and Health, 2016).

Nevertheless, Inspiration of Public Mind (PM) had direct effect to SW with effect of 0.57 while PM was predicted by observed variables of Person as Role Model (Y7), Impressive Event (Y9), Public Mind (Y10) and Impressive Environment (Y8) are able to predict the PM with weight 0.57, 0.54, 0.54 and 0.53 respectively. These were in the line with abundant studies of Thiengkamol and her colleagues Thiengkamol, 2013k; Saisunantharom et al., 2013a; Maporn et al., 2015; Wongsueb et al., 2015).Thus, this research results should help us to use the environmental education, social justice, and economic justice as vital variables to formulate in the national and local policy to develop the affective action plan to provide to enhance the agriculturists competency to attain sustainable wellbeing in all aspects of social wellbeing, economic wellbeing, physical wellbeing, psychological wellbeing, environment wellbeing and political wellbeing Eurostat, 2010; Marks et al., 2006; Abdallah, 2009; McGregor, 2008).

4. Conclusion

The structural model confirmatory factors of component analysis of Social Justice (SoJ), Economic Justice (EcJ), Environmental Education (EE) and Inspiration of Public Mind (PM) were able to elucidate the variation of endogenous latent variable of Sustainable Wellbeing (SW) with 95.00%. In addition, the exogenous variable of SoJ has the highest effect to PM with 0.51. The EE and EcJ were subsequent effect to PM with 0.34 and 0.30. Therefore, SoJ, EE and EcJ were able to clarify the variation of PM with 86.00%. Model verification was computerized with Structural Equation model (SEM) by considering on Chi-Square value differs from zero with no statistical significant at 0.05 level or Chi-Square/df value with lesser or equal to 5, RMSEA (Root Mean Square Error Approximation) value with lesser than 0.05, index level of model congruent value with GFI (Goodness of Fit Index) and AGFI (Adjust Goodness of Fit Index) between 0.90-1.00.

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Efficacy of Integrated Method between Gravid *Aedes* Trap (GAT) and Space Spray for Controlling Dengue Vectors in Bangkok

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Abstract

Aedes Aegypti is the main vector of dengue viruses, and they are also competent vectors for several exotic pathogens such as Zika and Chikungunya viruses. As they are a growing public health concern, methods to control these mosquitoes need to be implemented to reduce their potential for disease transmission. There is a crucial need to evaluate methods as a part of an integrated mosquito control strategy in Thailand. This study is divided into two parts: 1) to study hot spot of dengue fever in the past five years at Pom Prap Sattru Phai district, Bangkok, Thailand and 2) to evaluate the effectiveness of dengue controlling method which space spray technique by Gravid *Aedes* Trap (GAT) in the focus areas. The efficacy of integrated method between GAT and Space Spray for controlling Dengue vector in Bangkok was studied. The 398 dengue cases data was collected for five years, from 2011 to 2015. Data were analyzed indicating the pattern of hotspot Dengue prevalence distribution by GIS –based maps. The 5 dengue cases were chosen to treat with integrated methods by space spray, larvicide method and Gravid *Aedes* Trap (GAT). These approaches may use for increasing effectiveness of integrated vector management (IVM) in the future.

***Keywords*: dengue fever; GIS; gravid aedes trap (GAT)

1. Introduction

Dengue fever (DF) and its severe form, dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS), are the most importance mosquitoes borne viral disease occurs more over 100 countries in the tropical and subtropical regions, affecting humans health more than 2.5 billion people in urban, peri-urban and rural areas. Rapid urbanisation, inadequate sanitation, increase movement of human populations, and spread of insecticide resistance in the mosquito vector populations are some of the reasons for the increasing of dengue transmission in recent years. The objectives of this study was to analyse the epidemic outbreak patterns of DF/DHF/DSS in Pom Prap Sattru Phai district, Bangkok, Thailand, in terms of geospatial distribution, and to evaluate the effectiveness of the standard method for controlling dengue in Bangkok by Gravid *Aedes* trap (GAT) in focus areas. The methodology and the results could be useful for public health officers to increase the effectiveness of integrated vector management (IVM) in the future.

Mosquitoes borne diseases are the most common worldwide health hazard and represent a constant and serious risk to a large part of the world's population. Among these diseases, dengue fever, especially known in Southern Asia, It is spreading worldwide, settling in the countries with tropical and warm climates. It is transmitted to humans by the mosquito of the genus *Aedes* and exists in two forms: the Dengue Fever (DF) or classic dengue and the Dengue Hemorrhagic Fever (DHF), which may evolve into a severe form known as Dengue Shock Syndrome (DSS). There are four dengue virus serotypes, called DEN-1, DEN-2, DEN-3, and DEN-4. They belong to the genus *Flavivirus,* family Flaviviridae.

In Thailand, after the first dengue outbreak in 1958 (Rojanapithayankorn, 1998), there has been an upward trend in the incidence of dengue, and acute and severe forms of dengue virus infection. In 2012, according to the dengue surveillance data, the total number of reported cases of dengue infection in Thailand is 79,593 cases with 84 deaths nationwide. The number of reported cases in Bangkok in the same period is a total of 10,108 cases with 7 deaths. The number of reported cases in Pom Prab Sattru Phai district in the same period is a total of 177 cases and no deaths. Although, in many decades, space sprays, larval survey and larvicide methods have been shown to be effective in the controlling dengue in Bangkok. However, in the year 2012, there are high incident dengue cases at Pom Prab Sattru Phai district, Bangkok. Although, there are many measures of disease control such as integrated vector management (IVM) and biting prevention but the epidemic is still remaining. The method to reduce the abundance of female *Aedes Aegypti*, the main vectors of dengue by killing trap, Gravid Aedes Trap (GATs), the low cost and practicality of operation were chosen for study the efficacy in focus areas, 100 meters in and around dengue patient's house.

Geographic Information System (GIS) technologies have long been applied in public health studies and related issues such as disease outbreak during natural disasters, at the regional or country level, to assess and identify potential risk factors involved in DF/DHF/DSS incidence transmission such as socio-economic, climatic, demographic and physical environment variables to better understand essential characteristics of predicted risk areas (Nakhapakorn and Tripathi, 2005). In spatial analysis such as kernel density estimation (KDE), spatial autocorrelation analysis (SAA), hotspot, or mean centre, temporal dynamics are commonly used to symbolise spatial patterns of diseases and to test whether there is a considerable occurrence of clustering of diseases incidences in particular areas. Kernel density estimation (KDE) represents a very popular subject of statisticians' investigations, and it is base on the value of the standard deviation in the Gaussian equation. Today, the growing interest in the detection of disease clusters or "hotspot", for public health surveillance and for improving our understanding of the disease such dengue incidence are increasing, therefore, a technique for spatial analyses at focus scale (KDE) was used to investigate hotspot of DF/DHF/DSS incidence.

In this study, The main objectives were to find a hotspot pattern map of DF/DHF/DSS incidence that occurred in Pom Prab Sattru Phai district, Bankok, Thailand from 2011 until 2015 by using GIS elements for a better understanding of DF/DHF/DSS outbreak dynamics, and to find the efficacy of GAT that used for capture female gravid Aedes mosquito in focus areas, 100 meters in and around dengue patient's house for increase the effectiveness of current measurements for controlling dengue in Bangkok, Thailand.

2. Study Areas, Materials and Methods

2.1. Study Areas: Pom Prab Sattru Phai District, Bangkok, Thailand

Pom Prab Sattru Phai District had a morbidity rate of 369.13 per 100,000 population among districts under the surveillance of the Division of Health of Bangkok, Thailand for 2012 (Table 1). Pom Prab Sattru Phai, a district in the central part of Bangkok, Thailand was selected as the study areas (Fig. 1). This district was selected as the study areas because it has reported high incident rates in the years 2012, the prevalence is the second of top ten highest morbidity rates of dengue incidence in Bangkok. Pom Prab Sattru Phai district included 5 sub-districts, which are Pom Prap, Wat Thepsirin, Banbart, Khlong Maha Nak and Wat sommanat. The district is in the central part of Bangkok and covers areas of 1.93 sq.km. The district has population of about 50,092 people (Department of Administration, 2012).

Table 1. Top three morbidity rates of DF/DHF/DSS incidence by district in Bangkok in the year 2012

Rank	District	Morbidity rate (per 100,000 population)
1.	Samphanthawong	379.20
2.	Pom Prap Sattru Phai	369.13
3.	Bang Rak	336.14
4.	Bang Bon	290.98
5.	Pathum Wan	289.36
6.	Yan Nawa	287.01
7.	Phra Nakhon	269.75
8.	Ratchathewi	257.91
9.	Bang Khun Thian	231.15
10.	Bangkok Noi	228.91

Source: Division of Health, Bangkok, Thailand

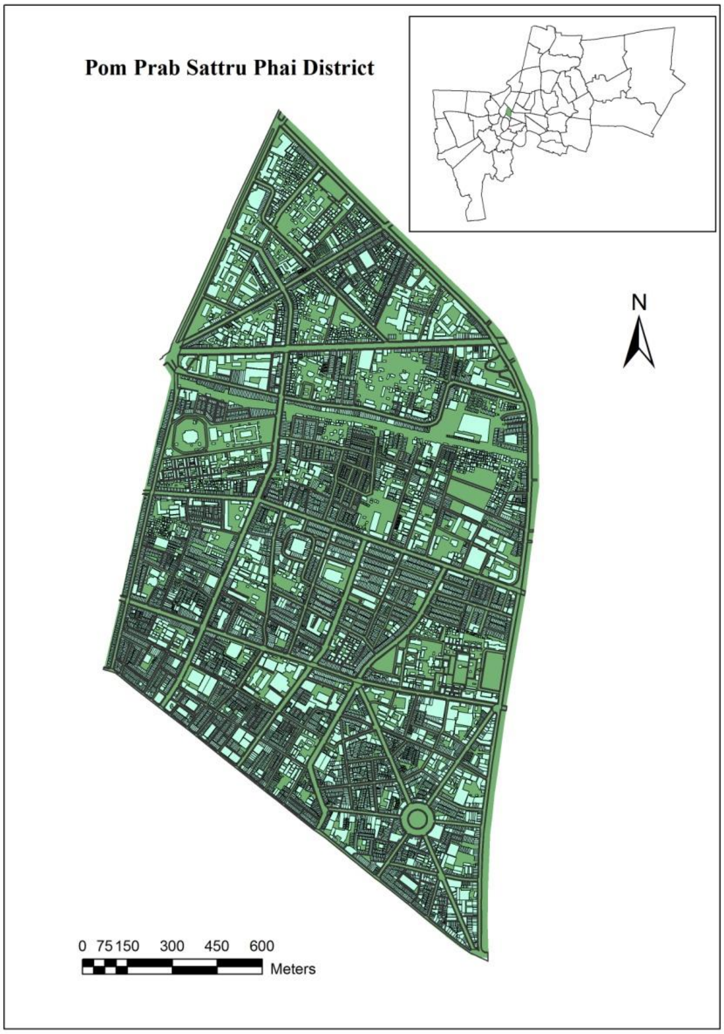

Figure 1. Study areas: Pom Prab Sattru Phai District, Bangkok, Thailand

2.2. Hotspot Mapping Approach

2.2.1 Data preparation

The study of a spatial-temporal diffusion pattern of DF/DHF/DSS incidence covers the data in the year 2011 – 2015 in Pom Prab Sattru Phai District, Bangkok. Pom Prab Sattru Phai district was selected for the case study because of the high incident of dengue in the years 2012. The data were collected from the Environmental and Sanitation Section, Pom Prab Sattru Phai District office, with regard to the number of reported cases per day, to record the confirmed DF/DHF/DSS cases. Data represents only the patients who visit the hospital and fill the official form 506 from the Bureau of Vector bone Disease, Ministry of Public Health, Thailand.

2.2.2 Data Analysis (Jeefoo, 2012)

The hotspot by using kernel density estimation (KDE) method was carried out for finding the DF/DHF/DSS incidence hotspot zonation map. KDE technique is the point density pattern analysis at any location in the study areas. This density was estimated bycounting the number of dengue cases in Pom Prab Sattru Phai district. That calculating the radius of each point connected to another point with the specified range of bandwidth defined the density. KDE relates to location data and refers to a kernel method for obtaining a spatially smooth estimate of the local intensity of events over Pom Prab Sattru Phai District, which essentially amounts to a "Dengue risk zone" for the show occurrence of those events. In this study, the UTM zone 47 North and WGS 84 coordinate system was adopted and used coordinates system (x, y) to define the location of dengue incidence and 100 meters, the distance of *Aedes* mosquitoes' flight range were used to specify a range of bandwidth.

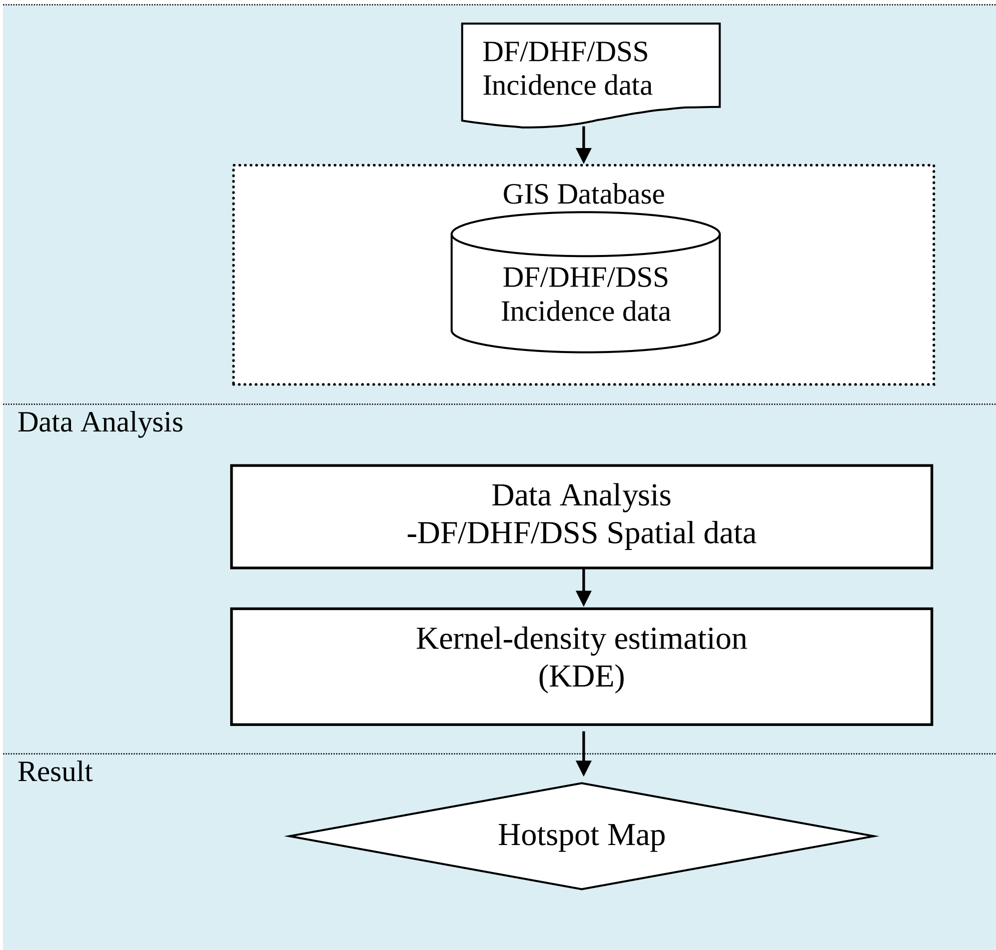

Figure 2. Methodology for mapping Hotspot of DF/DHF/DSS

2.3. Gravid Aedes Trap (GAT) and Space Spray for Controlling Dengue Vectors

2.3.1 Gravid Aedes Trap (GAT)

Traps are widely used for survey and monitoring of mosquito population. Mass trapping using odour baits has been suggested as a means to reduce adult population of mosquitoes. Dengue vector control by sampling adult *Aedes aegypti* recently has been used to replace both larval and pupal surveys (Ritchie *et al.*, 2014). The Gravid *Aedes* Trap (GAT) concept relies on visual and olfactory cues to lure gravid *Ae. aegypti* and an insecticide net to kill trapped mosquitoes, it is an effective, practical, low cost (Heringer *et al.*, 2016). The trap consists of four basic components: 1) black plastic bucket; 2) translucent plastic chamber; 3) nylon mesh impregnated with a pyrethroid insecticide and 4) a black funnel inserted into the top of the translucent chamber. The infusions used as oviposition attractant to lure mosquitoes were weekly prepared with ≈ 10 mg of dry alfalfa grass per litre of tap water and placed in the black plastic bucket. The nylon mesh provides a barrier between mosquitoes and the infusion as well as to retain dead mosquitoes without damaging them. The 5 dengue cases were specific sampling by the official form 506 from the Bureau of Vector bone Disease, Ministry of Public Health, Thailand for treated with integrated methods by space spray, larvicide method and Gravid *Aedes* Trap. GATs were randomly placed at shaded areas in and around 8 nearest houses, with radius 100 meters of the dengue case's house. The trapped mosquito's data were collected within 28 days of the period for controlling dengue vectors.

2.3.2 Space Spray for Controlling Dengue Vectors

In Bangkok, pyrethroids are sprayed with thermal fogging to reduce rapidly abundance of *Aedes* females, particularly during epidemics. There are mainly used pyrethroids because of their relative safety for humans, their high insecticidal potency at low dosages and their rapid knockdown effects. Unfortunately, pyrethroids are toxic to non-target insect species, aquatic invertebrates and fish. However, thermal fogging with pyrethroids are applied mainly for controlling dengue vectors and cooperated with larvicide in epidemic areas. Then, searching for a new method to increase the effectiveness of measurement for controlling dengue is very importance.

3. Results and Discussion

A hotspot incidence map using kernel density estimation (KDE) method was constructed from the cumulative number of cases from the years 2011 to 2015, the result showed that the dengue cases were clustering and confirmed that dengue cases were spreading all around the Pom Prab Sattru Phai District especially in Khwaeng Pom Prap at the year 2012. (Fig. 5)

The field experiments were conducted to study the efficacy of the GATs in 28 days from 5 focus areas of dengue cases. The results showed that the GAT captured a little number of female *Aedes* mosquitoes in the first 7 days and captured more female *Aedes* mosquitoes in the last 21 days in study periods. (Fig. 6) The maximum numbers of captured female *Aedes* mosquitoes are 20 per GAT per 28 days and The average numbers of captured female *Aedes* mosquitoes are 7.61 per GAT per 28 days, The maximum numbers of captured female Aedes mosquitoes are 10.91 *Aedes* mosquitoes per GAT per 28 days respectively.

Figure 3. Gravid *Aedes* Trap (GAT).Components include a 3 liter black bucket **(a)**, Transparent chamber **(b)**, black plastic entry funnel **(c)**, long-lasting insecticide-treated nets **(d)**, black net **(e)**.

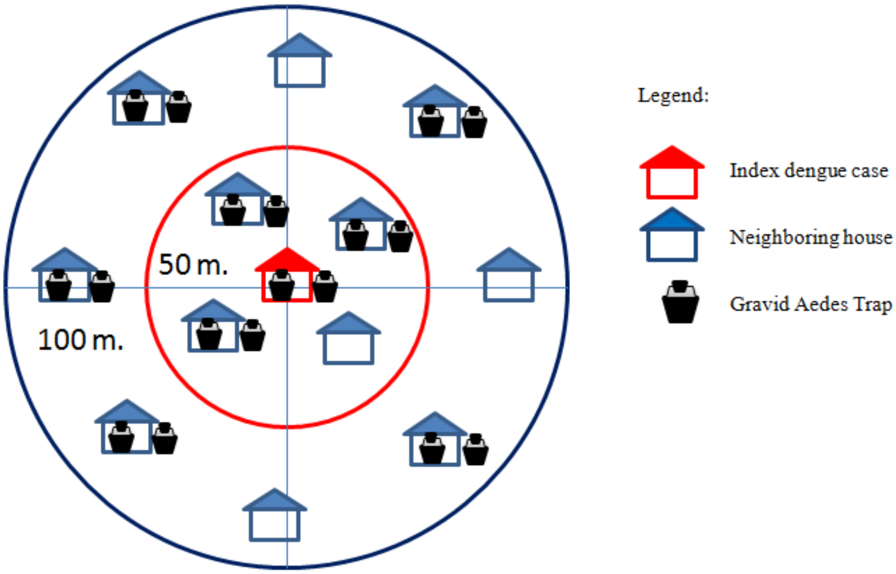

Figure 4. Gravid *Aedes* Trap (GATs) positioning design in field trial areas.

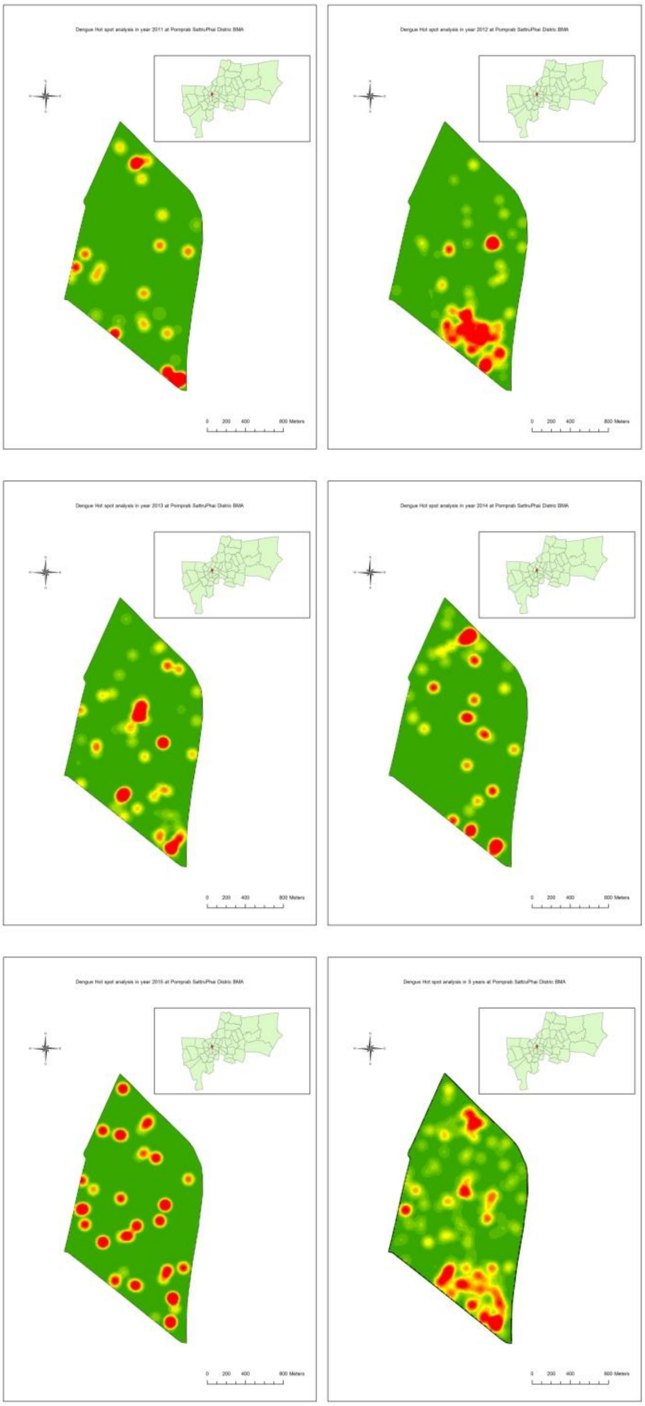

Figure 5. Incidence map showing dengue hotspot with cumulative data from the year 2011 to 2015 using kernel-density estimation (KDE) method

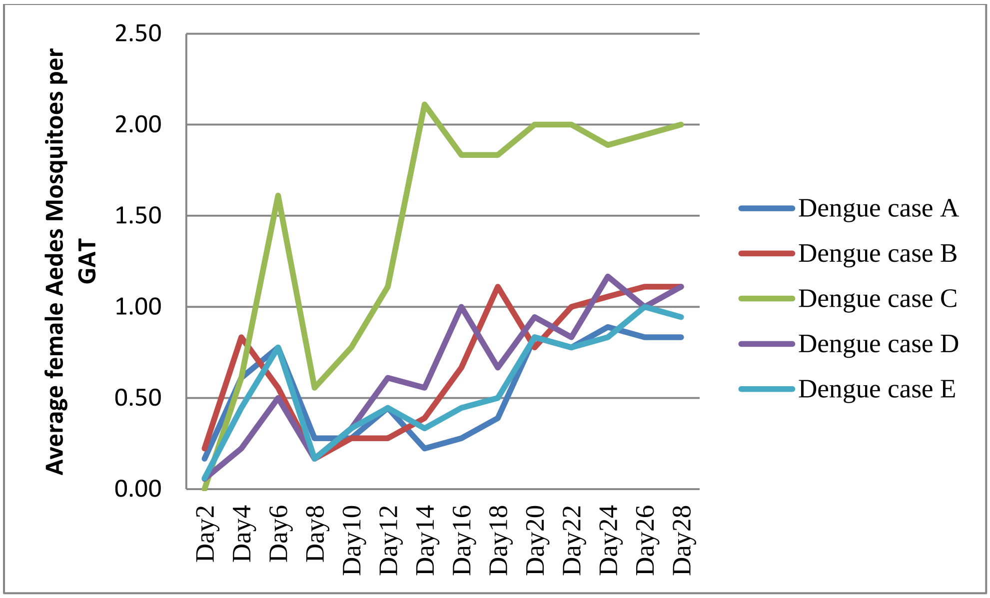

Figure 6. Average numbers of captured females *Aedes* mosquitoes per GAT per 2 day

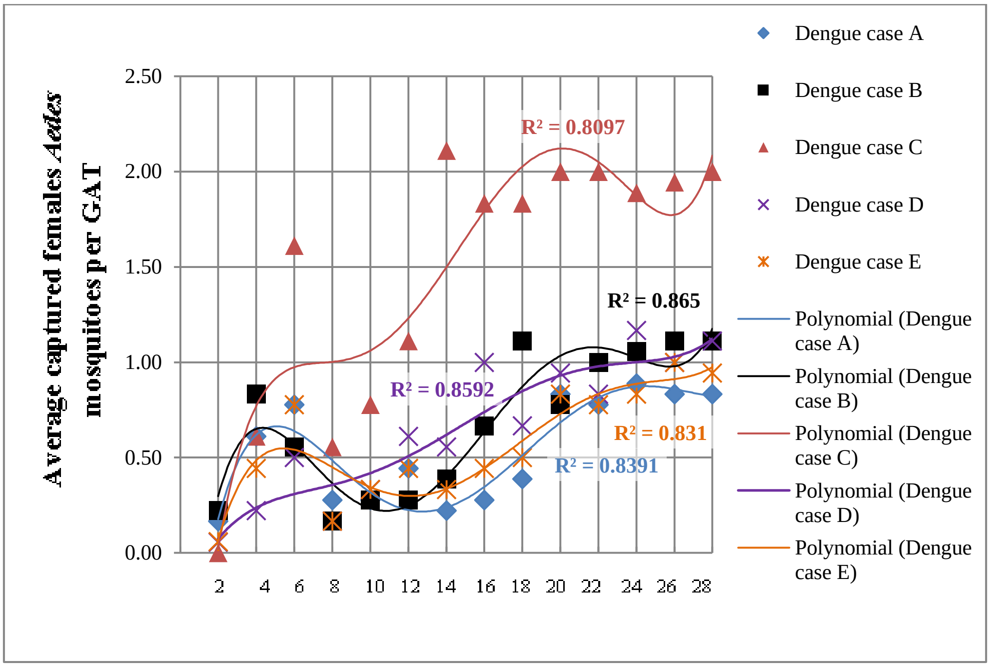

Figure 7. Correlation of average numbers of captured females *Aedes* mosquitoes per GAT collected every 2 days in 28 days of trial period

As shown in Fig. 7, the correlations of average numbers of female *Aedes Aegypti* per GAT per two day were increased during the trials period. After thermal fogging in day 1 and day 7 of the trials, numbers of captured females *Aedes aegypti* mosquitoes were decreased in short period and *continuously* increasing during the time of the trials. As the result, the efficacy of GAT has proved to be used for monitoring female *Aedes aegypti* mosquitoes in focal endermic areas.

4. Conclusion

The dengue hotspot map showed the high-density areas of dengue case, which refers to the dengue diseases were remained and clustered. There is a crucial need to increasing the level of measurement for controlling and preventing dengue disease in these areas. Furthermore, GAT can be used to decrease the abundance of females *Ae. aegypti* mosquitoes and increasing the efficacy of integrated vector management (IVM) in the future.

Acknowledgements

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Adverse Birth Outcomes among Infants Born to Women Living Near a Sanitary Landfill Site in Nonthaburi, Thailand

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Abstract

Nonthaburi province's population size has increased continuingly due to its rapid economic growth. An isolated area for its sanitary landfill formerly with limited residences has become crowded with new residences for past two decades. Therefore, its surrounding communities might be exposed to fugitive landfill pollutants, especially sensitive population like pregnant women. This landfill exposure may risk them for adverse birth outcomes. In Thailand, the knowledge about the relationship between adverse birth outcomes and living nearby a sanitary landfill was well limited. This work then determined prevalence of 5 adverse birth outcomes around a sanitary landfill of Nonthaburi and explored the risk of the outcomes related to living neighboring to the sanitary landfill site by applying a case control epidemiological study. A number of 3,584 birth records of infants whose mothers had deliverance at the Sainoi hospital between 2009-2017 were classified for preterm birth, intrauterine growth retardation (IUGR), stillbirth, low birthweight (LBW) and very low birthweight (VLBW) or cases (n=519) and for normal deliverance or control (n= 3065). Case and control were geocoded as an exposed group (n = 2,107) and a reference group (n= 1,477). The exposed group was infants whose mother's landfill-residence distance was less than 9 km. The reference group was infants whose mother's landfill-residence distance was equal or more than 9 - 40 km. For the results, we noticed that characteristics of mother and infant (infant's sex, year of birth, maternal age, marital status, alcohol consumption, and smoking) between two groups were not different. This similarity between groups would help to control for confounding effects of such variables. The estimated prevalence was for IUGR (7.52%), LBW (7.51%), preterm birth (1.05%), VLBW (0.63%), and stillbirth (0.26%). Only the prevalence of preterm birth showed a statistically significant increase in the exposed infants ($p < 0.05$). For the association between the landfill-residence distance and adverse birth outcomes, the odd ratios (OR) results showed that 3 of 5 outcomes were positively associated with the sanitary landfill exposure. These were VLBW (OR and 95% CI: 1.61, 0.62 - 4.2), preterm birth (2.12, 1.03 - 4.35), and stillbirth (1.64, 0.42 - 6.34). Only the preterm birth outcome was statistically associated with the living in the vicinity of the sanitary landfill of mothers. The results were in agreement with works in other countries that the infants whose mother lived closer to the landfill site had a higher risk of the adverse birth outcomes. However, landfill monitoring data was not available and the analysis did not account for influence of any confounders or other factors that can affect the adverse birth outcomes.

Keywords: landfill; adverse birth outcomes; case control study

1. Introduction

The increased of the world's population is a main cause of increased amount of solid waste because human activities have continuously generated municipal solid waste (MSW) (Periathamby *et al.*, 2009). For the waste disposal, there are many methods to eliminate the waste, such as open burning and open dumping into the ground or the sea. The landfill is the main disposal method in waste management systems because it is the simplest and most cost-effective method for storing the MSW waste (Samadder *et al.*, 2017). However, these methods are poor solid waste management and can lead to environmental impact and adverse human health (Giusti, 2009). Furthermore, the communities around those sites are directly exposed from chemical substances which are contaminated in air, water and soil (Palmiotto *et al.*, 2014). Nevertheless, improper landfill sites may produce harmful waste products, there are solid (wastes), liquid (leachate) and gaseous (landfill gas) (Mavakala *et al.*, 2016; Melnyk *et al.*, 2014). Most of health problems came from leachate and landfill gas. Moreover, several odorants were released during landfill operations, and uncontrolled their emission. Although, knowledge of landfill had published, people around it would be exposed inescapably (Palmiotto *et al.*, 2014). Human could be exposed to those pollutant by main pathways are inhalation and water consumption. Nonthaburi province had aggressive development not only economic expansion but also transportation and residence expansion. People from the other provinces were moving into Nonthaburi. The more residents, the greater number of waste and problems of waste disposal. Although Nonthaburi has a sanitary landfill, it can still affect people living nearby, especially sensitive population like pregnant women, because the amount of the waste is in high load. There were many works in other countries, which did and did not find significant increased risks of adverse birth outcomes in infants whose mothers living nearby landfill sites. However, there has been no such study of adverse birth outcomes associated with living near landfill ever conducted in Thailand. The motivation of this study was to compare prevalence of birth outcomes between an exposed area and a reference area and to assess the risk of adverse birth outcomes associated with living near MSW landfill site. The finding of this study could be applied for waste management strategy around the studied sanitary landfill.

2. Method and materials

2.1 Study area

The studied sanitary landfill site operated by the Nonthaburi provincial administrative organization is located in Tambon Klongkwang, Amphoe Sainoi, Nonthaburi (Fig. 1). A whole solid waste disposal site has a total area of 472 acres coordinated at 14.005564 N and 100.316478 E. The landfill site had an average of waste in a load of 1,200 tons per day (Nonthaburi Provincial Administrative Organization, 2015). It has started an operating since 1997 and was overhauled in 2005. Moreover, this landfill site was a waste disposal center which received solid waste from 17 municipalities, 16 privates and 28 sub-district administrative organization.

2.2 Participants

This work was a case control analysis of adverse birth outcomes in infants whose mother who admitted in the Sainoi hospital between 2009 and 2017. The 5 interested adverse birth outcomes of cases included LBW (<2,500 g), VLBW (<1500 g), preterm birth (< 37 completed gestation weeks), intrauterine growth retardation (IUGR, an unborn infant who was smaller than it should be because it is not growing at a normal rate inside the uterus) and stillbirth (an infant who was born with no signs of life at or after 28 gestation weeks). Controls were those infants born normally without those adverse outcomes. The cases and controls were divided into 2 groups, an exposed group and a reference group. The exposed group was infants whose mothers lived near the MSW landfill site within a radius 9 km and the reference group was infants whose mothers lived far from the MSW landfill site from 9-40 km.

Figure 1. The studied landfill of Nonthaburi provincial administrative organization

2.3 Data preparation

A number of 3,623 birth records of infants whose mothers admitted between 2009 and 2017were acquired from the Sainoi hospital with a given permission from the Nonthaburi Provincial Health Office. A study proposal was submitted to the Nonthaburi Provincial Health Office and an ethics review committee. The obtained birth records consisted of address, maternal age, marital status, smoking, alcohol consumption, birth date, birth weight, infant's sex, and ICD 10 codes. The birth outcomes can be determined from ICD 10 codes and/or infant's characteristics as following:

- Preterm birth: ICD 10 codes O60: preterm delivery and O601: preterm labour with preterm delivery
- LBW and VLBW: birth weight of each infant lower than 2,500 g and 1,500 g respectively
- IUGR: Infants without ICD 10 codes O60 or O601 with birth weight lower than 2,500 g
- Stillbirth: ICD 10 code Z371: single stillbirth

2.4 Measurement of the landfill-residence distance

Each mother's address was reassigned using her sub-district's center or Tambon's center instead for each participant's location. To measure the distance from each Tambon center to the landfill site, Google Earth with a Geographic Information System (GIS) function was used to find latitude and longitude of each Tambon. A landfill origin was located as for its coordinate. All Tambon center's coordinates were spotted as they were important to calculate the distance between the landfill and each Tambon. Then the distance between the landfill and each Tampon was calculated by using a ruler based on the latitude and longitude GIS function. it was an application by Andrew Headges (http://andrew.hedges.name/experiments/haversine). The exposed zone within a radius of < 9 km from the land fill and reference zone out with in radius of 9-40 km were shown in Fig. 2.

2.5 Statistical analysis

Hospital admission records were imported to the SAS® University Edition for descriptive statistics analysis for adverse birth outcome prevalence and inferential statistics analysis for a crude odds ratio (OR) with its 95% confident interval. A chi square test was used to find the distribution of differentiation between each interested variable. In this study, it was used to compare the prevalence of adverse birth outcomes between exposed and reference residence zones, and compare characteristics of infants and their mothers between zones. OR and 95% CI were computed for the association between the prevalence of five interested adverse birth outcomes and the zone of residence. The OR represents the odds that the adverse birth outcomes will occur in the exposed group, compared to the odds of the adverse birth outcomes occurring in the reference group.

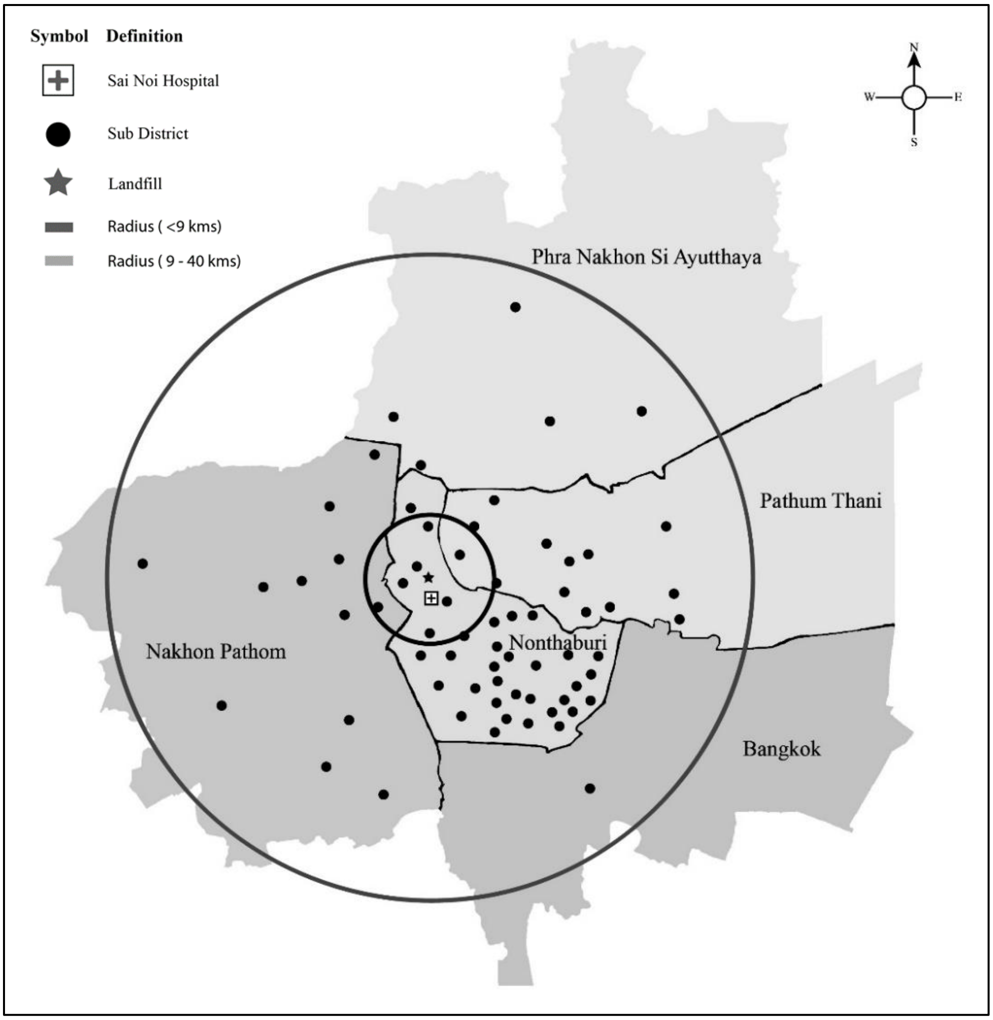

Figure 2. Exposed zone within a radius of <9 km from the landfill

The crude odd ratio can be calculated from a 2×2 table (Table 1) by equation (1) with the standard error of log odds ratio as shown in equation (2) and 95% confidence interval in equation (3). For an association interpretation of landfill pollution and infant's adverse birth outcome impacts, it can determine from OR and 95% CI. If an odds ratio is less than or equal to 1 that means no association between the prevalence of interested adverse birth outcomes and the zone of residence while an odds ratio is greater than 1 that means living near landfill associated with a risk of an adverse birth outcome. If its lower bound of the 95% confidence interval is greater than 1 it indicates that infants are at statistically significant risk of an adverse birth outcome with $p < 0.05$.

Table 1. Table 2×2 showing number of infants with and without adverse birth outcomes in exposed and reference area.

Participants	Adverse birth outcomes	
	Yes	No
Exposed	(A)	(B)
Reference	(C)	(D)

$$\mathrm{OR} = \frac{A/B}{C/D} = \frac{AD}{BC} \tag{1}$$

$$\mathrm{SE}\{\mathrm{In(OR)}\} = \sqrt{\frac{1}{A} + \frac{1}{B} + \frac{1}{C} + \frac{1}{D}} \tag{2}$$

$$95\%\ \mathrm{CI} = \exp\,(\mathrm{In(OR)} \pm 1.96 \times \mathrm{SE}\{\mathrm{In(OR)}\}) \tag{3}$$

Where A = number of exposed infants with an adverse birth outcome

B = number of exposed infants without an adverse birth outcome

C = number of reference infants with an adverse birth outcome

D = number of reference infants without an adverse birth outcome

SE = standard error

3. Results and discussion

A total of 3,623 birth records from Sainoi hospital between 2009 and 2017 were analyzed but some records had no participant’s address resulting in valid records of 3,584. A number of exposed participants in exposed zone and a number of reference participants in reference zone are show in Table 2. It presents a distribution that almost 58.79% of participants were in the exposed zone and about 41.21% were in the reference zone. The characteristics of infants and their mother in each zone were observed and noticed that their characteristics were not difference in both groups including infant’s sex, year of birth, maternal age, marital status, alcohol consumption, and smoking (p <0.05, the result not shown). It can conclude that infants and mothers in the exposed group and reference group have approximately similar characteristic and family environment. This would help control for other confounding effects from these variables associated with adverse birth outcomes.

Table 2. Distribution of participants by residence zones

Residence zone	**Landfill-living distance (km)**	**n (%)**
Exposed	0 to 9	2,107 (58.79)
Reference	9 to 40	1,477 (41.21)
Total		**3,584 (100)**

The prevalence of interested adverse birth outcomes between the exposed zone and the reference zone are shown in Table 3. A number of total cases and controls were 519 and 3065 respectively. The prevalence of adverse birth outcomes in average for both zone was estimated as for IUGR (7.52%), LBW (7.51%), preterm birth (1.05%), VLBW (0.63%), and stillbirth (0.26%). When comparing differentiation of those in the exposed zone and the reference zone, we observed that 3 out of 5 adverse birth outcomes had greater prevalence in the exposed zone than those in the reference zone. These 3 outcomes were VLBW, preterm birth and stillbirth. Moreover, the prevalence of preterm birth was the only one outcome that was statistically increased for mothers living in the exposed zone ($p < 0.05$). The prevalence of five interested adverse birth outcomes of infants in the exposed zone and the reference zone are shown in Fig. 3. Three out of five adverse birth outcomes (VLBW, preterm, and stillbirth) with a less number of participants were observed but they showed lightly higher prevalence in the exposed zone. However, for LBW and IUGR with a more number of participants, their prevalence in the exposed zone were not higher than reference zone. Other work in an e-waste community also showed significantly higher prevalence rates of still birth (4.72% vs. 1.03%), LBW (6.12% vs. 4.12%) and VLBW (3.40% vs. 1.57%) in an exposed city of Guiyu, China (Xu *et al.*, 2012).

Table 3. The prevalence (%) of adverse birth outcomes (case =519)

Adverse birth outcomes	Exposed zone		Reference zone		p-value
	n	%	n	%	
LBW	126	7.01	99	8.01	0.3028
VLBW	14	0.78	6	0.49	0.3262
Preterm birth	30	1.42	10	0.68	0.0362*
IUGR	122	6.79	102	8.25	0.1300
Stillbirth	7	0.33	3	0.20	0.4707

*Statistically significant difference ($p < 0.05$)

The result of the association between the residence zones and the adverse birth outcomes in terms of crude OR and 95% CI were estimated a in Table 4 for each interested adverse birth outcome. The ORs of three out of five interested adverse birth outcomes were positive in the exposed zone (preterm birth, stillbirth, and VLBW). These positive association (ORs greater than 1) between the residence zone and the prevalence of adverse birth outcomes were estimated for risks as for VLBW (OR, 95%CI = 1.61, 0.62-4.20), preterm birth (2.12, 1.03-4.35), and stillbirth (1.64l, 0.42-6.34). The statistically significant increased risk was only observed in preterm birth as its OR lower bound greater than 1. The crude ORs and CIs of 5 adverse birth outcomes were also plotted in Fig. 4. The line of null value of 1 is referred to the reference group in the reference zone. It was ensured that preterm birth showed the most excess risk and statistically significant increased, followed by stillbirth and VLBW. Large 95% CI was observed in VLBW, preterm birth and still birth as lack of statistical power due to a small number of participants in each outcome.

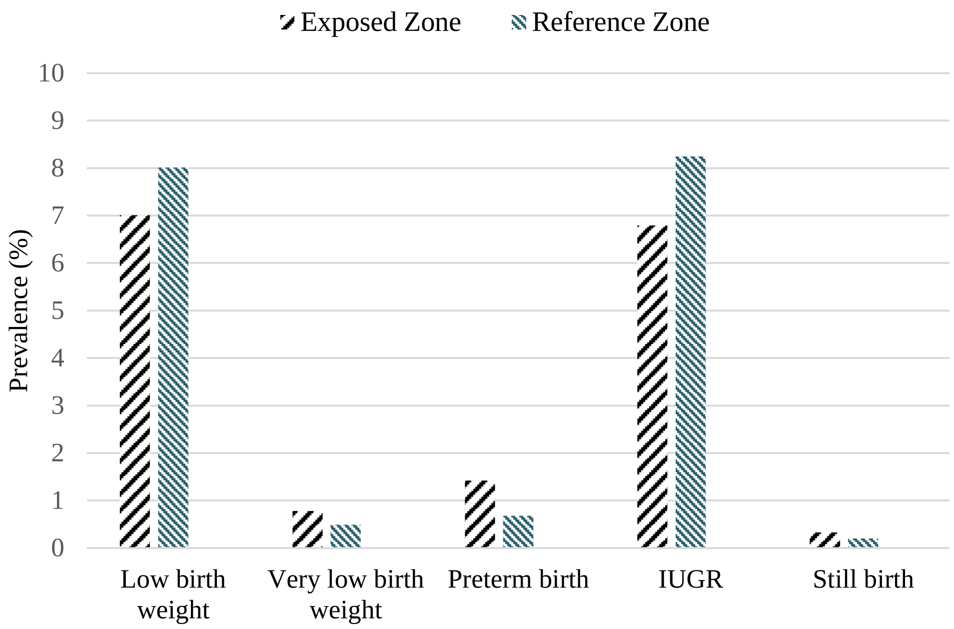

Figure 3. The prevalence of 5 interested adverse birth outcomes of infants in the exposed and reference groups

These findings exhibited that although most infants and mothers had healthy characteristics, adverse birth outcomes still occurred in both groups and showed that residences located near the landfill would have an increased risk of adverse birth outcomes in infants because residents might be exposed to fugitive pollutants from the landfill. The estimated prevalence and ORs were consistent with other studies. A study in Great Britan found small excess risks of LBW (OR = 1.05, 1.047-1.055) and VLBW (1.04, 1.03-1.05) in the populations who lived near landfill sites but the risks were statistically significant (Elliott *et al.*, 2001). A cross-sectional community-based survey investigated the area of high heavy metal and pesticide pollution in waste water drain in Punjab, India and reported that spontaneous abortion and preterm births were highly significant (Thakur *et al.*, 2010). Moreover, the risk of stillbirths was about 5 times higher compared to other studies conducted in South Asian countries. So, heavy metal and pesticide exposure may increase risk factors of adverse reproductive and child health outcomes. Another study conducted at Quebec's land fill site found the OR of LBW was significant in the exposure zone (1.20, 1.04-1.39) and the OR of small gestational age was increased as well but the relationship was not as strong as LBW (1.09, 0.96-1.24) (Goldberg *et al.*, 1995). A retrospective cohort study of open dumpsites in Alaska found the OR of LBW was significant in mothers who lived in intermediate hazard dumpsites (2.06, 1.28-3.32) and in high hazard dumpsites (3.98, 1.93-8.21) but did not see the positive significant risk for VLBW or for preterm birth because of impossibility to evaluate confounders and lack of exposure monitoring data (Gilbreath and Kass 2006). Other results from an e-waste study in Guiyu, China reported that there was a 4-time higher risk of stillbirth in mothers living in an exposed city of Guiyu compared with a control city of Xiamen (Xu *et al.*, 2012). In England hazardous landfill site, mothers living within in 3 km of the site had no significant increased risk of LBW (1.03, 0.98-1.08) (Morgan *et al.*, 2004). A work of birth outcomes and landfill in Scothland found no significant increased risk for LBW (1.01, 0.9-1.07) and VLBW (1.01, 0.9-1.15) (Morris *et al.*, 2003). The birth weight in the PCB-contaminated waste site in New York was shown to be on average 21.6 g less than that in other control area ($p < 0.001$) (Baibergenova *et al.*, 2003). A 20-year birth certificate study of parents living near a landfill site observed significant increased risk for low birth weight (5.1, 2.1-12.3) and but did not observe for preterm birth (2.1, 1.0-4.4) (Berry and Bove 1997). Another large study of living in proximity to hazardous waste site did not see significant increased risk for LBW weight but concluded that integrating a large population data with environmental data may not be efficient when assessing the risk. From all previously mentioned works, we believed that this study was reliable to confirm there were positive risks but not significant for VLBW and stillbirth and only preterm birth showed strongly a significant increased risk with living near the studied landfill.

Table 4. OR with 95% CI of adverse birth outcomes

Adverse birth outcomes	**Crude odds ratio**	**95%CI**	
		Lower	**Upper**
LBW	0.86	0.66	1.14
VLBW	1.61	0.62	4.20
Preterm birth*	2.12	1.03	4.35
IUGR	0.81	0.62	1.06
Stillbirth	1.64	0.42	6.34

*Statistically significant increased risk ($p < 0.05$)

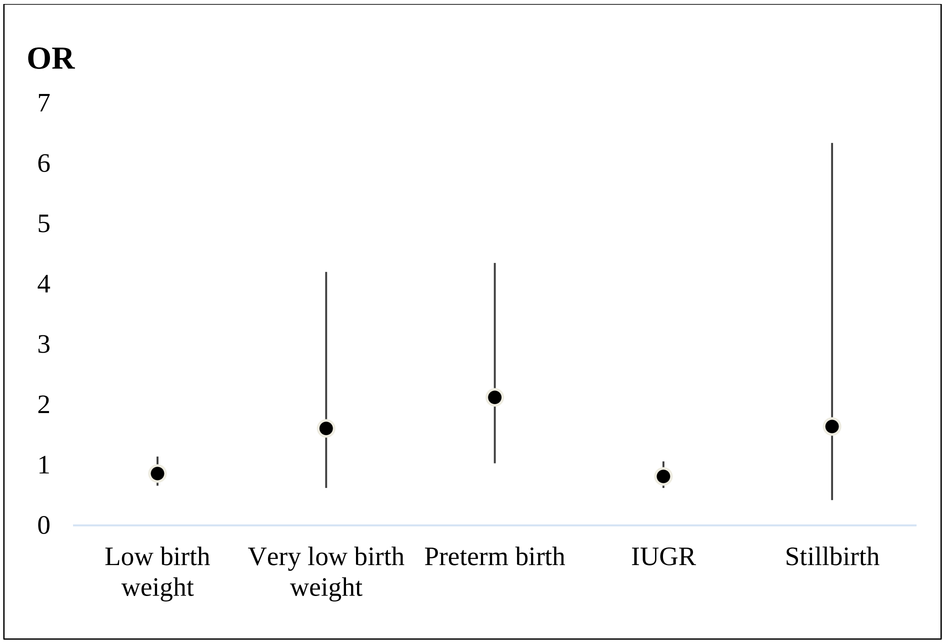

Figure 4. Crude odds ratio of adversed birth outcomes

The results can be used for further for municipality health care planning and can be applied for appropriate solid waste management measure. Unfortunately, landfill monitoring network was not available and other pollutants sources such as traffic, industrial or crematorium were not taken into account. The analysis also did not adjust for characteristics of infants and mothers' for confounding effects that might cause adverse birth outcomes. The risks we reported may not be as strong as those in other works due to a small number of cases and lack of quantitative exposure assessment.

4. Conclusion

Mothers who lived near the landfill site might be exposed from fugitive landfill pollutants. This work analyzed 3,623 birth records from Sainoi hospital. Although characteristics of mothers and infants were not different between the exposed zone and the reference zone, we found higher prevalence for adverse birth outcomes of VLBW, preterm birth, and stillbirth in the exposed zone. However, preterm birth was the only outcome that was statistically significant higher. For the association between living near the landfill and adverse birth outcomes, OR results showed positive association for VLBW, preterm birth, and stillbirth but only preterm birth were statistically significant. We can say that when the distance between the landfill and mother's residence decrease the risk of preterm birth would increase significantly (OR = 2.12, 1.03-4.35). However, there were other confounders related to adverse birth outcomes that should be controlled for in further work.

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Respiratory Hospitalizations of Children Living near a Sanitary Landfill in Nonthaburi, Thailand: a Case Control Study

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Abstract

Recently, a number of new communities surrounding a sanitary landfill in Nonthaburi province have increased from a high residence demand. Thus, sensitive population of children in those communities could be exposed to fugitive landfill contaminants. This landfill exposure may risk them for an excess risk of respiratory illness. In Thailand, there was a knowledge gap of the association between children's respiratory health effects and living near a sanitary landfill. This study aimed to survey prevalence of landfill-related respiratory disorders and to estimate the excess respiratory health risk in children living near the sanitary landfill site. We acquired hospital admission records of 6,097 children aged 0-14 years old admitted with respiratory disorder as cases (n= 3,223) and infectious disease and digestive disorders as controls (n= 2,874) at the Sainoi hospital from June 2008- May 2017. The exposed participants were those living inside a radius of 10 km from the landfill center while the reference group lived outside it. The results showed that 3,605 participants lived in an exposed zone (59.13%). Their characteristics (sex, age, admission season and family smoking) between exposed and reference groups were not quite different in terms of proportions. These undistinguishable characteristics between groups could alleviate confounding effects from such variables. The greater prevalence of all 6 respiratory outcomes was observed in the exposed group and 5 of them were statistically significant increased ($p < 0.05$). For the association between children's respiratory outcomes and living near the landfill, we found positive association in all six respiratory outcomes. Their crude odd ratios (OR) were for acute-upper-respiratory infections (OR=1.164, 95%CI: 1.038-1.305), acute respiratory infections (1.277, 1.152-1.415), pneumonia (1.186, 1.035-1.359), asthma (1.039, 0.826-1.307), acute bronchitis (1.203, 1.101: 1.444) and all- combined respiratory symptoms (1.293, 1.167-1.432). All 5 respiratory outcomes considered as acute effects showed statistically and significantly increased risk except asthma considered as a chronic effect. The findings were consistent with other works confirming the closer living to the landfill site, the greater respiratory health risk in children. Nevertheless, quantitative landfill contaminant monitoring was not available and the analysis did not account for any other confounders or other pollutant sources that may cause adverse respiratory illness in children.

Keywords: landfill, respiratory symptom, respiratory hospitalization, and children

1. Introduction

Municipal solid waste (MSW) was generated by many communities and was increasing due to economic developing growth. Waste generated in Thailand in 2007 had a component of organic compound (48%) and glass, plastic, and paper (40%). The treatments used for MSW in Thailand were open dumpling (65%), composting (10%), incineration (5%), landfill (5%) and other (15%) (Kaosol 2007). Solid waste situation in Thailand in 2015 had total MSW quantity around 26.75 million tons per year or 73,560 tons per day and rate of generation was 1.13 kg per capita per day (Pollution Control Department, 2015). The Nonthaburi province's landfill is one of the largest sites in Thailand operating since 2006 (originally an open dumpsite since 1985). The landfill site received MSW from municipalities, private and sub district administrative organizations all of Nonthaburi province. The loading rate of MSW was 1,200 tons per day mostly from municipalities (Nonthaburi Provincial Administrative Organization, 2015).

Landfills can produce adverse odors and landfill gas. Many toxic substances can be found in landfill. Carbon dioxide (CO_2) and methane (CH_4) were generated in largest quantities and remaining gases include nitrogen, oxygen, ammonia, sulfides, hydrogen and other various gases (Agency for Toxic Substances and Disease Registry, 2001). Odors from day-to-day landfill activities were indicative of gases and microorganism moving above ground. Gases and microorganism may also move through the soil underground and can accumulate in nearby communities. Microorganisms are dispersed from the landfill to the atmosphere with the wind. Their existence depended on their resistance, meteorological conditions, air pollution and time spent in the atmosphere. Odor and bio-aerosol can cause respiratory illness and irritant. Irritation of respiratory and mucous membrane was reported when residents exposed to bio-aerosol pollution (Herr *et al.*, 2003). Many adverse health impacts caused by landfill were an important and sensitive topic to community health (Deloraine *et al.*, 1995; Epps, 1991). Another cross-sectional study indicated risk of respiratory symptoms among waste-picking children in a landfill who had a significantly increased odds ratio (OR) when compared to a non-waste-picking children group (Romero *et al.*, 2010). In addition, children aged less than 2 years old who lived near landfill was significantly risked in respiratory symptoms (Corrêa *et al.*, 2011). Children were more vulnerable when exposed to fugitive landfill pollutants than adults. In Thailand, there was a knowledge gap of the association between children's respiratory health effects and living near a sanitary landfill. The motivation of this study was to compare prevalence of landfill-related respiratory disorders in exposed and reference children and to estimate an excess respiratory health risk in children aged 0-14 years living near the landfill site using case control epidemiological study.

2. Method and materials

2.1 Study Site

The studied landfill was a sanitary landfill located in Tambon Khlongkwang, Amphoe Sainoi, Nothaburi. The whole waste management area was 465 rai of which

263 rai was for areas of landfill site, leachate treatment system, surface water ponds and garden. The landfill site was coordinated at 14.004210 N and 100.190258 E (Fig. 1). It has started operating since 1997 and was overhauled in 2005. Its ability to keep accumulating wastes was estimated up to 2019. The composition of the waste was mostly community organic waste. This selected study area was a rapid growing town having many schools with a tremendous load of MSW daily from municipalities so there might be a chance that children's health may be affected by the landfill through environmental media air, water, and soil. As children are more sensitive to fugitive pollutants emitted from the landfill than adults, the associated respiratory outcomes could be worse. Participants were those children admitted at the Sainoi hospital, located south of the landfill (Fig. 1).

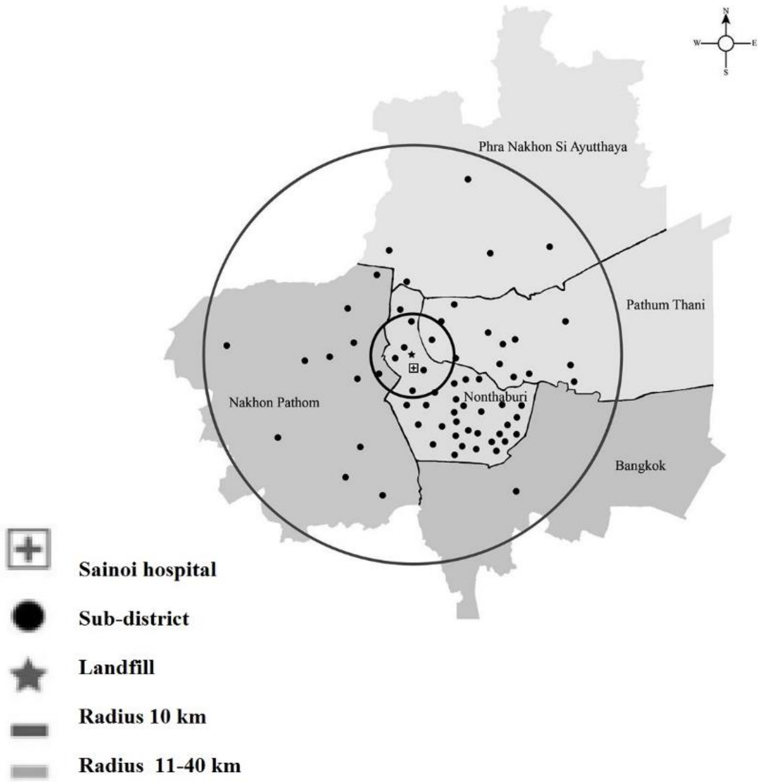

Figure 1. A 10 km radius of an exposure zone from the land fill site

2.2 Participants

This study was an epidemiological case-control study analyzing children's hospitalization admission records acquired from the Sainoi hospital. **Cases** were children aged 0-14 years old who were admitted with a primary diagnosis of 6 respiratory symptoms of acute-upper-respiratory infections (AURI), acute respiratory infections (ARI), pneumonia, acute bronchitis, asthma and all-combined respiratory symptoms. From June 2008 to May 2017. These cases were compared with children who were admitted urgently at the Sainoi hospital during the same period of time with other morbidity including infection and parasite diseases, digestive system disorders, symptoms, sign and abnormal clinical findings and other illness as **controls**. Diagnostic codes for defining cases and controls were based on the International Classification of Diseases 10th revision (ICD-10) in Table 1. The hospitalization admission records came with information of each patient's characteristics including sex, date of admission and discharge, address, ICD-10, body weight, and self and family smoking behavior. Most characteristics were well complete except smoking with 25% complete.

By each patient' address using its sub-district (Tambon), the **exposed** participants were defined as children who lived within a radius of 10 km from the landfill site and the **reference** participants were defined as children who lived more than 10 km away from the landfill (Fig. 1).

The proposal of this work was submitted and reviewed by the ethics review committee of Nonthaburi Provincial Public Health Office. The work was approved for the ethic terms. The acquired hospital admission records were given without patient's ID, name, or house number or other info that can identify patient's identity. Other patient's characteristics were kept confidentially for analyzing only

Table 1. ICD-10 disease codes used to define patients as the cases or controls

Diagnosis	**ICD-10 codes**	**N= 6,097**
Cases		
Acute respiratory infections (ARI)	J00-J06, J09-J18, J20-J22	2,836
Acute-upper-respiratory infections (AURI)	J00-J06	988
Pneumonia	J12-J18	1,069
Acute bronchitis	J20-21	537
Asthma	J45-J46	320
Respiratory symptoms	J00-J99	3,223
Controls		
Infection and parasite diseases	A00-B99	1,763
Diseases of digestive system	K00-K95	333
Symptoms, sign and abnormal clinical findings	R10-R99	631
Other illnesses		154

2.3 Measurement of living distance

Each participant's address was assigned to use its sub-district center location as patient's living location. Each sub-district was coded for example, 111 for Khlong Khwang, 112 for Sainoi, etc. The sub-district code was helpful when statistical analyses were programmed by the statistical software, SAS University Edition. To estimate the distance from the landfill to each participant's living location, we used a measurement by the Google Earth Pro. Google Earth had a high accuracy and was very useful for distance measurement. Fig. 2 shows an area within a radius of 10 km as an exposed zone that covered some area of Nothaburi, Nakhon Pathom and Pathum Thani provinces and an area outside a radius of 10 km as a reference zone. Each point indicates a sub-district location. The Sainoi hospital was located 3 km away from the landfill.

2.4 Statistical analysis

The prevalence of 6 respiratory diseases was estimated for those living in the exposure and reference zones. A chi square (X^2) statistic was used to investigate whether distributions of categorical variables of patient's characteristic differ from one another. In this study, this test was used to compare the prevalence of each respiratory disorder between exposed and reference zones and compare the characteristics between the exposed and the reference participants. For the association between living near the land fill and the respiratory illness, excess risks of respiratory outcomes for the exposed children were calculated using a crude odds ratio (OR) and its 95% confidence interval (95% CI) in Equations 1, 2 and 3 respectively by using the SAS university edition. This OR can identify the presence of risk or can confirm the association between living near the landfill and respiratory illness. The OR measure described can be expressed based on the contingency table "2 x 2", as demonstrated in Table 2. The risk between the landfill exposure and respiratory illness statistically exists if the lower CI of OR is greater than 1.

Table 2. The contingency table used to calculate a crude odd ratio

Living	**Illness**	**No illness**	**Total**
Exposure	a	b	a+b
Reference	c	d	c+d

$$\text{OR} = \frac{ad}{bc} \quad (1)$$

$$SE\lfloor \ln(OR) \rfloor = \sqrt{\frac{1}{a} + \frac{1}{b} + \frac{1}{c} + \frac{1}{d}} \quad (2)$$

95 % CI= exp (ln(OR)-1.96SE(ln(OR)) to exp (ln(OR)+1.96SE(ln(OR))   (3)

Where a = Number of exposed children with an illness
b = Number of exposed children without an illness
c = Number of reference children with an illness
d = Number of reference children without an illness
SE = standard error of ln (OR)

3. Results and Discussion

We analyzed 6,117 hospitalization records of children but some records had unknown causes of illness or ICD10 codes resulting in 6,097 complete records consisted of 3,223 cases with respiratory illness and 2,894 controls with non-respiratory illness. A number of children living in the exposed zone and the reference zone were reported in Table 3. Majority of children (59.13%) lived in the exposed zone and the rest of children (40.87%) lived in the reference zone**.** For patient's characteristics of sex, age, admission season and self and family smoking, these were not statistically significant different between the exposed zone and the reference zone (*p* < *0.05*). The characteristics were not presented here. These similar characteristics of two groups could help control for confounding effects associated with these characteristics.

Table 3. Distribution of children according to living zone

Living zone	Distance to landfill (km)	n (%)
Exposed zone	0-10	3,605 (59.13)
Reference zone	>10	2492 (40.87)
Total		6097 (100)

3.1 Prevalence result

For prevalence comparison, Table 4 presents the prevalence of all 6 respiratory illnesses of children by the living zone. The prevalence of 6 illnesses in the exposed zone were higher than those of the reference zone. High prevalence was observed for ARI, Pneumonia, AURI, acute bronchitis, and asthma respectively. This illness prevalence of participants in the exposed zone was 28.5%, 10.96%, 10.09%, 5.56%, 3.15%, respectively. Five of six illness prevalence in the exposed zone were significantly greater than those in the reference zone (*p* < *0.05*). These 5 illnesses were AURI, ARI, pneumonia, acute bronchitis and all combined respiratory symptoms. Asthma showed a greater prevalence in the exposure zone but not statistically higher. This could be due to a small number of patients leading to a lower statistical power. Fig. 2 shows the prevalence of 6 respiratiry illness groups. As can be seen, participants living in the exposed zone had 1-12% prevalence higher when compared to those living in the reference zone. This high prevalence of respiratory illnesses found in the studied children was in agreement with other works finding that the ARI was common in children and was the highest mortality rate in children. This was a main problem in developing and underdeveloped countries. Pneumonia has also been listed as one of the three major causes of death in children since at least the 1950s. About 15 million under the age of five died every year in the world but 4 million of them died from pneumonia (Savage, 1987; Zhang, 1986). In India, a couple works studied prevalence of ARI in children under five years of age and reported that prevalence of ARI was found to be higher than other diseases (Bourke, 2012; Yousef and Hamed, 2016). In preschool children, researchers studied about upper respiratory morbidity and found that acute otitis media, tonsillopharyngitis, and common cold were quite common (Kvaerner *et al.*, 2000). Other school children studies also reported higher prevalence of wheeze (Miyake *et al.*, 2005) and other respiratory hospitalization from living near landfill (Nirel *et al.*, 2015). Another work investigating a landfill as a risk factor for respiratory diseases in school children also reported the higher respiratory diseases in children aged up to 13 years exposed to a landfill site closed 6 years previously (Corrêa *et al.*, 2011). However, another work investigating at the same studied landfilled site as of this work reported the prevalence of wheeze, runny nose, and cough-sneeze were also high but slightly increased as the landfill-school distance decreased (Pratoomma and Puangthongthub, 2016).

Table 4. The prevalence (%) of respiratory illnesses by living zone

Respiratory illness	Exposed		Reference		p-value
	n	%	n	%	
AURI	615	10.09	373	6.121	0.0293*
ARI	1759	28.85	1065	17.47	<0.0001**
Pneumonia	668	10.96	401	6.58	0.0138*
Asthma	192	3.15	128	2.10	0.7443
Acute bronchitis	339	5.56	198	3.25	0.0483*
All respiratory symptoms	2,000	32.80	1,223	20.06	<0.0001**

* Statistically significant difference at $p < 0.05$

** Statistically significant difference at $p < 0.01$

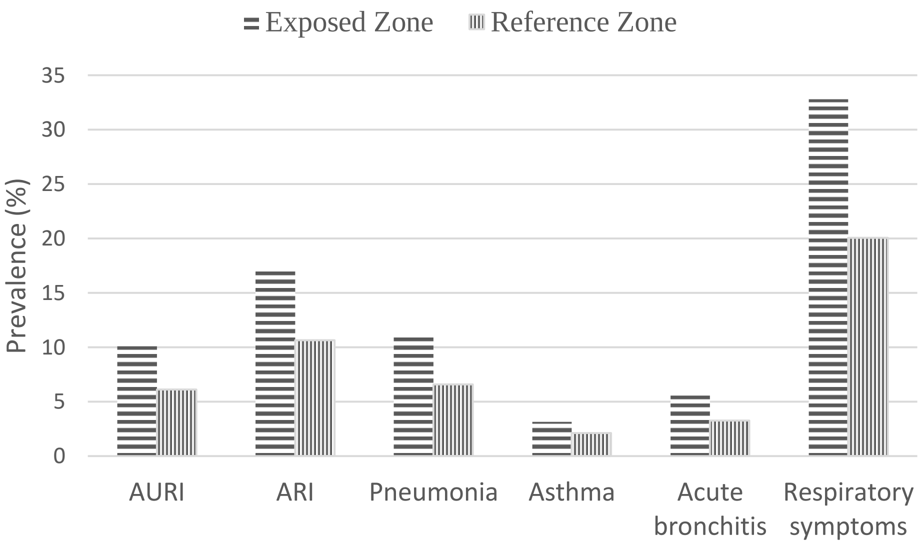

Figure 2. The prevalence of 6 symptoms of children in living zone

3.2 Associated Risk

For the relationship between living near the landfill and respiratory illness, the crude ORs and CIs were assessed as shows in Table 5. We found positive association in all 6 illness groups (ORs greater than 1). Their crude ORs were statistically significant higher in the exposed zone for AURI (OR = 1.164, 95%CI: 1.038-1.305), ARI (1.277, 1.152-1. 1.415), pneumonia (1.186, 1.035-1.359), acute bronchitis

(1.203, 1.101-1.444) and all combined respiratory illnesses (1.293, 1.293-1.432). Asthma was positively associated with the exposure zone but not statistically significant (1.039, 0.826-1.307). This could be due to several assumptions such as a number of asthma patients were well limited in this study resulting in a low statistical power and a large CI (Fig. 3) or it is considered as a chronic effect which may not be well associated with the landfill exposure. Other studies also reported risk of respiratory illness in children who lived nearby a waste site. A crossectional study in children labours indicated an increased risk of respiratory symptoms among waste-picking children in a landfill with a significantly increased ORs when compared to a non-waste-picking group (Romero *et al.*, 2010). Another work investigating the same studied landfilled site of this work reported the significant risks of wheeze, runny nose, and cough-sneeze increased as the landfill-school distance decreased and these 3 symptoms: OR = 1.31, 1.06-1.63; 1.31, 1.1-1.54; and 1.42, 1.17-1.73 respectively) also significantly associated with landfill odor exposure (Pratoomma and Puangthongthub, 2016). In children aged 1-5 years who lived in an exposed zone of an open waste disposal site showed a greater risk of respiratory symptoms (OR = 1.37, 1.17-1.60) (Giron *et al.*, 2009). A work in Japan studied the relationship between distance of schools from the nearest municipal waste incineration plant and child health and found positive association with an increased prevalence of wheeze (OR = 1.08, 1.01–1.15). In Taiwan, a case control study also reported respiratory and irritant health effects of a population living in a petrochemical-polluted (Nirel *et al.*, 2015). Another case control study reported about respiratory hospitalizations of children living near a hazardous industrial site adjusted for prevalent dust and found children aged 0-1 year who lived within 10 km had significantly in respiratory symptoms with OR = 2.31, 1.39-3.1 and after adjustment by PM_{10}, the risk was still significantly (OR = 1.96, 1.09-3.51).

Table 5. Association between living zone and respiratory symptoms, 2008-2017

Respiratory illness	OR	95%CI	
		Lower	Upper
AURI	1.164*	1.038	1.305
ARI	1.277**	1.152	1.415
Pneumonia	1.186*	1.035	1.359
Asthma	1.039	0.826	1.307
Acute bronchitis	1.203*	1.101	1.444
All respiratory symptoms	1.293**	1.167	1.432

* Statistically significant difference at $p < 0.05$

** Statistically significant difference at $p < 0.01$

A study in an e-waste area investigating heavy metals in $PM_{2.5}$ and in blood, and children's respiratory symptoms and asthma from an e-waste recycling area and showed that living in exposed area was positively associated with blood lead (beta coefficient = 0.196, p < 0.001), blood cadmium (beta coefficient = 0.148, p < 0.05) and cough (OR = 2.37; 1.30-4.32; p < 0.01) and blood lead >5 mg/dL was significantly associated with asthma (OR = 9.50; 1.16-77.49) (Zeng, 2016). Another work investigated landfills as risk factors for respiratory disease in children and confirmed the relationship between exposure to a landfill site closed 6 years previously and respiratory symptoms in children aged up to 13 years. After their adjustment for OR, there was a significant risk (OR = 1.53) in children less than 2 years old (Corrêa *et al.*, 2011). A study using a self-reported dairy in a community investigated the relationship between malodor, ambient hydrogen sulfide, and health in a community bordering a landfill and reported excess risks that odor was strongly associated with reports of alteration of daily activities (OR = 9.0, 3.5- 23.5), negative mood states (OR = 5.2, 2.8- 9.6), mucosal irritation (OR = 3.7, 2.0- 7.1) and upper respiratory symptoms (OR = 3.9, 2.2- 7.0) (Heaney et al. 2011). Thus, our findings can confirm the significant association between living near the sanitary landfill in Nonthaburi and respiratory illness in children aged 0-14. However, our analysis did not account for other pollutant sources such as traffic or industry nearby and did not adjust for other confounders related to children's characteristics. Unfortunately, monitoring data from air, soil and water around the landfill site were not available to reflect children's quantitative exposure. More participants from other nearby hospitals would also help improve a statistical power.

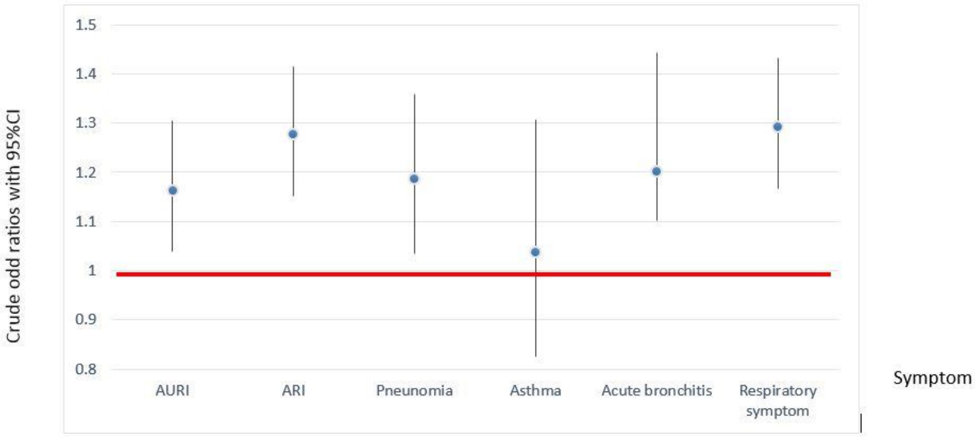

Figure 3. ORs and 95% CI by respiratory illness

4. Conclusion

This landfill-respiratory illness association study found that children's characteristics of sex, age, admission season and self and family smoking in the exposed and reference children were not different. These undistinguishable characteristics between groups could alleviate confounding effects from such variables. Children living near the landfill had statistically significant higher prevalence in all 6 respiratory illness groups than those living in the reference zone. This work reported positive association in all 6 respiratory illnesses with statistically significant increased risks in 5 illnesses for AURI, ARI, pneumonia, and acute bronchitis and all-combined respiratory symptoms. Nevertheless, quantitative landfill contaminant monitoring was not available and the analysis did not account for any other confounders or other pollutant sources.

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The Model of Khok Hin Lad forest conservation community school, Mueng, Mahasarakham, Thailand

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Abstract

Community forest is important for community livelihoods and environmental quality since it is the natural and environmental resources. In order to maintain the balance of the community forest, learning and maintaining the community forest are required. Therefore, the researchers were interested in creating the learning process by developing the model of Khok Hin Lad forest conservation community school, Mueng district, Mahasarakham province, Thailand with the objective to create the model of participatory learning of Khok Hin Lad forest conservation community school for contributing to sustainable forest management. The study areas were nine community forests of Khok Hin Lad forest conservation community.It was a 4-month learning process, which was administered only on Saturdays. The instructors were the community forest leaders. The students were from the Faculty of Environment and Resource Studies, Mahasarakham University. It consisted of 9 learning units, including history of Khok Hin Lad forest, Khok Hin Lad area, forest, wildlife, mushrooms, forest ecology, ecological culture, participation in forest conservation and the map of Khok Hin Lad community forest. The study indicated that the model of Khok Hin Lad forest conservation community school can be used to create a real learning process in the area which resulted in participatory learning process. After attending the class, the students had more knowledge, awareness and participation than before attending the class.

Keywords: Khok Hin Lad forest conservation community school; knowledge; awareness; participation

1. Introduction

Forest is an important resource for human life. Human beings can make use of the forest for their livelihoods, such as food, housing, medicine and wildlife can use the forest as their shelter. In addition, the forest is also the origin of water. It also helps to maintain soil moisture, absorb water, reduce erosion of fertile soil and slow down the flow of water. It is also a source of environmental protection, contributing to rainfall and reducing the evaporation of water and it is a source of carbon dioxide absorption in the atmosphere which is a major cause of climate change (Wongchantra, 2015).

Community forest is the forest that the community helps to manage and maintain it from forest fire, intrusion for destroying of the forest and to protect the forest from people who look for forest products which is beyond the ability of the forest that can bear. The approaches used to manage the community forest are similar. The community or the village that carries out community forest care will have the rules for taking care of and taking advantages of the forest. Fire line, patrols, rules for collecting mushrooms or shoots are administered. The community forests are divided into two areas: conservation area and living area. For the legal status of the community forest area, it may be established as the National Forest or the public area and it is probably in the area of the National Park, wildlife sanctuary (in case of the announcement of the forest reserves that overlaps with the National Forest which had been used to be the community forest before) (Seub Nakhasathien Foudation, 2017).

"Khok Mai Ngam Forest" or "Khok Hin Lad Forest" was formerly a fertile national park with more than 5,000 rais of land. But now, there are only 2,682 rais, covering 16 villages, 5 sub-districts, and 2 districts, namely Nong Pling sub-district, Khok Kor sub-district, Bua Kor sub-district, Don Van sub-district, Mueng district and Wang Sang sub-district, Kae Dam district. It is a deciduous dipterocarp forest. The abundance of Khok Hin Lad Forest is like the "consumable warehouse" that produces water into the Khok Kor Reservoir (Huai Hin Hern) and Huai Khakang Reservoir and it is also a "food depot" that the community around the forest has relied on from the past until now. There are several kinds of mushrooms such as termite mushroom, mycorrhiza mushroom, bolete mushroom, black cap mushroom, basa mushroom, crab mushroom, and vegetables such as cratoxylum formosum, adenia vindiflora craib, careya sphaerica roxb, cissampelos pareira and tiliacora triandra diels as well as animals like ants, insects, butterfly lizards, bullfrogs, birds, rats, squirrels, boars and foxes. The villagers' way of life is so closed to the forest because in addition to consumption in the community, they also sell the products from the forest for family income. They also adhere to the principle that "Do not kill chickens to get eggs". So, the villagers and the forest can sustainably depend on each other forever. But, this forest was invaded when Isan Forest Nursery Center with the cooperation JICA used the area of the Khok Hin Lad Forest as "the demonstration forest project" in the late 1997. Plowing of forest areas for planting rapid growth trees like eucalyptus, acacia mangium, black wattle and white cheesewood damaged the natural food sources of the community, the area for raising animals and planting herbs, as well as biodiversity and forest ecosystem. This was a threat to the community way of life. The villagers then claimed for accuracy and justice to protect this forest as an inheritance (Wongchantra *et al.*, 2014).

Therefore, for the purpose of continuing, stronger and more powerful preservation of Khok Hin Lad community forest, the researchers were interested in creating the pattern of Khok Hin Lad forest conservation community school, Mueng district, Mahasarakham province, Thailand to create a learning pattern and to conserve the community in order to preserve the community forests of Khok Hin Lad. It is consistently stronger and more energetic. The researcher was interested in creating a pattern of community forest in Khok Hin Lad, Muang District, Mahasarakham province to create a participatory learning and conservation pattern for community forests.

2. Research Method

This was the research and development for studying and developing the model of Khok Hin Lad forest conservation community school. The research area was Khok Hin Lad forest conservation community school located at the Environmental Education Foundation, Ban Sriwilai, Nong Pling sub-district, Mueng district, Mahasarakham province. It is located in Khok Hin Lad community forest which consists of 9 community forests. Eight forests are in Mueng district, including Baan Sriwailai community forest Moo 8, Nong Pling sub-district, Ban Nong Koon community forest, Moo 7, Bua Kok sub-district, Ban Nam Jan community forest, Moo 6, Bua Khor sub-district, , Ban Nong Jod community forest, Moo 9, Khok Khor sub-district, Ban Nong Jod community forest, Moo 13, Khok Khor sub-district, Ban Nong Lom community forest, Moo 3, Don Wan sub-district, Ban Nong Ku, Moo 3, Nong Pling sub-district, Ban Pa Kung, Moo 2, Nong Pling sub-district and there is one community forest in Kae Dam district which is Ban Nong Bua, Moo 7, Wang Sang sub-district. The communities' forest zone is delimited by the provincial forest office and the community agreement under the community forest act. They are the community forests which are important resources for the communities around them and the people in Mahasarakham province as well as the neighboring provinces as the food warehouse, especially mushrooms. And statistics used are frequency, mean, standard deviation and test statistic paired t-test.

The data collection was divided into 2 phases. Phase 1: studying and creating the model of Khok Hin Lad forest conservation community school and Phase 2: a trial period of using the model.

Phase 1 : Creating the model of Khok Hin Lad forest conservation community school

The researchers designed the process of creating the model as illustrated in Fig. 1.

1.1 The scope of the construction of the model of Khok Hin Lad forest conservation community school consisted of 9 learning units, including history of Khok Hin Lad forest, Khok Hin Lad area, forest, wildlife, mushrooms, forest ecology, ecological culture, participation in forest conservation and the map of Khok Hin Lad community forest.

1.2 The purposes of the model of Khok Hin Lad forest conservation community school were to create the knowledge base for Khok Hin Lad community forest conservation, to raise awareness on community forest conservation and to contribute to participation of the conservation of the Khok Hin Lad community forest.

1.3 The instructors were the community forest leaders from 9 community forests.

1.4 The students were 97 second year students majoring in Environmental Education, Faculty of Environment and Resource Studies, Mahasarakham University: the semester 2/2016.

1.5 According to the teaching process of Khok Hin Lad forest conservation community school, 9 community forests were used as the base for learning. The teaching was administered every Saturday for 4 months.

1.6 The place of study was at Khao Hin Lad Forest Community School located at the Environmental Education Foundation, Ban Sriwilai, Nong Pling sub-district, Mueng district, Mahasarakham province and 9 community forests of Khok Hin Lad community forest.

1.7 For the evaluation, the researchers used pre-test and post-test process in assessing the knowledge and the awareness of the community forest conservation of the students. The evaluation of participation in community forest conservation before and after doing the activities was also administered.

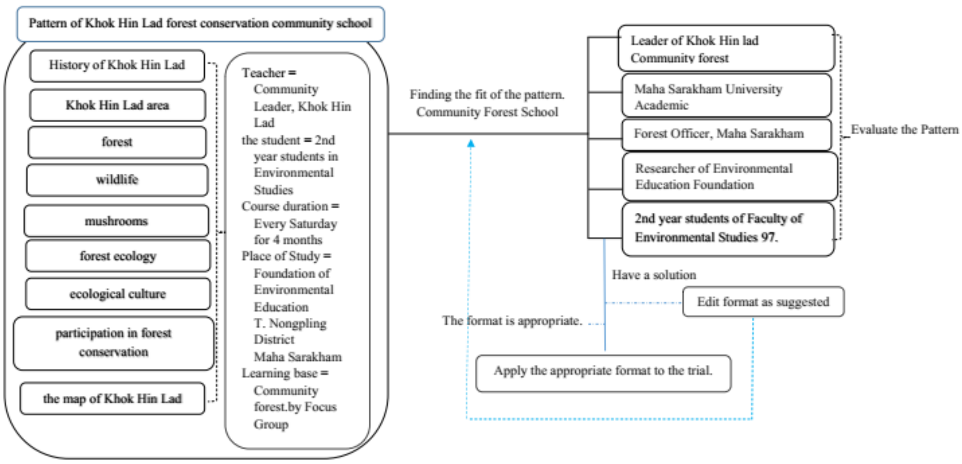

Figure 1. The process of creating the model Khok Hin Lad forest conservation community school

After the researchers had created the model of Khok Hin Lad forest conservation community school, the appropriateness of the model was evaluated by five groups of experts which were 11 community forest leaders from 9 community forests, 6 academicians from Mahasarakham University, 3 officers from Mahasarakham Forest Office, 7 Forest Researchers from Environmental Education Center and 97 second year students majoring in Environmental Education, Faculty of Environment and Resource Studies, Mahasarakham University. The results of the evaluation showed that the content of the curriculum was appropriate in the highest level ($\bar{x}$=4.96). The appropriateness of the purposes of the model was also at the highest level ($\bar{x}$=5.00). The appropriateness of the instructors was at the highest level ($\bar{x}$=4.95). The appropriateness of the learners was also at the highest level ($\bar{x}$=4.90). The teaching process was at the highest level ($\bar{x}$=4.96). For the place of learning, it was also in the highest level ($\bar{x}$= 5.00). The appropriateness of the evaluation was also at the highest level ($\bar{x}$= 5.00). In conclusion, the appropriateness of the model of Khok Hin Lad forest conservation community school was in the highest level at all aspects and met the criteria set. So, it can be implemented.

Phase 2 : A trial period of using the model of Khok Hin Lad forest conservation community school

After the researcher team had created and evaluated the model of Khok Hin Lad forest conservation community school, it was piloted with the following process.

Step 1: Teaching on Classroom

1) The committee of Khok Hin Lad community forest were invited to be the instructors at Khok Hin Lad forest conservation community school. Then the director, the deputy director and the instructors of Khok Hin Lad forest conservation community school were elected and appointed.

2) The details, the topics of the teaching and the duration of the semester were classified to the instructors of Khok Hin Lad forest conservation community school by the researchers.

3) The second year students majoring in Environmental Education, Faculty of Environment and Resource Studies, Mahasarakham University went to Khok Hin Lad forest conservation community school and they had to take the test of knowledge and awareness and the evaluation of participation in community forest conservation.

4) The instructors of Khok Hin Lad forest conservation community school taught the 9 topics, including history of Khok Hin Lad forest, Khok Hin Lad area, forest, wildlife, mushrooms, forest ecology, ecological culture, participation in forest conservation and the map of Khok Hin Lad community forest in the class.

Step 2 Teaching on Focus group

1) The students were divided into 9 groups based on Khok Hin Lad community forest areas and the instructors were also divided based on the responsible community forest group.

2) The instructors of Khok Hin Lad forest conservation community school brought the students into the community to learn outside the classroom. The students learned from the committee of Khok Hin Lad community forest and the villagers. They would learn the 9 topics but outside the classroom. The learning process was to explore the facts, to build community and student participation as well as to collect the geographic data of Khok Hin Lad community forest.

3) The instructors of Khok Hin Lad forest conservation community school led the students to make the map based on the fire lines of the Khok Hin Lad community forest in order to gather information for making a community forest map.

4) The students and the instructors of Khok Hin Lad forest conservation community school jointly made the map of the Khok Hin Lad community forest map model.

5) The instructors and the students of Khok Hin Lad forest conservation community school reviewed the content and discussed about the map model and presented the knowledge by focus group learning.

6) The students were required to take the knowledge test and evaluate the awareness and the participation after doing the activities of Khok Hin Lad forest conservation community school.

7) The results were summarized and discussed. The results of the pilot using the model of Khok Hin Lad forest conservation community school were presented to the Khok Hin Lad community forest leaders and the students. The suggestions from the community forest leaders and the students were taken for further improvement.

3. Results and Discussion

The study on the model of Khok Hin Lad forest conservation community school can be summarized and discussed according to the objectives which were to create the model of Khok Hin Lad forest conservation community school and the trial of the model of Khok Hin Lad forest conservation community school as follows (Table 1).

1. The process of the creation of Khok Hin Lad forest conservation community school started from the researchers studied the articles and the research studies on creating and evaluating the model. Then, the researchers created the model of Khok Hin Lad forest conservation community school and it was evaluated by five groups of experts which were 11 community forest leaders from 9 community forests, 6 academicians from Mahasarakham University, 3 officers from Mahasarakham Forest Office, 7 forest researchers from Environmental Education Center and 97 second year students majoring in Environmental Education, Faculty of Environment and Resource Studies, Mahasarakham University. The results of the evaluation showed that the appropriateness of the manual was in the highest level. When each aspect was considered, it was found that the content of the curriculum was appropriate in the highest level ($\overline{x}$=4.96). It appropriateness of the purposes of the model was also at the highest level ($\overline{x}$=5.00). The appropriateness of the instructors was at the highest level ($\overline{x}$=4.95). The appropriateness of the learners was also at the highest level ($\overline{x}$=4.90). The teaching process was at the highest level ($\overline{x}$=4.96). For the place of learning, it was also in the highest level ($\overline{x}$= 5.00). The appropriateness of the evaluation was also at the highest level ($\overline{x}$= 5.00). It was because the researchers reviewed literature and the research studies on constructing the model, as well as finding the appropriateness and interrelation of the model and applying the theory

focusing on integration with the environment. Wittayanukorn (2009: 83) stated that creating the pattern or the model is done for being the guidelines for studying or conducting research on a particular subject. Therefore, concepts or theories muse be analyzed into components or related variables when creating the model. Then, the components or the variables were linked into a relationship structure. These elements or variables may be derived from the experience of the researchers and the comparison based on the metaphorical principles with the previous research studies or the existing theories. The results of the assessment of the appropriateness of the model of Khok Hin Lad forest conservation community school were consistent with the study of Noppakroh (2012: 128) studying the development of environmental education school model. The components were divided into 4 areas: policy, area, learning and activities. The results of the assessment of the appropriateness of the model were at the highest level. When considering each aspect, it was found that the appropriateness of all aspects of the model was at the highest level. The appropriateness of the model in this study was similar to the current study and the results of the appropriateness of the model were in the same direction. It was also consistent with the study of Boonlue (2007: 73) studying the development of teaching style by using PBL virtual classroom in higher education level. A 13-step model was used. According to the evaluation of the appropriateness of the model by the experts, it was at the highest level. This was consistent with in terms of using virtual classroom and the samples of studying in higher education. The results of the appropriateness of the model were also in the same direction as of the model of Khok Hin Lad forest conservation community school created by the researchers.

2. The model of Khok Hin Lad forest conservation community school was evaluated before and after the trial. The results of the pre-test and post-test on the knowledge assessment revealed that before participating in the activities, the average score of the students' knowledge was in the moderate level, but after participating in the activities, their average score was in the highest level (Table 2). This was because the learning process of the model of Khok Hin Lad forest conservation community school was organized as a continuous learning process by using the group process and focusing on creating participation between the learners and the instructors and the focus group learning process which was an important learning process was used. This was consistent with the concept of Wongchantra (2015:16) stating that group discussion is another way to study the community which helps save both money and time. Group discussion is the conversation of interviewees in a group, usually about 6-12 people, but in some cases there may be exceptions for about 4-5 people. During the conversation, the moderator is raising the issues for the conversation and inducing the people in the group to express their views on the issues as deeply and thoroughly as possible. The moderator also has to create a friendly atmosphere in order to obtain qualitative information. Therefore, in the current study, the learning outcomes were developed when comparing to the knowledge scores of before and after attending the activities. This was in accordance with the results of the study conducted by Kongpetch *et al.*, 2015 studying the development of a homestay village for environmental conservation tourism services in Nong Bua Lamphu Province and the results of the study of Nimit *et al.*, 2015 studying a model development of

environmental laws training for police in Mahasarakham Province. The results of the development revealed that after organizing the activities based on the model, the average score of after attending the activities was higher than that of before attending the activities. It was also consistent with the results of study on the development of environmental education learning the process of field trips to promote the conservation of natural resources and the environment for high school students of Suthiboon, 2015 using focus group in the study of places. This was consistent with the process of creating knowledge and with the findings which found that after learning through the environmental education learning model using the environmental education process for high school students, the average learning achievement was higher than that of before learning. This showed that the model of Khok Hin Lad forest conservation community school can create knowledge for the students who participated in activities in a better way.

Table 1. The model of Khok Hin Lad forest conservation community school

Learning units	Teaching process	Evaluation
History of Khok Hin Lad forest	Giving a lecture by the instructors of Khok Hin Lad forest conservation community school and studying each community forest by focus group	Assessing the knowledge, the awareness and the participation before and after doing the activities
Khok Hin Lad area	Giving a lecture by the instructors of Khok Hin Lad forest conservation community school and the officers from Mahasarakham Forest Office and studying in the community area to collect the data of the Khok Hin Lad forest community	Assessing the knowledge, the awareness and the participation before and after doing the activities
Forest	Giving a lecture by the instructors of Khok Hin Lad forest conservation community school and the officers from Mahasarakham Forest Office and visiting the area to observe and analyze the biodiversity of Khok Hin Lad forest community	Assessing the knowledge, the awareness and the participation before and after doing the activities
Wildlife	Giving a lecture by the instructors of Khok Hin Lad forest conservation community school from the past to the present and the ways to increase the diversity of wildlife in the Khok Hin Lad community forest and learning from the community and asking about the approaches of conservation from the villagers living around the community forest.	Assessing the knowledge, the awareness and the participation before and after doing the activities

Table 1. (Continuous) The model of Khok Hin Lad forest conservation community school

Learning units	Teaching process	Evaluation
Mushrooms	Giving a lecture in class and learning from the villagers by focus group about types, situations, utilization and income from mushrooms in Khok Hin Lad community forest	Assessing the knowledge, the awareness and the participation before and after doing the activities
Forest ecology	Giving a lecture by the forest researchers from Environmental Education Center and the instructors of Khok Hin Lad forest conservation community school and trekking to study Khok Hin Lad community forest ecosystem	Assessing the knowledge, the awareness and the participation before and after doing the activities
Ecological culture	Giving a lecture by the instructors of Khok Hin Lad forest conservation community school and learning about the process from focus group on the culture of Khok Hin Lad community forest and the communities around the forest	Assessing the knowledge, the awareness and the participation before and after doing the activities
Participation in forest Conservation	Learning process and discussing to find ways to participate in community forest conservation, the study and mapping of Khok Hin Lad community forest	Assessing the knowledge, the awareness and the participation before and after doing the activities

According to the results of the study and the comparison of the level of awareness of the students before and after attending the activities, it was found that before attending the activities, the score of the awareness of the students towards the conservation of Khok Hin Lad community forest was at a moderate level, but after attending the activities the average score of awareness was at the highest level. When comparing the scores of before and after attending the activities, it was found that the average scores of awareness after attending the activities was higher than that of before attending the activities with statistical significance at .05 level. This was because the model of Khok Hin Lad forest conservation community school was created by focusing on learning from real experiences and stimulating the thinking and creating an appropriate atmosphere of learning. Therefore, the awareness of the students towards Khok Hin Lad forest conservation can be raised. This was consistent with the concept of Good, 1973 stating that awareness is the result of the cognitive process, that is, when a person is stimulated by the stimulus, he or she becomes aware and the next step is to understand it. It is the mindset that leads to learning. That is, he or she has knowledge and it then leads to awareness. Knowledge and awareness will lead to the act or behavior of the person towards that stimulus which is in the same direction of the results. This is in accordance with the study conducted by Vichiannit *et al.*, 2016 studying the development of environmental education camping activity model on forest resource conservation and restoration for youths in Kalasin Province, Thailand. The results showed that the activities of youth education camps for the youth in Kalasin province were effective and helped to develop the environmental awareness in forest conservation and protection of natural resources. This study used the learning process that allowed the samples to be close to the nature as much as possible in order to absorb the nature. This was similar to the model of Khok Hin Lad forest conservation community school which found that it could raise awareness of conservation of the Khok Hin community forest in a better direction. After the students attending the activities, the average awareness score was higher than that of before attending the activities with statistical significant at .05 level.

The results of the study on participation in conservation of Khok Hin Lad community forest of the students showed that before joining the activities, the average score of participation was at a low level: 1.67. But after joining the activities, the average score of participation was at a high level: 4.05. When comparing the average scores of before and after joining the activities, the students had the average score of participation in Khok Hin Lad community forest conservation after the promotion higher than before the promotion with statistical significance at .05 levels. This was because the model of Khok Hin Lad forest conservation community school gave the opportunity to the students to participate in sharing and in decision making as well as taking action. This was in line with the concept of Wongchantra, 2015 mentioning that the participatory process is to allow individuals or groups to participate in activities both directly and indirectly by participating in realizing and cooperating to achieve the objectives in the time and in order of efficiency with timing and appropriateness. The action is made with a sense of commitment and trust. Participation is the heart of empowering the collaboration with effectiveness and the support of the change, especially for those involved in the situation to aware and dedicate for the changes and the development. This was consistent with the process of creating the participation of the model of Khok Hin Lad forest conservation community school which created good relationships among the students, the instructors and the community. So, the results of the comparison of the participation were higher. This corresponded to the findings of Champapho *et al.*, 2016 studying the development of environmental education activities by using the environmental slogan media for bachelor degree students, Chaiyaphum Rajabhat University. The study indicated that after organizing the activity, the students had different levels of participation. After the activity was organized, the students had a higher level of participation than before the activity was organized. The success factor in this operation was the operational process that allowed everyone to participate and recognize the benefits of the operation and the process was systematic. This was consistent with the pattern and process of the model of Khok Hin Lad forest conservation community school which focused on creating the participatory learning process in order to allow the participants to participate in the learning process simultaneously. This was also consistent with the study of Machan, 2013 studying learning process for develop model of community forest management a case study: Kok Hinlad and Kok Yai in Mahasarakham province by organizing participatory learning activities to access to and recognize the conditions and the problems of the resources which led to the problem solving process. The results showed that after organizing the learning process, knowledge, attitude and participation of the people around the forest significantly increased at .05 levels.

Table 2. The comparison of the average score of knowledge about Khok Hin Lad forest before and after organizing the activities by using t-test

Aspect	Before			After			df	t	P
	$\bar{x}$	SD	Knowledge level	$\bar{x}$	SD	knowledge level			
Knowledge	28.67	2.55	Moderate	40.24	2.28	Highest	96	-40.74	.000*
Awareness	3.02	0.76	Moderate	4.60	0.49	Highest	96	-15.84	.000*
Participation	1.67	0.59	Low	4.05	0.61	High	96	-27.68	.000*

* $p < .05$

4. Conclusion

The model of Khok Hin Lad forest conservation community school can be summarized as follows.

1. The model of Khok Hin Lad forest conservation community school consisted of 9 learning units. The instructors were the community forest leaders. The students were the faculty members of the Faculty of Environment and Resource Studies, Mahasarakham University. It was a 4-month learning process, which was administered only on Saturdays from October to January. The learning area was the Environmental Education Foundation and Khok Hin Lad community forest, Mueng district and Kaedam district, Mahasarakham province. The evaluation of the model was divided into 7 aspects: the content of the curriculum, the purposes of the model, the instructors, the students, the teaching process and the evaluation. The results of the experts' evaluation showed that appropriateness of all aspects of the model was at the highest level.

2. The learning process of the trial on the use of the model of Khok Hin Lad forest conservation community school was divided into 2 phases: classroom teaching and focus group. The results of the trial showed that after organizing the model of Khok Hin Lad forest conservation community school, the students had more knowledge, awareness and participation in forest conservation of Khok Hin Lad

community forest than before organizing the activities. In addition, the model of Khok Hin Lad forest conservation community school was practical and can be implemented.

Conclusions of the pattern of Khok Hin Lad forest conservation community school is a pattern that was suitable for use in teaching. It can create knowledge, awareness and participation in forest conservation in Khok Hin Lad. This was one way to conserve community forests by creating community engagement with educational institutions for the sustainable development of natural resources conservation.

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Teaching Environmental Science to Promote Thai Qualifications Framework for Higher Education

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Abstract

Environmental science is an environmental knowledge that integrates knowledge in various sciences disciplines associated with environment such as ecosystems, biodiversity, pollution and environmental ethics in order to be used in the prevention, remediation and management of natural resources To apply the knowledge in the occupation under professional ethics as will be rate in both knowledge conserving and sustainable natural resources and the environment. Therefore, the researchers were interested in studying the teaching of environmental science based on Thai Qualifications Framework for Higher Education to compare students' learning achievement in environmental science course and to study the standard assessment of learning outcomes of environmental science course. The samples were 117 first year undergraduate students studying in environmental education, Faculty of Environment and Resource Studies, Mahasarakham University, academic year 2016. The instructional material of environmental science course and the test of environmental science course, the attitude measurement on environmental science, the environmental ethics test and the standard assessment form of environmental science course were the research instruments. The study indicated that after the teaching and learning of Environmental Science Course, the knowledge about the environment, the attitude towards environmental science and the environmental ethics of the students were higher than those of before learning. According to the standard assessment of learning outcomes according to Thai Qualifications Framework for Higher Education; the overall environmental science course of undergraduate students was in a high level.

Keywords: teaching; environmental science; knowledge; attitude; environmental ethics; learning standards based on Thai qualifications framework for higher education

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1. Introduction

Thai qualifications framework for higher education is a framework that shows the system of higher education qualifications of the country with a link from one level of qualification to the higher qualification. There is an opportunity to transfer the learning from experience which promotes lifelong learning as well as systems and mechanisms that ensure the effectiveness of the implementation according to Thai qualifications framework for higher education of the higher educational institutions that are capable of producing graduates to achieve quality standards of learning outcomes (Chapha, 2013). According to the Ministry of Education Announcement on Thai Qualifications Framework for Higher Education, 2009, the higher educational institutions are required to use Thai Qualifications Framework for Higher Education as a guideline for the development of the curriculum of the institution which must be consistent with the Ministry of Education Announcement. In addition, all educational institutions must be supervised, monitored and evaluated by Higher Education Commission in order to meet the quality of educational management which is in accordance with Thai Qualifications Framework for Higher Education and for the sake of benchmarking with national and international courses. The desirable characteristics of graduates are defined in six aspects: morality and ethics, knowledge and intellectual skills, interpersonal relations and responsibility, numerical and analytical skills and communication and information technology and professional practice skills (Na Songkhla, 2011).

Environmental Science is a course taught in the Environmental Education Program. The program is open to students in order to allow them to have knowledge about the environment. The teaching is integrated knowledge in science associated with environment, ecosystems, biodiversity, pollution and environmental ethics in order to be used in the prevention, remediation and management of natural resources and environment, and to apply knowledge in the occupation under professional ethics as well as to apply knowledge for preserving sustainable natural resources and the environment (Wongchantra, 2011). It also aims to encourage graduates to link their knowledge and skills to keep up with changes of environmental situations in the future. The instructional material of environmental science course is a printed material used for teaching or learning of students in environmental science course. The content covers the purposes of learning to achieve the learning outcomes that have been set as well as to create a positive attitude towards the environment and environmental ethics. The students of Environmental Education Program must have knowledge about environment. In addition, in order to have knowledge about environment, the following key elements: knowledge, skills, attitude and ethics towards environment are required (Ketsing, 2015). These are the key elements enhancing the consciousness and the spirituality of conservation to general people to achieve sustainable development and conservation under the environmental education process.

The teaching of environmental science course is managed to be in accordance with The National Education Plan and to meet the Qualifications Framework of Bachelor of Science (Environmental Education) in order to enhance the ability of students to be more effective and to encourage students to have academic knowledge, values, consciousness, seeking new knowledge and the ability to create solutions to environmental problems. The desirable characteristics of graduates Environmental Education Program in six aspects are also defined. Therefore, the researchers have recognized the importance of curriculum development in accordance with the National Education Plan to study and to compare knowledge about environmental science before and after studying environmental science course and to study and compare attitudes towards the environment before and after studying environmental science course as well as to study and compare environmental ethics before and after studying Environmental Science Course. The study of the standard assessment of learning outcomes in environmental science course was also done in order to be a guideline for the development and improvement of learning and teaching and the development of students in Environmental Education Program to meet to the Qualifications Framework of Bachelor of Science (Environmental Education).

2. Materials and Methods

2.1 Research design

This was quasi experimental research using one group pretest – posttest design, the process was as follows

Stage 1: Developing the instructional material of environmental science course and preparing for teaching: the researcher prepared the teaching materials, including the instructional material, the knowledge test, the attitude test, the environmental ethics test and teaching media.

Stage 2: Teaching environmental science course: pre- test was administered before teaching of 14 units of environmental science course generating insights and stimulating critical thinking about environmental preservation, attaining ethical, attitudes and ethics based on the learning objectives.

Stage 3: Evaluation: post-test, the knowledge test, the attitude test, the environmental ethics test and the standard evaluation of environmental science course were administered with the samples.

2.2 Population and sample

The sample of this study were 117 undergraduate students studying in Environmental Education program, Faculty of Environment and Resource Studies, Mahasarakham University, academic year 2016.

2.3 Research instruments

1. The instructional material of environmental science course: It was prepared and consisted of 14 units: unit 1: environment, unit 2: ecology system, unit 3: biodiversity, unit 4: natural resources, unit 5: cultural environment, unit 6: environmental pollution, unit 7: environmental ethics, unit 8: environmental management, unit 9: environmental science, unit 10: environmental technology, unit

11: environmental economics, unit 12: environmental health, unit 13: environmental engineering and unit 14: environmental education.

2. The environmental science knowledge test consisted of 4 choices and there were 50 items. The difficulty level was at the moderate level: the lowest was 0.366 while the highest was 0.766. The discrimination power was ranged from 0.363-0.684. The reliability was 0.70 and the IOC was 0.94.

3. The attitude test on environmental science was a 4 level scale. There were 20 items. The discrimination power was ranged from 0.355 - 0.777. The reliability was 0.723 and the IOC was 0.93.

4. The environmental ethics test was the test with 4 choices. The difficulty level was at the moderate level: the lowest was 0.433 while the highest was 0.433. The discrimination power was ranged from 0.367-0.733. The reliability was 0.752 and the IOC was 0.93.

5. The standard evaluation of environmental science course was a 3 level scale. It consisted of 20 items in 5 aspects: Morality and ethics, knowledge, intellectual skills, interpersonal relations and responsibility and analytical skills and communication and information technology. The discrimination power was ranged from 0.378 - 0.755. The reliability was 0.768 and the IOC was 0.92.

2.4 Statistics used in data analysis.

Statistics used in data analysis were mean, standard deviation, and paired t-test was employed to test the hypothesis.

2.5 Duration of conducting research

The duration of conducting research was one semester which was the first semester of academic year 2016.

3. Results and Discussion

The results of the study on environmental science course teaching to promote Thai Qualifications Framework for Higher Education can be discussed as follows.

1. The effectiveness of the development of the instructional material of environmental science course was 90.44 / 80.88, which met the 80/80 criteria set and the Effectiveness Index (E.I.) was 0.894. This meant that the knowledge of the students studying environmental science course using the instructional material of environmental science course was higher as of 89.40 percent (Table 1 and 2). This was because the instructional material of Environmental Science Course had a systematic process of creating and developing based on appropriate academic procedures by studying the course objectives in order to provide instructional activities in accordance with the curriculum. The instructional material of environmental science course was divided into chapters covering the content of environmental science according to the concept of

Sunthornprasert, 2001, who stated that the instructional material is a tool to use for one of the subjects of the courses in the institute. It must contain comprehensive content and topics in all aspects. This type of instructional material will result in more effective student learning. This is consistent with the study of Wongchantra, 2016, studying the teaching of ASEAN natural resources and environment by using the instructional material for undergraduate students. The results showed that the effectiveness of the instructional material of ASEAN natural resources and environment was 87.00/90.00, and the students learning progress increased by 66.70 percent. This was because the instructional material had undergone a systematic process of development that can develop students to behave in accordance with expectations. This findings were in accordance with the study conducted by Kulsuwan, 2017 studying the teaching and learning of economics with sustainable pollution management for undergraduate students at Mahasarakrm University. The study found that the effectiveness and the effectiveness index of the teaching and learning of economics with sustainable pollution management were based on the hypothesis as of 91.56/90.00. The students improved their learning progress as of 70.40 because the instructional material was effective and offered the instructions enabling self-learners to practice in the nature of self-study. The lecturer was a facilitator and closely gave advice.

Table 1. Effectiveness of the instructional material of environmental science course (E_1/E_2)

Effectiveness of the instructional material	**Total score**	$\bar{x}$	**S.D.**	**percentage**
Effectiveness of the process of the instructional material (E_1)	50	46.15	1.58	80.82
Effectiveness of the results (E_2)	50	45.02	1.47	80.02
Effectiveness of the instructional material:80.82/80.02				

Table 2. Effectiveness Index (E.I.) of the instructional material of environmental science course

Total score before attending class	**Total score after attending class**	**Number of students**	**Total score of knowledge**	**Effectiveness Index (E.I.) of the instructional material**
2440	5490	117	5850	0.894

2. The results of the comparison of the teaching of environmental science course revealed that the students had the average scores before learning in the moderate level. The average score was 20.85.Afterstudying environmental science course, it was 45.02, which was in a very good level. When comparing the average score of knowledge, it was in accordance with the research hypothesis. The knowledge about environmental science of the students after studying was higher than that of before studying statistically significant at the .05 level as shown in Table 3. This indicated that the teaching of environmental science course

was appropriate to the students and had a variety of teaching methods suitable for the content and the teaching and learning allowing the students to change in knowledge about environmental science. This was based on Bloom's concept, 1986 which stated that knowledge can be interpreted to understand the content when the person gets the story from learning to practicing through senses. The facts of the story, which will be the experience of the person that is accumulated and transferred to be knowledge, can be obtained. This was consistent with the study of Sukngam *et al.*, 2015, studying on the development of the ASEAN Natural Resources and Environmental Training Manual: Lao PDR. The study revealed that the students in the experimental group had higher score after training than that of before training since the researcher used a variety of training techniques which helped the students to develop knowledge. The findings were also accordance with the study conducted by Nachairit *et al.*, 2016 conducting a study on the development of integrated teaching and learning model by using case study to promote critical thinking, problem-solving and teamwork learning of the undergraduate students, Faculty of Education. The findings revealed that the students who learned with this model had critical thinking higher than before learning. Because of the composition of the integrated teaching and learning model by using case study to promote critical thinking, problem-solving and teamwork learning enriched the critical thinking skills of the undergraduate students, Faculty of Education.

Table 3. Comparison of mean scores before and after learning in environmental science course

Aspect	Before learning (n=117)			After learning (n=117)			t	df	p-value
	$\bar{X}$ (N=50)	SD	Level	$\bar{X}$ (N=50)	SD	Level			
Environmental knowledge (N = 50)	20.85	2.94	Moderate	45.02	1.47	Very good	-45.80	116	.000*

*P < .05

3. According to the comparison of attitude towards environment, the average score of students on the attitude towards environment was higher than that of before attending class. Before attending class, the overall attitude towards environment was in the level of uncertainty. The average score was 3.16. But, after learning in environmental science course, the average score of attitudes towards environment was4.66 which was at the level of strongly agree. When comparing the average score of attitude towards environment, it was consistent with the research hypothesis. The attitude towards environment of students after studying environmental science course was higher than that of before attending the class with statistical significance at .05 level (Table 4). This indicated that instructional material of environmental science course and teaching methods incorporating activities to promote good attitude

towards environmental science resulted in the increase of students' attitudes. This was in accordance with the concept of Wiratchawong, 1999 which stated that the learning that comes from teaching leads to the accumulation of experience through the direct experience of the individual and the stimulus that motivates people to have attitude towards impressive events several times. This will lead to an accumulation of experience which finally leads to attitude. This was consistent with the study of Wongchantra, 2009 studying the teaching of ASEAN natural resources and environment using the instructional material for undergraduate students. The results showed that the students had the average score of attitude after teaching higher than that of before teaching since the instructional material for teaching ASEAN natural resources and environment was interesting and allowed the students to easily understand the issues, so it enabled students to change their attitude towards ASEAN natural resources and environment. This was in accordance with the study of Yenjai, 2011 studying the development of environmental education curriculum for basic education institutions. The results revealed that the attitude towards environment of students learning by using the lesson of action in the environment conservation camp with a group of regular students was statistically significant difference at .01 level. Because of technology was introduced in the teaching to help in teaching and learning as well as teaching styles of environmental education helped increase attitude towards environment.

Table 4. Comparison of the average scores on attitude towards environment before and after learning in environmental science course

Aspect	**Before learning (n=117)**			**After learning (n=117)**			**t**	**df**	**p-value**
	$\overline{X}$	**SD**	**level**	$\overline{X}$	**SD**	**Level**			
Environmental Attitude (N=20)	3.16	0.41	uncertain	4.66	0.14	Strongly agree	-21.12	116	.000*

4. According to the comparison of environment ethics, before learning the average score of environment ethics of the students was 2.46 while after learning, the average score of environment ethics was 2.85 which was at the level of for society. This was consistent with the research hypothesis that after learning in environmental science course, students had environment ethics higher than that of before learning with statisticalsignificanceat.05 level (Table 5). This showed that the process of teaching environmental science by giving sample scenarios and focusing on raising awareness of environmental principles by using ethical reasoning can contribute to environmental ethics, as Chaikaew, 1998 stated that environmental ethics can be created by teaching and cultivating value of nature and environment. This corresponded to the study of Wongchantra, 2009 which found that the students in the experimental group had higher average score on environmental ethics than that of the control group. This pointed out that the ethical teaching process developed as a process of teaching environmental ethics can establish environmental ethics. It was also consistent with the study of Suanchupon, 2014 studying the learning outcomes of Human Living and

Ethical Development Course of the students in Hospitality Service in Airline Industry Program, Valaya Alongkorn Rajabhat University under the Royal Patronage. The research found that the students studying in Bachelor of Arts in Services in Hospitality Service in Airline Industry Program had environmental ethics score after attending class than that of before attending class. This might be because learning from the instructional material focused on raising awareness of environmental principles for human beings that adhere to goodness, morality and compassion for the environment. The students were allowed to search for information, see examples, discuss and there was systematic evaluation. As a result, the students had higher development in environmental ethics.

Table 5. Comparison of the average scores on environment ethics before and after learning in environmental science course

Aspect	**Before learning**			**After learning**			**t**	**df**	**p-value**
	$\bar{x}$	**SD**	**Level of ethics**	$\bar{x}$	**SD**	**Level of ethics**			
Environmental Ethics	2.46	0.43	For relatives and friends	2.85	0.36	For society	-3.927	116	.000*

5. According to the evaluation of standardized learning outcomes according to Thai Qualifications Framework for Higher Education after learning environmental science course of undergraduate students, the average score was 2.89, which was at a high level (Table 4). The nature of environmental science course is the interdisciplinary with mixed learning to create environmental knowledge, ethics, intellectual skills and good relationships with individuals and the environment. There was the analysis leading the transmission process through the use of technology for communication. As a result, the learning outcomes of the students were evaluated according to Thai Qualifications Framework for Higher Education in environmental science course in a very high level. This was in line with the study of Chapha, 2013 stating that implementing the operations according to Thai Qualifications Framework for Higher Education can produce graduates to achieve quality standards for learning outcomes. It can also communicate to society and community confidently about the learning outcomes that graduates have developed. It was also consistent with the study of Chapha, 2013 studying the learning outcomes based on Thai Qualifications Framework for Higher Education in Community Health Nursing Practicum Course according to the perception of the Air Force Nursing students, academic year 2012. The results revealed that the overall learning outcomes based on Thai Qualifications Framework for Higher Education in Community Health Nursing Practicum Course was in a very good level. The mean was 3.26. This was because Community Health Nursing Practicum Course was a community health assessment by learning from the community. The students had to write the project plan and create health innovation with appropriate technology. This was the process of enhancing

the characteristics of nursing students. As a result, the Air Force Nursing students, academic year 2012 had a very high level of academic achievement based on Thai Qualifications Framework for Higher Education.

Table 6. Evaluation results of standardized learning outcomes according to Thai Qualifications Framework for Higher Education in each aspect

Standardized learning outcomes of Environmental Science Course	**After learning**		
	$\bar{x}$	**S.D.**	**Level**
1. Morality and ethics	2.95	0.76	High
2. Knowledge	2.80	0.36	High
3. Intellectual skills	2.80	0.49	High
4. Interpersonal relations and responsibility	2.97	0.09	High
5. Analytical skills and communication and information technology	2.84	0.39	High
Total	**2.87**	**0.41**	**High**

4. Conclusion

The results of Teaching Environmental Science to promote standards of learning in accordance with Thai Qualifications Framework for Higher Education can be summarized as follows.

1. The effectiveness of the development of the instructional material of environmental science course was 90.44 / 80.88, which met the 80/80 criteria set and the Effectiveness Index (E.I.) was 0.894. This indicated that the knowledge of the students studying environmental science course using the instructional material of environmental science course was higher as of 89.40 percent.

2. The students had the average scores before learning was in the moderate level. The average score was 20.85. Also, after studying environmental science couse, it was 45.02, which was in a very good level. When comparing the average score of knowledge, it was found the knowledge about environmental science of the students after studying was higher than that of before studying environmental science couse.

3. The overall of attitude towards environment of the samples was in the level of uncertainty, which the average score was 3.16. But, after learning in environmental science course, the average score of attitude towards environment was 4.66, which was at the level of strongly agree. When comparing the average score of attitudes towards environment, it was found that the attitudes towards environment of students after studying environmental science course was higher than that of before attending the class.

4. Before learning, the average score of environment ethics of the samples was 2.46, which was in the level for relatives and friends. But, after learning, the average score of environment ethics was 2.85, which was at the level of for society. This indicated that after learning in environmental science course, the students had environment ethics higher than that of before learning.

5. According to the evaluation of standardized learning outcomes according to Thai Qualifications Framework for Higher Education after learning environmental science course of undergraduate students, the average score was 2.89, which was in a high level. When considering in each aspect, morality and ethics was in a high level with the mean of 2.95. Knowledge was also at a high level with the mean of 2.80. For intellectual skills, it was at a high level with the mean of 2.80. For the aspect of Interpersonal relations and responsibility, it was also at a high level with the mean of 2.97.Finally, according to the aspect of analytical skills and communication and information technology, it was at a high level with the mean of 2.84.

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Legal Compliance of Health Spa Business in Ubon – Ratchathani Province

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Abstract

The purpose of this research was to study the level of legal compliance and knowledge of health spa business, the suggestions of entrepreneurs and service providers of the health spa in Ubon Ratchathani province. Data were collected by interviewing and analyzing with descriptive statistic, distribution frequency and percentage. Content validity test was applied, consistency index of part 1, entrepreneurs questionnaire was 0.96 and part 2 service providers questionnaire, was 0.98. The results showed that all entrepreneurs able to follow up the health spa law with high level and knowledge about business in health spa are in high level. For the service providers of the health spa able to follow up the health spa law with high level (51.60%). All of the service providers have knowledge about service and safety in health spa with high level. The health spa standard in Ubonratchathani province are suggested that entrepreneurs should participant in period of related regulation setting for the benefit in both entrepreneurs and health spa standard supervision officers. The regulations should not conflict with services and customer. The registration process of health spa should be clarify.

***Keyword*: legal compliance; health spa business**

1. Introduction

Currently, spa business and Thai massage can continue to increase the revenue and create a career in this service business. In 2011 the number of establishments that are registered and certified by the Ministry of Public Health, were 1,436 places; Including 453 health spa (31.62%) 952 Massage (64.42%) and 57 salon massage (3.97%) (Department of Trade Negotiations Ministry of Commerce, 2009).

Generally, when the spa business is open, the service must be registered for the certification of health spa establishments or health massage establishments from the Ministry of Public Health according to Public Entertainment Act B.E.2509 and the aim of the Act announcement is to protect and separate the health spa out from the general spa. The service provider must be trained and certified by the Ministry of Public Health. The Provincial Health Office will issue a certificate once a year and once it has been verified, it can be found that the service provider has the standard set by the Ministry of Public Health. However, if the audit found that the establishment does not meet the standards set. The Ministry of Public Health will not undertake further business operations. Until the notice has been updated. And the examination of the officer will be checked in the case of registration with the Division of medical practice or complaint to the Ministry of Public Health.

Ubon Ratchathani Economic growth is relatively high. The business is characterized by a massage and spa increasing. But not certified to the health spa business. The reason may be from the legal is under the Ministry of Public Health and the certified is a voluntary accreditation, Not mandatory, so the service provider does not realize the importance. In addition, local authorities and public health officials play an important role in promoting the service provider of healthy workplaces as the announcement of the Ministry of Public Health that will get the standard certification. This is a guarantee of quality and ensure the consumer to use the service by the standards of the service provider in all 5 parts. Including place standard, service provider standard, service operator standard, service standard and safety standard. It must be the service provider that provides spa massage services without the debauchery of both cigarettes. And there will be no other hidden services. Especially prostitution. The service operator must be trained by a certified institution or institution (Ubon Ratchathani Provincial Health Office, 2014).

Ubon Ratchathani Provincial Public Health Office has a policy focus on improving the quality and standards of law and international standards. In order to deliver better services. In year 2014, there were 3 health spa and 5 health massage that applied to be audited and all of them has been certified (Public Health and Consumer Protection Group Ubon Ratchathani Provincial Health Office, 2011).

As reviewing data, researchers was interested in studying legal compliance and knowledge of entrepreneurs and service operator. Due to the health spa is related to health care and can prevent the onset of many diseases without medication. It also provides consumers with a choice of standard spa services. It also gives consumers confidence in the quality of the spa's services. And the economic sector of the health service business of the country better. Researchers expect the health spa to be a new alternative to public health, to be safe and have good standards when accessing the service. It also requires the responsible agency to know the results of this study and it should be a guideline to solve problems related to the legal practice of the spa business in Ubon Ratchathani.

Objectives

1) To study the level of legal compliance in health spa business of entrepreneurs and service providers of health spa in Ubon Ratchathani province.

2) To study the knowledge of health spa business and suggestions of entrepreneurs and service providers of the health spa in Ubon Ratchathani province.

2. Methodology

2.1 The study design

The study is Cross – sectional descriptive.

2.2 The study population

There were 2 population groups;

1) The entrepreneurs of health spa business. All 3 places that applied with the Public Health and Consumer Protection Group, Ubon Ratchathani Provincial Health Office in 2014 (Ubon Ratchathani Provincial Health Office, 2014)

2) The health spa service providers 31 persons from 3 places that applied with the Public Health and Consumer Protection Group, Ubon Ratchathani Provincial Health Office in 2014.

2.3 The study instruments

The instrument was the interview questionnaire which divided into 2 series;

1) For the entrepreneurs of health spa business divided into 3 section;

Section 1: General information of the health spa entrepreneurs, including gender, age, education experience trained and obtaining certification, with 9 questions.

Section 2: The legal compliance involving health spa businesses, with 27 questions.

Section 3: The knowledge about the health spa business with 48 questions.

2) For the health spa service provider from 3 places, divided into 3 section;

Section 1: General information of the health spa service provider, including gender, age, education, experience trained, with 7 questions.

Section 2: The legal compliance involving health spa business, with 21 questions.

Section 3: The knowledge about service and safety in the workplace, with 24 questions.

2.4 Study instruments quality check

Content validity by 5 experts that found Item Objective Congruence (IOC) in the first questionnaire, that used for interview the health spa entrepreneurs, was 0.96 and the second questionnaire that used for interview the health spa service providers, was 0.98.

2.5 Data analysis

The completed interview will be analyzed by Descriptive statistics as follows:

- General information with quantitative variable such as age, number of employees in the store, duration of service time, duration of working time, frequency of spa audit., were analyzed by Median Maximum and Minimum and Qualitative variables such as sex education experience, training and obtaining certification, were analyzed by frequency and percentage

- The legal compliance involving health spa business, were analyzed by frequency percentage Mean and standard deviation ,define the legal compliance involving health spa business into 3 levels ; high moderate and low.

- The knowledge about the health spa business and knowledge of service and safety in the workplace, were analyzed by frequency percentage Mean standard deviation. Criteria of knowledge about the health spa business and knowledge of service and safety in the workplace, health spa. According to Benjamin Bloom define 3 level: high moderate and low.

3. Results

Using a questionnaire to collect data from 2 groups;

Group 1 the health spa entrepreneurs

All 3 persons were divided into 4 parts;

Part 1: All are women, aged 29, 31 and 58 years, all are bachelor degree. The spa owner for 2 stores (66.67%) and one stores (33.33 %) is spa operation representative, the service staff in health spa for 2, 12 and 17 persons and has general staff for 0, 3. and 12 persons. Duration of operating as of October 2014 were 4, 5 and 10 years. All of the operators have no experience of working in the Spa business which has been trained from government agencies 66.67% and all places have been certified by the loal authorities.

Part 2: The compliance of health spa found all of health spa entrepreneurs complied with the legal in high level. For incorrect regular practice with found most of all practice was the staff is under 18 year old (33.33 %) and incorrect practice for sometime is to allow the consumer select the service operator by themselves and the health spa do not conduct health screening such as chronic diseases, high blood pressure and pregnant (66.67%).

Part 3: Information about the health spa business operation found all of the entrepreneurs has knowledge about business operation in high level. For most incorrect knowledge was the health spa entrepreneurs able to allow the consumer select the service operator by themselves, age of spa’s staff able to be under 18 year old and the health spa able to provide the 5 other service for 33.33%

Part 4: information on the problems and suggestions. \

Barriers to comply with the announcement of Ministry of Public Health including,

1. All of the entrepreneur consider that there are too many regulations. The common practice which always perform such as providing welfare for staffs, ensure

the health spa is available before opening daily.

2. All of the entrepreneur consider that the local authority did not inform the new or change of the requirement.

3. One of the entrepreneur consider that the standard is not international standard that impact to the foreigners to invest

Suggestion to following the announcement of the Ministry of Public Health.

1. All of the entrepreneur suggested that should clear on the regulation of health spa register.

2. All of the entrepreneur suggested that they should be involved in the requirement setting for benefit of both parties.

3. 2 persons proposed to improve the standard to be international standard for attract the investors.

4. One person suggest that the regulation should flexible for the requirement of consumer.

Group 2: the health spa service providers

All 31 people were divided into 4 part;

Part 1: Overview of providers in the health spa found that all of spa provider/ operator are female. Age average is 41.06 year old and graduated in high school level of 35.50%, followed by the primary school 25.80%, most of them has experience in another service 71.00%. Working experience for spa about 3 years. They never had the spa service experience 90.30% and they have been trained on spa business from government agency 90.30%

Part 2: The compliance of health spa found all of health spa providers/operators complied with the legal in high level. For incorrect regular practice with found most of all practice was the health spa do not conduct health screening such as chronic diseases, high blood pressure and pregnant (22.60%), then wearing jewelry such as necklaces, earrings, rings, while providing services to clients of 9.70%. For incorrect practice with the health spa provider/operator perform mostly was suggest friend or relative who are under 18 year old to working in the health spa (29.00%)

Part 3: Information about the service and safety in the workplace found that all of service provider/ operator had a service and safety knowledge in high level. For incorrect knowledge were the health spa able to provide the 5 other service and service provider/operator able to service the customer without wearing mask for 6.50%. Then the health spa staff allow person who are under 18 year old to working.

Part 4: Information on the problems and suggestions.

Barriers to comply with the announcement of Ministry of Public Health including.

1) 7 service providers/ operators consider that some customers had to much

issues/ requirement that lead them to perform with the regulation difficulty.

2) 6 service providers/ operators consider that some day they finish working too late because of the customer coming late at night then the service time is not enough.

3) 4 service providers/ operators consider that most entrepreneurs tend to choose employees who look rather than capable and service skills.

Suggestions to follow the announcement of Ministry of Public Health including.

1) 8 service providers/ operators suggested that the government should provide training and always testing the health spa service providers/operators to comply with a standard.

2) 7 service providers/ operators suggested that there should be no restrictions that violate the service and customer demand such as the selection of their own service providers/ operators. Because customers tend to place at self-assertion. This makes it vulnerable to competition with other spa.

3) 3 service providers/ operators suggested that should have field service. To promote the health service and make the impression and comfort to the people.

4) 3 service providers/ operators suggested that the health spa should be a place where massage parlors are legitimate. And not a place of immorality. Fair service, be friendly too and the same standard service.

3. Discussion and Conclusion

As resulted found that the entrepreneurs had the legal compliance and knowledge in spa business in high level. Because of the entrepreneurs need to build credibility and added value to the service of their establishment. This is an incentive to follow the notification of the Ministry of Public Health. This is only a voluntary sector. And when the health spa certified, they will create rules and regulations for their spa as a guideline for service providers and services to comply with the announcement of Ministry of Public health.

In the case where the business operator does not comply with the law of the health spa business, staff under the age of 18 are allowed to work, allowing the customer to choose their own service providers/operators. And health spa service providers/operators do not screen patients with underlying medical conditions such as high blood pressure or pregnant, etc. before serving. Because the operators understand that service recipients can choose the service they are satisfied. Both will impress and then return to the new service. This is a highlight of the spa itself. Hiring a person under the age of 18 to work in a health spa. Because entrepreneurs understand that they can get people under the age of 18 to work in other areas not related to health spa services. This is a channel for the smuggling of people under the age of 18 to work in the area related to health spa. The non-screening of customers is because those who come to the service are familiar with the operator, the customer does not consent to the information or the spa had the history of the information so the information did not re-screened. Therefore, there should be clear regulations for registration as a health spa establishment. And the entrepreneurs should be involved in the requirement setting for benefit of both parties.

All of the entrepreneurs has knowledge about business operation in high level. It may because of the entrepreneurs need to study licensing procedures and service performing, so they need to know the relevant requirements. Because the investment turned into a health spa establishment that will require a lot of money. The entrepreneur does not want to risk problems that will occur, such as abuse, certificate revocation, suspension of temporary establishment. It will cause revenue and reliability in service. For most incorrect knowledge was the health spa entrepreneurs able to allow the customers select the service operator by themselves, age of spa's staff able to be under 18 year old and the health spa able to provide the 5 other services. Because they understand that customer can choose the service provider/operator they are satisfied. Because it will impress and then will be back. This is a highlight of the spa itself. Hiring a person under the age of 18 to work in a health spa. Because entrepreneurs understand that they can get people under the age of 18 to work in other areas not related to health spa services. This is a channel for the smuggling of people under the age of 18 to work in the area related to health spa. Because of unclear regulations and the definition of health spa. Therefore, the entrepreneurs ignore this requirement. For the other service, they are allowed to provide at least 3 other service in the health spa. So the government should announce the clearly registeration of health spa rule same as the study of Jiratjinda ,2007 who studied the legal compliance of spa business in Bangkok that found the entrepreneurs had a legal compliance with high level and had spa business knowledge in high level. As studied of Marinwimol, 2005 who studied the Law enforcement found that the law would help protect the rights of consumers. And it will be useful to develop standards and quality. To provide services of spa facilities in the country to be able to compete with foreign countries when services are liberalized.

The health spa providers/operators complied with the legal in high level and had a service and safety knowledge in high level also. Due to the service providers/operator in the health spa have been trained or transferred the curriculum from agencies certified by the Ministry of Public Health. It show that service providers/operator are knowledgeable about service and safety, resulting in certification and the qualification that providers in health spa which need to be available to everyone. For incorrect practice was the health spa do not conduct health screening such as chronic diseases, high blood pressure and pregnant, wearing jewelry such as necklaces, earrings, rings, while providing services to customers .and the health spa provider/operator suggest friend or relative who are under 18 year old to working in the health spa. The non-screening of customers is because those who come to the service are familiar with the operator, the customer does not consent to the information or the spa had the history of the information so the information did not re-screened. For hiring the person who are under 18 year old, it may be from the understanding that that they can get people under the age of 18 to work in other areas not related to health spa services.

All of service providers/ operators had a service and safety knowledge in high level. For incorrect knowledge were the health spa able to provide the 5 other services and service provider/operator able to service the customer without wearing mask. Because of they understand that customer can choose the service provider/operator they are satisfied. Because it will impress and then will be back. This is a highlight of the spa itself. And the unclear of the regulation and definition. And they also confuse on the health spa able to provide at least 3 others services. Therefore, there should be regulations contrary to the service. And the needs of customers, such as the choice of service providers they like to serve. Because customers tend to choose the place that self-indulge. This is a weakness in competing with other place. Same as the study of Jiratjinda, 2007 who studied the legal compliance of spa business in Bangkok that found the service providers/operators had a legal compliance with high level and had spa service and safety knowledge in high level.

4. Suggestions for further apply

- The local authority and staff responsible for a standardization of health spa should have a public relations or provide clear information to the entrepreneur and service providers/ operators and also provide the knowledge, understanding, and the propers implementation and useful services.

- The local authority and staff responsible for a standardization of health spa should review the suggestion for improvement including the entrepreneurs should be involved in the requirement setting, there should be no restrictions on services and customer requirements, clear on the regulation of health spa register, the government should provide training and always testing the health spa service providers/operators to comply with a standard.

5. Suggestion for further study

- It should be further studied what factors contribute to the entrepreneurs of a health spa in Ubon Ratchathani follow the laws.

- There should be further study in other tourist destinations with many health spa places. Because there are foreigners who come to visit. This makes it possible to provide useful feedback on how to improve the spa standard or legal control that is close to the international standard.

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The Model of Solid Waste Management in Mahasarakham province

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Abstract

This research were to study solid waste management in Mahasarakham Province and to study the solid waste management model in Mahasarakham province. The research area was made up of 13 districts in Mahasarakham province. The amount of solid waste in Mahasarakham province was found at 379,9 tons per day. There were 28 waste disposal sites in Mahasarakham. Over the past five years, 693,542.5 tons of solid waste has been accumulated. The used budget for garbage collection totals 34,262,280 Baht per year. There were 39 solid waste management personnel and there are 111 garbage collection trucks. The frequency of solid waste collection was about 115 times per day collected from Monday through Friday. The solid waste management of Mahasarakham was divided into centers: cluster 1: a district waste energy plant (mueng districts), cluster 2 (Chiang Yuen districts), cluster 3(Borabuesubdistrict districts), cluster 4 (Phayakkhaphum districts) and cluster 5 (WapiPathum districts) were a landfill site for waste disposal to be transported to the waste electrical power plant.

***Keywords*:** solid waste management in Mahasarakham province

1. Introduction

Solid waste has been a major problem in Thailand for many decades and with the way of life of the present generation it is likely to be intensified, due to the increase in the volume of solid waste each year as a result of the increase in the population, economic expansion and changes in the consumer behavior of Thai people. Meanwhile, the volume of waste received is not properly managed by the local government authorities concern. The present infrastructure in place is not enough to manage the amount of solid waste collected, which is on an annual increase. In 2012 the amount of municipal solid waste was approximately 24.73 million tons. The amount to be properly disposed of theoretically was approximately 5.83, but that which was successfully recycled and utilized was approximately 5.28 million tons of solid waste. Reports hold that the remaining 13.62 million tons are not properly disposed and large amounts are being burnt in the open air (Pollution Control Department, 2013).

According to Thai law, all local governments are responsible for the waste disposal management in their respective local government areas. Unless the local government agency is not able to effectively manage its solid waste, then it can be given to private solid waste management firms under the supervision of the local government municipality concern. This measure as defined in the laws of local governments, such as municipalities, Bangkok, Pattaya Provincial Administration, and Tambon Administration Organization Given the private sector in the implementation of legislation to promote and maintain the quality of the environment.

In solid waste management, it is necessary to make a good deal since the waste transported to landfills is left to degrade, processed waste into energy used other procedures which will result in a variety of waste types at the end. Local governments have limitations to properly manage their solid waste due to lack of coordination with relevant authorities, shortage of manpower, lack of adequate budget, which includes the provision of space for garbage trucks to properly dispose of the solid waste. Waste management is an important issue that the government always raises in its national agenda, together with the Prime Minister with the solid waste management system of the country published in 2014, Volume 131, Special 189, dated September 25, 2014 and other books, including solid waste and hazardous waste management plan, which was approved by the National Peacekeeping on 26 August 2014, with the due process operations. Solid waste residues are a major crisis in many local government areas. Solid and hazardous waste should be properly disposed of by focusing on reducing and sorting waste from its source. A solid waste management center needs to be created by the removal of solid waste by hybrid technology focuses on processing power optimization measures regulating the management of solid waste and hazardous waste. With an emphasis on discipline in the national drive towards sustainable management. To educate the public and the strict enforcement of the law (Gen. Audacious site).

Mahasarakham has a total of 13 districts and 141 sub-districts, but the garbage problem overflowed the city as a result of an expanding economy and a fast-paced society. The impact on the environment is seen in the water, air and soil pollution, which is a danger to public health in Mahasarakham and the provincial authorities are in no way close in solving the solid waste management problems. There's a lack of understanding of proper solid waste management because most of the current solid waste collected from the community is gathered to heap on the ground to let it decompose naturally. In some cases, it may be burned in the open air, which raises environmental health concerns.

In this study, the researchers aimed to investigate the situation of solid waste management in Mahasarakham province and to provide suggested solutions to solve the solid waste problems in Mahasarakham province.

2. Research Methodology

This research was a survey to determine the amount and form of waste disposal of the local government in Mahasarakham.

2.1 Areas of research

In the space of 13 districts were Muang Mahasarakham District, Kae Dam District, KosumPhisaidistrict, Kantharawichai district, Chiang Yuen District, Borabue district, Na Chueak district, Phayakkhaphum Phisai District, Wapi Pathum district, Nadun District, Yang Sisurat District, Kut Rang District and Chuan Chom district. The area was divided into 141 local government organizations. The district was divided into a number of municipalities and was divided into nine administrative areas and 132 Sub-District Administrative Organization.

2.2 Population and sample

1) Population used in the study were local administrative organizations in Mahasarakham province.

2) The samples used in this study were 141 local administration organizations, consisting of 9 municipalities, 132 sub-district administrative organizations.

2.3 Research Methodology

1) Study the history and problems of waste management in Mahasarakham. And the general context of the local administration and the province of Mahasarakham; 13 districts, 141 sub-districts.

2) Situation, problems and the impact of solid waste generated in the province of Mahasarakham. Studies and research papers related to the theory and concepts to create a series of interviews of local government waste management of Mahasarakham.

3) Research design, data collection, which will be divided into two phases.

Phase 1: The preliminary study was the study of relevant research papers. To provide information and preparation of documents for the construction of tools, including interviews for solid waste management and problems in solid waste management in Mahasarakam community by created interview being determined 5 experts on the appropriateness and accuracy of the interview.

Phase 2: The data were collected from a real-time survey by interviewing using the waste management, interviewing form of local government organization of the Mahasarakham province to analyze the data. The data was analyzed by means of statistics to find the mean percentage.

4) Study and design of solid waste management model in Mahasarakham province.

Study preliminary information on the establishment of waste disposal plants and the establishment of transfer stations and study related research papers. To provide information on proper formulation of solid waste management and to study problems of solid waste management in Mahasarakam community. Five experts were selected for the appropriateness of the waste disposal area by using the zone classification scheme for waste management in Mahasarakham Province.

3. Results and Discussion

The study was conducted to collect data on the waste management of 13 districts in Mahasarakham province using interview forms as a tool to collect data. The results were as follows:

3.1 Situation of solid waste management in Mahasarakham province

3.1.1 Solid waste management of Mahasarakham province total 13 districts. Based on local interviews, the government found 141 units in Mahasarakham. The amount of solid waste collected in 65 units was about 379.9 tons per day. In one year the volume was 138,663.5 tons per day and the amount of solid waste accumulated in the last five years is 693,542.5 tons. In Mahasarakham, there were 28 dump ponds and the total amount of budget for garbage collection was 6,515,790 Baht per month, and 34,262,280 Baht per year (Table 1 and 2). There were 76 unoccupied units because the local government had no waste disposal facility. There was no budget to buy trash cans and garbage trucks to provide services in solid waste collection in the community so most people need a way to get rid of it manually. The local administration had no place for solid waste and there was no garbage collector and garbage bins in the community so there was no way to get rid of it, thus causing pollution in the community, such as burning or disposing of in the forest which corresponds to the study of (Wongchandra, 2014). Solid Waste Management of Local Government in Muang District, Lop Buri Province. The total area of 24 sub-districts of Lop Buri Province, It was found that there were 24 sub-district areas of Muang District, Lop Buri Province, including 22 Local government units. Most local governments had 14 units of solid waste management services. Each household owns 8 units of waste, there were 247 solid waste management personnels. There were 52 garbage trucks. The amount of solid waste was about 327 tons per day. For a place, the solid waste in Muang District, Lop Buri, had 5 units and the total amount of budget for garbage collection was 1,596,893 Baht per month, 20,960,320 Baht per year.

3.1.2 Solid waste management of local administrative organization in Mahasarakham province had 359 solid waste management personnel and 111 garbage trucks. The frequency of solid waste collection service is about 115 times per day. Most days and times stored garbage collected on Monday - Friday. Solid waste collection services started at 08.00 onwards. The solid waste services are not providing enough services due to the lack of storage facilities, thus the collection frequency was only 115 journeys per day, and the weekday period was only 5 days (Table 1). There were also some trash leftovers in some areas where the garbage was not collected thus producing a bad smell.

Table 1 Solid Waste Management of Mahasarakham Province was classified as a garbage collection agency, a number of storage vehicles, the frequency of storage, the amount of solid waste and the budget for garbage collection

District	Number (Municipality/ sub-district)	Department to store (Municipality / sub-district)	Number of garbage trucks (cars)	Frequency of garbage collection (excursion)	Waste Management Budget	
					Baht/ month	Baht / year
Amphoe Muang	14	10	32	20	309,200	3,710,400
Kae Dam	6	2	3	2	40,000	480,000
KosumPhisai	18	12	20	10	427,700	5,132,400
Kantharawichai	11	6	13	10	406,733	4,880,796
Chiang Yuen	9	9	12	19	428,066	5,136,792
Borabue	16	14	8	16	333,021	3,996,252
Na cheurk	11	2	3	3	161,390	1,936,680
PhayakkhaphumPhisai	15	4	4	3	141,080	1,692,960
Wapipatum	15	5	7	12	305,000	3,660,000
Na dun	9	2	3	7	121,000	1,452,000
Yangsisurat	7	5	2	7	42,000	504,000
Kud rang	5	4	1	2	50,000	600,000
HingChuenchom	4	3	3	4	90,000	1,080,000
Total	**141**	**65**	**111**	**115**	**6,515,790**	**34,262,280**

Table 1.2 Local Waste Management Government of Mahasarakham Province classified as solid waste and solid waste disposal.

District	Amount of waste (tons/day)	Amount of waste (tons/year)	Quantity of waste (tons / 5 years)	Number of garbage dumps
Maung MahaSarakham	49.3	17,994.5	89,972.5	4
Kae Dam	2.5	912.5	4,562.5	1
KosumPhisai	59.8	21,827	109,360	7
Kantharawichai	47.5	17,337.5	86,687.5	3
Chiang Yuen	50.2	18,323	91,615	1
Borabue	71.5	26,097.5	130,487.5	5
Na chuek	21	7,665	38,325	4
Phayakkhaphum- Phisai	11.3	4,124.5	20,622.5	2
Wapipatum	27	9,855	49,275	1
Na dun	13	4,745	23,725	2
Yangsisurat	5.5	2,007.5	10,037.5	1
Kud rang	10.5	3,832.5	19,162.5	3
Chuenchom	10.8	3,942	19,710	0
Total	**379.9**	**138,663.5**	**693,542.5**	**28**

The amount of solid waste each day in Mahasarakham was on the rise. The ponds used to dispose of waste were not hygienic and not sufficiently efficient. And there were also parts that have to be disposed of by the wrong way, such as burning. Lack of knowledge and awareness of Waste management contributes to air pollution. Which corresponds to the study of (Sawatichitang *et al.*, 2014) study on the development of solid waste management model of community in Udon Thani Municipality. This research aimed to: 1) Survey to confirm the solid waste management indicator. 2) Create the format using the information from Step 1. Examine the suitability and feasibility of the model by a qualified person. The study indicated that the indicator for community solid waste management consists of four components, 15 variables as follows: Element 1 is knowledge. Element 2 was 3Rs. Element 3 was participation. (Par) Element 4 was community context. 2) Community solid waste management model and community context are: 1) Current Situation, Problems and Needs of the Community (2) Legislation / Laws on Solid Waste Management Policy of the Government, Pollution Control Department Environmental Agency Region 9, Municipalities and Communities (3) Experimental results of the community solid waste management model through evaluation from the office.

3.1.3 Policy, obstacle, and problem-solving in waste management. Solid waste of local government, found that most local government administration had a policy of purchasing, waste bins, garbage truck and solid waste collection service for people in the community. Community solid waste collection policy and the waste collection were completed within a day and the policy of a campaign to raise awareness in the management of household solid waste problems and obstacles in the solid waste management of local administration organizations. The problem was most people in the community lack cooperation in waste management and the lack of consciousness in disposing of solid waste where there was no place for waste disposal. Damaged garbage trucks make it difficult to collect garbage. This was in line with the study by (Silpasuwan, 2014). The study of municipal solid waste: The Significant problem of Thailand. The problem of municipal solid waste was a major problem for the Thai society as long as the amount of waste produced was increasing. To address the problem of implementation in 2012-2016, the steps to address policy implementation issues must be recognized and addressed by the government. As well as creating support tools for troubleshooting. There were additional suggestions: 1. The government must push the problem of solid waste management into a national agenda and set it in the urgent government policy. The enactment of the Law on the promotion, Reduction, Separation and Recycling of Rubbish Cover details of design, production, consumption, recycling as well as the removal of non-reusable scrap that is technically correct and does not cause any adverse effect on the environment. Speeding up the drafting of the Economic Instruments Act for Environmental Management under the Ministry of Finance's Legal Development Plan. To provide the opportunity for the relevant government agencies to use the power of this Act to issue ordinances and ministerial regulations in detailing the use of economic instruments for environmental management. Establish a policy-making organization. Make an action plan and oversight to make the management of the Local. Government or Private Corporation is aligned in the same direction. Support research, develop technologies that are efficient, clean energy, and develop alternative energy that best suits the utilization and management of waste throughout the system.

3.1.4 Solving problems of solid waste management of most local administrative organizations by publicity encourage people to know how to sort waste before disposal and reuse of garbage to give people a good sense of the waste and make them be aware of the benefits and the consequences. There was an educated approach to waste management to reduce air pollution. Since solid waste was disposed of by the incineration method and to reduce the amount of solid waste left over after storage, which may be smelly. Which corresponds to the study of Chaijit and Viwattanadej, 2012, community waste management model KohSamui District, Surat Thani Province was studied. It is a study of solutions to overflowing urban waste problem in the municipality of Koh Samui, Surat Thani Province by targeting to eliminate all current waste and support future growth with the right cost and return. The ultimate benefit to the community as a whole as shown by the present time results (April 2012). Koh Samui district waste problem is very serious. There were more than 15,000 tons of garbage being dumped at the moment, while 168 tons of garbage are increasing daily. Today, the disposal of landfills cannot be completely cleared with poor hygienic conditions that can affect the health of the population. Therefore, it has introduced a comprehensive waste management approach to community waste collection from sources. Wet waste is disposed of the landfill to produce biogas. The recyclable dry waste is not sent to the solid waste junk fuel.

3.2 Appropriate Waste Management Model of Mahasarakham Province

It was found that the waste disposal model of Mahasarakham was able to eliminate the solid waste effectively in the province by setting up the waste disposal area. It can be designated as a loading and unloading station for solid waste disposal in the area, and it was responsible for transporting the waste that were transported to a daily solid waste disposal plant. The solid waste transfer station is a station for small solid waste trucks. Solid waste is poured into large trucks containing large quantities of solid waste. Small, solid waste trucks do not have to dispose of solid waste to the disposal site if the disposal site is far from the haulage facility. Private or large storage units should have a data store in the warehouse that can store data.

Zone 1 (center cluster) It will the area where the power plant from solid waste is located at Moo 8, Nong Pling, Mueang Mahasarakham district, Mahasarakham province. It will control all 3 districts which include Mueang Mahasarakham district, Kantharawichai district and Kae Dam district. From the interview, zone 1 was a waste disposal area. There is 58.05 tons of waste per day. It is the landfill area where most garbage in the city and is located in the appropriate urban district as the center of each cluster, which is the central point in the transport of solid waste.

Zone 2 (cluster 2) It will the transfer station located at Chiang Yuen District, Mahasarakham province. Zone 2 will control 3 districts, consists of Chiang Yuen district, Chuan Chom district, and Khosoompisai district. The area is suitable for the establishment of transfer station for the solid waste of all three districts, Phon Ngamsubdistrict. The former area is a waste disposal area. There is 6 tons of waste per day. It has a distance of 64.2 kilometers from Chiang Yuen district to the factory.

Zone 3 (cluster 3) It will the transfer station located at Borabue district, Mahasarakham province. Zone 3 will control 3 districts, consists of Borabue district, Na Chueak district and Kud Rang district. The area is suitable for the establishment of transfer station for the solid waste of all three districts. The conveyor station will be located in Borabuesubdistrict, Borabue district, Mahasarakham province. The former area is a waste disposal area. There is 62 tons of waste per day. It has a distance of 25.4 kilometers to the factory.

Zone 4 (cluster 4) It will the transfer station located at Wapi Pathum district, Mahasarakham province. Zone 4 will control 2 districts, including Wapi Pathum and Na Dun districts. The transfer station will be located at Nong Saengsubdistrict, Wapi

Pathum district, Mahasarakham province. The former area is a waste disposal area. There is 23 tons of waste per day and distance of 22.2 kilometers of garbage transportation to the plant.

Zone 5 (cluster 5) It will the transfer station located at Phayakkhaphum Phisai district, Mahasarakham province. Zone 5 will control 2 districts, including Phayakkhaphum Phisai district and Yang Sisurat district. The transfer station will be located at Palan sub-district, Phayakkhaphum Phisai district Mahasarakham province. The former area is a waste disposal area. There is 6 tons of waste per day and the garbage transportation distance to the factory is 67 kilometers.

The study of a waste management model of Mahasarakam province as a method to reduce the amount of solid waste in the municipality. It will be used to partition the area for the daily disposal of solid waste. Mahasarakham province will have a form of waste disposal, which will be divided into five clusters, which will be used as waste disposal areas in each district. There is a sorting of solid waste before dumping into bins, storage and transportation, and Mahasarakham can choose the appropriate technology for solid waste management. By setting up a loading and unloading station, it will be a place to collect solid waste from direct disposals of people or from garbage trucks. The collected garbage will be discharged into the transportation system of the high-efficiency station in the garbage transport. And it is appropriate for the system of waste management facilities beyond the origin. In other cases, in addition to changing the garbage transportation system. The area within the garbage dump station can also be used to carry out various tasks, such as the reuse of useful garbage. Power generation from solid waste and the transformation of garbage to use. The waste material or waste left over from various processes will be transported to further disposal. This is in line with the study of Pluak Daeng sub-district Administrative Organization (Sub-district Administrative Organization, 2016). Feasibility Study of Solid Waste Transfer Station Project of the Pluak Daeng sub-district Administrative Organization (SAO) in Pluak Daeng district, Rayong province, found that it was appropriate for the area. There were techniques and potential to support the amount of waste in the future. There was a way to unload garbage properly. There were two types of operation: unloading without compaction and loading and unloading using waste compactors. Two types of waste disposal systems were available, the horizontal compression system and vertical compression system. In terms of economic feasibility, it was found that it helps reduce waste management costs and reduce the amount of residue left in the area. Study on the model of establishing an electric power plant from solid waste with Mahasarakham, the amount of solid waste is 379.9 tons /day, which was 138,663.5 tons /day in a year and the amount of solid waste accumulated in the past 5 years, makes it appropriate to undertake a waste disposal program to convert solid waste into electricity. Electricity by design details of the factory was to be of sanitary compliance. The characteristics of the solid waste disposal system used in the production process of the solid waste conversion plant for the production of energy bars to be the electricity from the increased amount of waste. The factory was designed and built to meet the goal of eliminating waste incineration in volume from 300-450 tons per day. The factory will be designed to meet the standards for pollutants as prescribed by the laws of the Kingdom of Thailand, which is in line with the research of Channoi *et al.*, 2009.

Study on community waste management approach for integrated renewable energy (Community level). The main objective of this research is to study the technology of waste management by using waste to energy technology and gasification technology. Utilization of waste is beneficial and alternative/incentive for waste management at various levels. (Focus on the community level) as well as to develop the knowledge gained to the level of national policy, both economically, socially and environmentally towards sustainable development of the country. Study the use of recycled waste to reduce the amount of waste to be disposed of and use it as a waste fuel by developing a suitable RDF (Refuse Dump Fuels) for energy production. From the study of solid waste management in Mahasarakam province, there was an increasing amount of waste every year, which clearly shows that the amount of waste that is being stated is not available because Mahasarakam has no effective waste disposal occurring per day. Nowadays there is only a partial solution to the problem of landfill disposal. In this survey, the study of solid waste management model of Mahasarakham province was carried out in Mahasarakham province, which is of great importance to the national agenda of the government. Published in the Royal Thai Government Gazette, Volume 131, Special Issue 189, dated September 25, 2014, and the Letter of Incorporation, including the Waste Management and Waste Management Plan of the country. Danger Approved by the National Peace Corps on 26 August 2014, with operational procedures. It is the disposal of solid residue accumulated in critical areas. (Old waste) creates a proper disposal model for solid waste and hazardous waste. (New waste) with emphasis on the reduction and separation of solid waste from the source. Integrated Waste Management and the removal of solid waste by integrated technology, focusing on energy conversion or maximizing the use of waste and hazardous waste management. By emphasizing national discipline towards sustainable management. By educating the people and strict enforcement as a way to effectively and efficiently remove solid waste.

4. Conclusion

Solid Waste Management of the Mahasarakham Local government, the researcher concluded the study as follows:

4.1 Solid Waste Management Situation in Mahasarakham Province

4.1.1 The study of solid waste management in Mahasarakham Province by interviewing Local government officials in Mahasarakham found that there were 141 stations in Mahasarakham province. There was a 65-day solid waste collection system with an annual waste volume of 379.9 tons/day, which was 138,663.5 tons/day in a year. 5 years ago, there were 693,542.5 tons and 76 non-storage areas.

4.1.2 Solid waste management of Local Administrative Organization, Mahasarakham Province, there were 359 solid waste management personnel and 111 garbage trucks. The frequency of solid waste collection service was about 115 times a day. Most days and times stored garbage collected on Monday - Friday. Solid waste collection services started at 08.00 onwards. The solid waste services were not providing enough services due to the lack of storage facilities, thus the collection frequency was only 115 journeys per day, and the weekday period was only 5 days.

4.1.3 Policies and barriers to solving problems of solid waste management. Most local governments had the policy to purchase waste bins, garbage trucks for solid waste collection service in the community. Community solid waste collection policy and the waste collection are completed within a day and the policy of a campaign to raise awareness in the management of household solid waste problems and obstacles in the solid waste management of local administration organizations. The problem was most people in the community lack cooperation in waste management and the lack of consciousness in disposing of solid waste where there was no place for waste disposal. Damaged garbage trucks make it difficult to collect garbage.

4.1.4 Solving problems of solid waste management of most local administrative organizations by publicity encourage people to know how to sort waste before disposal and reuse of garbage to give people a good sense of the waste and make them be aware of the benefits and the consequences. There is an educated approach to waste management to reduce air pollution. Since solid waste is disposed of by the incineration method and to reduce the amount of solid waste left over after storage, which may be smelly.

4.2 Appropriate Solid waste management model of Mahasarakham province

Appropriate solid waste management model of Mahasarakham province is a method that has a waste disposal process that is capable of eliminating solid waste in a hygienic and effective manner in the management of solid waste by setting up a waste disposal area in Mahasarakham. It will be used to partition the area for the daily disposal of solid waste. The model can be divided into 5 zones; zones 1, the center cluster1, which will be the power plant area for waste from solid waste (located in Nong Pling, Mueang Mahasarakham). Zone 2 is cluster2 (located at the Phon Ngam District, Chiang Yuen District). Zone 3 is cluster3 (located in Borabue sub-district, Borabue district, Mahasarakham province.) Zone 4 is cluster4 (located at Nong Saeng sub-district, Wapi Pathum district, Mahasarakhamprovince.) Zone 5 is cluster5 (located at Palan sub-district, Phayakkhaphum Phisai district, Mahasarakham province.) Each cluster will be set up as a waste dump station to serve as a waste disposal point to be transported to the power plant.

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Environmental Health Impact Assessment of Community Solid Waste Management Project in Ban Donyom, Thakhonyang sub-district, Kantharawichai, Mahasarakham, Thailand

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Abstract

Waste is an environmental increase severe problem cause from population increase, development of economic social and technology. It affected quality of life and contaminated environment causing environmental pollution. Researcher was interested to study environmental health impact assessment of community solid waste management project in Ban Donyom, Thakhonyang sub-district, Kantharawichai district, Mahasarakham province. The results were dividing in 4 directions as follows: 1) environmental impact assessment as physical environment resources assessed on states of terrain and soil resources, meteorology and air quality, hydrology of surface water and groundwater, aquatic ecology, terrestrial ecology, land use, and socio-economic, concluded that the project does not impact both in construction and operation phase, 2) community feedback to the project, mostly knew about the project and relatively confident in project management, and people in community agreed and appropriated for construction of waste management project. 3) Health impact assessment in constructional phase and operational phase as body, mental, intelligence and social. The impact was low level and 4) preventive and corrective measures for environmental quality monitoring were implementing to prevent and correct measures strictly on environmental quality monitoring and used as a guide to direct supervision, monitoring and control of department, people and related organizations.

***Keyword**:* environmental health impact assessment; community waste management project

1. Introduction

Present, solid waste was a major social problem of people, communities, villages, as well as government agencies to aware and fine solutions with systemic waste management and correct academic principles for no effects to the quality of life of people, community and environments. Solid waste is increasing by population.

There were many types of waste disposal, especially the sanitary landfill with starting from the selection area, space design of landfill, and design and provide the necessary infrastructure system in full engineering, including academic principles and method in time for use and after expiration of system (Cheuwchan, 2016).

Mahasarakham province is a city of education, thus increasing the latent population, especially in Ban Don Yom area adjacent to Mahasarakham University. The main cause of solid waste management problem is the rapid increase in population having led to increase in amount of solid waste. Problems of community solid waste management incorrect waste management and so much waste to store in one day to left in the community. It cause of smell problem from waste residue to enormous environmental and health impact both directly and indirectly (Usuk, 2008).

In the study of waste management and waste volume in Thakhonyang subdistrict, Kantharawichai district, Mahasarakham province was about 12-15 tons/day. At present, the waste landfill has been removed were close. It made villagers, community and dormitories in this areas where solid waste must be disposed by means of burning and landfilling, or sent to the neighboring provinces as a result, a lot of waste residue. In this Ban Donyom Thakhonyang sub-district, Kantharawichai district, Mahasarakham was sustainable and effective solving to waste management, environmental health impact assessment and researching to guideline, policy support information, for improve processes, methods and tools to solve waste management problem with consistent in conceptual framework of community participation and stakeholders in environmental health impact (Chayangkhakul, 2012).

Ban Donyom, Thakhonyang subdistrict, Kantharawichai district, Mahasarakham province was implement waste management project for construction standardized and sanitary waste disposal landfill, effective operation, prevention on environment health impact. Therefore, the researcher was studying for environmental health impact assessment environmental health impact assessment of community solid waste management project in Ban Donyom, Thakhonyang sub-district, Kantharawichai, Mahasarakham. To study the basic information about the general environment within 1 kilometers. The area around the place established project. The study of environmental impact assessment as physical environment resources assessed on states of terrain and soil resources, meteorology and air quality, hydrology of surface water and groundwater, aquatic ecology, terrestrial ecology, land use and socio-economic, to analyze and evaluate the environment health impact and the study of the project management community health premium garbage In order to focus on community participation with equity from the impact on health and the environment in the community.

2. Materials and Methods

Study of environmental health impact assessment of community solid waste management project in Ban Donyom waste management project, Thakhonyang subdistrict, Kantharawichai district, Mahasarakham province was set scope of study within 1 kilometer radius (Fig. 1.) The project's environmental resources include: environmental resources and factors related to project development, expected factors may be affected by the project both in the construction and operation phase. This study was include the steps as:

2.1 Population were households that located in study area within a radius of 1 km.

2.2 Samples were determine from Taro Yamane’s table of reliability at 95 percent to 333 households from all 2,031 households using systematic sampling by house number and household agents who can provide information.

2.3 Instrument consisted of 1) questionnaire for physical and biological resources surveyed, 2) Questionnaire of community health and 3) questionnaire for collecting opinion from the project.

2.4 Collecting Data

1) Collect and review related secondary information as: reports, maps and other projects information in nearly area.

2) Field data collection, project area survey and field survey and sampling.

3) Analysis of current environmental conditions in each environmental quality factor for environmental status of the project area.

4) Study the project details as construction and operation of the project, location, route into the project area, work process, standard landfill systems, transportation systems, and security systems.

5) Community poll for knowledge and understanding with people in the community for project details, survey community's opinion in the educational area regarding the establishment of the project using questionnaire for households, community leaders and agencies around the project area.

6) Environmental impact assessment from project details and current environmental condition to analyze and evaluate the expected environmental impacts on the project.

7) Environmental health impact assessment for consider the potential positive and negative health effects of the project to linkages of reasons and factors of project impact.

8) Proposed measures to prevent, correct and reduce the environmental health impacts and environmental and health monitoring measures include construction period and operation period.

9) Conduct a summarizing report of opinions from stakeholders and the public with statement and present scope of guidelines for environmental and health impact assessment to community leaders and publicize.

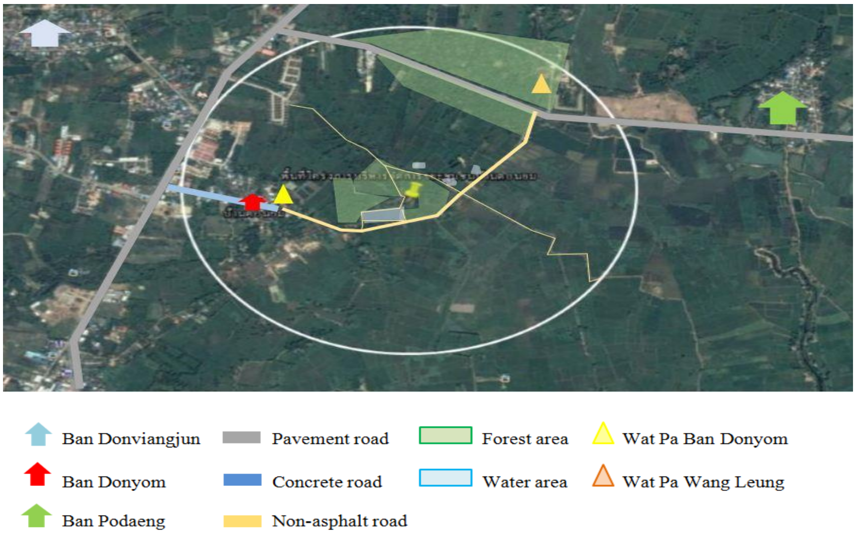

Figure 1. Structure and surrounding area of the project

3. Results and Discussion

This study was summarize and discuss the study results into 4 areas as: environment impact assessment, community feedback on the project, health impact assessment and measures to prevent and correct environmental quality monitoring.

3.1 Environmental impact assessment, the results can be summarized into 2 phases: construction phase and operational phase as follows:

3.1.1 Construction phase:

1) States of terrain and soil resources: community waste management project was locate in Ban Donyom, Thakhonyang subdistrict, Kantharawichai district, Mahasarakham province which is flatland. The project area has importance natural water resources as: Nongprem, Nongkrugrith, Nongkhudphiyod, and personal swamp. Initially, the development of the project included some land reclamation activities to suit the landfill of the project, when considering the impacts on terrain of this area were change the terrain only in the project area. So, the impact on the terrain was expected to be low for soil resources and result in permanent loss of 5 hectares of land resources were expected to use of land resources in the wilderness and other unused areas will increase, so the impact on soil resources was expected to be low.

2) Meteorology and air quality: the main pollutants that occurred during the construction of the project were particulate matter, especially during landfill activities. Because of this activity, the ground must be opened. In addition, transportation of the soil will also have the consequent effect of diffusion of dust.

3) Hydrology of surface water and groundwater: surface and groundwater sampling found that water pH values were in surface water sources water quality standards.

4) Aquatic ecology: activities in the construction phase did not affect aquatic ecology anyhow because there was no discharge of water or workers' shelter.

3.1.2 Operational phase:

1) States of terrain and soil resources: when the construction project was completed and opened. There will be no activity or disturbance of terrain or additional soil resources or cause additional impact on the terrain of the area. The project did not affect the terrain within the project.

2) Meteorology and air quality: when the project is completed and opened there will be no activity disturbing the weather. Therefore, it is expected that during the operation of the project will not affect the weather in any way.

3) Hydrology of surface water and groundwater: the project will make the amount of water flow in most of the basin area decrease. However, the project will have drainage so the effect on the reduction of water quantity of the project. Is expected to affect the watershed in the low level.

4) Aquatic ecology: waste water generated from solid waste will not be discharged from waste water into external water source of the project.

3.1.3 Terrestrial ecology:

1) Forest resources: implementation of project was less affected to natural forest because the project area was quite far from forest and plants along head of field both in construction and operation phase.

2) Wildlife resources: in the project area was not find wildlife from survey.

3.1.4 Land use:

The land surrounding the project was mostly wilderness. The project implementation did not affect the land use surrounding site during construction and operation phase.

3.1.5 Socio-economic:

Economic and social impact expected of project construction both positive and negative effects as: positive impact was increased employment and local income distribution, negative impact was an indirect effect of noise pollution from machines that cause nuisance to people in communities near or adjacent to the project but it has low impact both in construction and operation phase.

Environmental impact assessments were must covering the expected area to affect and consider direct impacts on the environment because indirect impacts were impacted against to other factors, then return to impact on environment (Fakkum, 2013). Office of Natural Resources and Environmental Policy and Planning, 2013 said that environmental impact analysis is a planning process using academic principles to predict or predict both positive and negative impacts before making a project decision. It was analyze and explain the feasibility of all potential impacts on both physical and biological resources, human quality, human utilization, value to quality of life, proposed measures to prevent or mitigate the impact of the project and to monitor environmental changes, and utilizations of natural resources and the environment is maximized, consistent with the research of Phataramanawong, 2010 in Preventive Protection: Environmental Impact Assessment, the result found that: There are several ways to assess environmental impacts as: preparation of initial environmental impact report, preparation of environmental impact assessment report, and preparation strategic environmental assessment, etc. Section 46th of the National Environmental Quality Promotion and Conservation Act determined for required to prepare an EIA report before developing area project for prevent environmental impact.

3.2. Community feedback on the project

Researchers were collecting Socio-economic data of households in the study area using interviews from head of household or household representative with household economy, sanitation public utility system and state of problem of waste management, current living conditions and community satisfaction, project information perception, attitude/opinions on the project, public relations, and community participation. Samples were 80 head of household or household representative from purposive sampling with households located nearby within 1 km of the project site. The results found that:

3.2.1 General information of interviewees and community households: gender as: female 41.60 percent, male 39.20 percent, status: head of household 50.00 percent, inmate 50.00 percent, age: 41 - 50 years old 23.80 percent, 31 - 40 years old 10 percent, 51 – 60 years old 17.4 percent, 61 years old up 18.30 percent, education: primary 52.5 percent, bachelor 25.00 percent, secondary 18.70 percent, vocational/high vocational 18.70 percent, religion: 100 percent of Buddhism.

3.2.2 Household economy found that: occupation as: farmer 60 percent, contractors 11.30 percent, trade 2.50 percent, personal business 1.30 percent, and government/state enterprise 2.50, household income as: 9,00-12,000 bath per month 70 percent, 12,000-18,000 bath per month 16.30 percent, 18,000-22,000 bath per month 7.50 percent, 22,000-32,000 bath per month 2.50 percent, and 32,000 bath per month up 3.80 percent, housing condition as: detached house 91.30 percent, shed/cabin and Twin House 1.30 percent, utilization of housing as: housing only 90.00 percent, shop/service 5.00 percent, office and a private business 2.50 percent, engine repair shop, and household handicrafts 1.30 percent.

3.2.3 sanitation public utility system and state of problem of waste management found that: illness with various diseases Caused by waste management as: colds and asthma 38.80 percent, conjunctivitis 6.30 percent, diarrhea 5 percent, muscular disease 1.30 percent, and no disease 42.50 percent, medical care as: State hospital 80 percent, sub district Health Promotion Hospital 13.80 percent, private hospital/clinic 1.30 percent, heal yourself 3.80 percent.

The use of water was divided into three categories as drinking water, consumption water, and farm water, The result found that: 1) drinking water as: drinking water from purchase 67.50 percent, water supply 20.00 percent, and rain water 12.50 percent, consumption water as: water supply 86.30 percent, and rain water 13.70 percent.

Waste disposal found that: disposed by community operations 78.80 and others dispose 21.30 percent, in others dispose as: heap and burn 66.30 percent, Leave space outside 25.00 percent, junk hole and dropped to the public 2.50 percent. Environmental impact/community waste management found that: there was a negative impact on the smell of garbage 46.30 percent, impact of waste water from garbage 26.30 percent, waste overwhelmed 18.80 percent, and soot from waste incineration 8.80 percent.

3.2.4 Current living conditions and community satisfaction found that: satisfied with their living conditions 88.80 percent, dissatisfied with their living conditions 5.00 percent, and not satisfied 6.30 percent. Cause of satisfaction with their living conditions as: villagers assisted 63.80 percent, have peace of mind in life and property 22.50 percent, utmost utilities 6.30 percent, have good environment, 5.00 percent, and employed 2.50 percent. Social problems in the community were as: drug problem 56.30 percent, controversy 13.80 percent, theft problem 10.00 percent, and problem of unity of people in the community 20.00 percent. Infrastructure and services that the community needs were as: solid waste management of 45.00 percent, Wastewater management 22.50 percent, water supply 17.50 percent, road 13.80 percent, and electricity 1.30 percent.

3.2.5 Project information perception and attitude/opinions on the project found that: received information from headman/village director 83.80 percent, received information from neighbors 12.50 percent, recognized by the village headman 2.50 percent, perceived by teachers 1.30 percent. Most of the information about the project was 76.30 percent and unknown information only 23.70 percent. Community was quite confident in project management that there will be no impact on environment and community 43.70 percent, not trust 33.80 percent and strong confidence 22.50 percent. Appropriate use of technology in community solid waste management was appropriate 70.00 percent and inappropriate 70.00 percent. Community opinion on the construction of waste management project was approved 52.50 percent, strongly agreed 25.05 percent, disagreed with 17.50 percent, and strongly disagreed 5.00 percent.

3.2.6 Attitude/opinions on the project, public relations, community involvement found that: the information should be publicized/clarified information of the project 88.80 percent, uncertainty 8.80 percent, and not necessary 2.50 percent. Publicity should have the appropriate format by providing information through community leaders 35.00 percent, reported information through the newsroom 30.00 percent, organized a clarification meeting 27.50 percent, and made letters/documents to the public directly 7.50 percent. Participation in project dissemination to the community was of course, 45.00 percent, probably 37.50 percent, not sure 11.30 percent, and not likely to be 6.30 percent. Participation, attending, and listening to community projects were should attend the meeting 66.30 percent, not sure 27.50 percent, and not attend the meeting 6.30 percent.

Therefore, public participation plays an important role in responding to the basic right of people to receive information. Public awareness of environmental issues was played an important role in exchanging information between people and project operators. Environmental impact assessment and analysis to comply with public participation guidelines and environmental impact assessment were has been arranged for understanding and adds channels for feedback and impact of the project (Burikul *et al.*, 2016) Public Participation Operations was important for the real development of the project. Environmental impact studies are measures that must be taken within the framework of mandatory legislation and specified in the current constitutional law. It is necessary to involve people in the area and jointly decide on upcoming projects to significant public participation. Implementation of development projects for sustainable development goals, maintain integrity and wide variety of sustainable natural resources, consistent with the project of the Center for Energy and Environment Engineering, 2016 in Public hearings in the area of Nopparat Administrative Organization, Nong Suea district, Pathum Thani Province (According to the regulations of the Prime Minister's Office With the public hearing of 2005) for community based waste management promotion program found that attendees were known the details about the project implementation 77 percent and did not know the details about the project implementation 23 percent, Knew and understanding of project implementation increased at a high level 95 percent and Knew and understanding of project implementation is the same 5 percent, agreed with the public hearing 77 percent, no comment 18 percent, and disagree 5 percent. Public relations project details and step of background clarification, operational guidelines, and presentation of project scope for people to correct understanding about project, and target group acknowledges and understands the importance of participating in solving the problem of solid waste management.

3.3 Health Impact Assessment

Health impact assessment may occur to nearby communities from project activities during construction and operation phase in 4 area as: physical, mental, intellectual and social were as follow:

3.3.1 Construction period

1) Health impact assessment on physical was affects the health of neighboring communities at low levels. The impacts were limited to the project area but workers in the project area are most likely to be exposed to

toxic substances and the impact of project construction with dust from the preparation area.

2) Health impact assessment on mental was stressed community anxiety from the implementation of the community solid waste management project

3) Health impact assessment on intellectual was little relevance to local cultural change due to the construction of the measures used by the local people. The project had implemented corporate social responsibility (CSR) policy continuing with the people in the community each year.

4) Health impact assessment on social as: impact on the health service system of construction workers who may not have access to public health services in the area or may increase the burden on local public health services due to increase in construction labor. The project had focused on easing the burden of providing public health services to local authorities by requiring the contractor to provide first aid units in the project area in case of minor injuries. The project had coordinated with local health service agencies in case of referral to patients in case of severe injury expected to use the services of a local hospital together with people in the area and may affect the public service in some areas during the project construction period. However, the impact is low. The study found that, in the area of health service system in Kantharawichai district, Mahasarakham province had public health service and a lot of private with potential to serve the people in the community.

3.3.2 Operational phase

1) Health impact assessment on physical of people in nearby communities and staff of the project was low level. Health impact on employees of the project was possible to work from a place of risk cause accidents if the strict safety rules are not followed.

2) Health impact assessment on mental was likely to cause low to moderate mental health effects with feeling nervous and stressed due to dust, smell, from transportation of garbage trucks in the community and unsafe working conditions and environment of workers.

3) Health impact assessment on intellectual was little effect on local cultural change because the project requires first-to-local employees.

4) Health impact assessment on social was low Impact on social health that may occur in implementation phase of staff working on the project. Impact on public health services that may not have access to public health services in the area or may increase the burden on local public health services but the area has enough local health service agencies. And there are many options for the community already and contribute to the development of people's participation and health promotion to the community.

Therefore, the project provides adequate safety, occupational health and environmental measures and health promotion program develop public health for people in the community. It contributes to the development of public participation and public health in the area of health surveillance, set measures to relieve anxiety, encourage community participation, provide a complaint center to answer community questions and promotes better change. The World Health Organization had established strategies that address critical risk and health management issues as: reduce risk factors of disease and threat to health with environmental, economic, social and behavioral factors (Office of Natural Resources and Environmental Policy and Planning, 2012). Health impact assessment was important tool to public health policy. Environmental degradation with health impact and health effects needed to be taken care of both environmental, social and health outcomes can be improved consistent with the research of Srikuta and Inmoung, 2011 studied in health impact assessment of communities living around landfill sites, Khonkaen Municipality, Khonkaen province. Result found that: 1) negative health effects as: foul odor from waste, dust, smoke, 2) positive Health Impact as: regular health check-ups from Khonkaen Municipality Health Check-up Unit, 3) negative mental health effects as: feeling nervous about their health and their families, 4) positive mental health impact as: pleased with Khonkaen Municipality to issue health check-up, 5) negative social health effects as: conflict between the community and Khonkaen Municipality, 6) impact on positive social health as: communities dare to protect their rights and their communities against the effects of pollution. And make a career to earn a family. Negative health impacts both community, social, economic, cultural and environmental health with living and Community Health. Therefore, proper public health planning is required. Corrective and preventive measures, mitigation measures, including measures to monitor and promote health to control and minimize the impact.

3.4 Measures to prevent and correct environmental quality monitoring. Action plan and measures to prevent, correct, and reduce environmental impacts of Ban Don Yom community waste management project Thakhonyang subdistrict, Kantharawichai district, Mahasarakham province had following details:

3.4.1 Air quality: prevention and mitigation measures as: sprinkle water on the construction site and roads within the project at least twice a day for prevent dust from spreading to the atmosphere. And affect nearby communities, limited runway speed of project area did not exceed 30 kilometer per hour, control not to get rid of garbage by burning outdoors in the construction area, planting trees around the project area for dust protection in the fast.

3.4.2 Surface hydrology and drainage: design of rainwater drainage system for sanitary landfill, install leachate system, inspection and maintenance of vehicles and all kinds of machines regularly, check regularly the waste leachate drainage system of the project if found damaged which repair should be completed immediately.

3.4.3 Aquatic ecology: monitoring aquatic ecology along with quality of surface water continuously.

3.4.4 Transportation: strictly keep garbage truck used within scheme strictly adhered to traffic rules, plan to move transportation of solid waste into the project area.

3.4.5 Waste management and residue management: do not burn garbage in the project area, required to separate waste and construction materials that can be reused of recycle waste from general waste to sell.

3.4.6 Public health, hygiene, occupational health and safety: coordinate with the nearest hospital and local health authority for provide knowledge and advice to workers in the prevention of diseases.

3.4.7 Public participation: meet government agencies at provincial level, publicity through the village line, set up village committee to monitor the environmental impact, organize training courses on environmental management and monitoring of environmental impacts of the project.

Study of environmental and health impact assessment of Ban Don Yom community waste management project Thakhonyang subdistrict, Kantharawichai district, Mahasarakham province. It may cause environmental impacts, community economy Impact on water quality, transportation, quality of life in occupational health and safety. Environmental impact measures and appropriate environmental monitoring plans were required and possible in academic practice for approach to correct and mitigate the impact of violence is acceptable. Environmental impact assessment was important to establish preventive and corrective measures for the environment (Office of Natural Resources and Environmental Policy and Planning, 2015) and guidelines on how to behave Management Systems Impacts may occur in each aspect according to the nature of the project with standard or benchmarking standards and criteria are used as controls or surveillance when measurement results beyond the specified standard are indicative of potential problems. The impact or risk of a problem. Monitoring of environmental quality in main measures as: emission environmental measurement, environmental quality measurement, etc. which corresponds to Viengsra municipal office and Lucky Clean Energy Co., Ltd., 2016 had study of paperwork for the waste processing project for power generation, Surat Thani province. The study indicated that impact, preventive and mitigating effects of project implementation was the air before venting out of the chimney will be treated and disposed of in accordance with the strict standards prescribed by the law which smoke is just steam, smell of garbage was not out of the area since the waste processing plant is energy-intensive. It had an odor-absorbing system to burn it in a standardized waste incinerator and leachate will had a waste water treatment and disposal system in the waste refinery area as energy. All garbage trucks are limited in speed and cleaned every time the garbage is disposed of in a garbage processing plant. The project has set out guidelines to prevent and reduce the impact of the operation of the waste processing plant into electricity to generate electricity in 3 phase as: Appropriate study phase (before construction), construction phase, power generation phase. Establishment of preventive and corrective measures and measures to monitor the environmental impact of project-related environmental factors to be more appropriate.

4. Conclusion

Environmental health impact assessment of Ban Donyom community waste management project Thakhonyang subdistrict, Kantharawichai district, Mahasarakham province. Results can be summarized as follows:

1. Environmental impact assessment include states of terrain and soil resources, meteorology and air quality, hydrology of surface water and groundwater, aquatic ecology, terrestrial ecology, land use, and socio-economic, the project did not have any impact both in construction and operation phase.

2. Community feedback on the project: project information perception, attitudes toward project get information from village headman and village council was known, community was quite confident in project management that it will not affect the environment and the community. People in the community agreed and found it appropriate to construct a waste management project.

3. Health impact assessment in before construction phase and construction phase found that: It may affect the general public in some areas with low level on physical, mental, intellectual and social.

4. Measures to prevent and correct environmental quality monitoring was implementation of measures to prevent and correct environmental impacts and measures to monitor environmental quality in the form of a strict environmental action plan for guidelines for monitoring, monitoring and control of public agencies and organizations involved in air quality, surface hydrology and drainage aquatic ecology, transportation waste management and waste management public health, hygiene, occupational health and safety and public participation.

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This research has been successfully completed with cooperation from the community and community leaders in Ban Donyom Thakhonyang subdistrict, Kantharawichai district, Mahasarakham province. Thanks to all the villagers for their cooperation in answering the questionnaire and thanks Center of Environmental Education Research and Training, Faculty of Environment and Resource Studies, Mahasarakham University, Mahasarakham, Thailand.

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Health risk assessment of PM_{10} and $PM_{2.5}$ in Chiang Mai, Thailand

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Abstract

Human exposure to fine particulate matter with the aerodynamic diameter of less than 10 μm, (PM_{10}) and 2.5μm ($PM_{2.5}$) are found to be associated with respiratory symptoms and diseases. The ultra fine and fine particulates concentrations are increasing in urban areas. Chiang Mai a big city in north Thailand is also facing serious air pollution problems. The government designated the National Ambient Air Quality Standards (NAAQS) and implemented countermeasures for criteria air pollutants such as Total suspended particulate matters (TSP), PM_{10}, $PM_{2.5}$, sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2) and ground level ozone (O_3). In this work, daily ambient air particulate concentrations were analyzed and calculated as Hazard quotient (HQ) of PM_{10} and $PM_{2.5}$. HQ value with less than 1 is considered to be of minimal risk for adverse health effect arising from exposure. The higher HQ is from a value of 1 or > 1 indicated the potential of a risk from pollution exposure in the area, HQ in Mueang Chiang Mai district from January to May 2016 was higher than 1.

Keywords: air pollution; health risk assessment; particulate matter; hazard quotient

1. Introduction

Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of air pollution (WHO, 2016). Particles can either be directly emitted into the air or be formed in the atmosphere from gaseous precursors such as sulfur dioxide, oxides of nitrogen, ammonia and non-methane volatile organic compounds. Primary PM and the precursor gases can have both man-made and natural sources. Anthropogenic sources include combustion engines, solid-fuel combustion for energy production in households and industry, other industrial activities, and erosion of the pavement by road traffic and abrasion of brakes and tyres. Agriculture is the main source of ammonium. Secondary particles are formed in the air through chemical reactions of gaseous pollutants. They are products of atmospheric transformation of nitrogen oxides and sulfur dioxide resulting from the combustion of sulfur-containing fuels. Secondary particles are mostly found in fine PM.

There is good evidence of the effects of short-term exposure to PM_{10} on respiratory health, but for mortality, and especially as a consequence of long-term exposure, $PM_{2.5}$ is a stronger risk factor than the coarse part of PM_{10} (particles in the 2.5–10 µm range). All-cause daily mortality is estimated to increase by 0.2–0.6% per10 µg/m^3 of PM_{10}. Long-term exposure to $PM_{2.5}$ is associated with an increase in the long-term risk of cardiopulmonary mortality by 6–13% per 10 µg/m^3 of $PM_{2.5}$. Susceptible groups with pre-existing lung or heart disease, as well as elderly people and children, are particularly vulnerable. For example, exposure to PM affects lung development in children, including reversible deficits in lung function as well as chronically reduced lung growth rate and a deficit in long-term lung function. There is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur. The exposure is ubiquitous and involuntary, increasing the significance of this determinant of health (WHO, 2013).

Recently, in Thailand, agricultural production and the use of private vehicles have dramatically increased. Previous studies indicate that overall private vehicle ownerships in Thailand increase as the income levels grow; after personal income reaches a certain level, people will shift from motorcycle to car ownership for prestige, convenience, comfort and safety. The emergence of contract farming as an institution for facilitating market exchange and appears to have played a major role in Thailand for decades. These phenomena caused several subsequent air pollution problems, as imperfect combustion of rotten agricultural waste biomass and traffic exhaust produced trace gaseous species, carcinogenic polycyclic aromatic hydrocarbons, carbonaceous aerosols and mutagenic particles. Without exception, the largest and most culturally significant city in northern Thailand, Chiang-Mai, has experienced the worst air pollution during the past few years. During the haze episode in March 2013, the weekly average $PM_{2.5}$ levels in Chiang-Mai were between 2.8 and 7 times higher than the World Health Organization's (WHO) recommended 24 hour average concentration (Siwatt and Tassanee, 2015).

2. Materials and Methods

2.1. Data collection and Analysis

The available air monitoring data used in this study was from January to December 2016. PM_{10} and $PM_{2.5}$ were monitored at Yapparaj Wittayalai School, Mueang Chiang Mai district, Chiang Mai province, as shown in Figure 1. The monitoring site is operated by Pollution Control Department (PCD). Daily average (24 hours average) of PM_{10} and $PM_{2.5}$ were used in this study.

Figure 1. The monitoring site of PM_{10} and $PM_{2.5}$ concentrations at Yapparaj Wittayalai School

2.2. Health risk assessment

Health risk associated with PM_{10} and $PM_{2.5}$ were an estimated based on ambient PM_{10} and $PM_{2.5}$ concentration for non-cancer endpoint, using the conventional approaches developed by the US.EPA (US.EPA., 2009). Hazard Quotient (HQ) will illustrate in this study. If HQ is greater than 1, then it can be interpreted that there is adverse health effects and if HQ less than 1, then there is no adverse health effects to the population in the study area. For the exposure assessment, inhalation exposure was evaluated using Eq. (1) and Eq. (2), while HQ was applied using Eq. (3) (MOPH, 2015).

$$PM_{10}\_I = \frac{C \times IR \times ET \times EF \times ED}{BW \times AT} \quad (1)$$

$$PM_{2.5}\_I = \frac{C \times FR \times FA \times IR \times ET \times EF \times ED}{BW \times AT} \quad (2)$$

Where, I is the inhalation exposure (mg/kg/day), C is the exposure concentration (mg/m^3), IR is the inhalation rate (m^3/hr), FR is the factor of retention, FA is the factor of absorption, ET is the exposure time (hr/day), EF is the exposure frequency (day/year), ED is the Exposure duration (year), BW is the body weight (kg), and AT is the averaging time (day).

$$HQ = \frac{Exposure}{RfC} \quad (3)$$

Where, HQ is the hazard quotient, exposure (mg/kg/day), and RfC is the reference concentration (mg/kg/day).

3. Results and Discussion

The plot of PM_{10} and $PM_{2.5}$ concentration was examined from January to December 2016 as shown in Figure 2. As for of PM_{10} it was found that there was an increasing tendency of monthly arithmetic mean concentrations from January to April were within 57 – 118 µg/m^3, from April to December were dramatically decreasing and was within 118 – 24 µg/m^3 (daily average of PM_{10} equal to 120 µg/m^3). As for of $PM_{2.5}$ it was found that there was an increasing tendency of monthly arithmetic mean concentrations from January to April were within 34 – 81 µg/m^3, from April to December were dramatically decreasing and was within 81 – 10 µg/m^3 (daily average of PM_{10} equal to 50 µg/m^3) (PCD, 2017).

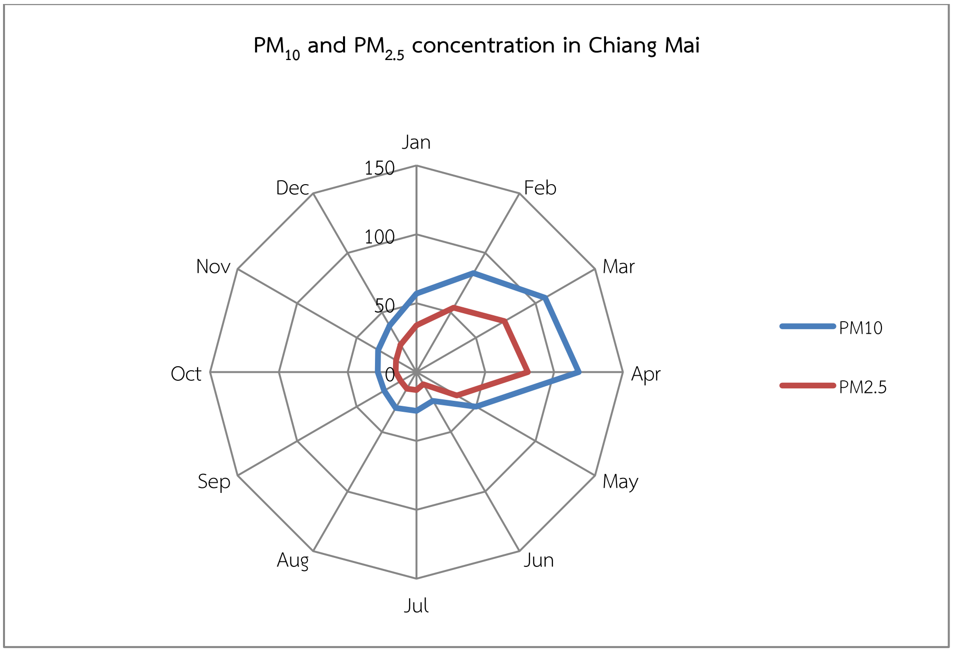

Figure 2. Monthly average PM_{10} and $PM_{2.5}$ concentration from January to December 2016

The concept of hazard quotient (HQ) was applied in this study. HQ of PM_{10} and $PM_{2.5}$ are calculated by using the available air pollution monitoring data from the Pollution Control Department (PCD). Calculated results of HQ for PM_{10} from January to December 2016 was within 0.5 – 2.5 and HQ for $PM_{2.5}$ was within 0.5 –

3.8. The results indicated that HQ for PM_{10} from January to May 2016 was greater than 1 as shown in Table 1. HQ for $PM_{2.5}$ from January to May and December 2016 was greater than 1 as shown in Table 2. HQ less than 1 are considered to be of minimal risk for adverse health effect arising from exposure. The higher HQ is from a value of 1, the greater risk as shown in Figure 3 and Figure 4.

Table 1.HQ of PM_{10} are calculated by using the available air pollution monitoring data

Month	PM_{10} (mg/m^3)	IR (m^3/day)	ET (hr/day)	EF (day/year)	ED (year)	BW (kg)	AT (day)	PM_{10}-I (mg/kg-day)	RfC (mg/kg-day)	HQ
Jan	0.057	0.875	24	365	34	63.19	17520	0.013	0.011	1.2
Feb	0.083	0.875	24	365	34	63.19	17520	0.020	0.011	1.8
Mar	0.108	0.875	24	365	34	63.19	17520	0.025	0.011	2.3
Apr	0.118	0.875	24	365	34	63.19	17520	0.028	0.011	2.5
May	0.050	0.875	24	365	34	63.19	17520	0.012	0.011	1.1
Jun	0.024	0.875	24	365	34	63.19	17520	0.006	0.011	0.5
Jul	0.028	0.875	24	365	34	63.19	17520	0.007	0.011	0.6
Aug	0.030	0.875	24	365	34	63.19	17520	0.007	0.011	0.6
Sep	0.027	0.875	24	365	34	63.19	17520	0.006	0.011	0.6
Oct	0.028	0.875	24	365	34	63.19	17520	0.007	0.011	0.6
Nov	0.032	0.875	24	365	34	63.19	17520	0.008	0.011	0.7
Dec	0.039	0.875	24	365	34	63.19	17520	0.009	0.011	0.8

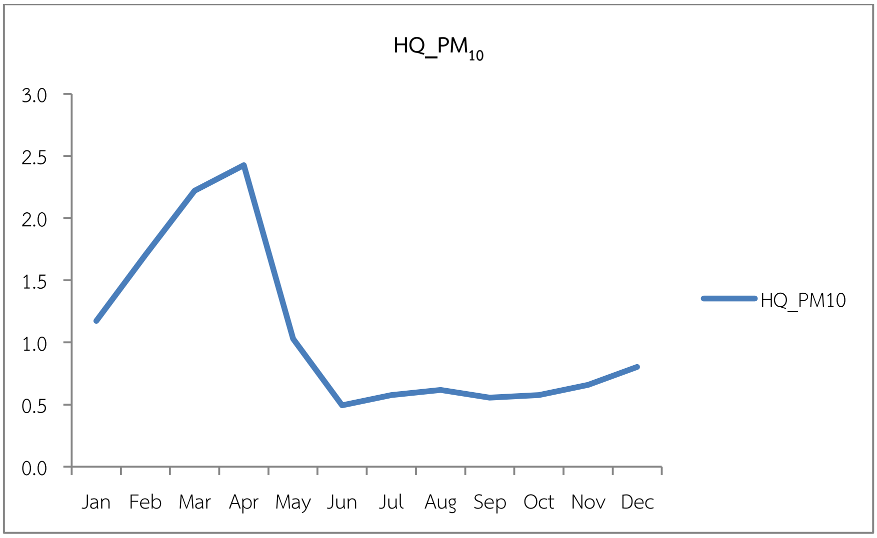

Figure 3. The plot of HQ for $PM_{2.5}$ concentration from January to December 2016

Inhalation exposure is typically the primary route of direct exposure to particulate bound trace elements. The HQ value is higher than the safe limit (=1) indicated that PM_{10} and $PM_{2.5}$ pose non-carcinogenic risk (Sridevi and Gurdeep, 2017). The limitation of calculation of risk assessment following US.EPA and EU legislation, including inhalation rate and reference concentration could result in an over or under estimation. The value of inhalation rate was that recommended for the US population, but might not be appropriate for Thai people (Navaporn et al, 2016). The value of exposure duration (ED) and the averaging time (AT) recommended for Saraburi province but might not be appropriate for Chiang Mai province (MOPH, 2013).

Table 2. HQ of $PM_{2.5}$ are calculated by using the available air pollution monitoring data

Month	**$PM_{2.5}$ (mg/ m^3)**	**FR**	**FA**	**IR (m^3/ day)**	**ET (hr/ day)**	**EF (day/ year)**	**ED (year)**	**BW (kg)**	**AT (day)**	**PM2.5-I (mg/kg-day)**	**RfC (mg/kg-day)**	**HQ**
Jan	0.034	1.0	1.0	0.875	24	365	34	63.19	17520	0.008	0.005	1.6
Feb	0.054	1.0	1.0	0.875	24	365	34	63.19	17520	0.013	0.005	2.5
Mar	0.074	1.0	1.0	0.875	24	365	34	63.19	17520	0.017	0.005	3.5
Apr	0.081	1.0	1.0	0.875	24	365	34	63.19	17520	0.019	0.005	3.8
May	0.034	1.0	1.0	0.875	24	365	34	63.19	17520	0.008	0.005	1.6
Jun	0.010	1.0	1.0	0.875	24	365	34	63.19	17520	0.002	0.005	0.5
Jul	0.013	1.0	1.0	0.875	24	365	34	63.19	17520	0.003	0.005	0.6
Aug	0.014	1.0	1.0	0.875	24	365	34	63.19	17520	0.003	0.005	0.7
Sep	0.013	1.0	1.0	0.875	24	365	34	63.19	17520	0.003	0.005	0.6
Oct	0.015	1.0	1.0	0.875	24	365	34	63.19	17520	0.004	0.005	0.7
Nov	0.017	1.0	1.0	0.875	24	365	34	63.19	17520	0.004	0.005	0.8
Dec	0.023	1.0	1.0	0.875	24	365	34	63.19	17520	0.005	0.005	1.1

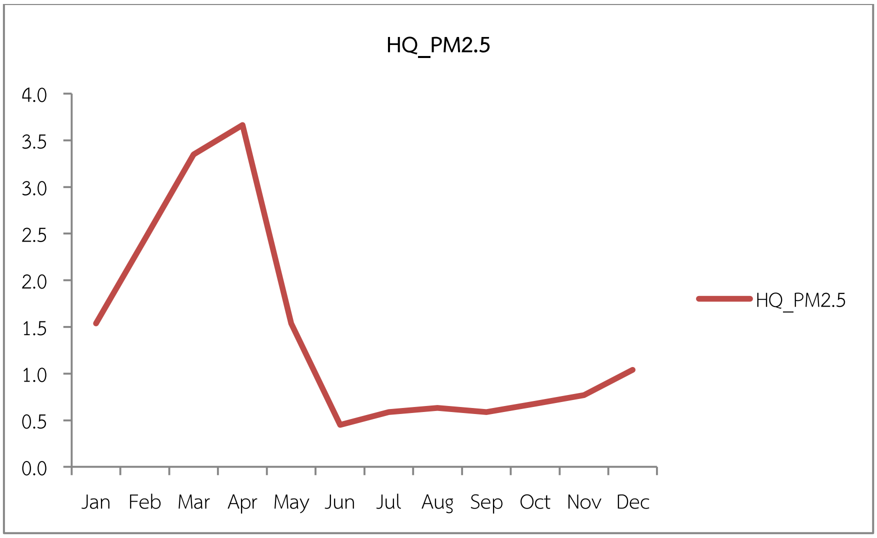

Figure 4. The plot of HQ for $PM_{2.5}$ concentration from January to December 2016

4. Conclusions

The plot of PM_{10} and $PM_{2.5}$ concentration was examined from January to December 2016, it was found that there was an increasing tendency of monthly arithmetic mean concentrations from January to April after that were dramatically decreasing until December 2016. The calculated results of hazard quotient (HQ) of PM_{10} at Mueang Chiang Mai district from January to May 2016 was greater than 1 and $PM_{2.5}$ from January to May and December 2016 was greater than 1. HQ less than 1 are considered to be of minimal risk for adverse health effect arising from exposure. The higher HQ is from a value of 1, the greater risk.

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The Results of Public Participation Process for the Compensation of the Socio and Environmental Impact of a Crude Oil Leak Samet Island Rayong Province

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Abstract

This research investigate the results of the implementation of the public participation process that was run for compensation of the socio and environmental impacts of a crude oil leak in the Samet Island Rayong Province. The area, a tourist area of the Samet Island Rayong Province has been divided over a number of sub-areas that all have been separately assessed in July 2013. The areas include: Samet Island community, Harbor village, Ruby Bay, Nual Bay, Custard Apple Bay, Bamboo Bay, Phrow Bay, Crescent Bay and Crystal sand Bay. The result of study show that public participation included: providing consultation, involvement, collaboration were implemented in Samet Island community mostly. This was calculated as percentage over the sub items as 72.22%, 68.89%, 72.22% and 74.44%. Except for the topic of empowerment, which was implemented in Custard Apple Bay only and calculated as 71.43%. In all arrears where implemented the public topic were implemented the level of participation varied between moderate (60.00 - 69.99%) to well (from 70 - 79.99%). However, all forms of participation that were assessed in Phrow Bay reach the level pass-moderate. The main conclusion of this study is that sectors in developing project organization that manage environment should improve public participation process. This research may be as the tool of management to assess public participation in environmental tasks by more improving and developing.

Keywords: compensation of environmental impact; public participation; Samet Island crude oil leak

1. Introduction

According to crude oil leak in Phrow Bay of Samet Island Rayong province on the 26th July 2013, it took impact of environment widely in aspect of physical, biological, human use value and human life quality of people of island and there were implementation to solve the impact of environment and resources comprehensively and concisely among. In this implementation, it should be solving of people life quality that was impacted from crude oil leak in both physical health and socio economic. Once of impact of socio economic impact problem, there should be compensation process for the losing of people income from career especially the career concerning tourism. Because the information about the impact of Phrow Bay took losing of income of people living and career concerning tourism all Samet Island.

Besides, compensation of impact being occurred with socio economic and life quality of peoples impacted for careers about tourism in Samet Island that in addition compensated being completely for income losing. It should be public participation implementation altogether for consistent of impacted people needs. In public participation implementation mentioned might be run by concerning sectors by without recognition for the truth of public participation and it might be not implemented effectively and thoroughly in all stake holder people in area of island.

By this suspect mentioned above, there should be study to check and compare the result of public participation implementation for environmental impact compensation separated by tourism area in Samet Island.

2. Materials and Methods

2.1. Method 1 Applying process to measure Public participation from the principle of International association for public participation, 2014 that divide as 5 patterns in Table 1.

Table 1. Shows 5 patterns of public participation by the principles of the International Association for Public Participation

Pattern of Public participation	Participation activities of each patterns
1. Inform	Printing media, Billboard, Radio, local TV.
2. Consultation	Meetings, Public forums, etc.
3. Involve	Representative of the people attending the event.
4. Collaboration	Representatives of the people into consideration.
5. Empowerment	Committee of people to set the measurement

2.2 Setting questionnaire to question samples (impacted people) about the attitude of Public participation implementation in compensation of environmental impacts from crude oil leak in Samet Island Rayong and setting scale of attitude as 5 level as follow.

2.2.1 Most	=	5
2.2.2 Much	=	4
2.2.3 Moderate	=	3
2.2.4 Little	=	2
2.2.5 Least	=	1

2.3 Separating area of Samet Island to analyze data by character of data as follow

2.3.1 Samet Island community

2.3.2 Harbor village

2.3.3 Ruby Bay

2.3.4 Nual Bay

2.3.5 Custard Apple Bay

2.3.6 Bamboo Bay

2.3.7 Phrow Bay

2.3.8 Crescent Bay

2.3.9 Crytal sand Bay

2.4 Collecting data by formula of W.G. Cochran (cited in Teerawut, 2000) that calculated as 323 cases. Because of fitting of people proportion who career concerning tourism in Samet Island, the number of samples were collected data as 241 cases

2.5 Data Analysis

2.5.1 Setting the calculation of raw data to be percentage of public participation in environmental impact compensation by formula of Danai and Deachit, 2013 below.

$$\frac{Total\ scores\ of\ public\ participation\ in\ compensation\ (\sum score\ case\ 1\ to\ 241)}{Total\ highest\ score\ of\ public\ participation\ in\ compensation\ (5\times 241)} \times 100$$

2.5.2 Setting Public participation implementation measuring by consider the percentage of public participation in impact compensation as 5 levels follows

2.5.2.1 Since 50.01 to 60.00 percent	=	pass
2.5.2.2 60.01 to 70.00 percent	=	moderate
2.5.2.3 70.01 to 80.00 percent	=	well
2.5.2.4 More than 80 percent up	=	very good.

2.6 Discussing public participation implementation in compensation in environmental impact compensation of tourism place.

3. Results and Discussion

3.1 Result 1 General data of sample

3.1.1 Number and percent of sample separated by area were summarized in table 2 and Fig. 1.

3.1.2 Primary data of samples; gender, education, time of residents, and occupational summarized in table 3 to table 6**.**

Table 3 - 4 shows that most of the sample 59.34 as female and 46.06% as male, education proportion of sample in primary school is the most proportion as 41.91% and the proportion of higher than bachelor as 2.08% is the least, most of sample are peoples from another province as 59.34% and live in Samet Island average as 22 years, sample as people come from other countries and lives in Samet Island average 17 years as 2.07% is the least, samples trading is the most proportion as 26.14% and pick-up truck service is the least as 4.17%.

Table 2. Number and percentage of samples by area

Area	Amount	Percent
Samet Island community	18	7.47
Harbor village	59	24.48
Ruby Bay	16	6.64
Nual Bay	16	6.64
Custard Apple Bay	21	8.71
Bamboo Bay	33	13.69
Phrow Bay	19	7.88
Moon crescent Bay	28	11.62
Crytal sand Bay	31	12.86
Total	241	100.00

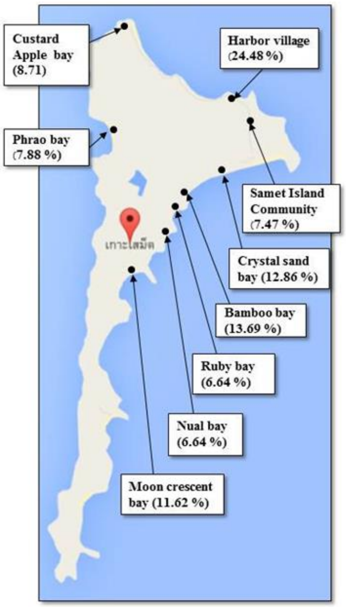

Figure 1. Map presents area of data collection

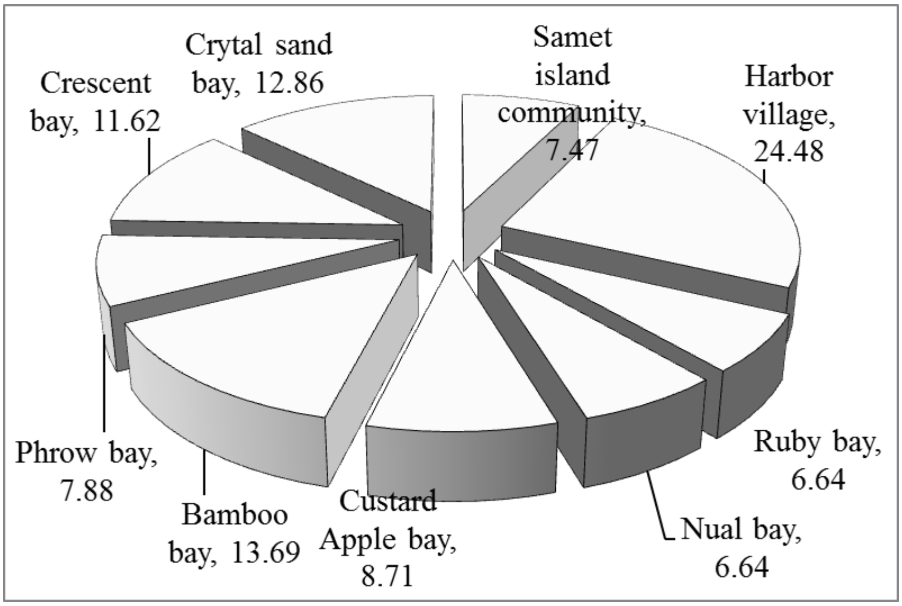

Figure 2. Circle chart presents proportion of sample separated by area

Table 3. Presenting of gender and education of sample.

Gender	Number		Education	Number	
	Cases	Percent		Cases	Percent
Male	111	46.06	Primary school	101	41.91
			Secondary school	44	18.26
			High school/ Vocational	41	17.01
			diploma	9	3.73
Female	130	53.94	Bachelor degree	27	11.20
			Higher than bachelor	5	2.07
			Others	14	5.81
Total	241	100.00	Total	241	100.00

Table 4. Presenting of homeland living period and career of sample.

Homeland	Number		Living period (average)	Occupation	Number	
	Cases	Percent			Cases	Percent
Local people	93	38.59	45 years	Rental Housing	26	10.79
				Food shop	25	10.37
				Pick-up truck service	10	4.15
Other provinces	143	59.34	22 years	Rental motorcycle	21	8.71
				Trade	63	26.14
Other countries	5	2.07	17 years	Employee	46	19.09
				Others	50	20.75
Total	241	100.00		Total	241	100.00

Table 5. Summarizing of public participation implementation percentage in environmental impact compensation of tourism by the opinion of sample.

Area	Information	Consultation	Involve	Collaboration	Empowerment
Samet Island community	72.22	68.89	72.22	74.44	67.78
Harbor village	67.80	65.76	66.10	69.15	64.07
Ruby Bay	66.25	*58.75*	63.75	65.00	68.75
Nual Bay	63.75	62.50	60.00	65.00	70.00
Custard Apple Bay	66.67	64.76	65.71	63.81	71.43
Bamboo Bay	69.09	*58.18*	63.03	66.67	67.27
Phrow Bay	66.32	62.11	61.05	*57.89*	63.16
Crescent Bay	67.86	66.43	65.71	65.71	65.00
Crystal sand Bay	70.32	61.94	63.87	70.32	69.68

3.2 Measuring public participation implementation in environmental impact compensation separated by tourism area in Samet Island; the result of measuring is concluded in table 5 and further described below.

Table 5 shows percent of public participation in impact compensation of tourism by the opinion of sample. For the pattern of participation, it could be considerate that there were implementations of all patterns in all area mostly in moderate level (60.01 to 70.00%) and well level (70.01 to 80.00%). Except in Ruby Bay and Bamboo Bay, public participation was implemented in Consultation as pass level. As same as Phrow Bay, there was public participation implementation in Collaboration as pass level too.

3.3 By bar chart showing public participation percent of impact compensation by area, it is able to explain as follow.

3.3.1 Fig. 3 by the opinion of sample, pattern “Information” was implemented in Samet Island community area mostly as 72.22% being in good level. There was implementation in pattern of information in Nual Bay area at least as 63.75% being in moderate level. Meanwhile Phrow Bay the direct impacted area was implemented as 66.32% being in moderate level. Anyway by overview, pattern information of public participation implementation was implemented since good to moderate level.

3.3.2 Fige 4 by the opinion of sample, pattern “Consultation” was implemented in Samet Island community area mostly as 68.89% being in moderate level but it is less than pattern of information. For the least implementation in pattern of consultation area is Bamboo Bay as 58.18% being in pass level. For Phrow Bay the direct impacted area directly was implemented as 62.11% being in moderate level. In overview, pattern consultation of public participation implementation was implemented since moderate to pass level.

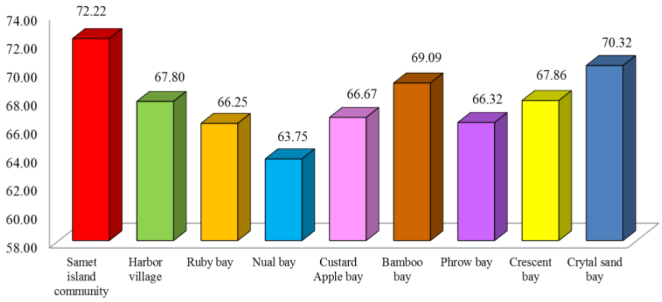

Figure 3. Bar chart compares percent of samples opinion about public participation in compensation of socio and environmental impacts in pattern “information” separated by area.

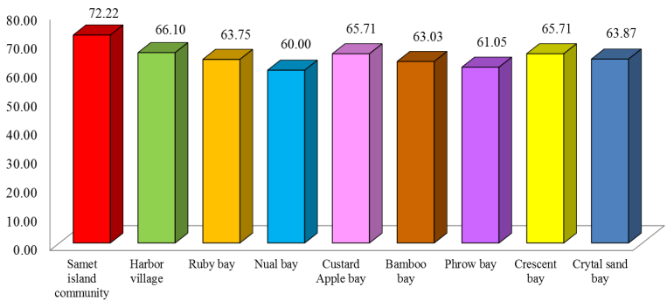

Figure 4. Bar chart compares percent of samples opinion about public participation in compensation of socio and environmental impacts in pattern “consultation” separated by area.

3.3.3 Fig. 5 by the opinion of sample about pattern "Involve", there was implementation in Samet Island community area mostly as 72.22% that is equal with information pattern and in same level in good. For area that was implemented in pattern of involve at least was Nual Bay as 60% being in moderate level. Phrow Bay the direct impacted area was implemented as 61.05% being in moderate level. In conclusion, there were public participation implementation in pattern of involve since good to moderate level.

3.3.4 Fig. 6 by the opinion of sample of public participation, pattern "Collaboration" was implemented in Samet Island community area mostly as 74.44% that was most percentage in all area and in moderate level. Meanwhile are that there was implementation of collaboration at least is Phrow that was direct impacted area as 57.89% in pass level. In overview, pattern collaboration of public participation implementation was implemented since good to pass level.

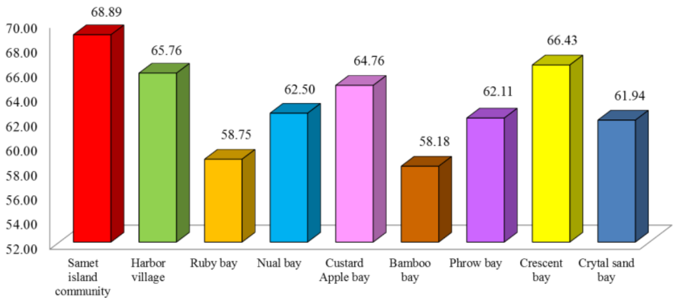

Figure 5. Bar chart compares percent of samples opinion about public participation in compensation of socio and environmental impacts in pattern "involvement" separated by area.

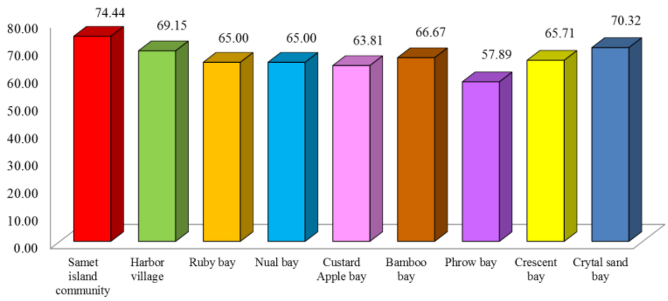

Figure 6. Bar chart compares percent of samples opinion about public participation in compensation of socio and environmental impacts in pattern "collaboration" separated by area.

3.3.5 Fig. 7 by the opinion of sample in pattern "Empowerment", there was implementation in custard apple Bay area mostly as 71.43% in good level that is different from the result of another 4 patterns. Meanwhile, the area that was implemented in pattern of empowerment at least was the direct impacted area Phrow Bay as 63.16% being in moderate level. When considering in overall image, the pattern of empowerment of public participation was implemented since good to moderate level.

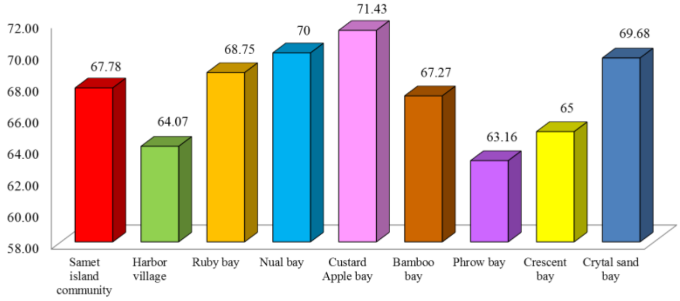

Figure 7. Bar chart compares percent of samples opinion about public participation in compensation of socio and environmental impacts in pattern “Empowerment” by area.

3.4 In overview of percent of public participation percentage patterns and area by the opinion of sample is showed and compared as bar chart in Fig. 8.

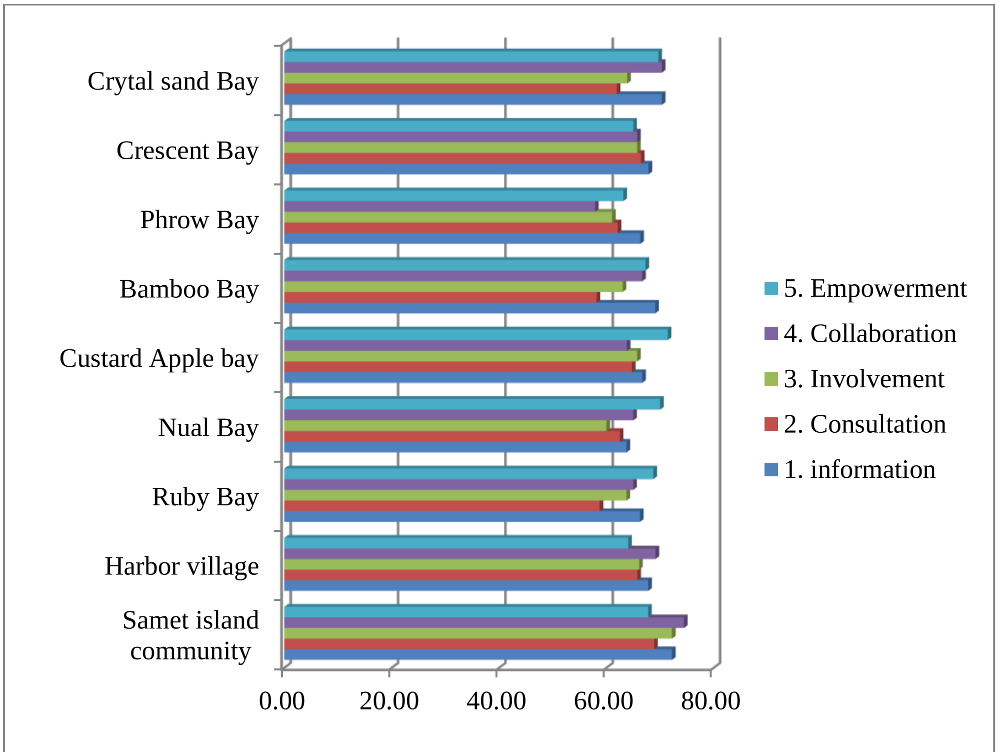

Figure 8. Bar chart compares percent of opinion of sample about public participation implementation in environmental impact in overview of all patterns and all area.

4. Conclusion

The result of research concerning public participation implementation for environmental impact compensation in case of crude oil leak Samet Island Rayong Province separated by tourism area is able to be summarized the results of the inspection and the relevant facts are as the following.

1. Noted in overview of public participation implementation result in all patterns, it found that the most number of sample area “Harbor village” as 24.48% was not area that sample’s opinion showed result of public participation implementation in all pattern mostly. Anyway, when considering the result of sample opinion of public participation in overview. The result found that although the percentages of public participation implementation would rather be different in each patterns and each area, it would able to be considered that the percentage is still since pass to good level.

2. The methodology of this research was developed by applying 5 patterns of public participation principle (Inform, Consultation, Involve, Collaboration, Empowerment) to use as process by basic statistic for inspecting the efficiency of public participation implementation in any public participation of all environmental task that various sectors among government and private sectors can apply it to evaluate their own public participation implementation.

3. The result of this research presents that developing project implemented public participation effectively in emergency case of crude oil leak in tourism place. It is different from the result of Danai and Deachit, 2013 that study the public participation in environmental monitoring of Bangpakong Combined Cycle Power Plant number 5 in case of normal situation that the result found 5 patterns of public participation implementation in both environmental preventing and monitoring are average as < 60% that is lower than case of Samet Island crisis.

4. By the issue in last line of 3, it is possible to set hypothesis that the situation of crisis and emergency may take high or low efficient of public participation implementation. Anyway, this hypothesis needs to be proved by more depth researches. Besides, there also should be the hypothesis about relationship among the patterns of public participation and area that would be analyzed and discuss in detail in the future.

Acknowledgements

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Non-formal Leaders as Intermediates for the Creation of Environmentally Aware Behavior with Regard to Arsenic Contamination of Surface Water from the Klongkram Watershed, Tha Utae Sub-district, Kanchanadit District, Surat Thani Province

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Abstract

The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Chaipatthana Foundation and environmental faculty of Kasetsart University Bangkhen campus implemented a study on the environmental impact of a disaster in 2015. This assessment was conducted at the Klongkrarm watershed in the Tha Utae sub-district of Kanchanadit district in Surat Thani province. During the assessment there was discovered the landslide area contain arsenic contamination in the surface water. As a result this research focused on the possibility of setting up an environmental education program for knowledge transfer on the properties of arsenic by addressing non-formal leaders of the local population. This knowledge transfer about acknowledgement, understanding and applying measures with regard to the arsenic contamination is separated into 3 parts: (1) the knowledge about the arsenic compounds and its toxicity (2) the point sources and (3) the removal of arsenic. The assessment in the pretest sampling showed that 47.15 percent of the interviewees know arsenic. 50.50 percent of them understanding the problems of the compound and only 49.78 percent can apply knowledge to deal with the compound. And the assessment in the posttest 75.57 percent of the interviewees knows arsenic. 78.97 percent of them understanding the problems of the compound and 77.05 percent can apply knowledge to deal with the compound. From the study research showed that after the target group received the information about arsenic contamination in surface water by the lecturer in training program they are more increased knowledge, understanding and are able to apply measures of arsenic contamination respective. The sampling group for this research included 11 volunteers

Keywords: non-formal leaders; environmental behavior; arsenic contamination

1. Introduction

The research area located at the klongkram watershed, Tha-Uthae Sub-district, Kanchanadit District in Surat-Thani province. The area comprises about 23.10 km^2 where a fan shaped characteristical, and meandering stream is present. The physical landform includes high mountains and there are many mineral resources present. Rock formations comprise predominantly granite and limestone. Most of the parental materials of the minerals present contain arsenic elements. A landslide occurred in 2015 and since was expected that this would impact the surface water quality, a project was started by The King's Royally Initiated Laem Phak Bia environmental research and development project, and Chaipatthana Foundation conducted research in 2015. An action plan was written and the assessment 's result were presented in a water quality report (Onanong Phewnil, 2015) there was found that there was arsenic contamination in surface water and sediment at 9 sampling stations level varied from: SW1>0.0015, SW2>0.0201, SW3>0.0088, SW4>0.0018, SW5>0.0083, SW6>0.0090, SW7>0.0089, SW8>0.0068, SW9>0.0068 mg/L. The samples of surface water showed that arsenic contamination is present in all station. Especially, station 2 SW2 where the concentration of arsenic is 0.0201 mg/l which exceeds water quality standards in surface water set.

The villagers living at Klongkram watershed ThaUtae sub-district, Kanchanadit district, Surat thani province. Live in the area with the arsenic contamination. These people have no knowledge of the toxicity of arsenic, how it enters into the body nor, what threats are present to health. It is also not known to them, how one could remove the toxic compound out of the surface water. Bearing this in mind, the objective of this research study is to investigate the possibility of setting up an environmental education program for knowledge transfer on arsenic through Non-formal Leader as intermediates for Environmentally aware Behavior with regard to Arsenic Contamination in Surface Water at the Klongkram Watershed, ThaUtae Sub-district, Kanchanadit District, Surat Thani Province.

Herewith, this research creates scientific knowledge on the protection methodology, by knowledge transfer through non-formal leaders as intermediate for creating awareness with local inhabitants at the Klongkram watershed.

1.1 Problems

The presence of the arsenic contamination in surface water and sediment is shown in table 1 below.

As shown in Table 1, the presences of heavy metals such as Arsenic matter (As) in surface water and sediment in the rainy season and dry season for 9 sampling stations at Klongkram watershed. The amount of arsenic compounds especially SW2 (station 2) is 0.0201 mg/L there exceeds water quality standards and found the arsenic compound in sediment at the similar station in rainy season higher to 132.421 mg/L and 102.89 mg/L on dry season. Herewith, found the arsenic compound on the SW2 higher than other stations because of this station it's a headwater

2. Materials and Methods

To conduct the assessment this researching studies on experimental creating by tool Medias about knowledge transfer of the arsenic contamination to Non-formal leaders at Klongkram watershed, Tha-Utae Sub-district, Kanchanadit District, Suratthani province. Next , an analysis and assessment of the target group was conducted by pretest and posttest questionnaire. This wile comparing before and after the execution of the training program in which in total of 11 volunteers participated.

Table 1. Water quality and sediment

Sampling station	Parameters		
	Arsenic (As) (Stream water) (mg/L)	Arsenic (As) (Sediment) (mg/Kg)	
	Rainy/Dry	Rainy	Dry
SW1	<0.0015	2.098	1.54
SW2	0.0201	132.421	102.89
SW3	0.0088	4.009	4.62
SW4	0.0018	4.463	6.22
SW5	0.0083	7.653	17.55
SW6	0.009	3.937	11.99
SW7	0.0089	13.004	9.93
SW8	0.0068	4.779	15.3
SW9	0.0068	3.685	5.72
Standard	0.01	Not exceeds 3.9	

Source: Alisa Doungsawat, 2017

Sources of standard: Unite sated Environmental Protection Agency (US EPA). 2015

2.1 Method

2.1.1 Assign the target group

2.1.2 Construct training course

2.1.3 Data collection

2.1.4 Analysis

2.2 Materials

2.2.1 Questionnaires: pretest – posttest

2.2.2 Lecturer

2.2.3 Handbook

2.2.4 Poster

3. Result and Discussion

This research was separated into 3 parts. The first consisted of making the theoretical frame word by developing and using a questionnaire for pretest and posttest. The second, creating a medium for knowledge transfer to the target group and finally the result of knowledge transfer about arsenic contamination for Non-formal leaders (Volunteer group) as described bellows:

3.1 Non-formal leaders analysis

The sampling group in this study is non-formal leaders of local people they are no headman, no personnel but they know the people in the area well. The non-formal leaders have expertise in the different aspects of the area and its population such the forest, tree species, rivers, geography the area. According to, the survey in 11 peoples could be analyses as shown in Table 2.

Table 2. Demographic characteristics (non-formal leaders for natives)

Gender (%)	Age (Both average)	Education (%)	Status (%)	Religion (%)	Family member	Time of living at
90.91	49	81.82	100	100	4	30

As shown in table 2, the information of the 11 interviewees is 10 persons are male (90.91%) and female 1 person is female, (9.09%). The age ranges (including both male and female) between: 41-55 years, with an average of 49 years. 81.82% has obtained primary education (grade 6) while the secondary (grade 8) accounted for 18.18%. The marital status was 100 percent and 100 percent of these people were farmers. All of them are Buddhist and the number of members in the household range between 2-9 people, with an average of 4 persons/family of these people 18.18 percent was born at Na-Tham village. The time people spent living at Na-Tham village was between (14-40) years with at an average of 30 years

3.2 Non-formal leader behaviors

3.2.1 Water consumption behavior

The data analysis of interviews on the preliminary data collection, the target group (Non-formal leader for natives) as shown in table 3, Water is used mostly during the morning (90.90%), followed by 72.72 percent in the evening and 45.45 percent during the day, as show in table 3

Table 3. Water consumption behavior in a daily

Type of activities	Number of peoples			%		
	Morning	Noon	Afternoon	Morning	Noon	Afternoon
Cooking	9	2	7	81.82	18.18	63.63
Dishwasher	7	3	8	63.63	27.27	72.72
Toilet	10	5	7	90.90	45.45	63.63
Washing	7	3	2	63.63	27.27	18.18
Other activities	2	2	2	18.18	18.18	18.18

3.3 Arsenic knowledge and management approach (pretest)

Knowledge and comprehension of arsenic matter and management practices was assessed in an interview with the total of 55 questions from the primary questionnaire. These questions can be divided into three parts such as knowledge, comprehension, and application (Bloom, 2010) as follows:

Table 4. The knowledge, comprehension and applicable on arsenic matter of target group (pretest)

Approach	Amount of people	Percentage (%)
Knowledge	11	47.15
Comprehension	11	50.50
Applicable	11	49.78

As shown in table 4, the data analysis in the body of knowledge about arsenic matter shows that of the sampling group only 47.15 percent knows about arsenic matter, 50.50 percent has comprehension of arsenic and 49.78 percent are able to apply measures (arsenic removal methodologies).

3.4 Arsenic knowledge and management approach (posttest)

On the table 5, the data researcher of knowledge, comprehension and apply of arsenic matter in the posttest questionnaire shows that 75.57 percent knows about arsenic matter, 78.97 percent has comprehension of arsenic and 77.05 percent are able to apply measures. As the result there are increased of knowledge, understanding and apply. That mean the training program is successful.

Table 5. The knowledge, comprehension and applicable of arsenic matter of target group (posttest)

Approach	Amount of people	Percentage (%)
Knowledge	11	75.57
Comprehension	11	78.97
Applicable	11	77.05

3.5 The requirement for training course

On the table 6, we can observe a suitable time period for non-formal leaders. The ones who can be able to join training course during week day on average 45.46 percent, followed by Saturday and Sunday 18.18 percent, Monday to Friday 9.09 percent respectively.

Table 6. The suitable weekday for training

Day	Time		Percentage (%)
	Morning	Afternoon	
Everyday	-	5	45.46
Mon-Friday	-	1	9.09
Weekend	-	2	18.18
Monday	-	-	-
Tuesday	-	1	9.09
Wednesday	-	-	-
Thursday	-	-	-
Friday	-	-	-
Saturday	-	2	18.18
Sunday	-	-	-

3.6 The suitable place for training course for non-formal leader for natives

As showed in table 7, Most of the volunteers (Non-formal leaders) requested suitable places for the training course. Suitable place included: the village community (54.55%), then 36.36 percent at the volunteer house and 9.09 percent at the headman house.

Table 7. The place for training

Places	Amount of peoples	Percentage
The village community	6	45.45
The headman house	1	9.09
The volunteer house	4	36.36

3.7 The suitable media to using for training

As shown in table 8, the media use for training the non-formal leader for natives can choose more than one answer. (multiple answer). About 63.63 percent want the human media (lecturer), about 54.54 percent asked handbook and 27.27 percent for poster as a guide.

Table 8. The media to be used for training

Type of media	Amount of peoples	Percentage (%)
Handbook	6	54.54
Human media (lecturer)	7	63.63
Poster	3	27.27
Remark: In this section the volunteers can select multiple answers		

3.8 The format used in the training for non-formal leader for natives

As shown in table 9, the format in use for training for non-formal leader for natives found that 63.63 percent they agree for brainstorming and 36.36 percent for lecture

Table 9. The training activity for non-formal leader for natives

Activity	Amount of peoples	Percentage (%)
Brainstorming	7	63.63
Lecture	4	36.36
Total	11	100

3.9 Public relations styles in the community

As table 10, the personal public relations in the community found that 72.73 percent, agrees in knowledge transfer through non-formal leader for natives (volunteer groups) and 27.27 percent through the headman village.

Table 10. The personal media for public relation

personal media	Amount of peoples	Percentage (%)
Through volunteers	8	73.73
Through headman	3	27.27
Total	11	100

Possibility environmental education program on Non-formal leader

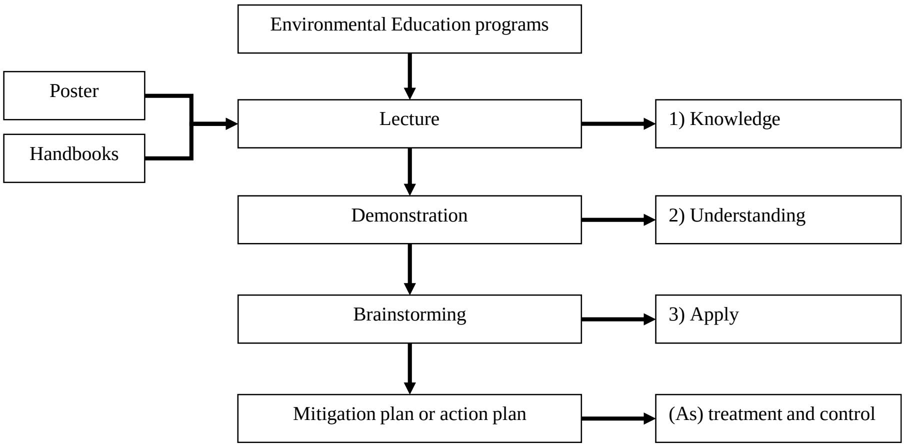

Figure 1. Environmental Education program for Non-formal leaders

4. Conclusion

This study assessed Non-formal Leaders as intermediate for the creation of environmentally aware behavior with regard to Arsenic Contamination of Surface Water from the Klongkram Watershed, Tha-Utae Sub-district, Kanchanadit District. It showed that that the non-formal leaders have limited knowledge on arsenic. These people do not known about the point source, toxicity, how the compounds enter into the body and how arsenic matter could be removed from the surface water. The data analysis of theoretical framework about arsenic showed that of the sampling group (non-formal leaders) before make the training program only 47.15 percent has knowledge of arsenic matter, 50.50 percent has understanding and only 49.78 percent can knowledge about applicability of measures, and after the training program measurable in 75.57 percent has knows of arsenic matter, 78.97 percent has understanding and 77.05 percent are able to apply of measures. As the result, there are increased of knowledge, understanding and apply. That mean the training program is successful. The knowledge transfer needs the right application of media appropriate for the sampling group. This requires an effective selection of media for training by means of lecturer, poster and handbook

Acknowledgment

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Public Participation in Environmental Impact Assessment of Real Estate Development Projects in Nakhon Ratchasima, Thailand

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Abstract

This study aims at investigating the public participation (PP) process in Environmental Impact Assessment (EIA) of real estate development projects in Nakhon Ratchasima, Thailand. The investigation was conducted based on key aspects of PP in EIA as suggested by ONEP (B.E.2549) and Nadeem and Fischer (2011). Public participation legal requirements, stakeholders, information quality, timing & venues of PP, and public consultation methods are the focus when assessing how public participation in EIA was conducted according to 21 approved EIA reports of real estate development projects (between B.E. 2537-2558), prior to semi-structured and in-depth interviews related to cases of focused project type (condominium projects). The findings suggest that legal enforcement of such regulations are subject to area and community context. Meanwhile, paying attention to delivering project information to stakeholders is key which could help ensure that most relevant stakeholders can take part in the EIA process as well as mitigating conflicts among them.

Keywords: public participation; environmental impact assessment; real estate development project

1. Introduction

The policy driver on public participation in environmental impact assessment (EIA) at international level was initially addressed in Rio Declaration on Environment and Development in 1992 at the United Nations Conference on Environment and Development (UNCED); "*Environmental issues are best handled with participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities"* (Principle 10). This has led to the implementation of such approach at the national level, and Thailand is one of countries applying public participation in EIA processes as suggested by the National Environmental Quality Act (NEQA). At present, public participation in the EIA process has been conducted regarding section 6 of NEQA B.E. 2535 as well as a guideline suggested by Environmental Impact Evaluation Bureau of ONEP in 2006 (B.E. 2549). Real estate project development which is a project type requiring EIA by legal regulation has emerged increasingly leading to undesirable consequences. For example, landscape characters/ impacts (Pattaya Daily News, 2016), visual impacts/ intrusion, and affected public infrastructure. These issues could lead to conflicts if there is a lack of effective public participation in EIA processes. Therefore, this paper focuses on how public participation in the EIA process has been conducted and what gaps are requiring mending in terms of stakeholders, information quality, timing & venues of PP, public consultation methods, and legal requirements of public participation.

Table 1. Key informants related to 7 projects of condominium development in Nakhon Ratchasima

Group	**Code**	**Area**		**Type of interview**		**Total**
		Maung district	Pak Chong district	Unstructured interviews	Semi-structured interviews	
Community members	CM#1 CM#2 CM#3 CM#4 CM#5 CM#6	1	5	4	2	**6**
Local authorities	LA#7 LA#8 LA#9 LA#10 LA#11	-	5	-	5	**5**
Total		**1**	**10**	**4**	**7**	**11**

2. Materials and Methods

A qualitative approach is applied in this study. Data collection was conducted based on documentary analysis prior to interviews (semi-structured and in-depth) (Yin, 2009). Approved EIA reports of 21 real estate development projects in Nakhon Ratchasima between B. E. 2537-2558 were accessible from ONEP database website (http://eia.onep.go.th/index.php) for investigating public participation in EIA process. Semi-structured and in-depth interviews were conducted, later on, with 11 stakeholders (community members (CM) and local authority (LA) representatives, as shown in Table 1); related to 7 projects of condominium development, the focused project type in this study, developed in Maung district (n=1) and in Pak Chong (n=6).

The framework based on PP in the EIA guideline as suggested by ONEP, 2006 and Nadeem and Fischer, 2011 was applied, as well as thematic analysis of the data collected.

3. Results and Discussion

The framework based on PP in EIA guideline as suggested by ONEP (2006) and Nadeem and Fischer (2011) applied in this study includes ***public participation legal requirements, stakeholders, information quality, timing & venues of PP, and public consultation methods.*** Regarding the documentary analysis, the 21 approved EIA reports of real estate development project types include: land allocation (n = 6), hospital (n = 4), hotels/ resorts (n = 4), and condominium (n=7) projects, the results are presented in Table 2.

In terms of ***legal requirement***, 19 projects had applied public participation in the EIA process, timing in conducting PP in EIA is considered appropriate according to a suggestion provided by ONEP (Natural Resource and Environment Ministerial Notification Re: specification of types and scales, rule and regulations for projects or activities which require to conduct the environmental impact assessment and report preparation), as shown in Table 2. Interviewed key informants agree that availability of legal regulations related to PP in EIA process are sensible but levels of enforcement vary, depending on the area context. However, it was commented that public participation practice as suggested in relevant regulations are not sufficiently clarified associate with project type characteristics such that minimum requirement was applied to save cost PP (LA#8, LA#10). It has been highlighted that contextual factors, i.e. 'characteristics of actors', could influence governance mechanisms towards different outcomes (Arts *et al.*, 2012).

In terms ***timing and venues***, Public participation in EIA processes in this study were conducted at the stages of scoping and public review of the EIA process. It was considered appropriate, as suggested by the legal requirements, that PP at each stage was conducted between 2-3 days, as presented in Table 2. Meanwhile, PP venues were located in the neighbourhoods of project zones. For example, surrounding communities and local authority offices where stakeholders were be able to gather and take part in PP process.

As demonstrated in Table 2, ***stakeholders*** taken part in EIA process of the 19 projects include (a) community members residing near project locations, (b) local authority leaders/ representatives, (c) receptors in sensitive zones adjacent to the project location i.e. schools, religious places, hospitals, (d) project proponents and (e) EIA practitioners. However, interview findings suggest that there were stakeholders who missed the opportunity of PP in the EIA process, due to not being informed. I.e. community member residing in adjacent of 360 Pano @ khao yai project (CM#5), local organizations related to the location of Baan Rub Lom project (LA#7). This could suggest that there were still gaps in delivering information or project updates between project developer/ EIA practitioners and stakeholders. It is essential that project developer should support any possible opportunity that relevant stakeholders can participate in EIA process so that agreement between them can be achieved with the least conflict level (Soponpats, 2012).

Concerning ***information quality***, it is essential that suitable patterns of information related to the project, i.e. language used and contents, should be provided while paying attention to the background of stakeholders who derive from various groups; as well as opportunity to share their views/ anxiety towards project development (Environmental Impact Evaluation Bureau, 2006; Nadeem and Fischer, 2011). Documentary analysis results based on 21 EIA reports showed that the information provided to the stakeholders include: the project description, positive and negative impacts, and impact mitigation measures. It was commented by the interviewees that the language used in information delivery was too complicated, with a massive contents thus too time consuming for reading (LA#8). After the EIA process, in some cases local authority had not received final version of the EIA reports (LA#7). This could lead to lack of public confidence towards environmental impact mitigation in project development (LA#9, LA#11). This suggests that there are gaps in communication between project developers / EIA practitioners and relevant stakeholders. Creighton, 2005 emphasized that it is vital that two-way communication as well as interaction among relevant authorities and stakeholders should be taken into account when conducting public participation.

In terms of ***public consultation methods***, most cases adopted questionnaire surveys (quantitative method). In only 2 cases questionnaire surveys were applied along with public and 2 cases applied qualitative method; in-depth interviews coupled with focus group approach, as shown in Table 2. It can be considered that level of public participation in the EIA process of the cases in this study are at initial levels as public information and consultation, referring to the International Association for Public Participation, 2007). Interviews results suggested that public participation methods should be conducted based on community context and level of understanding among involved stakeholders towards project development and EIA practice. (LA#7, LA#9). As it was considered by the interviewees that delivering information as well as its methods were applied in limited patterns (i.e. via leaflets and notice board), therefore, number of participants in EIA process was limited (LA#8, LA#10, LA#11). According to the research findings, methods and techniques applied in the public participation process should be integrated based on relevant stakeholder groups and their backgrounds so that they can see their roles, contribute their parts, and recognise its impact clearer. Sujitto, 2003 suggested that applying multiple/ diverse methods in EIA public participation could lead to better understanding as well as significance of findings gained from public participation in EIA process.

Table 2. Public participation in EIA process of real estate development project in Nakhon Ratchasima (B. E. 2537-2558)

<table>
<tr><th>Project name / B.E.</th><th>Type of project</th><th>PP in EIA process</th><th>Legal requirement</th><th>Stake holders</th><th>Timing & venues of PP in EIA process</th><th>Information quality</th><th>Public consultation methods</th></tr>
<tr><td>Land and House Park Korat[1]/2540</td><td>Land allocation</td><td>-</td><td>- NEQA B.E. 2535</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Maharat Nakhon Ratchasima Hospital[2]/2551</td><td>Hospital</td><td>-</td><td>- NEQA B.E. 2535</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>P. Phaet 2 Hospital[3]/2554</td><td>Hospital</td><td>Yes</td><td rowspan="19">- NEQA B.E. 2535
- ONEP B.E.2549 (Guidelines of public participation and social impact assessment of environmental impact assessment)</td><td>a & e</td><td rowspan="19">Timing;
- scoping stage
- public review stage
- 2-3 days

Venues;
- near project locations such as, surrounding communities and local authority offices</td><td rowspan="19">Include;
- project description
- positive & negative impacts
- impact mitigation measures</td><td>- Questionnaire survey</td></tr>
<tr><td>Baan Eua Arthorn (Sung Noen)[4]/2554</td><td>Land allocation</td><td>Yes</td><td>a, b, d & e</td><td>- Questionnaire survey
- Public meeting</td></tr>
<tr><td>Baan Eua Arthorn (Phimai)[5]/2554</td><td>Land allocation</td><td>Yes</td><td>a & e</td><td>- Questionnaire survey</td></tr>
<tr><td>Baan Eua Arthorn (Chok Chai) [6]/2554</td><td>Land allocation</td><td>Yes</td><td>a, b, d & e</td><td>- Questionnaire survey</td></tr>
<tr><td>Suranaree University Of Technology Hospital[7]/2554</td><td>Hospital</td><td>Yes</td><td>a, b, c, d & e</td><td>- Questionnaire survey
- Public meeting</td></tr>
<tr><td>C.P. Leadership Development Institute[8]/2555</td><td>Condominium</td><td>Yes</td><td>a, b, c & e</td><td>- Questionnaire survey</td></tr>
<tr><td>Magnolias 4 Hotel[9]/2555</td><td>Hotel/ Resort</td><td>Yes</td><td>a, b, c & e</td><td>- Questionnaire survey</td></tr>
<tr><td>Baan Eua Arthorn (Ban Ko)[10]/2555</td><td>Land allocation</td><td>Yes</td><td>a & e</td><td>- Questionnaire</td></tr>
<tr><td>CPL City[11]/2555</td><td>Hotel/ Resort</td><td>Yes</td><td>a, b, c & e</td><td>- Questionnaire</td></tr>
<tr><td>Baan Rub Lom[12]/2555</td><td>Condominium</td><td>Yes</td><td>a, c & e</td><td>- Questionnaire</td></tr>
<tr><td>Kantary Hotel[13]/2555</td><td>Hotel/ Resort</td><td>Yes</td><td>a, c & e</td><td>- Questionnaire survey
- Focus group</td></tr>
<tr><td>Muang Mai Phaendinthong 8[14]/2556</td><td>Condominium</td><td>Yes</td><td>a & e</td><td>- Questionnaire survey</td></tr>
<tr><td>Baan Eua Arthorn (Hua Thale 2)[15]/2556</td><td>Land allocation</td><td>Yes</td><td>a & e</td><td>- Questionnaire survey</td></tr>
<tr><td>23 Degree Estate (Condo)[16]/2556</td><td>Condominium</td><td>Yes</td><td>a, b, c & e</td><td>- Questionnaire survey</td></tr>
<tr><td>Bangkok Hospital Ratchasima[17]/2556</td><td>Hospital</td><td>Yes</td><td>a & e</td><td>- Questionnaire survey</td></tr>
<tr><td>360 Pano @ khao yai[18]/2556</td><td>Condominium</td><td>Yes</td><td>a & e</td><td>- Questionnaire survey</td></tr>
<tr><td>DusitD2 Khao Yai Hotel[19]/2556</td><td>Hotel/ Resort</td><td>Yes</td><td>a, b, c & e</td><td>- Questionnaire survey
- In-depth interviews</td></tr>
<tr><td>Swan Lake Khaoyai[20]/2558</td><td>Condominium</td><td>Yes</td><td>a, b, c & e</td><td>- Questionnaire survey</td></tr>
<tr><td>Khao Yai Foresta[21]/2558</td><td>Condominium</td><td>Yes</td><td>a, b, c & e</td><td>- Questionnaire survey</td></tr>
</table>

Source: [1]Pre-Development Consultant Co., Ltd. (1997)
[2], [7] Khon Kaen University (2008, 2011)
[3], [18] Consultants of Technology Co., Ltd. (2011, 2013)
[4], [14], [17], [21] Southeast Asia Technology Co., Ltd. (2011, 2013a, 2013b, 2015),
[5], [6], [15] Asia Lab and Consultant Co., Ltd. (2011a, 2011b, 2013)

Remarks: a: community members residing near project locations
b: local authority leaders/ representatives
c: receptors in sensitive zones adjacent to the project location.
d: project proponents
e: EIA practitioners

4. Conclusion

The findings in this study suggest that the availability of legal requirements of public participation of the EIA process in Thailand provides the opportunity to stakeholders to participate in the EIA of real estate development projects. Legal regulation enforcement would require more strengthening while the opportunity for stakeholder engagement should be ensured for all groups. Area context is a key factor that needs to be taken into account when conducting PP in EIA, particularly for communicating with the stakeholders as well as for delivering the information. Selecting suitable public consultation methods for PP in EIA is essential in achieving desirable outcomes. It is vital that stakeholders are allowed to participate open mindedly in this process. It is also recommended that more research studies in this field are required such that gaps arising in EIA public participation process can be improved.

Acknowledgements

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The Impact of Land Use Land Cover Change on Ecosystem Services in the border zone of Kasungu National Park, Malawi

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Abstract

The ecosystems are affected by land use land cover changes that require understanding of their impacts for the sustainable management of ecosystems to continue benefiting from their services. The increase in demand for more agricultural land, new settlements and high dependence on fuel wood exerts pressure to adjacent protected areas. The pressure is evidenced by illegal activities that include illegal tree cutting, encroachment, poaching and fence vandalism in protected areas such as national parks as well as forest reserves. This study was conducted in the border zone of Kasungu National Park (KNP) to assess the impacts of the land use land cover changes on ecosystem services. Valuation of ecosystem services has been employed using Constanza model reviewed in 2011. The model uses the Value Coefficients for land class and its coverage to estimate the value of ecosystem services. Remote sensing technique was employed to analyze changes for the period of 20 years from 1995 to 2015 using supervised classification. The results show the decline of ecosystem services from $367m in 1995 to $321m, in 2015, representing an average rate of $2.3 million per year. The largest loss was between 1995 and 2005 greatly contributed by loss of forestry resources at a rate of $8.7 million per year. The results of the study will be useful in raising awareness in KNP border zone and providing information for decision making on land use land cover.

Key words: ecosystem services; land use land cover; remote sensing; supervised classification; community based natural resources management; environmental degradation

1. Introduction

The interaction between built, social, human and natural capital (assets) produce the human well-being through ecosystem services (Constanza *et al.*, 2014). The ecosystem services categories include provisioning services, regulating and cultural services (McVittie and Hussain, 2013). Many of these ecosystem services do not have market values. This often result to undervaluation of ecosystems services in decision making process. In case of land use land cover (LULC), decision makers face a great challenge to choose between conservation of ecosystems and the increasing of human activities (Intralawan and Rueangkitwat, 2016). For this reason, better accounting for the ecosystem goods and services is needed.

1.1 Ecosystem in Malawi

The total surface area of Malawi is approximately 11.85 million hectares (m ha) where 9.41m ha (80%) is land and 2.44m ha is water (Yaron *et al.*, 2011). Protected areas cover about 55% of land and play a great role in providing ecosystem services (GoM, 2014). Provisioning services provided by forestry include fuel wood, poles, shelter and fruits (Chiotha and Kayambazinthu, 2009). For instance, communities at Majete Wildlife Reserve generate \$8,000 annually from sales of resources such as bamboos, reeds and thatch grass (Chana, 2015). Research also shows that natural resources contribute as much as 12.8% to the country's Gross Domestic Product (GDP) (Yaron *et al.,* 2011). Out of the three natural resources sectors, forest contributes the highest value in form of charcoal and firewood which is not accounted for in the national statistics. The other two sectors are fisheries which is one of the major sources of protein and wildlife that generates income through tourism.

Aquatic ecosystems comprise of largely Lake Malawi, but there are also other water bodies including small lakes, lagoons, wetlands, rivers and man-made reservoirs (GoM, 2014). These provide home to a diversity of fish and other vertebrate species e.g. Lake Malawi species accounts for 4% of the world fish species, 95% of them are endemic. The aquatic ecosystem such as wetlands also provide diversity of ecosystem services.

1.2 Degradation of Ecosystems

Ecosystems services are being affected by environmental degradation that result in habitat loss which is a threat to plant and animal species (GoM, 2015). One of the contributing factors is high dependence on agriculture for livelihood. FAO, 2013 found that the major changes of LULC correspond to the expansion of agricultural areas at the expense of tree areas. For instance, agricultural land increased by 1.6% which is similar proportion of decrease for tree areas between 1990 and 2010. This is because almost 90% of the country's population rely on agriculture that contributes up to 80% of export earnings dominated by tobacco (53%) (GoM, 2009). Tobacco has contributed to forest degradation as mentioned by ECODIT (2013) and give an example of southeast of Nyika National Park in the Henga Valley in Rumphi District. In this area, the demand of forest products rises when tobacco growing increases due to construction of tobacco sheds and racks. Tobacco farming system experienced changes in 1990s resulting from political and public service reforms in the country. There was market liberalization that led to the increase in number of small holder farmers including tobacco famers (Nsiku and Botha, 2007). The increasing demand and use of biomass energy has also led to conversion of natural ecosystems and habitats thereby causing biodiversity loss. The main source of energy is biomass energy, 89% and household has the highest demand of 83% (Fig. 1) (GoM, 2009).

Such human activities have caused ecological as well as economic impact affecting community livelihood. The negative impacts of environmental degradation include water shortage and pollution, reduction of wind breaks as well as siltation or drying up of rivers (Chiotha and Kayambazinthu, 2009). There has also been loss of wildlife over the years due to poaching and encroachment. For example, elephant population at Kasungu National Park (KNP) declined by 86% from 2,853 in 1979 to 391 in 1995, and nationally declined by 50% (Mauambeta and Kafakoma, 2010). Encroachment has resulted to loss of 60km² in all protected areas to neighbouring communities contributing to high incidences of human wildlife (GoM, 2007)**.** There is also a decline of fish catch in most water bodies especially the key fish species such as Chambo due to overfishing (GoM, 2015).

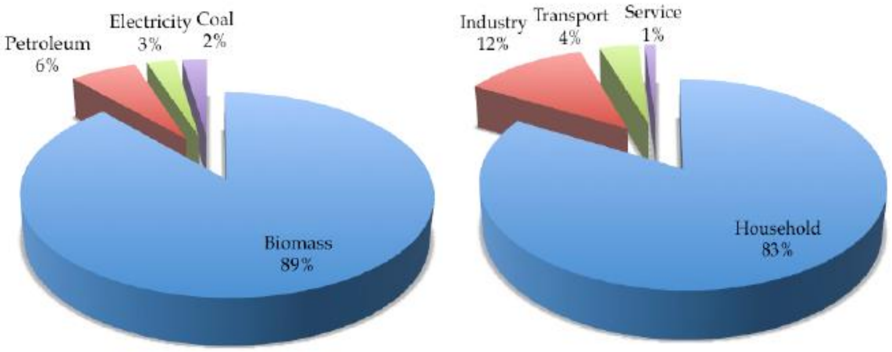

Figure 1. Total energy demand by source (left) and sector (right) (GoM, 2009)

1.3 Initiatives in Managing Natural Resources

There have been various initiatives to address environmental degradation. One of them is Community Based Natural Resources Management (CBNRM) that promote managements of natural resources by communities on customary land (Mauambeta *et al.*, 2010). ECODIT, 2013) indicates that about 785 hectares of natural woodlands regenerated in border zones of 5 protected areas in Malawi while 8.3 million trees were also planted. The Collaborative Management (Co-management) approach is a modified form of CBNRM that encourages stakeholders such as bordering communities, Private sector and NGOs to actively participate in management of protected areas. This has led to benefit sharing scheme in form of revenue sharing and Resource Use Programs (RUP) (GoM, 2007). For instance, community organisation for Liwonde National Park received $20,000 between 2014 and 2015 from park revenue (Chana, 2015). Communities also harvest resources such as wild fruits, mushroom, honey, bamboo, reeds, palm leaves, thatchgrass (GoM, 2007). Government also adopted Public Private Partnership (PPP) approach that allow private sector to manage national parks and wildlife reserves through the contract agreement. African Parks-Majete became the first case of PPP in 2003 when African Parks Network (APN) took over Majete Wildlife Reserve to improve tourism (Chana, 2015). Energy saving technologies such as fuel-efficient stoves are being promoted to reduce reducing consumption of wood and for sustainable management of forests.

1.4 Problem Statement

As Malawi is experiencing rapid land conversion and degradation, this is also the case with Kasungu district where tobacco is the major cash crop. There are CBNRM and co-management initiatives for KNP (Kasungu National Park) border zone that has led to RUP and establishment of VNRCs. **However,** there are also numerous illegal activities such as illegal tree cutting and animal poaching. Below is the figure of illegal activities related to habitat degradation for period of 1995 to 2000 (6 years) and 2011 to 2016 (6 years) at KNP. It shows most of the illegal activities are increasing.

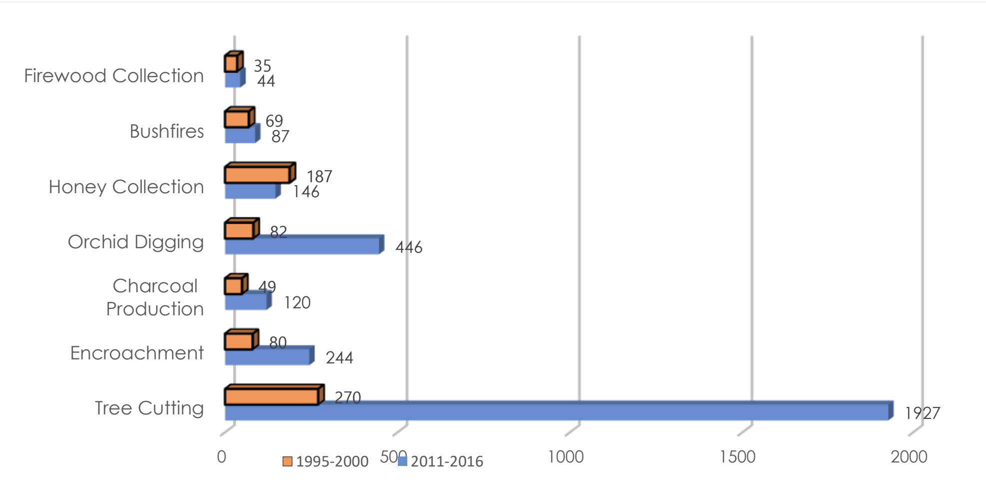

Figure 2. Illegal activities related to land cover for 1995-2000 and 2011-16

Note. The numbers represent number of (site of) incidences for firewood collection; bush fires; honey collection; charcoal production, and encroachment. They also represent the actual numbers for tree cut and orchids dug. (Source: DNPW Kasungu; GoM, 2014)

The availability of such data might be a subject to effective approaches on park management such as patrol coverage and data collection system that result to data availability. It may also reflect the scarcity of natural resources on the land or inadequate knowledge on sustainable management of resources. This study therefore focuses on the pressure from border zone on park resources related to land cover. This research aims to assess the impact of the LULC changes using an ecosystem services approach. This research will focus in the bordering zone of Kasungu National Park (KNP) as a case study by assessing the change in land cover classes using remotely sensed images for 1995, 2005 and 2015. The specific research objectives are:

a. Estimate LULC changes and assess their impact on ecosystem services in the bordering area by using remote sensing and ecosystem service valuation technique.

b. Discuss the interventions for sustainable management of natural resources to improve land cover in the border zone for any protected area

2. Materials and Methods

There are many valuation methods for ecosystems services including market approach, contingent valuation technique, travel cost, hedonic pricing, avoided cost and benefit transfer technique. Parks and Gowdy, 2012 say that the choice of the method is determined by the objective of the study. The objectives can be: raising awareness and interest; policy analysis; urban and regional land use planning; and payment for ecosystem services. Type of ecosystem services as well as budgets and time also influence choice of valuation method. Talberth, 2015 adds that types of benefits and their use values also require to be considered when choosing methods.

Researchers have also combined valuation techniques and incorporated technology such as remote sensing and Value Coefficients (VC). The global VC for biosphere ecosystems were estimated by Costanza *et al.*, 1997. This approach involves merging some ecosystem biomes and estimate their unit values per hectare (VC) to valuate ecosystem services. The use of remote sensing can also be combined with the traditional methods while VC can be adjusted to reflect local conditions. For example, Whitham *et al.*, 2015 used three different valuation approaches which were: valuation coefficients from Constanza, 1997 model; adjusted coefficients using the local knowledge; and social survey. The model was reviewed in 2011 by considering the criticisms, increased stress on ecosystems, recent studies as well as changes in human, social and built capital (Constanza, 2014) (see also section 2.5).

2.1 Techniques for processing remote sensing data

LULC has been preferred in this study because it is one of the most easily detectable indicators of human intervention on land as indicated by Di Gregorio *et al.*, 2016. This is because it can change quickly over time and can also show dynamics of the earth surface resulting from a variety of drivers and factors. The technique requires selection from a range of options including image type, classification algorithm, training/validation data, processing techniques, ancillary data, and target classes (Khatami *et al.*, 2015). To make these decisions image analysts utilize their individual experience and expertise as opposed to the collective knowledge of the field.

2.2 Study Area

The study area is the border zone is on the eastern side of KNP (Kasungu National Park) stretching for about 128,000 meters covering 124,800 ha. KNP is located on the western side of Kasungu district extending along the international boundary of Zambia, central Malawi, Southern African region (see figure below).

Kasungu district is located between 12^0 48' S and 33^0 21' E while KNP centers upon 12°55'S, 33°08'E. The altitude ranges from 1020 m to 1130 meters above sea level with minimum temperature of 12^0C and 24^0C maximum (Kuyah *et al.*, 2016).

Just like most parts of the country, Kasungu is dominated by agricultural land that constitutes about 47 percent (FAO, 2013). Kasungu district had a population of about 606,000 and density of 80 people/km^2 in 2008 while the border zone had 152,900 (NSO, 2008). Farmers established Kasungu Farmers Trust in 2000 during market liberalization and formed partnership with Limbe Leaf Tobacco Company for support (Nsiku and Botha, 2007). According to data sourced from DNPW Kasungu, communities also derive their livelihood from harvesting wild resources through RUP (Resource Use Program). For example, about 2000 people each year harvested mushroom, caterpillar, thatch grass and honey worth MK16.8m ($80,600) between 2009 and 2013. KNP border zone lies within the Lilongwe Kasungu plain livelihood that base on similarity of factors for agricultural production (MVAC, 2005). Households are categorized basing on income: poor income households who earn 70 – 85 $/year; middle income with 245 to 280 $/yr; and better off income who get 550 to 635 $/yr.

This zone experiences some hazards such as dry spells, waterlogging and localized wash-aways. There are also periodic hazards such as drought and outbreaks of army-worm on maize every ten years (MVAC, 2005).

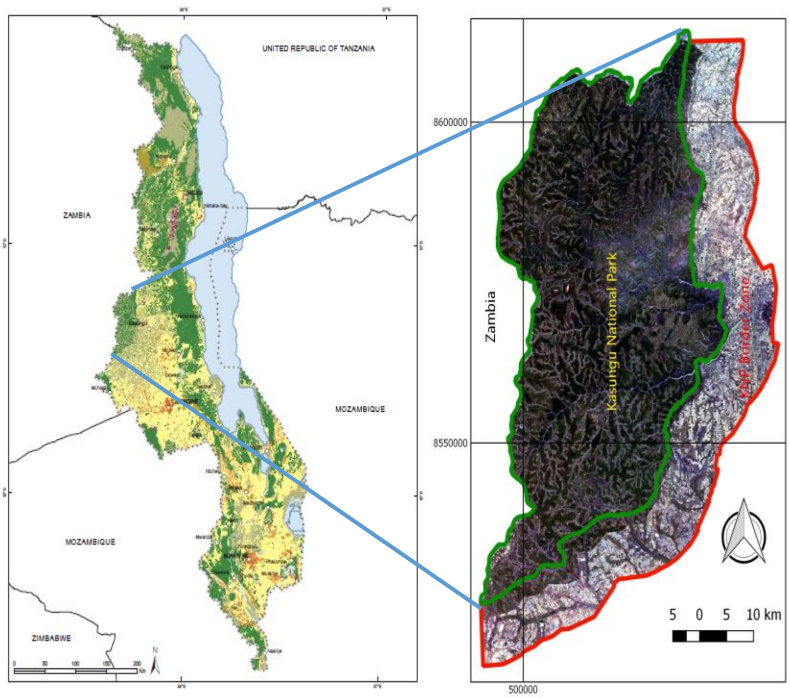

Figure 3. Map of Malawi showing location of Kasungu National Park and the border zone (zoomed section) (Source: FAO, 2013)

2.3 Data Collection Methods and Instruments

The remote sensing imagery was the principal data sourced from US Geological Services on EarthExplorer: http://earthexplorer.usgs.gov/. The satellite images had resolution of 30x30m captured by the following satellite sensors:

- Landsat 5 Thematic Mapper (TM) that captured imagery on August 1, 1995 and June 09, 2005
- Enhanced Thematic Mapper Plus (ETM+) Landsat 8 for 2015 imagery, captured on June 15, 2015.

The images captured during this period were preferred as it is dry season while vegetation is still green and the cloud cover is low. About 400 Ground Coordinate Points (GCPs) were collected for image classification and accuracy assessment within 10km border zone. This classification used the Constanza *et al.*, 1997 classification of biome such that the study area falls under the terrestrial biomes, presented in the table below. Ancillary data included topographic map of Kasungu and shapefile for KNP boundary were sourced from DNPW Kasungu.

Table 1. Description of land class types for the study area

Land Class Type	**Description**
Bare Areas	Unproductive areas such as rocks and degraded land
Built Areas	These include houses, roads, schools and trading centers
Cropland	Currently cultivated areas
Forest	Areas of trees including shrubs
Rangeland	Areas of grass, herbaceous plants
Rivers	Open water bodies, sedentary or flowing
Wetlands	Marshes, seasonally or permanently flooded areas

2.3 Image Classification

Remote sensing imagery was analyzed using QGIS software Version 2.18.2 and Geographical Resources Analysis Support System (GRASS) Version 7.0.5. The satellite imagery was re-projected to UTM WGS84, Zone 36 S to correct geometric errors. This research employed supervised classification of the Maximum Likelihood Classification (MLC) algorithm. Half of GCPs, 200 points were used for the 2015 imagery classification to identify land classes with similar spectral characteristics. This classification criteria were based on putting all areas with identical reflectivity in a certain spectral band into the same class (Elachi and van Zyl, 2006). Visual interpretation was also integrated because it is an effective method for the studying of changes in LULC (Butt *et al.*, 2015). Different combinations in the RGB (Red-

Green-Blue) format were made for visual interpretation as recommended by Mather and Koch, 2011. Vectors for training areas were created in QGIS basing on the identified land class types at a scale ranging from 1: 5,000 to 1: 10,000. The image classification was processed in GRASS and post classification processes were done in QGIS. Classification process was repeated to minimize noise for the images.

The other half of the GCPs (200) were used for assessing the accuracy of the classification technique for 2015 imagery. Equivalent sets of GCP were captured from 2005 and 1995 images for their respective assessment. A confusion matrix table was created on actual classification (producer accuracy) and predicted classifications (user accuracy). It provides the basis for describing classification accuracy and help in refining the classification (Foody, 2001). The accuracy was measured by computing overall accuracy, omission error (and user accuracy) and commission error (and producer accuracy).

- The overall accuracy is the percentage was calculated by dividing 'Number of correct points' by 'Total number of points' multiply by 100%.
- Omission error refers to the proportion of observed features on the ground not classified in the image.
- Commission error indicates the probability that a pixel classified into a given category represents that category on ground

2.5 Estimating Ecosystem Services Values

Before calculating, each of the LULC (land use land cover) classes was matched with the appropriate biome of the Constanza model and its value coefficients (VC) reviewed in 2011 (Table 2).

This model is used because there are no regional VC available for this nature of study in Malawi. However, the application of this model has considered the availability of services in the study area, the land use systems and the socio-economic status for the country. The available services in the study area were identified and those which are not applicable have been excluded, an approach employed by Whitham *et al.*, 2015. The criteria of exclusion based on the following:

- The location of the study area which is rural such that services like waste treatment occur at negligible proportion
- The nature of grassland is a result if forest degradation and abandoned cultivation where succession is disrupted by bush fires and cultivation.
- The impact of farming on ecosystem services presented in Section 1.2 and the major ecosystem services in the area. For example, genetic resources and recreation has negligible value on the cropland.

To calculate ESV, the coefficient value for each class was multiplied by the size of the area obtained from classified images for each land class using the formula: $ESV=\sum (Ak \times VCk)$ where Ak is the area (ha) and VCk is the value coefficient ($/ha/yr) for land class category 'k'.

Table 2. Value Coefficients for ESV

Ecosystem Service	**Land Class Type**				
	Forest	**Rangeland**	**Lakes/Rivers**	**Cropland**	**Urban**
Gas Regulation	4	9			
Climate Regulation	711	40		411	905
Disturbance Regulation	19				
Water Regulation	3	3	7514		14
Water Supply	143	60	1808	400	
Erosion Control	100	44		107	
Soil Formation	14	2		532	
Nutrient Cycling	66				
Waste Treatment	120	75	918	397	
Pollination	9	35		22	
Biological Control	169	31		33	
Habitat/Refugia	619	1214			
Food Production	270	1192	106	2323	
Raw Materials	152	54		219	
Genetic Resources	448	1214		1042	
Recreation	953	26	2166	82	5740
Cultural	1	167			
Total Global VC	**3,801**	**4166**	**12512**	**5568**	**6659**
Adjusted VC	**3,681**	**1439**		**3096**	

Note. The highlighted VC were excluded to adjust VC for the KNP border zone. The unit values are for 2007 International Dollar per hectare per year (USD/ha/yr) (Constanza *et al.*, 2014)

3. Results and Discussion

The results from the image classification indicate area for each land class type, accuracy assessment of the image classification and the change in the ecosystems services values over time. The classification showed that there are five main classes of land types: built areas; crop land; forest; grass/range land; and rivers. Below are the classified images (Fig. 4).

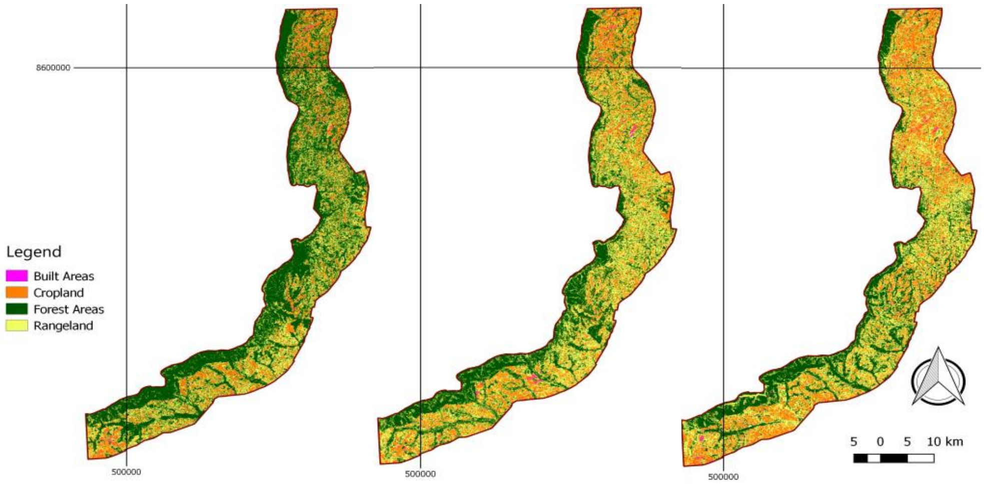

Figure 4. Classified images for 1995 (left), 2005 (center) and 2015 (right)

Summary statistics was processed for each time-period to show the coverage for each land class type for the study area covering 124,800 hectares (Table 4). Using the adjusted VC for each land class (Table 3) and their respective coverage (Table 4), ESV were estimated. The change in ESV has been estimated by calculating the difference between the estimated values for each land category between 1995 and 2005, 2005 and 2015 (Table 5).

Table 3. Coverage for land class types in KNP border zone for 1995, 2005 and 2015

Land Class Type	Coverage (Hectares)			Coverage (Percent)			Average Rate (ha/yr)		
	1995	2005	2015	1995	2005	2015	1995-15	1995-05	2005-15
Built Areas	984	1,123	1,757	0.79	0.90	1.41	39	14	63
Crop Land	21,600	29,241	34,879	17.31	23.45	27.95	664	764	564
Forest Areas	68,400	45,936	38,331	54.81	36.84	30.72	-1,503	-2,246	-761
Range Land	33,817	48,392	49,816	27.10	38.81	39.92	800	1,457	142
Total	**124,802**	**124,692**	**124,783**						

Table 4. Estimated Values for Ecosystem services for KNP border zone

Land Class Type	Values			ESV Changes		
	1995	**2005**	**2015**	**2015 - 1995**	**2005 - 1995**	**2015 - 2005**
Built Areas	0	0	0	0	0	0
Cropland	66,873,136	90,528,990	107,985,415	41,112,279	23,655,855	17,456,424
Forest	251,781,688	169,092,183	141,095,380	-110,686,308	-82,689,505	-27,996,803
Rangeland	48,663,253	69,635,369	71,684,792	23,021,539	20,972,116	2,049,424
Total ESV	**367,318,077**	**329,256,542**	**320,765,588**	**-46,552,489**	**-38,061,535**	**-8,490,954**

Note. The values are in 2007 USD

3.1 Image Classification

The results for image classification indicate that the dominating land class types for the study period of 20 years (1995 to 2015) are cropland, forest and range land while built areas is almost negligible (Table 4). The land class type of water was not included because of its negligible proportion for the study area. This probably explains why FAO (2013) study did also not indicate coverage for water bodies for the study area. However, it indicates that the whole Kasungu district of 806,390 ha total size has 93 hectares of water.

Relatively high heterogenous land classes were observed in range land and cropland. This is reflected in the error matrix contributing to higher omission and commission errors ranging from 16 – 40%. This is probably because rangeland is a transition land class between forest and cropland. Heterogeneous characteristics in cropland may have resulted from land clearing methods and regeneration of species for newly opened or recently abandoned gardens. Built areas were also heterogeneous because of small sized buildings associated with play grounds, market grounds and trees. The overall accuracy indicates the reliability of the classification of the image and the report statistics. It was found to be 85% ranging from 83% for 1995 and 2015 to 89% for 2005. The overall producer accuracy was 84.2% and 80.2 for user accuracy. These results are within recommended range as shown by related studies. For instance, overall producer's accuracy for Tolessa et al. (2017) study was 82.1%, while overall user's accuracy was 87.9%.

3.2 Changes in Ecosystem Service Values

The results show that total ESV for the study area has decreased from \$367.31m in 1995 to \$320.77m in 2015 at an average rate of \$2.33m per year. This loss is mainly due to loss of forest values by \$110.69m at a rate of \$5.53m/yr. The overall decrease was highest during the first-time period when \$38.06m (\$3.81m/yr) was lost while forest had lost \$82.69m (see Table 4 above and Figure 4 below). This decrease in forest values is also shown by decrease in forest coverage by 24% at an average rate of 1,503 ha/yr and the highest rate of 2,246 ha/yr during first-time period. This forest cover decline is reflected in the increase of range land (13%) increase and cropland (11%). This implies that the changes in forest is at the expense of rangeland and cropland. This is largely contributed to by forest degradation where forests are cleared to open new farms close to national parks.

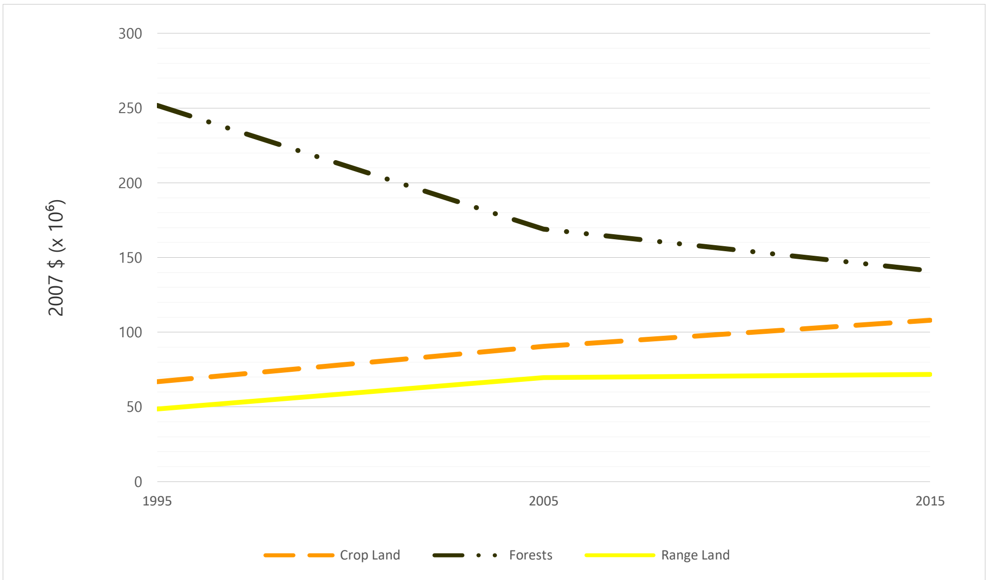

Figure 5. The trend of ESV values of land class types from 1995 to 2015

The first-time period coincided with the period of public service reforms such as market liberalization because of changes in political era from 1902 to 1994. The reforms resulted to negative response by communities that escalated deforestation through charcoal production on both private and customary land (Mauambeta, *et al.*, 2010). This trend is also supported by data on illegal activities at KNP that indicates high number of illegal incidences between 1995 to 2000 dominated by tree cutting where 270 were cut and 77 incidences of encroachment were observed. The market liberalization also led to increase of number of farmers who were encouraged to invest in tobacco production because of its high profits. Its price was highest in 1998 generating \$338m and thereafter decreased to \$249m in 2003 (Nsiku and Botha, 2007). The trend of declining ESV is therefore reflecting this scenario where reforms that influence LULC did not incorporate environmental aspect.

During the second-time period, there was reduction in the rate of decrease for the ecosystem services (Fig. 4). Total ESV decreased by \$8.49 (\$0.85m/yr) while forest decreased by \$27.0m (\$2.8m/yr). This is also shown by reduced rate of conversion of forest to other land uses from 2,246 ha/yr (1995-2005) to 761 ha/yr (2005 to 2015). The declining tobacco prices might be one of the contributing factors that affected investment in the crop.

Even though the rate of increase of cropland of 564 ha/yr during the second-time period is lower than first time-period (764 ha/yr), the rate of increase remains relatively high shown by the graph (Fig. 4). The rate of conversion of other land uses to rangeland greatly reduced from 1,457 ha/yr to 142 ha/yr which confirms that the loss of forest areas is mainly due to agriculture during the second-time period. One of the possible causes is increasing food production to meet the food demand by the ever-increasing population. Despite the declining tobacco prices, Malawi continues to rely on tobacco production due to unsuccessful efforts to diversify cash crops (Nsiku and Botha 2007). This implies that expansion of agricultural land into marginal and forest areas will continue lowering the ESV and well as causing climate change effects. This also show that policy on CBNRM and co-management had little impact to address unsustainable resource use. This is possibly because of inadequate capacity and technical support for co-management programs after the policy was adopted. Birdlife project is probably the major initiative after 12 years of policy adoption on co-management approach. The program was implemented by WESM Lilongwe in collaboration with DNPW to sustainably manage bird habitat around KNP. It led to increase in number of VNRCs from 48 in 2011 to 130 in 2016 and supported forestry as well as efficient energy programs. Co-management at Kasungu has been mostly RUP (Resource Use Programs) that has also been characterized by violations of rules shown by illegal harvest of honey and caterpillar (Fig. 1). This suggests poor implementation of the policy does not give maximum contribution to the achievement of the goal.

The loss of forest and the relative steady increase of cropland also suggests the pressure on land and scarcity of forestry resources. This is supported by data on illegal activities for the period 1995 to 2000 (6 years) and 2011 to 2016 (Fig. 1). The figure shows increase of illegal activities such as tree cutting (from 270 to 1,927), firewood collection (from 35 to 44) and encroachment (from 80 to 244). This confirms the dependence of border zone community on agriculture and forestry resources for livelihood. These illegal activities may further reflect lack of understanding on the impact of degradation of park ecosystem. Such incidences result to less attractive national park due to loss of animals thereby decreasing total ESV.

4. Conclusion and recommendation

This study used global value coefficients which were the readily accessible and comprehensive data set for ecosystem services valuation. These were then adjusted to reflect the local conditions. This has shown the need to develop regional VC that reflects the social economic status of the people in countries such as Malawi or southern African region.

The study has shown the declining of ecosystem services values from $367 million in 1995 to $321 million, in 2015. These results have therefore established directional change of ecosystem services which is helpful for generating interest, raising awareness and decision making. The decrease in value has been greatly contributed by loss of forests that are cleared for farming. However, synergistic can be made from forest conservation and agriculture promotion through agroforestry that requires greater government promotion and understanding of customary practices. The continued loss of ecosystem services in the border zone continues to exert pressure on protected areas, affecting the success of co-management approach. Recognition of co-management approach by sectoral policies such as land and agriculture would help to promote environmental programs.

Moreover, the results of this study can be used to as a dialogue platform for all stakeholders and bring awareness to the local authorities and communities. This would be useful incorporating environmental aspect in decision making to improve land use land cover.

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Effects of ZnO Nanoparticle on Plant Growth, Plant Stress, Zn Bioaccumulation in Water Hyacinth (*Eichhornia crassipes*)

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Abstract

The efficiency of water hyacinth (*Eichhornia crassipes*) to accumulate zinc (in any form) from zinc oxide nanoparticles (ZnO NPs) was investigated. Plants were grown hydroponically for 15 d in half-strength Hoagland's No. 2 solution with ZnO NPs at a concentration of 0, 3.5, 5 and 7.5 mg/L. The concentration of total Zn in the roots, stems and leaves was then determined by inductively coupled plasma mass spectrometry, while the oxidative stress and antioxidant enzyme activity of the plants were examined in terms of the leaf hydrogen peroxide (H_2O_2) level and catalase activity, respectively. By dry weight (DW), the relative growth rate (RGR_{DW}) of the roots was not significantly different in all treatments. However, while the RGR_{DW} of the stems and leaves were much lower than the roots, when grown in the presence of 3.5 mg/L ZnO NPs the stem and leaf RGR_{DW} were significantly greater than in 5 and 7.5 mg/L ZnO NPs. The levels of H_2O_2 and catalase activity in leaves of *E. crassipes* grown without ZnO NPs did not significantly differ over the 15-d culture period, but significantly increased in the presence of 3.5 mg/L ZnO NPs over the 15-d period. These plants could uptake high levels of Zn, with maximum Zn concentrations in the roots, stems and leaves after 15 d of culture with 7.5 mg/L ZnO NPs of 945.83±73.69, 129.11±5.93 and 61.44±3.13 mg/kg dry weight, respectively. Thus, *E. crassipes* has potential to be applied for phytoremediation of low concentrations of ZnO NPs from waste water or other solutions.

Keywords: ZnO nanoparticles; bioaccumulation; catalase activity; *Eichhornia crassipes*

1. Introduction

The contamination of heavy metals in aquatic environments is a major problem worldwide, especially in developing industrial countries, and threatens human health. Accordingly, wastewater contaminated with heavy metals can affect the ecosystem, including human health, through both direct consumption and indirect via aquatic foods derived from contaminated water (Tchounwou *et al.*, 2012).

Zinc oxide nanoparticles (ZnO NPs) are used in various industries in processing materials to products, including cosmetics, electronic and magnetic systems and amalgam for dental clinics. However, increasing concentrations of ZnO NPs in the environment, such as through the release of industrial and urban wastewater and leachates from sanitation land fields, will have a negative impact on the ecosystem, including human health. A high concentration of ZnO NPs in aquatic systems can readily be absorbed and accumulated in aquatic plants because Zn is an essential micronutrient for plants, although exposure to higher levels may detrimentally effect plants, such as causing retarded tissue, especially root, growth or degradation (Vaseem *et al.*, 2015; Zhao *et al.*, 2012).

Phytoremediation is one cleanup technology for a variety of organic and inorganic pollutants. There have been many studies on the efficiency of aquatic plants to clean up certain pollutants, such as the removal of chlorpyrifos by *Eichhornia crassipes* (Anudechakul *et al.*, 2015), duckweed (*Lemna minor*) and water lettuce (*Pistia stratiotes*) (Prasertsup and Ariyakanon, 2011), while the three aquatic macrophytes of *E. crassipes*, *P. stratiotes* and duckmeat (*Spirodela polyrrhiza*) were reported to be able to remove five heavy metals (Fe, Zn, Cu, Cd and Cr) as salts from wastewater to > 90% over 15 d. These plants accumulated the heavy metals in their tissues without any apparent toxicity or reduction in growth (Mishra and Tripathi, 2008). Likewise, water fern (*Azolla caroliniana*) was reported to have high toxic tolerant characteristics and a high bioconcentration ability to many heavy metals when grown on the surface water of an enriched fly ash pond from a coal based thermal power plant (Pandey, 2012).

Water hyacinth (*E. crassipes)* is a free-floating perennial aquatic plant that is widespread globally in tropical and subtropical climates (Rahmen and Hasegawa, 2011). It has a high tolerance to pollution and an ability to absorb heavy metals (Ingole and Bhole, 2003; Sighal and Rai, 2003) into its large biomass that has a relatively high production rate, making it of interest in wastewater treatment and remedial *in situ* environment treatment (Priya and Selvan, 2014).

When heavy metals enter plants tissues via the roots they elevate the level of reactive oxygen species (ROS), which can cause damage to the DNA, protein and lipids. Accordingly, plant cells have several antioxidative defence mechanisms, such as glutathione and glutathione reductase enzymes, superoxide dismutase, catalase, ascorbate peroxidase and polyphenol oxidase, to protect themselves against these oxidative stresses (Achille *et al.*, 2014). Previous studies have shown that heavy metals increased the activity of catalase and ascorbate peroxidase in plants (Lopez *et al.*, 2007). However, there is lack of information on the effects of ZnO NPs upon ROSs and catalase activity in aquatic plants.

In this study, the ability of *E. crassipes* to accumulate Zn in its tissues was investigated. In addition, tolerance to ZnO NPs, in terms of the hydrogen peroxide (H_2O_2) level, as an example ROS, and the activity of catalase (E.C 1.11.1.6), as an example detoxification enzyme, were determined.

2. Materials and Methods

2.1. Size analysis and morphology study of ZnO NPs

The ZnO NPs (particle size < 100 nm, density: 1.7 g/mL ± 0.1 g/mL) were obtained from Sigma-Aldrich. All suspensions were freshly prepared before each experimental setup and adjusted to pH 6.5. The as-obtained ZnO NPs were assayed with a PSD Laser particle analyzer (Mastersizer 3000 instrument, Serial n. MAL1099267, Malvern, U.K) to determine their hydrated size and density in solution. For their dry size and morphology, the ZnO NPs were dispersed in water, placed on carbon-coated 400 mesh copper grids and allowed to dry at room temperature before transmission electron microscopy (TEM) analysis using a HT 7700 (Hitachi, Japan) microscope, operated at 120 kV.

2.2. Experimental plants

The *E. crassipes* used in this study were collected from Prawet Burirom canal near King Mongkut's Institute of Technology, Ladkrabang at Bangkok, Thailand, and transported in polyethylene bags to the lab. Before any treatment, plants were disinfected by immersion in 0.01% (v/v) Clorox bleach for about 2 min to eliminate adhering algae and insect larva, and then rinsed with tap water followed by distilled water for 5 min each. The plants were then carefully examined and selected for a healthy appearance before being grown hydroponically for 2 weeks in an experimental tank containing half-strength Hoagland's No. 2 nutrient solution (without Zn). After this 2 week growth and adaptation period the plants were examined and selected to standardize them for wet weight (250 ± 5 g) and leaf size prior to use in the experiments.

2.3. Experimental design

The experimental design was based upon a complete randomized block design in two phases, as follows:

Phase 1. To evaluate the optimal concentration of ZnO NPs that is non-toxic but leads to the highest accumulated level of total Zn by *E. crassipes* over a 15-d period.

The treatments in this step were comprised of half-strength Hoagland's No. 2 nutrient solution (without Zn) and plant (i) ZnO NPs at 0, 3.5, 5 and 7.5 mg/L without plant (ii) and the same but also with plant (iii). The biomass, total Zn concentration in the plants and the Zn concentration in the culture solution in each treatment were measured after 0, 1, 3, 5, 7, 9, 11, 13 and 15 d of culture, with three replicates per treatment.

Phase 2. To investigate the tolerance of *E. crassipes* to ZnO NPs, in terms of the value of H_2O_2 and the catalase activity in the leaves, as examples of ROS and detoxification enzyme activity, respectively. The treatment in this step were comprised of half-strength Hoagland's No. 2 nutrient solution (without Zn) plus *E. crassipes* and ZnO NPs at 0 mg/L (control) and the optimal concentration determined in phase 1 above. The plant biomass and the leaf H_2O_2 concentration and catalase activity were determined on day 0, 1, 3, 5, 7, 9, 11, 13 and 15 of the culture, with three replicates per treatment.

2.4. Preparation of the nutrient solution and ZnO NPs

The culture vessels were placed in a greenhouse, each with 2.5 L of half-strength Hoagland's No. 2 nutrient solution (57.52 mg/L $NH_4H_2PO_4$, 1.43 mg/L H_3BO_3, 328.2 mg/L $Ca(NO_3)_2$, 0.04 mg/L $CuSO_4 \cdot 5H_2O$, 2.66mg/L $FeC_4H_4O_6 \cdot 2H_2O$, 120.38 mg/L $MgSO_4$, 0.008 mg/L H_2MoO_4 and 303.3 mg/L KNO_3, but no $ZnSO_4$ $7H_2O$). The volume of the solution in each container was maintained by adding distilled water daily as required to compensate for water lost through plant transportation and evaporation. The conditions in the greenhouse were controlled at 28–30 ºC, 65–75% relative humidity and 14 h/d light. The ZnO NPs were prepared as stock suspension in half-strength Hoagland's No. 2 nutrient solution at 100 mg/L and directly dispersed by ultrasonic vibration (Bandelin, Germany) for 30 min then diluted to 3.5, 5 and 7.5 mg/L

After the 2 week growth and adaptation period, plants were transferred to experimental pot with 2.5 L of half-strength Hoagland's No. 2 nutrient solution with ZnO NPs at 0, 3.5, 5 and 7.5 mg/L.

2.5. Plant sampling and analysis of total Zn levels in plant tissues

Plant samples were collected from each vessel on days 0, 1, 3, 5, 7, 9, 11, 13 and 15 of the culture period. Then, they were separated into roots, stems and leaves and weighed to derive the respective fresh weight (FW). They were then dried in an oven at 65 ºC for 48 h, cooled in desiccator and weighed to determine the respective dry weight (DW). The dried samples were then digested with 60%(v/v) HNO_3 at estimate 500 mg dry tissue/10 mL HNO_3 by microwave digestion (ETHOS One, Milestone, Italy) for 60 min. The obtained solution was diluted with distilled water to a final volume of 50 mL and analyzed for total Zn (in any form) content by inductively coupled plasma mass spectrometry (ICP-MS) using a Model iCAP Qc (Thermo scientific, Germany) instrument.

2.6. Determination of the leaf H_2O_2 concentration

The value of H_2O_2 in leaves was determined as described (Jena and Choudhuri, 1982). In brief, fresh leaves (50 mg) were ground in liquid nitrogen and homogenized in 500 µl extraction buffer (100 nM potassium phosphate buffer (pH 6.5) and 1 mM hydroxylamine). The mixture was then centrifuged at 10,000 *x* g for 15 min at 4 ºC (Universal 32R, Hettich Zentrifugen, Germany), the supernatant harvested and each 300 µL aliquot was added to 90 µL of reaction mix (0.3% (w/v) $Ti_2(SO_4)_3$ in 20% H_2SO_4). After 1 min the mixture was centrifuged at 10,000 *x* g for 10 min at 4 ºC and the absorbance of the supernatant was read at 410 nm using a UV-spectrophotometer (G1103A, Agilent, China). The H_2O_2 concentration was then estimated using a standard curve prepared with 7 known concentrations (0.25 –6 mM) of H_2O_2.

2.7. Determination of the leaf catalase activity

Catalase enzyme (E.C 1.11.1.6) activity was assayed in fresh leaves (100 mg). Leaves were ground in liquid nitrogen and homogenized in 1 mL of buffer (0.05 M potassium phosphate buffer (pH 7), 0.04 M dithiothretol, 1% (w/v) polyvinylpolypyrrolidone (PVPP) and 0.001 M phenylmethylsulfonyl fluoride (PMSF) in isopropanol), and then filtered. The filtrate was centrifuged (15,000 *x* g for 15 min at 4 ºC) and the supernatant was used as the source of the crude catalase enzyme. The total catalase activity was determined by adding 0.05 mL of the crude enzyme extract to 0.15 mL of reaction mix (50 mM potassium phosphate buffer (pH 7.0) and 10 mM H_2O_2) and incubated at 30 ºC. The absorbance at 240 nm was then measured in a UV-spectrophotometer during the first minute and up to 5 min of reaction time. Using the molar extinction coefficient of catalase (240 nm, $\varepsilon = 0.00436$ $M^{-1}cm^{-1}$) (Beers and Sizer, 1952; Mukhopadhyay *et al.*, 2012), the total enzyme activity was calculated, and then corrected for the amount of protein to give the specific catalase activity, as shown in Eq. (1);

$$\text{Specific catalase activity } (\mu\text{mole/min/mg protein}) = [(dA_{240}\text{min}^{-1}) \times Vf \times D]/(\varepsilon \times Vc \times Pc) \quad (1)$$

where Vf is the final volume (mL), D is the dilution factor, Vc is the volume of the crude extract (mL) and Pc is the total protein content of the crude extract (mg/mL).

The total protein in the leaf extract was determined as reported (Lowry *et al.*, 1951) using bovine serum albumin as the protein standard.

2.8. Statistical analysis

All the data were analyzed using the SPSS version 22 (Statistical package for the social science for windows) software using a One-way ANOVA followed by Turkey's HSD (Honestly Significant Difference) test, with significance being accepted at the $p < 0.05$ level.

3. Results and Discussion

3.1. Size analysis and morphology of the ZnO NPs

The hydrated size of the ZnO NPs was assayed using a PSD laser particle analyzer (Mastersizer 3000 instrument, Malvern, UK) at the Scientific and Technological Research Equipment Center (STREC), Chulalongkorn University Bangkok, Thailand. The result confirmed that the ZnO NPs used in this study had a size class estimate of 100 nm. (Fig. 1).

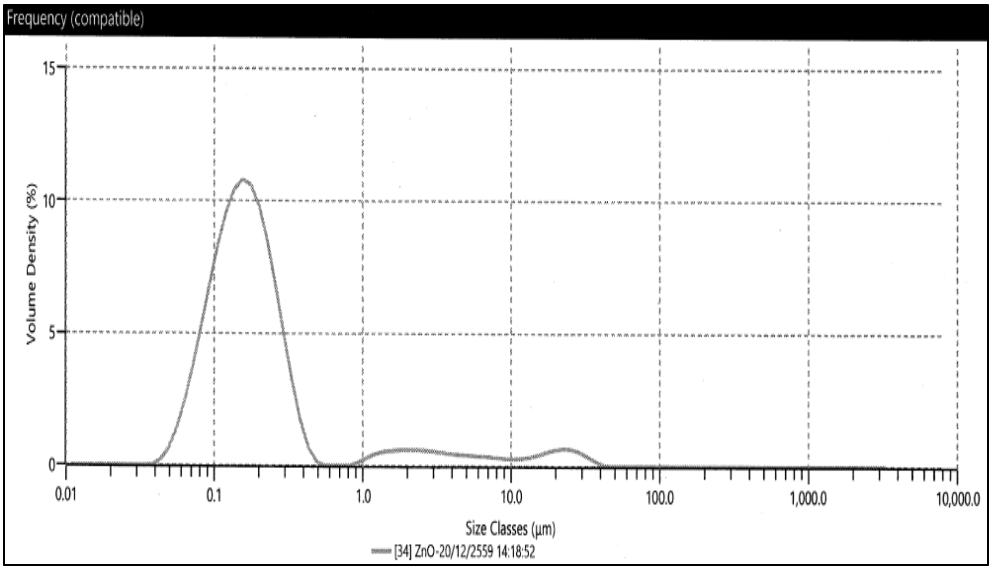


Figure 1. Hydrated size of the ZnO NPs used in this study, as assayed by the PSD laser particle analyzer.

The anhydrous size and morphology of the ZnO NPs were assayed by TEM analysis, where the morphology of the ZnO NPs was found to be in a wurtzite (hexagonal) structure form and of 20 ± 1 nm in size (Fig. 2).

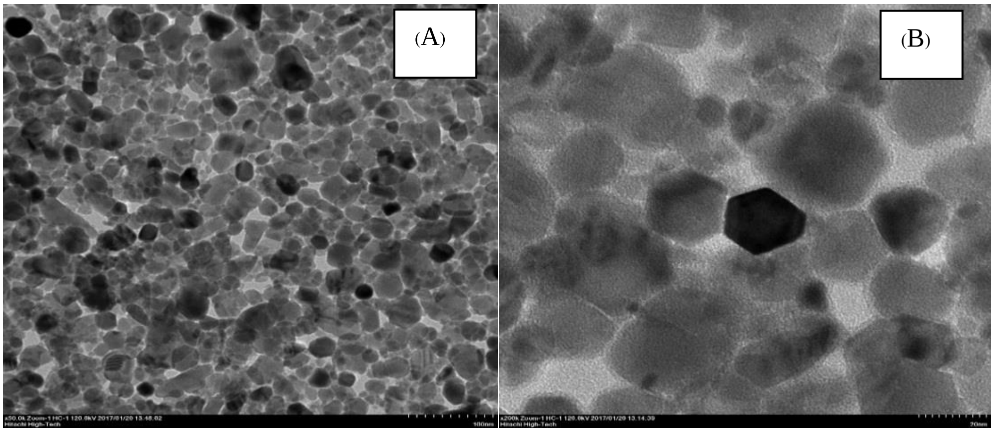


Figure 2. TEM micrographs of ZnO NPs Images are at (A) 50,000 x (scale = 100 nm) and (B) 200,000 x (scale = 20 nm).

The structure of the ZnO NPs was composed of interpenetrating closed hexagons, suggesting tetrahedrally coordinated Zn^{2+} and O^{2-}. The tetrahedral coordination of ZnO gives rise to the non-centro symmetric structure. In wurtzite hexagonal ZnO, each anion is surrounded by four cations at the corners of the tetrahedron, giving the tetrahedral coordination, and hence exhibits sp^3 covalent-bonding (hybrid orbital) (Lee *et al.*, 2011; Vaseem *et al.*, 2015).

3.2. Effect of ZnO NPs on the biomass of E. Crassipes

The relative growth rates (RGR) were calculated from the respective tissue DWs (RGR_{DW}) for the roots, stems and leaves, as reported (McGregor *et al.*, 2008) and indicated in Eq. (2);

$$RGR = [\ln(W_2) - \ln(W_1)] / t_2 - t_1 \quad (2)$$

Where W_1 and W_2 are the plant weights at time t_1 and t_2, respectively.

The RGR_{DW} of roots, stems and leaves of *E. crassipes* in the presence of ZnO NPs at 0 (control), 3.5, 5 and 7.5 mg/L after 15 d of culture are summarized in Table 1.

Table 1. Relative growth rate (RGR_{DW}) of roots, stems and leaves of *E. crassipes* grown hydroponically in half-strength Hoagland's No. 2 solution at different ZnO NP concentrations

ZnO NPs (mg/L)	RGR_{DW} (mg/g/d)		
	Roots	Stems	Leaves
0.0	1.516 ± 0.098^{a}	0.098 ± 0.006^{b}	0.081 ± 0.012^{b}
3.5	1.407 ± 0.091^{a}	0.089 ± 0.017^{b}	0.062 ± 0.005^{c}
5.0	1.310 ± 0.045^{a}	0.060 ± 0.011^{c}	0.038 ± 0.003^{d}
7.5	1.272 ± 0.079^{a}	0.059 ± 0.004^{c}	0.032 ± 0.010^{d}

Data are shown as the mean ± 1SD, derived from three replicates. Means followed by a different lowercase superscript letter are significantly different

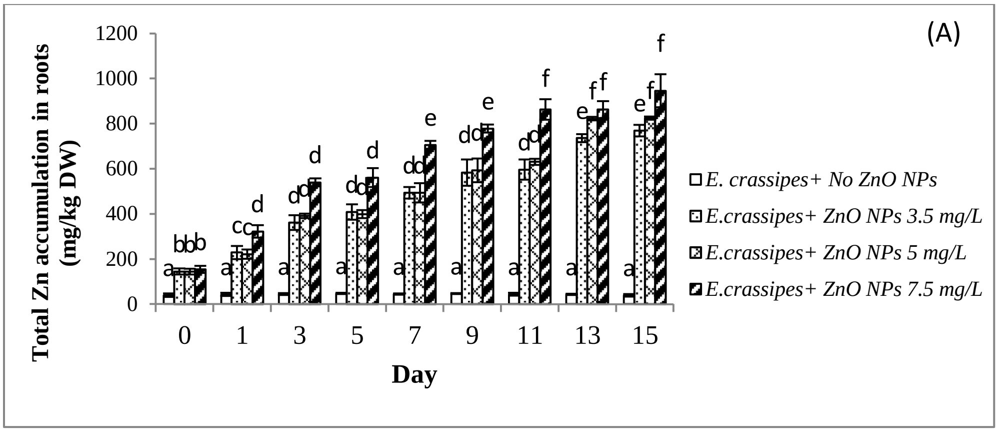
When cultured without ZnO NPs, the biomass of *E. crassipes* increased over the 15-d culture period with a RGR_{DW} of the roots, stems and leaves of 1.516 ± 0.098, 0.098 ± 0.006 and 0.081 ± 0.012 mg/g/d, respectively, over the entire 15-d period (Table 1). The biomass of *E. crassipes* cultured in the presence of ZnO NPs at 3.5, 5 and 7.5 mg/L also increased over this 15-d period. Although numerically reduced with increasing ZnO NP concentrations, the root RGR_{DW} showed no significant difference at all ZnO NP concentrations compared to that without any ZnO NPs, and so it is possible that ZnO NPs had no significant adverse effects on the root biomass. In contrast, the RGR_{DW} of leaves and stems of *E. crassipes* grown in the presence of 5 and 7.5 mg/L ZnO NPs was significantly lower than that at 0 or 3.5 mg/L, while even at 3.5 mg/mL ZnO NPs some reduced leaf and stem RGR_{DW} was evident. However, the morphology of plants grown in the presence of 3.5 mg/L ZnO NPs were healthy and no different from the control group (0 mg/L ZnO NPs). Therefore, a ZnO NP concentration of 3.5 mg/L was selected to evaluate the uptake of zinc into the plant tissues. The tolerance of *E. crassipes* to Zn is in accord with its previously reported ability to grow and tolerate wastewater containing chlorpyrifos (Anudechakul *et al.*, 2015) or cadmium (Vestena *et al.*, 2011), with this plant being considered as a hyperaccumulator for heavy metals.

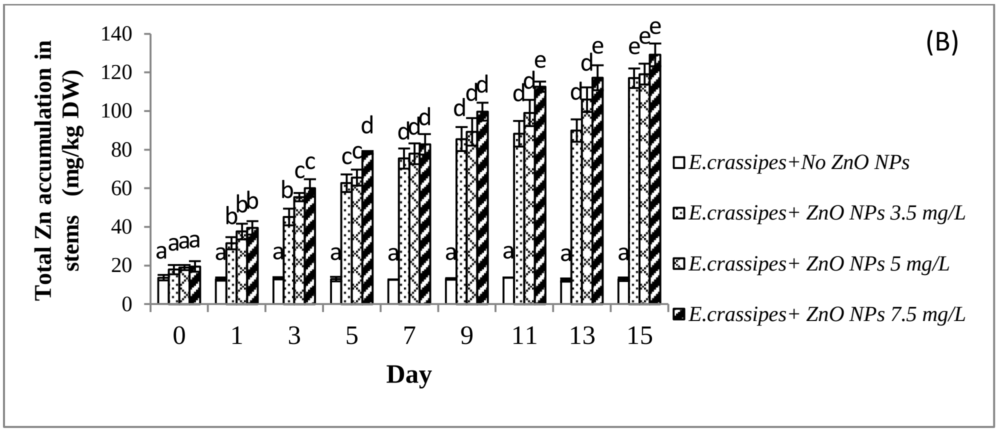
3.3. Zn accumulation in roots, stems and leaves

Although *E. crassipes* is an invasive species, and so requires containment if used for bioremediation, nevertheless it remains of interest since it has a high efficiency for the removal of heavy metals from contaminated water. In this study, the accumulation of Zn in the roots, stems and leaves of *E. crassipes* was found to increase steadily during the 15-d culture period, where the total Zn content in the plant tissues increased as the ZnO NPs concentration in the hydroponic solution increased (Figure 3). Because the *E. crassipes* used in this study was collected from natural canal that may be contaminated with heavy metals, including Zn salts, this could account for the concentration of Zn found in the control (0 mg/mL ZnO NPs) plants from day 0 onwards. However, the levels of Zn in all three plant tissues were very low compared to those in the plants cultured in the presence of 3.5, 5 or 7.5 mg/L ZnO NPs. The maximum concentration of Zn in the roots of *E. crassipes* cultured with a ZnO NP concentration of 3.5, 5 and 7.5 mg/L were 769.04 ± 25.69, 824.32 ± 7.45 and 945.83 ± 73.69 mg/kg DW, respectively, at day 15, while it was much lower in the stems at 117.03 ± 5.02, 119.13 ± 5.43 and 129.11 ± 5.93 mg/kg DW, respectively, and in the leaves at 57.63 ± 1.62, 59.70 ± 3.24 and 61.44 ± 3.13 mg/kg DW, respectively. Note that the levels of Zn accumulated in the stems and leaves by day 15 in each treatment were not significantly different.

The concentration of Zn in the culture medium in the treatment with *E. crassipes* was significantly lower than in the absence of plants over the 15-d period. The results showed that the efficiency of *E. crassipes* cultured with a ZnO NP concentration of 3.5, 5 and 7.5 mg/L were 93%, 91% and 87%, respectively, at day 15, while it was much lower in the absence of plants with a ZnO NP concentration of 3.5, 5 and 7.5 mg/L were 68%, 67% and 63%, respectively (data was not shown).

That *E. crassipes* cultured in the presence of ZnO NPs accumulated more Zn in the roots than in stems (15.8- to 21.8-fold more) and leaves (22.7- to 39.8-fold more) appears to follow the translocation route. In this study, the translocation factor of Zn from roots to shoots was calculated to be 0.23, 0.22 and 0.20 for a ZnO NP concentration of 3.5, 5 and 7.5 mg/L, respectively, which were lower than those reported in *Zea mays* (0.78–0.91) (Zhao *et al.*, 2013). One possible reason is that Zn is not easily transported from the roots to the stems and leaves in *E. crassipes*, accounting for the low tissue accumulation levels in these latter tissues. The translocation ability is controlled by two processes: root pressure and leaf transpiration. Some metals are mainly accumulated in the roots, probably due to some physiological barriers against metal transport to the aerial parts, while others are easily transported in the plants (Lu *et al.*, 2004).





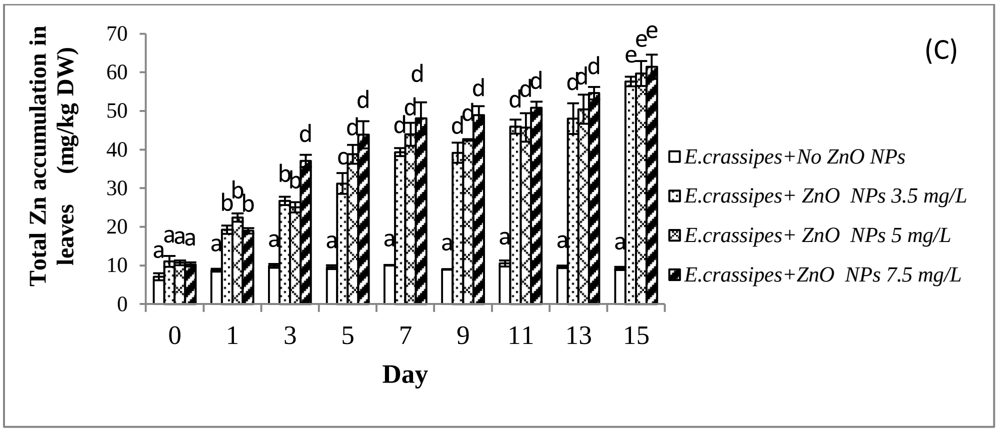


Figure 3. The concentration of Zn in the (A) roots, (B) stems and (C) leaves of *E. crassipes* grown for 15 d in the presence of different concentrations of ZnO NPs. Data are shown as the mean ± 1SD, derived from three independent repeats. Means with a different letter are significantly different ($p < 0.05$).

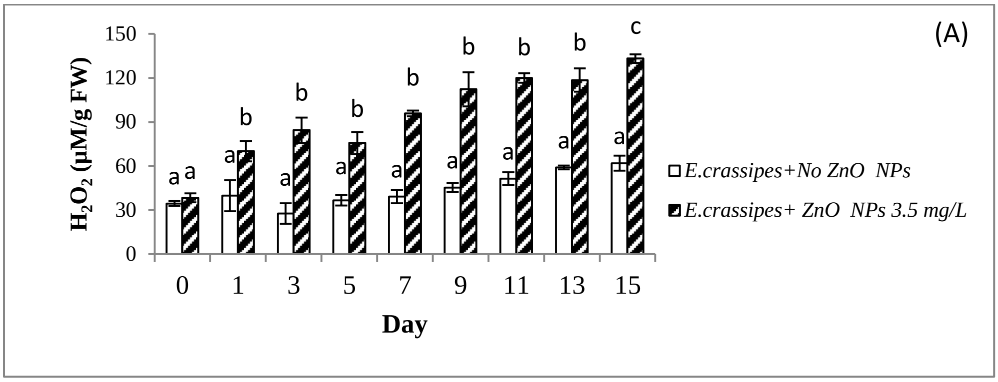
In general, NPs may be able to pass through the epidermis and cortex via the apoplastic pathway, where they have to cross the protoplast of the endodermal cells to enter into the vascular cylinder because the casparian strip between the endodermal cells would block any apoplastic transport. The presence of ZnO nanoparticles has previously been observed in the endodermal and vascular cells, indicating that ZnO NPs could enter the plant cell and move to the stele (Lin and Xing, 2008) like the research assessing *Pistia stratiotes* for uptake and translocatation silver nanoparticles (Ag NPs). Comparison root and leave in Ag NPs treatment result showed root more concentration Ag than leave. Furthermore, calculation translocation factor (TF) are low content in all concentration of Ag NPs. (Hank *et al.*, 2015) and study ZnO NPs magnetic in plant cell of maize (*Zea mays* L.) by optical fluorescence microscopy and transmission electron microscopy (TEM) found particle of ZnO NPs in root more than shoot so, ZnO NPs greatly adhered onto the root surface and individual nanoparticles were observed present in apoplast and protoplast of the root endodermis and stele. Translocation factor of Zn from root to shoot remained very low under ZnO nanoparticles treatments. (Lin and Xing, 2008; Jitao *et al*, 2015)

3.4. Leaf H_2O_2 levels and catalase activity

The ZnO NPs at the concentration of 3.5 mg/L was chosen for study the H_2O_2 and catalase activity because the highest biomass was investigated. Within plants, H_2O_2 plays a dual role, acting as a signal molecule involved in many factors, such as defective or excess nutrient, unsuitable environment, etc., and also acting as a key regulator in a board range of physiological process, such as senescence, photorespiration, photosynthesis, growth and development (Broadley *et al.*, 2006; Quan *et al.*, 2008; Souza and Devaraj, 2012). In the present study, the H_2O_2 level in the control plants did not significantly differ over the 15-d culture period, ranging from 27.69 ± 6.95 to 61.91 ± 5.04 µmol/g FW (Fig. 4A). However, leaves of *E. crassipes* grown in the solution with 3.5 mg/L ZnO NPs showed a significant increase in H_2O_2 levels from day 0 to 15, ranging from 38.29 ± 3.06 to 133.09 ± 3.02 µmole/g FW.

Catalase is one of a subset of enzymes that decrease ROSs in plants. Catalase is involved in the main defense mechanism against accumulation and toxicity of ROS, especially H_2O_2, in plants cell, where it eliminates H_2O_2 by breaking it down directly to form water and oxygen in the peroxisome (Mukhopadhyay *et al.*, 2012). In this study, the catalase activity in the leaves of the control plants (0 mg/L ZnO NPs) did not significantly differ from day 0 to 15, ranging from 50.64 ± 2.56 to 67.09 ± 3.89 µmol H_2O_2/min/mg protein (Fig. 4B). However, in the leaves of *E. crassipes* grown in the presence of 3.5 mg/L ZnO NPs the catalase activity was significantly increased from day 0 to 15, from 62.63 ± 4.80 to 169.70 ± 7.41 µmol H_2O_2/min/mg protein. That the high catalase activity broadly correlated with the high H_2O_2 level over this time period could be explained that the presence of ZnO NPs caused a strong H_2O_2 production under oxidative stress, which then induced the increased catalase activity, consistent with previous reports on the increased sensitivity of plants to environmental stress. For example, ZnO NPs increased the catalase activity in the roots, stems and leaves of velvet mesquite (*Prosopis juliflora-velutina*) (Hernandes-

Viezcas *et al.*, 2011). Moreover, when *E. crassipes* was cultured in water contaminated with heavy metals, such as Cd and Pb, the H_2O_2 concentration increased along with the catalase activity in addition to other antioxidative enzymes (Malar *et al.*, 2014; Vestena *et al.*, 2011).



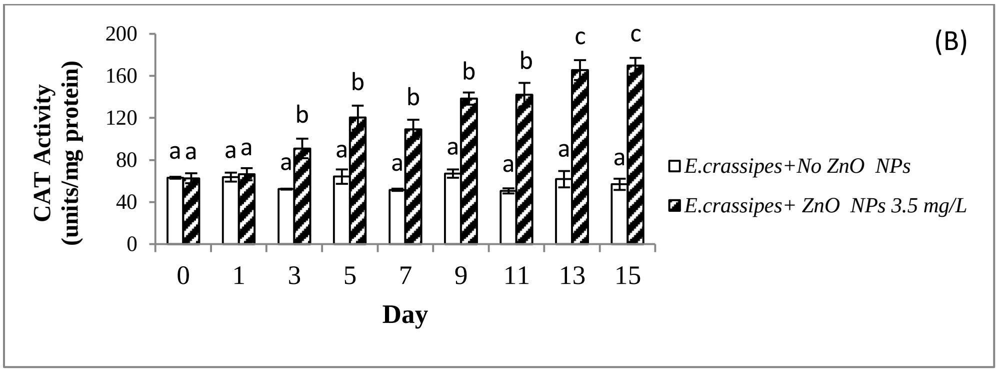


Figure 4. The value of (A) H_2O_2 and (B) catalase activity in the leaves of *E. crassipes* after exposure to ZnO NPs at 0 (control) or 3.5 mg/L for 15 d. Data are shown as the mean ± 1SD, derived from three independent repeats. Means with a different letter are significantly different ($p < 0.05$).

4. Conclusion

The ability of *E. crassipes* to accumulate Zn and the effects of ZnO NPs on the plants growth were investigated. Overall, *E. crassipes* grew well in the hydroponic solution contaminated with ZnO NPs at a concentration of 3.5–7.5 mg/L, as determined by the RGR_{DW} of the roots not being significantly different in all treatments. The morphology of the plants were healthy with fibrous and long roots. However, there was some chlorosis in the leaves, especially at a ZnO NP concentration of 7.5 mg/L.

A higher level of H_2O_2 and catalase activity was found in the leaves of *E. crassipes* when cultured in the presence of 3.5 mg/L ZnO NPs than without, suggesting the plants had some oxidative stress under this condition even though they looked normal in morphology. Further research is needed in order to increase the knowledge on the physiological impacts of ZnO NPs in plant growth.

The accumulation of Zn in the tissues of *E. crassipes* over a 15-d culture period were in the order of roots >> stems > leaves, with a maximum concentration of Zn in the roots, stems and leaves (in the presence of 7.5 mg/L ZnO NPs) being 945.83 ± 73.69, 129.11 ± 5.93 and 61.44 ± 3.13 mg/kg DW, respectively, on day 15, which may reflect a poor Zn translocation out of the roots. This study confirmed that *E. crassipes* has a high efficiency to remove ZnO NPs from contaminated in water and potentially could be applied to treat effluents containing a low concentration of ZnO NPs by continuously passing the wastewater through a bed of *E. crassipes* growing in ponds. This would potentially represent a cost-effective plant-based technology and a suitable alternative for the removal of metals from wastewater.

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Natural Radioactivity in Groundwater in Phra Nakhon Si Ayutthaya Province

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Abstract

This research work aims to study the specific activity of natural radioactivity in groundwater samples taken in the area of Phra Nakhon Si Ayutthaya Province, Thailand. Totally, sixty groundwater wells located in eight districts were monitored and determined for radionuclides ^{226}Ra, ^{232}Th and ^{40}K using Hyper Pure Germanium (HPGe) gamma ray spectrometry and gross alpha/beta using Canberra Tennelec Series 5 glass flow proportional counter. Most of studied wells serve for consumption purpose and some other for agricultural purpose. The results showed that the activity concentrations of the gross alpha/beta were 0.01 ± 0.007 and 0.15 ± 0.02 Bq/L and the specific activity values were averagely 0.77±0.13, 1.03 ± 0.19 and 15.56 ± 1.28 Bq/L for ^{226}Ra, ^{232}Th and ^{40}K, respectively. The gross alpha beta and specific activity of ^{226}Ra, ^{232}Th and ^{40}K found in these samples exhibited quite low concentration in comparison to the recommended reference level for human consumption reported by World Health Organization (WHO).

Keywords: natural radioactivity; groundwater; gamma ray spectrometry; Phra Nakhon Si Ayutthaya

1. Introduction

Water is the most important source for life and makes up 70-75% of total body weight. While seventy percent of the world's surface is covered by water, only 0.3% of the total water resources on earth is drinkable and suitable for daily use (Althoyaib and El-Taher, 2015). For instance, human uses of water are agriculture, industry, consumption, household uses and recreation. However, natural disasters have been more severe than before due to environmental balance is gradually destroyed. Significant reduction of rainfall and longtime of dry spells directly affected agricultural and industrial sectors, as well as water consumption. Groundwater resource is an alternative providing leverage to tackle a shortage of water supply in many areas. Groundwater is acknowledged about its risk of natural contamination from mineral dissolution of their host rocks, as well as anthropogenic contamination caused by human activities. Moreover, natural radioactive substances are also concerned; especially groundwater resources used as water supply in communities. Consumption of contaminated groundwater may cause adverse health effects.

The radioactivity in groundwater occurs mainly from radionuclides of the natural decay chains of ^{238}U, ^{232}Th and ^{40}K. Some radionuclides can be easily dissolved in water, depending on mineralogical and geochemical composition of soil and rock, redox condition and residence time of groundwater transporting through soil and bedrock, and reaction of groundwater with soil and bedrock (Turhan *et al.*, 2013). When the decayed radionuclides are taken into human body through ingestion or inhalation, radionuclides will cause internal exposure (Kobya *et al.*, 2015). Ingested radionuclides are absorbed into blood and accumulated in specific tissues causing damages (Canu *et al.*, 2011). Some radioactive substances can cause toxicity to kidney and increase risk of cancer.

Due to data of radioactive concentrations in groundwater in Thailand are quite rare, this study was to monitor natural radioactivity occurrence in groundwater located in Phra Nakhon Si Ayutthaya Province, Thailand. This study used activity concentrations of gross alpha/beta and radionuclides (^{226}Ra, ^{232}Th and ^{40}K) for consideration. The gross alpha/beta and radionuclides were determined by using Canberra Tennelec Series 5 glass flow proportional counterand hyper pure germanium (HPGe) gamma ray spectrometry, respectively. In addition, the data observed in this study was useful for evaluation of radioactive contamination level in this groundwater.

2. Material and Methods

2.1 Monitoring design

The study area in this work was located in Phra Nakhon Si Ayutthaya province, 76 kilometers northern distance from Bangkok, covering an area of 2,556 square kilometers and dividing into sixteen districts. This province is located in the flat river plain of the Chao Phraya river valley. The presence of four rivers, i.e. Chao Phraya River, Pasak River, Lopburi River and Noi River, flowing through the city makes this province a major rice farming area of Thailand. Due to drought phenomena have recently occurred, groundwater is widely used throughout the province as an alternative water reserve. Groundwater in this province serves for both consumption and agricultural purposes. Sixty wells were designated for groundwater samples collection during May to October, 2016 as illustrated in Fig. 1. Most of designated wells serve for consumption purpose through community water supply system. At least two liters of groundwater were taken for each sampling, then, preserved with 1N HCl to pH value of 2 in order to avoid loss of radionuclide fraction by adsorption with the container and to prevent any biological activities according to EPA methods of 900.0 and 901.1.

2.2 Determination of gross alpha/beta radioactivity

One liter of sample was filtered via filter paper (Whatman No.1) and put into two-liter beakers. The filtrate with certain volume was further evaporated on hot plate until almost dry and its residue appeared. Then, residues are transferred to clean planchet and further dried in oven equipped with infrared lamp at 105°C for 10 minute. After drying process, residues were weighted and stored in desiccator until analytical measurement. Weighted residues were analyzed for the radiation (in terms of gross alpha and beta) by Canberra Tennelec Series 5 glass flow proportional counter with counting time of 120 second per sample. In addition, the control sample (or blank sample) was required and had to be placed in the front sequence of sample series during the measurement. The calibration was also performed by using planchets containing certified solution of ^{241}Am and ^{90}Sr/^{90}Y. The counting efficiencies for the system were 23% for alpha and 36% for beta. Finally, the measurement result was used to calculate for radioactivity with the following equations (1) as shown below.

$$\text{Activity Concentration} = \frac{(A_s - A_b)\times 100}{\%\varepsilon \times V \times 60} \tag{1}$$

Where: A is the radioactive concentration of gross alpha/beta (Bq/L), As is count rate of samples (cpm), Ab is count rate of background (cpm), %ε is efficiency percentage of the detector, V is volume of water and 60 is conversion factor from dpm/Bq.

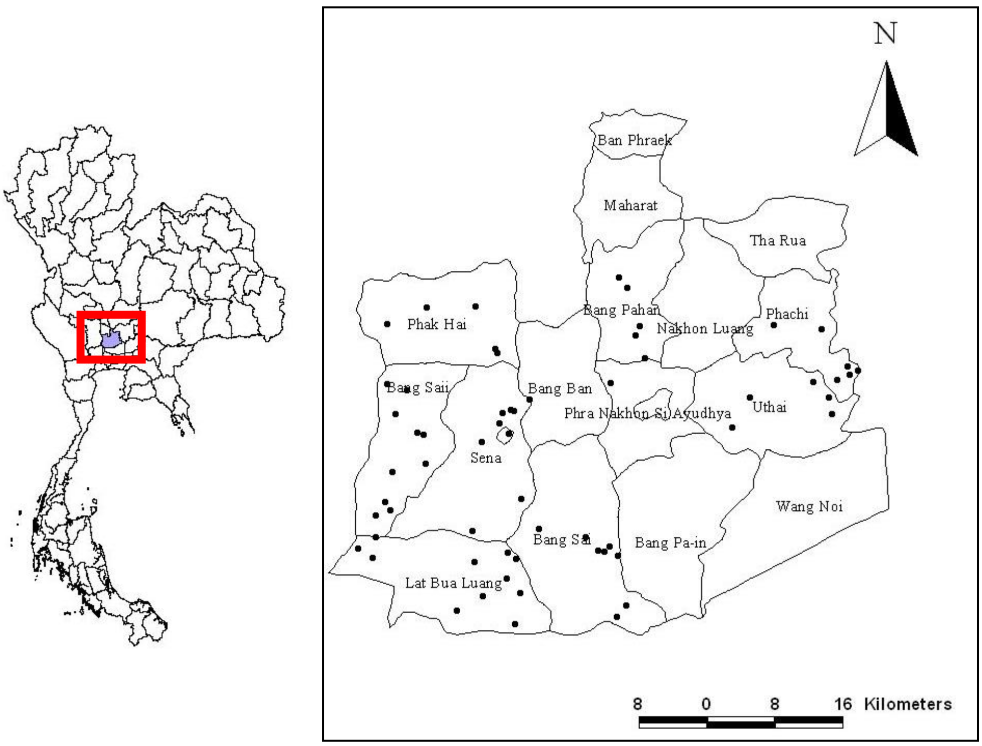

Figure 1. Sampling sites inPhra Nakhon Si Ayutthaya province

2.3 Determination of radioactivity of radionuclides (^{226}Ra, ^{232}Th and ^{40}K)

One liter of water samples were transferred into a Marinelli beaker. The beakers were subsequently firmly sealed for at least four weeks to ensure a state of secular equilibrium between radium isotopes and their respective daughters before measuring of gamma radiation (Ibrahim *et al.*, 2014). These samples were analyzed for ^{226}Ra, ^{232}Th and ^{40}K using the HPGe gamma ray spectrometry. The energy calibration of the HPGe system was regularly performed before measuring by using radiation standards of Cs-137 and Co-60, which the energy peakof Cs-137 was 661.66 ± 0.5 keV and those of Co-60 were 1173.2 ± 0.5 keV and 1332 ± 0.5 keV. Each water sample in a Marinelli beaker was determined for radionuclides using gamma spectrometry counting for 50,000 seconds. A result of which was further calculated for radioactivity with the equations (2) as shown below.

$$\text{Activity Concentration} = \frac{N_{(cps)}}{\varepsilon \times V \times P_{\gamma(E)}} \qquad (2)$$

Where: $N_{(cps)}$ is strength of radiation radionuclide in the samples (Bq/L), ε is the efficiency of energy detector, V is volume of water and $P_{\gamma}(E)$ is values of opportunity to decay and emit gamma ray energy.

2.4 Annual dose calculation

In this study, annual dose ingestion of ^{226}Ra contamination in groundwater were considered. Therefore, the radioactivity doses from annual consumption in each adult were estimated according to the following equation (3) (Harb et al., 2013); considering with consumption rate of 2 liters/day and the conversion factors of 0.28 μSv/Bq.

$$\text{Effective dose (mSv/y)} = A_w \text{ x } IR_w \text{ x } ID_F \qquad (3)$$

Where: A_w is activity concentration (Bq/L), IR_w is intake of water for person in 1 year (730 L/year) and ID_F is the effective dose equivalent conversion factor (μSv/Bq).

3. Results and discussion

The activity concentrations of gross alpha/beta and radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in groundwater samples in Phra Nakhon Si Ayutthaya Province are concluded in Table 1. From the results, pH values of sixty samples were observed in the neutral range of 6.7 – 8.4. Their conductivities were in the range of 232 – 3946 μc/cm (the average was 902 μc/cm).

Table 1. Radioactivity in groundwater samples collected in Phra Nakhon Si Ayutthaya Province during May – October, 2016.

Parameter	Maximum	Minimum	Average	Standard deviation
Alpha (Bq/L)	0.029	0.009	0.011	0.007
Beta (Bq/L)	0.345	0.063	0.156	0.018
^{226}Ra (Bq/L)	0.921	0.520	0.767	0.133
^{232}Th (Bq/L)	1.033	N.D.	-	0.194
^{40}K (Bq/L)	18.8	12.9	15.6	1.29
pH	8.4	6.7	7.6	-
Conductivity(μc/cm)	3946	232	902	-

The concentrations of gross alpha were found in the range of 0.009 – 0.029 Bq/L, as well as those of gross beta were in the range of 0.063 – 0.345 Bq/L. The averages of gross alpha and beta observed in this area were 0.011 ± 0.007 and 0.156 ± 0.018 Bq/L, respectively, which were comparatively lower than their recommended reference levels of 0.5 and 1 Bq/L, respectively (Figure 2). Especially, the maximum concentration of gross alpha (0.029 Bq/L) was considered as only 6% of the reference level (0.5 Bq/L). However, the maximum concentrations of gross beta (0.345 Bq/L) were in considerable percentage (about 35%) of the reference level of 1 Bq/L.

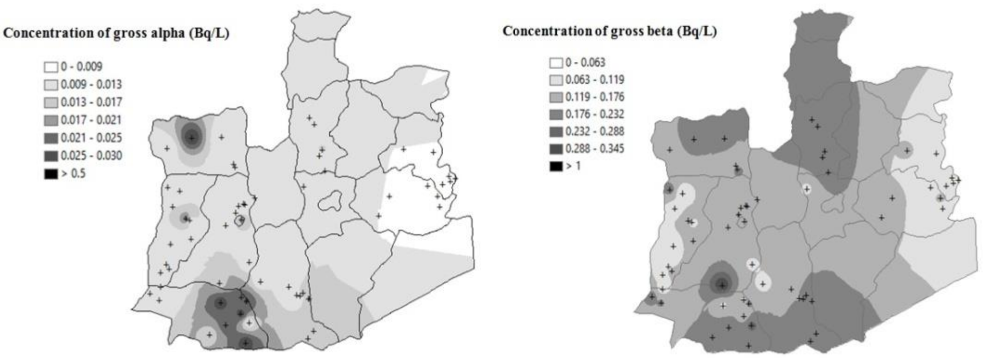

Figure 2. Interpolated radiological maps for alpha and beta in Phra Nakhon Si Ayutthaya Province.

Radium-226

The concentrations of radionuclides ^{226}Ra, ^{232}Th and ^{40}K were found in the ranges of 0.520 – 0.921, N.D. – 1.033 and 12.9 – 18.8 Bq/L, respectively (Fig. 3). Their averages were 0.77 ± 0.13, 1.03 ± 0.19 and 15.6 ± 1.29 Bq/L, respectively. In case of ^{226}Ra, their concentrations were observed in the range that its maximum concentration (0.921 Bq/L) was much closed to the recommended level of 1 Bq/L for water consumption announced by WHO. Table 2 gathered several reports of radioactivity monitoring in various areas in order to compare with our study. Similarly, Zhuo *et al.*, 2001 reported the maximum value of 0.93 Bq/L was found in groundwater sample taken in Fujian province (Table 2). Nonetheless, some samples contained higher concentrations of ^{226}Ra were observed in groundwater samples taken in Egypt (El Arabi *et al.*, 2006) and Yemen (Saleh *et al.*, 2015), as well as, some samples contained much lower ^{226}Ra were reported in Serbia (Ćuk *et al.*, 2013).

However, there was a report of ^{226}Ra monitoring in groundwater samples taken in Roi-Et province, northeastern part of Thailand (Quinram and Yenchai, 2015). Those were found in the range of <0.006 – 0.177 Bq/L, which were lower than those found in our study. This was probably due to different geology constituting water-bearing formations of groundwater system. Geological map of Thailand 1:250,000 of Phra Nakhon Si Ayutthaya province (Geological Survey Division, 1985a) illustrated some of igneous rocks in its geology, but there was none shown in that of Roi-Et province (Geological Survey Division, 1985b). Some literature reviews mentioned that ^{226}Ra and ^{228}Ra level in groundwater was related to certain types of rock (e.g. granite, sandstone) or rocks dissolution (Godoy and Godoy, 2006). Anyway, some admitted that wide ranges of radioactivity were observed with little correlationto the type of rock or sediment constitutingaquifer formation (Chau, *et al.*, 2011).

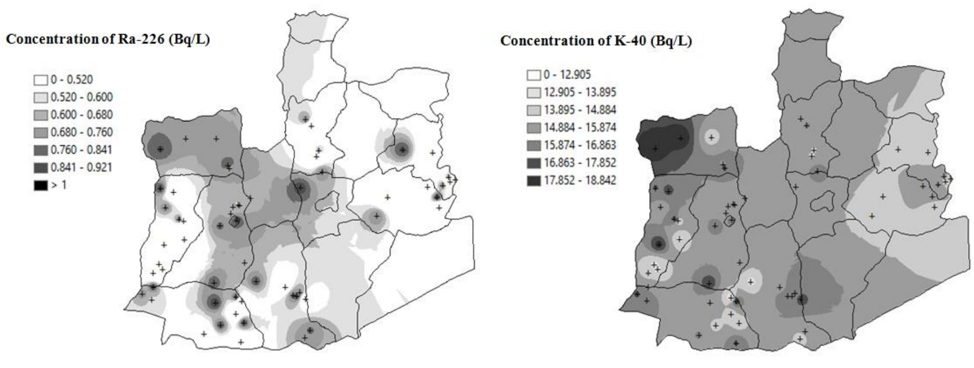

Figure 3. Interpolated radiological maps for ^{226}Ra and ^{40}K in Phra Nakhon Si Ayutthaya Province.

Thoriun-232

In case of ^{232}Th (radiological maps were not shown here), there was no data of ^{232}Th concentrations in the study of groundwater in Roi-Et province (Quinram and Yenchai, 2015). Usually, thorium content in crustal rocks is observed at low level. In addition, thorium typically forms complex compounds with ions in water either acidic or basic pH conditions. ^{232}Th concentrations observed in this study were averagely 1.03±0.19 Bq/L, similar range of which was reported in groundwater samples collected in Yemen (Saleh *et al.*, 2015) and hot spring water samples in Jordan (Saqan *et al.*, 2001). In contrast, the much lower concentrations of ^{232}Th in groundwater were mentioned in samples taken in Serbia (Ćuk *et al.*, 2013).

Potassiun-40

The ^{40}K concentrations monitored in this study were in the moderate level in comparison to elsewhere (Saleh *et al.*, 2015; Ćuk *et al.*, 2013; El Arabi *et al.*, 2006; Saqan *et al.*, 2001). Theoretically, the abundance of ^{40}K activity observed in groundwater was usually explained by the relevance to potassium fertilizer application in agricultural activities and transportation through groundwater system. Anyway, higher concentrations of ^{40}K were found in hot spring water samples studied in Jordan (Saqan et al., 2001). Similar concentrations were observed in groundwater samples monitored in Yemen (Saleh et al., 2015). Much lower concentrations were reported in a study of groundwater in Serbia (Ćuk et al., 2013). It is possible that moderate concentrations of ^{40}K activity found in this study area might be resulted from potassium fertilizer application. More statistical data of background level of ^{40}K activity and fertilizer application in Phra Nakhon Si Ayutthaya province are required for in depth discussion.

Annual dose of ^{226}Ra ingestion

The annual dose calculation for adults, considering only the ingestion from ^{226}Ra by the water consumption rate is 2 liters per day in this study were found in the ranges of 0.106 – 0.188 mSv/year. Although ^{226}Ra level found in groundwater samples taken in Phra Nakhon Si Ayutthaya Province during May – October, 2016 (data shown in Table 2) were compiled to WHO guideline of 1 Bq/L, all results of annual dose calculation exceeded the individual dose criteria (IDC) of 0.1 mSv/yr suggested by WHO (2011). However, this screening level for drinking water usually applied after either gross alpha activity or gross beta activity exceeded 0.5 and 1 Bq/L guidance concentrations, respectively, which those in this study were not in the case (Table 2). Anyway, this study attempted the annual dose calculation for ^{226}Ra in order to compare with the previous work in Roi-Et province (Quinram and Yenchai, 2015). Thus, the annual doses of ^{226}Ra in this study were higher than those in Roi-Et province due to higher ^{226}Ra concentration as previously mentioned. The most frequency of

38% (of total 60 data) were observe in the range of 0.101 – 0.120 mSv/yr as shown in Fig. 4. Nonetheless, WHO, 2011 also suggested that this IDC (0.1 mSv/yr) should be determined only in case of any radionuclide was to exceed the guideline concentration; consequently resulting in summary annual dose might exceed the IDC. Then, the continuation monitoring for a whole year should be applied before concluding that the water is unsuitable for consumption.

Table 2. The activity concentrations of water samples reported in various studies

Country	**Type of water**	**Activity concentration (Bq/L)**				
		Alpha	**Beta**	**^{226}Ra**	**^{232}Th**	**^{40}K**
Turkey (Turhan *et al.*, 2013)	Ground water	0.08-0.38	0.12-3.47	-	-	-
Hungary (Jobbágy *et al.*, 2011)	Spring waters	0.03-1.75	0.03-2.01	-	-	-
Bangladesh (Biswas et al., 2015)	Surface water	0.45×10^{-3} - 1.36×10^{-3}	0.06-0.28	-	-	-
Nigeria (Atsor et al., 2015)	Underground water	0.31-14.49	0.02-27.4	-	-	-
China (Zhuo et al., 2001)	Ground water	-	-	Max 0.93	-	-
Roi-Et Province (Quinram and Yenchai, 2015)	Ground water	-	-	<0.006-0.177	-	-
Egypt (Elba) (El Arabi *et al.*, 2006)	Ground water	-	-	1.6-11.1	0.2-0.97	9.1-23
Yemen (Saleh *et al.*, 2015)	Ground water	-	-	1.71±0.09	1.43±0.05	14.16±0.45
Jordan (Saqan *et al.*, 2001)	Hot spring water	-	-	3.8–6.8	1.42–2.37	23.2–34.8
Serbia (Ćuk *et al.*, 2013)	Ground water	0.12±0.04	0.68±0.26	0.16±0.04	0.08±0.04	0.56±0.24
Phra Nakhon Si Ayutthaya province (Present work)	Ground water	0.01±0.007	0.15±0.02	0.77±0.13	1.03±0.19	15.56±1.28

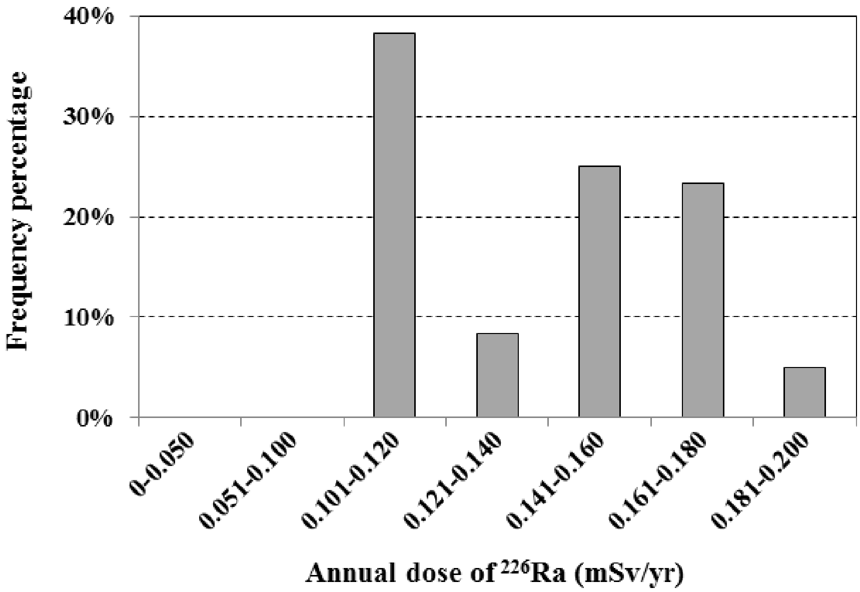

Figure 4. Frequency distribution of effective dose for ^{226}Ra in groundwater in water sample

4. Conclusion

The natural radioactivity levels of gross alpha/beta and radionuclides ^{226}Ra, ^{232}Th and ^{40}K observed in groundwater samples taken in Phra Nakhon Si Ayutthaya Province during May to October 2016 were considerably compiled to the guidance level for drinking water quality recommended by WHO. The ^{226}Ra levels in this area were in concern where their annual dose calculation resulted in exceeding the individual dose criteria adopted by WHO (2011). However, this was too early to conclude these groundwater samples were unsuitable for drinking purpose. Different seasonal monitoring will be further studied and their results will be compared and discussed with data presented here. Therefore, the annual dose for ingestion of the radionuclides found in groundwater will be more evaluated and discussed.

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An application of Geographic Information Systems for Wastewater Management Based on Land Use Characteristic in Chonburi Province

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Abstract

This paper aims to identify source of wastewater in residential area of Chonburi municipality and tourism area in Pattaya city. The steps taken into this study include BOD, structure of sewage network, wastewater treatment plant, outflow pipes, land use and then we integrated all of those data by GIS. BOD values of the wastewater from municipalities were 19 - 60 mg/l and of Pattaya city was 18 mg/l.

According to land use classification, it clearly showed that human activities were different between the two areas and wastewater quality in Pattaya city was better than that of Chonburi municipality. It was likely due to untreated wastewater in Chonburi municipality, had poor design of sewage network which were not covered the whole area yet. Expansion of the sewage network in each municipality is needed to receive wastewater that has increased with urban sprawls. Improvements of wastewater network and water quality will help us to access effective wastewater management in these areas.

Keywords: GIS; wastewater management; land use; Chonburi Province

1. Introduction

Chonburi Province is situated between 12° 30′ and 13° 43′ N and 100° 45′ and 101° 45′ E on the eastern coast of Thailand covering a total area of 4,363 square kilometers. As such, this coastal region has become a major economic ecosystem for fishing, recreation, tourism and most notably, human settlement. Due to these factors, the province's population is growing rapidly, with currently more than 1.4 million residents (National Statistical, 2016).

The rapid urbanization process as a result to the change of land use pattern and utility in the area, Firstly, a growing population directly influences how much additional water is required for personal and household uses. Secondly, population growth expands economic activities, such as agriculture and industry, which also requires additional demand of water. Overall, population growth results in an increasing demand for water and also increases water pollution. According to BOI, (2015), Thailand’s water demand is approximately 5.3 million cubic meters per day

(Pariyada et al., 2013). Pattaya city consumes water at the amount of 70 million cubic meter per year (Provincial Waterworks Authority, 2016). Demand for water in Thailand was estimated at 70 billion cubic meters annually in the next 10 years. The larger amount of water being consumed, the poorer treatment of wastewater which can lead to the discharge of untreated or partially treated sewage directly to the sea or indirectly via small rivers which finally reach the sea (WWDR, 2015).

Coastal water quality problems are caused by wastewater released from various origins and human activities including houses, communities, industries and agriculture. For instance, this can be seen from high nutrients and low dissolved oxygen found in the marine water at the estuaries which receive water released from rivers and canals (Thaiwater, 2017). Highly deteriorated water quality was found in the inner Gulf of Thailand at the estuaries of 4 major rivers (ChaoPhraya, ThaChin, MaeKlong and BangPakong) as well as their adjacent areas (Thailand State of Pollution Report, 2010). Detected water quality problems were low dissolved oxygen in coastal water, and high values of nutrients (ammonia, nitrate and phosphate). Major detected problem in small canal and certain tourist beaches were high values of total coliform bacteria (World Bank, 2011).

This study aims to identify the source of wastewater in Chonburi municipality and tourism areas in Pattaya city including BOD, Nutrient analysis and Land use classification by integrating GIS tools, in order to understand the status of management and finding a way to access effective wastewater management in these areas.

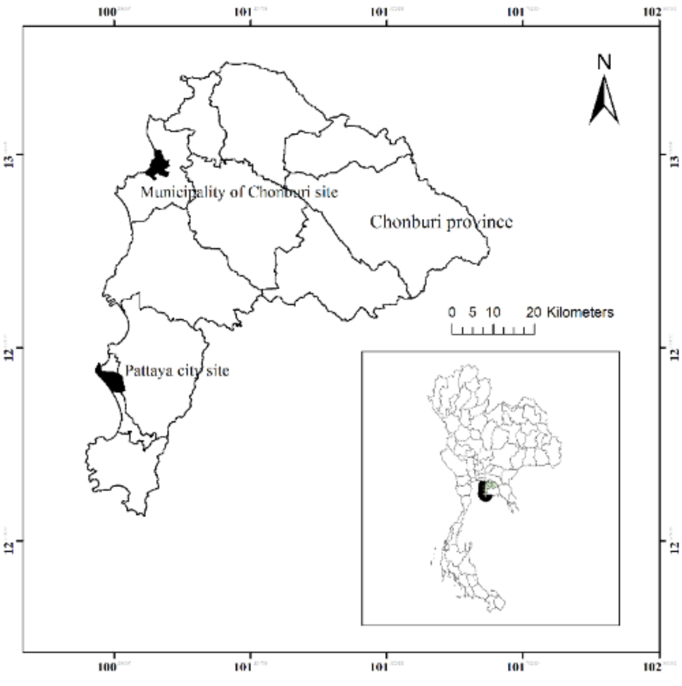

Figure 1. Location of Chonburi Province and map of sampling sites.

2. Materials and Methods

2.1. Study sites

Two study sites in Chonburi Province were selected (Fig. 1). Area of Chonburi municipality of (13°21′43″N 100°58′45″E) and Pattaya city (12°55′39″N 100°52′31″E), which are known for different anthropogenic activities: local settlements and tourism areas. A total area of 7.59 and 22.2 km^2, respectively.

2.2. Sampling and Analysis

Wastewater sampling and measurements of water parameters were done at 4 stations in 4 canel which receiving wastewater in Chonburi municipality and Pattaya city; Sungkep, Bangplasoy, Lamu and Khuy yai canels in Pattaya city during the dry (February to May) and wet seasons (May to October) in 2016. Wastewater samples were collected at outflow pipe nearshore. Water samples for BOD analysis were churned directly into 300 mL glass BOD bottles, and kept on ice and in the dark. Then samples were transported to the laboratory and incubation began the same day as sample collection. Water parameters (water temperature, pH, dissolved oxygen concentration, Conductivity) were measured with YSI 85 multiparameter with proper calibration as described by the manufacturer. For the concentrations of total nitrogen (TN) and total phosphorus (TP), water samples were taken at the surface. Water samples were then immediately filtered through a Whatman GF/F glass fiber filter (Whatman Inc., Clifton, NJ, USA) and stored in separate 50 mL polyethylene bottles. The filtered samples were kept frozen until analysis. Ammonia, nitrite + nitrate, and phosphate concentrations were determined colorimetrically (Grasshoff et al., 1983) with a continuous flow system Auto Analyzer 3 (BRAN+LUEBBE, Germany) (Natthamon and Thanomsak, 2013)

2.3 Land use classification methods

A modification of the Anderson scheme level I method was used to classify land use (Ashraf *et al.*, 2009; Anderson *et al.*, 1976). Ten different land use pattern were identified such as; settlement zone, commercial zone, road, route pipe, wastewater treatment plant, outflow source, pump station, river, hotels and boundary plant. In this research, ArcGIS 10.2 and a GIS method called Overlay were implemented. This method enables the comparison of two site maps (Chonburi municipality and Pattaya city) with using high-resolution imagery from Google Earth (2016) image resolution 0.5 x 0.5 m. (Agisilaos *et al.*, 2013). This is after digitizing a topographical map and Google Earth image (Fig.3 and 4). In addition, geospatial data including municipality boundaries and roads were used to produce GIS layers from source such as Royal Thai Survey Department (RTSD, 2006) topographic map (sheet no. 5135 I and 5134 I, scale: 1/50,000) as reference. Ultimately, it helped us to understand the wastewater management situation in this area, the position of route pipe, outflow source and the structure of the sewage network.

3. Results and Discussion

3.1 BOD

BOD concentrations of Chonburi municipality wastewater (Sungkep canal, Bangplasoy canel, Lamu canel) were significantly higher than Pattaya city (Khuy yai) (Table 1). Sungkep canal has received untreate wastewater from high-*density* residential *areas* of Chonburi municipality (Fig.3). Bangplasoy canal has received wastewater from settlement zone and commercial zone in low-*density* residential *areas. Therefore BOD* concentration were lower than Sungkep canal. Lamu canal has received treated wastewater from wastewater treatment plant showing BOD values lower than other stations in Chonburi municipality. Results from Pattaya city, Khuy yai canal which was outflow source from wastewater treatment plant has the lowest BOD.

3.2 Total Nitrogen (TN) and total Phosphorus (TP)

The balanced relationship among carbon, nitrogen and phosphorus in wastewater is crucial due to the effectiveness of biodegradation processes (Yan Sun *et al.*, 2016). These parameters can be a guide for treatment system design and configuration in order to achieve maximum nutrient removal efficiency. For efficient wastewater treatment, it has been widely stated that the BOD: N: P ratio should be in the range between 100:10:1 and 100:5:1 for aerobic treatment and 250:5:1 for anaerobic treatment (Tchobanoglous, 1991). High concentration of individual substance and unfavorable nutrient ratios can reduce the degradation efficient of micro-organism (Winkler *et al.*, 2008).

Nitrogen and Phosphorus concentration in Sungkep canal were highest. TN and TP in Sungkep, Bangplasoy, Lamu and Khuy yai canals ranged from 8.4 to 1.1 mg/L and 2.1 – 0.5 mg/L, respectively (Fig. 2a - b). TN and TP concentrations in Khuy yai canal (Pattaya city) were significantly lower approximately 70% than those in Sungkep canel (Chonburi municipality) due to wastewater in Pattaya city (Fig.4 only in boundary of plant) were treated on-site, (commercial establishments such as hotels, restaurants and shopping malls are well equipped with wastewater treatment facilities. On the other hand, wastewater in the settlement zone of Chonburi (Fig. 3) were not treated. Similar to the comparison of BOD removal in 4 stations (Fig. 2d), the greater removal efficiencies of nutrient were observed especially in Khuy yai canal. Compared to the criteria on the national discharge standard (Table 2), the average TN values of wastewater effluent in this study were satisfied.

Table 1. Wastewater effluent quality and nutrients from different sources in this study

Parameter	Sungkep	Bangplasoy	Lamu	Khuy Yai
pH	7.3	7.4	7.0	7.0
Temperature (°C)	28.1	33.2	35.6	30.2
Conductivity (μs/cm)	27.06	19.56	23.7	7.8
DO (mg/L)	0.3	3.4	1.9	0.6
BOD (mg/L)	60.3	22.9	19.4	18.3
DIP (mg/L) *	1.298 ± 0.177	0.660 ± 0.020	0.559 ± 0.052	0.119 ± 0.017
DOP (mg/L) *	0.549 ± 0.015	0.355 ± 0.009	0.041 ± 0.013	0.211 ± 0.029
PP (mg/L) *	0.273 ± 0.255	0.137 ± 0.119	0.422 ± 0.056	0.172 ± 0.030
TP (mg/L) *	2.120 ± 0.154	1.152 ± 0.115	1.022 ± 0.038	0.502 ± 0.017
DIN (mg/L) *	2.076 ± 0.180	2.441 ± 0.008	1.691 ± 0.040	0.957 ± 0.016
DON (mg/L) *	3.769 ± 0.236	2.268 ± 0.119	0.074 ± 0.074	0.119 ± 0.027
PN (mg/L)*	2.537 ± 0.064	0.567 ± 0.140	0.130 ± 0.147	0.098 ± 0.016
TN (mg/L) *	8.409 ± 0.087	5.277 ± 0.025	1.895 ± 0.093	1.174 ± 0.007

* = Mean ± Standard Division, n=3

Table 2. Water characteristics discharged into irrigation system, Pollution Control Committee, 2010.
Source: APHA, 1998

Parameter	Parameter Permitted level in the effluent
pH	5.5 – 9.0
BOD (mg/L)	< 20
SS (mg/L)	< 30
Fat, Oil and Grease (mg/L)	< 5
Total P (mg/L)	< 2
Total N (mg/L)	< 20

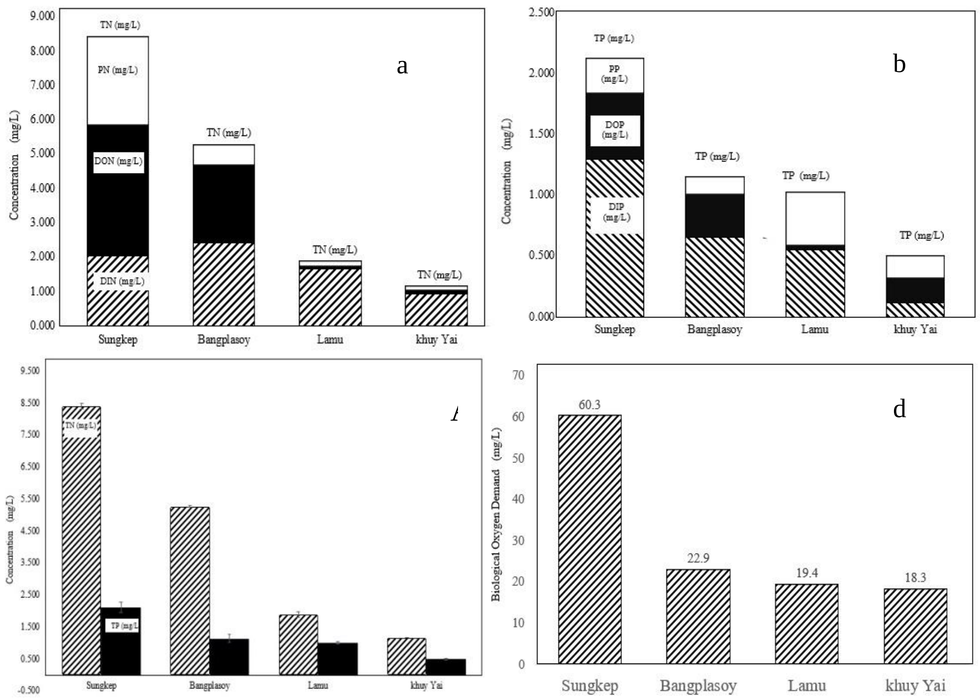

Figure 2. Concentrations of Total Nitrogen (TN) (a), Total Phosphorus (TP) (b), TN and TP (c) and BOD in wastewater in 4 sampling stations

3.3 Land use classification analysis

Land use classification analysis of Chonburi municipality is showed in Fig. 3. A boundary of treated wastewater covers 7.59 km^2 (gray area) in Chonburi municipality including Bang Sai subdistrict municipality, Bansuan subdistrict municipality and Mueng Chonburi municipality. Wastewater treatment plant located on coastline close to Lamu canal, capacity at wastewater at 22,500 m^3 per day, however it operates only 15,000 m^3 due to insufficient development of sewer collectors. The structure of the sewage network was observed on the north-south 4.5 km. along the shoreline, 2 pump stations at Sungkep and Bangplasoy canals. It serves some 80,000 - 100,000 residents in the existing town center. The water quality of Sungkep and Bangplasoy canals were highly polluted by phosphate, nitrogen and BOD pollutants due to untreated wastewater from fresh markets in high-*density* residential *areas* of municipality.

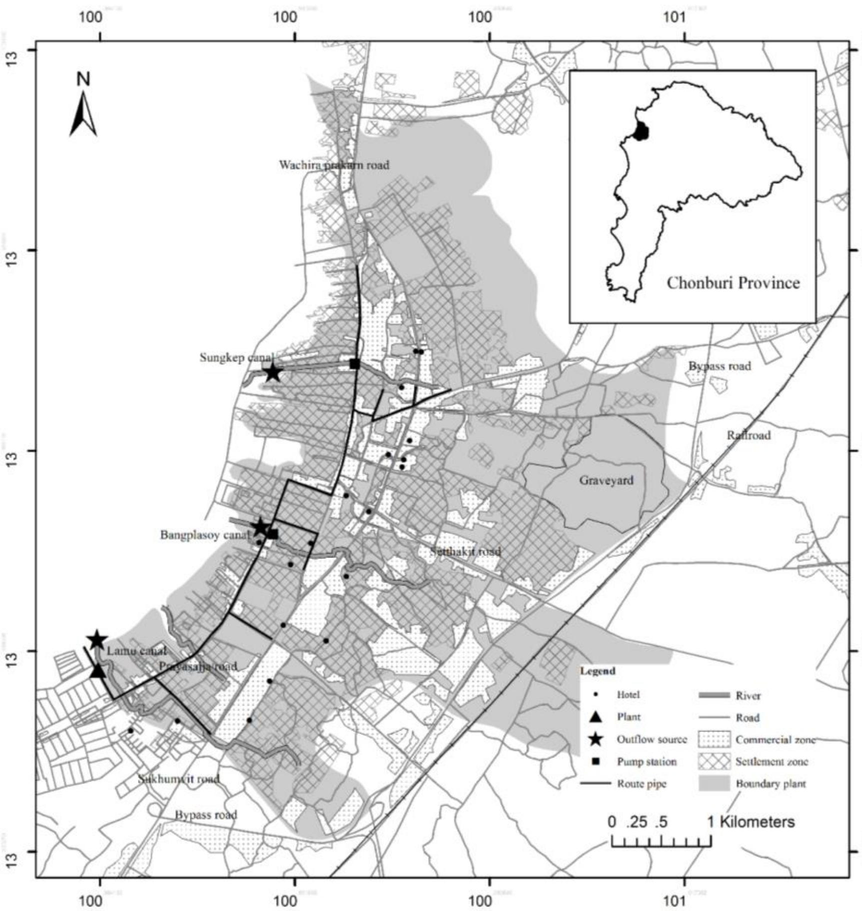

Figure 3. Land use classification analysis of municipalities in Chonburi city

Land use classification analysis of Pattaya city is showed in Fig.4. A boundary of treated wastewater covers 22 km^2 (gray area) in south side of Pattaya city (Na-jomtien shoreline). Wastewater treatment plant located on Bonkanchana road which was designed for a capacity of 20,000 m^3 per day, but actually treated 21,134 m^3 approximately 106% of carry capacity in 2010. Structure of the sewage network was observed on the north-south 6 km. along the shoreline, which the boundary of wastewater treatment plant covered is more than that of Chonburi municipality, 6 pump station at Jomtien, Bonkanchana, Chaiyaphruek and Thepprasit roads. It serves 130,000 - 150,000 residents in Pattaya city.

Wastewater quality in Pattaya city were significant better than that of Chonburi municipality due to installation of on-site wastewater treatment and sewage system according to the standards, determining regulations and criteria that business operators shall establish wastewater and waste management guidelines in order to request operating permit (Pollution Control Committee, 1996) but the carry capacity of plant is in need of improvement.

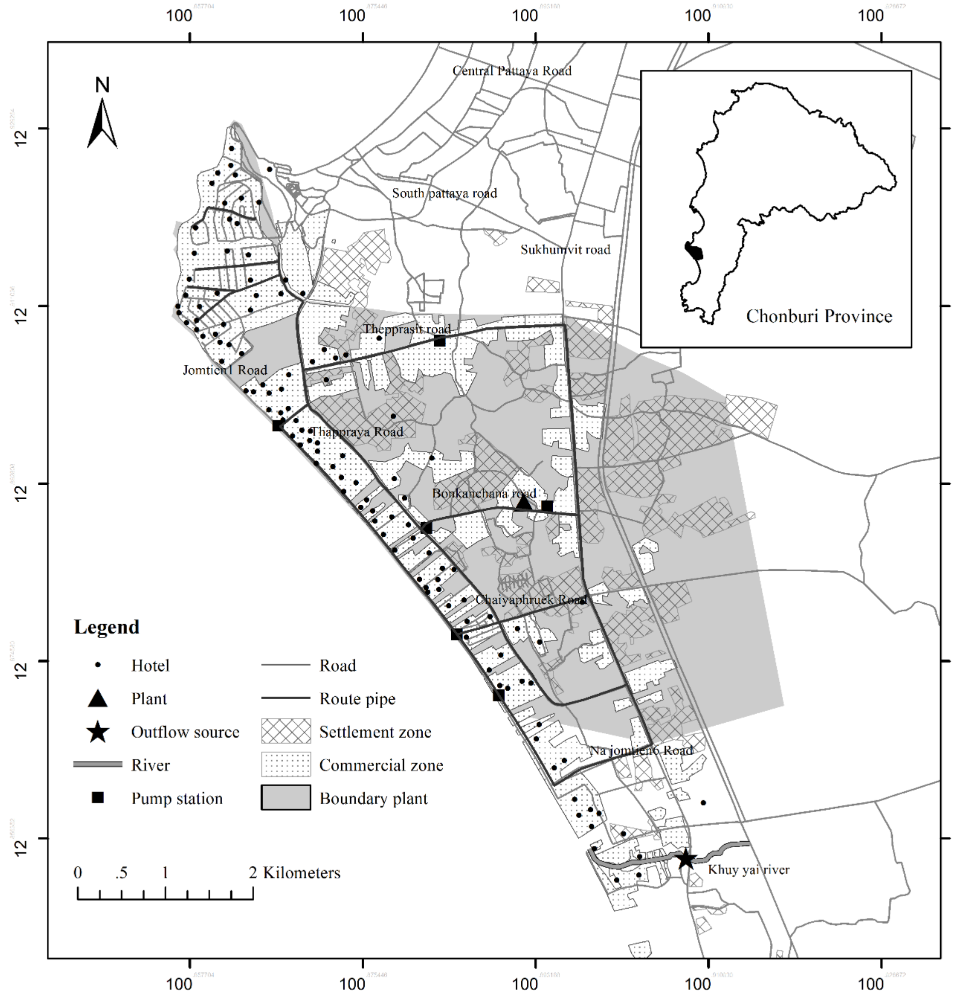

Figure 4. Land use classification analysis of Pattaya City.

4. Conclusion

According to land use classification analysis, it clearly showed that human activities were different between the two areas and wastewater quality of Pattaya city was better than that of Chonburi municipality. It was due to untreated wastewater in municipality, as poor design of sewage network which hasn't covered the whole area yet.

However, this study represented status of wastewater management, wastewater quality, sewage structure, outflow source in Chonburi Province. Thus improvements of wastewater network and water quality will help us to access effective wastewater management in this area.

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Environmental Health Impact Assessment and Its Defects in Thailand

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Abstract

Environmental health impact assessment (EHIA) has been legally implemented in Thailand since 2010 as denoted in a section 67 of the 2007 Thai constitution. This part stipulated that any project which may seriously affect a community in terms of environmental, natural resources, and health qualities, are required to be given opinions by the Independent Commission on Environment and Health (ICEH). According to regulation, there are currently 12 types of projects requiring EHIA. To date, a total of 26 EHIAs have been reviewed, 50 % of which were condemnable whereas the rest were accepted under conditional approval due to no alternative choices, lack of good practices and/or governance, poor assessments in environmental hazards and health impacts, as well as inadequate or inappropriate public participation. This paper aims to identify defects discovered in EHIA by the ICEH in order to improve the quality of EHIA in Thailand and to enhance the collaboration among all stakeholders of the society.

Key words: EHIA; public participation; environmental impact assessment

1. Introduction

It has been over six years since the Environmental and Health Impact Assessment (EHIA) was formally introduced in Thailand in 2010 as a consequence of the 2007 Thai constitution as to add the health impact assessment to the environmental impact assessment procedure, causing Thailand becoming one of the few countries to implement EHIA (Chanchitpricha and Bond, 2015). Since then, EHIA practice in Thailand has evolved and has conceptual understanding through an authorized agencies, i.e. The Office of Natural Resources and Environmental Policy and Planning (ONEP) and the Independent Commission on Environment and Health (ICEH), with 26 EHIA reports already submitted and approved. However, problems and controversy among counterparts still exists, often leading to severe conflicts in surrounding communities where EHIA has been performed, for example, Krabi coal-fired power plant, Pak Bara deep sea port in Satun and Map Ta Phut industrial estate in Rayong Provinces. This reflects distrust, unreliability and incredulity of the affected people to EHIA (Bankokpost, 2017).

Therefore, it is an urgent task to figure out the weak points in the EHIA and terminate them. Therefore, this paper aims to identify defects in the reviewed EHIA to increase its effectiveness and quality, as well as to help make decisions and positive impacts leading to enhanced trust and credulity among all stakeholders of the society.

2. Background of EHIA

2.1 What is EHIA

It is necessary to understand the meaning of environmental health:the, direct or indirect overall effects, of a policy, plan, program orproject on the health of a population. As a consequence, anything which alters a determinant of health may have an impact on health (Shafie *et al.*, 2013). However, not all potential impacts on health are negative, several activities may cause benefits which outweigh potential adverse impacts e.g. improved waste disposal or improved water supply and sanitation services. Therefore, it is important to discern the potential positive environmental health impacts from the negative ones. The World Health Organization, 1999 stated that the HIA is the combination of procedures, methods and tools by which a policy, program or project may be judged according to its potential effects on the health of a population, and the distribution of said effects.

Thus, on the basis of the above definitions of environmental health and HIA, EHIAcan be described as the process of examining or evaluating development policies, programs and projects for their potential impacts on the health status of human populations, and the distribution of such impacts among population/community groups (Hassan *et al.*, 2005). Additionally, EHIA provides a systematic process through which health hazards, risks and opportunities can be identified and addressed in a development activity planning process, to avoid transfer of hidden health costs and to promote multi-sectoral responsibility for health and well-being (Department of Health, 2010). EHIA is a multidisciplinary activity, crossing the boundaries between public health, healthcare, environmental and social sciences (BOI, 2014).

The process of EHIA is associated and often overlapping with EIA (Suwanteep *et al.,* 2016).Some countries have EIA procedures that need strengthening in terms of health, other countries have yet to develop any procedures for EIA (or for Health Impact Assessment). The terminology “EHIA” adopted in thisdocument refers to the strengthened health component within an EIA.Like an Environmental Impact Assessment, an EHIA includes a number of steps (Department of Health, 2010) (Fig. 1) below;

• Screening: The main purpose of this stage is to undertake a preliminary assessment (or screening) to see if a new proposal/program or policy is likely to pose any significant health impacts and effects and is therefore worth subjecting to a full HIA.

• Scoping: this stage sets out the boundaries of the impact assessment

• Assessment or appraisal: this stage is where the data will be collected in order to identify thepotential or actual impacts on health of a community/population

• Implementation and monitoring

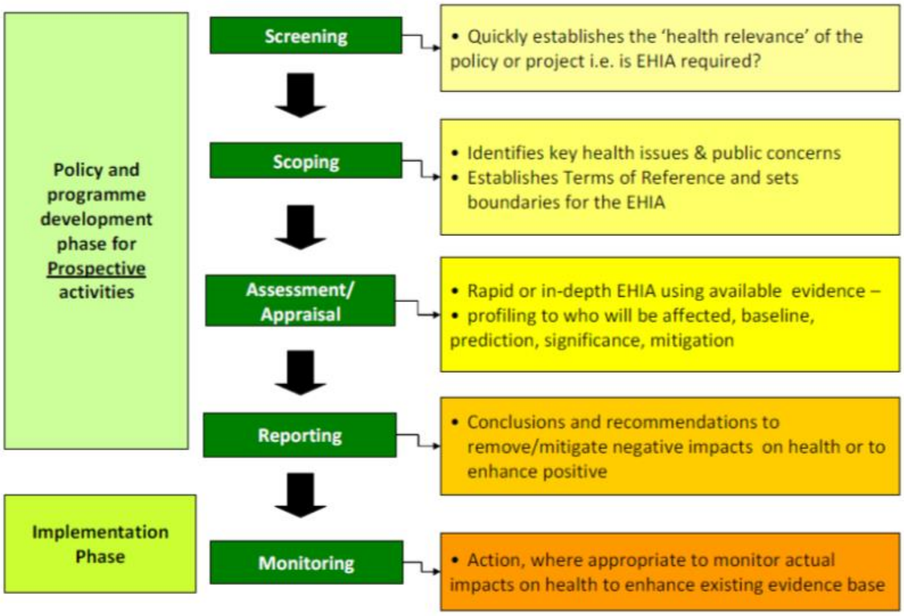

Figure 1. EHIA procedure of the World Health Organization (Department of Health, 2010)

2.2 EHIA in Thailand

EHIA in Thailand was legally instated since 2010 as mentioned by section 67 of Thailand's constitution 2007 "Any project and activity that may seriously affect the quality of the environment, natural resources and biological diversity shall not be permitted, unless its impacts on the quality of the environment and on health of the people in the communities have been studied and evaluated and consultation with the public and interested parties have been organized, and the opinion of an independent organization have been obtained prior to the operation of such project to activity". Byvirtue of such Article, the Ministry of Natural Resources and Environment announced a list of 12 industrial activities (see more detail in Appendix 1) that could potentially cause severe impacts to local communities in terms of natural resources, environment and health, for which environmental and health impact assessments must be conducted.

In order to complete the EHIA process, the project or activity proponent or the project approval authority must arrange a public hearing to review a draft of EHIA report. Any EHIA must contain opinions from people, stakeholders and the public together with comments and explanations to the expert review committee (ERC) for further consideration. The public hearing shall proceed according to both the EIA and HIA guidelines specified earlier.

In addition, The Office of Natural Resources and Environmental Policy and Planning (ONEP) issuing an EHIA guideline containing6 components to the EHIA: Screening, Public Scoping, Appraisal, Public Review, Decision Making and Monitoring (Fig. 2). All sections allow for greater participation by both stakeholders and concerned parties than a standard EIA study. Additionally, a comprehensive EIA report should address the severity of the impact of any project/activity upon human habitat by taking into consideration each category identified below. It should include a review of both biotic and abiotic factors as well as their value to humans and their effect upon the quality of human life. Biotic refers to living things that shape an ecosystem, while abiotic are non-living resources of an organism's environment, such as soil, water, air, temperature, and sunlight. (BOI, 2014)

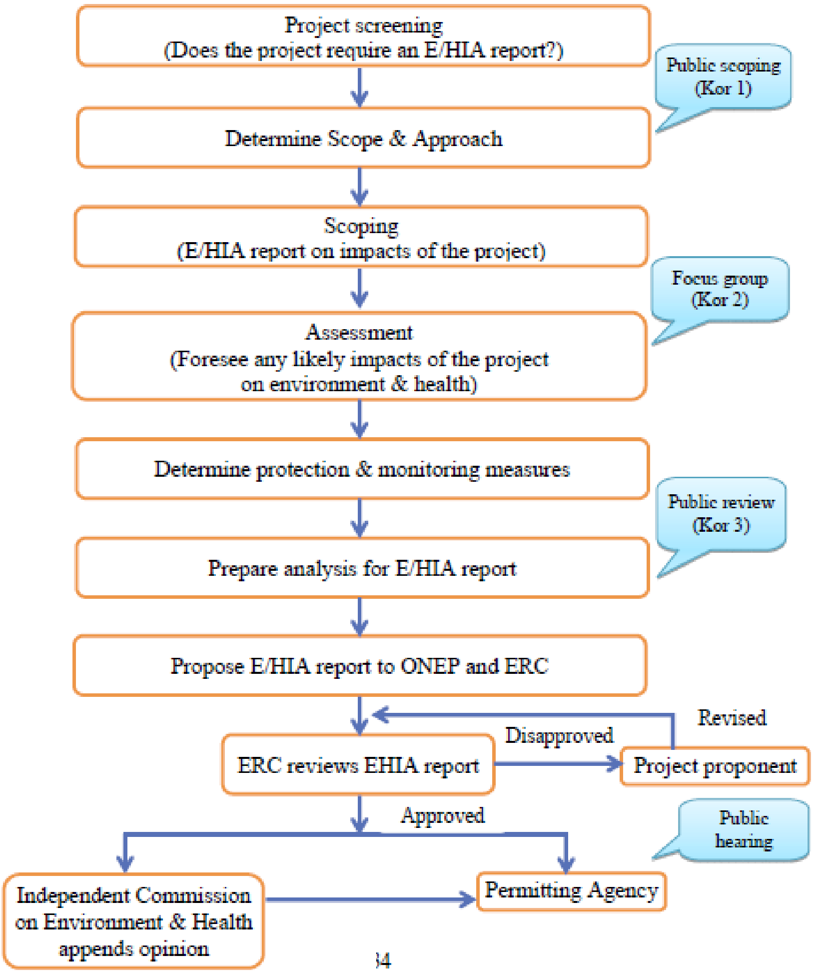

Figure 2. EHIA processes in Thailand (redrawn from ONEP, 2010)

2.3 The Independent Commission on Environment and Health (ICEH)

ICEH was established since 2010, according to section 67 of the 2007 Thai constitution, to assess any projects or activities which may seriously affect a community. IECH's task is not only limited to give comments on EHIA but also make suggestions on other issues of projects or activities. The 2007 constitution stated that the ICEH must protect and support the rights of community and people to take part in the preservation of the quality of environment and sustainable management of natural resources.

These responsibilities are aimed to reflect the view and opinions of all members of the society on the choices and decisions of the project. Thus, ICEH's opinions have to be based on academic facts and information, not on emotions or feelings. However ICEH has to complete and submit comments to the permitting agency within 60 days. The authorized agencies must take ICEH's comments into their consideration before approving or licensing that project.

3. Methods

A total of 26 EHIAs in Thailand have been approved by ONEP before revision by the ICEH during 2010 - 2016. According to ONEP's announcement (ONEP, 2010), these 26 EHIAs can be categorized and numbered (in parentheses) into 7 types of projects: 1) Mining (2); 2) Industrial estates (2); 3) Petrochemical industry (7); 4) Ore or metal smelting industry (6); 5)Central waste treatment or incinerator (1); 6) Port with berth length over or equal to 300 m.(1); 7) Thermal power plant (3 coal-fired and 4 natural gas power plants). The author, a commissioner of ICEH, had reviewed and gave comments to all of those EHIAs. Details of all 26 EHIAs are available online at www.iceh.or.th. Therefore, defects of these EHIAs were summarized and identified by using 5 criteria recommended by Hasson *et al.*, 2005 and the Department of Health, 2010 as the following;

1) Are there alternative choices to achieve a project's goals or products without conducting the project?
2) Whether or not the technology of the proposed project is academically suitable and would the impacts affect local communities and how to minimize or prevent them?
3) The quality of the monitoring and auditing processes.
4) In the case of being an extension of a previous project, are there any previous unresolved issues? As it may become common questions: will the proposed project solve or cause problems to the community?
5) The project's attention of the community's voice (public participation) and project contribution which is the source of much conflict.

4. Results and Discussion

The following points are defects that the author has encountered with 26 EHIAs (note: the points are not arranged in any particular order as all points have equal importance).

- Unclear engineering mass balance (Mackay and Seth, 1999).

Mass balance is necessary to keep track of the quantity of released and consumed materials, especially pollutants and natural resources. If the mass balance is unclear, how would it be possible to verify that the information of pollution treatment, pollution distribution, risk assessment of pollution exposure etc. on EHIA is reliable? ICEH already requested additional information from all projects, however, only a few projects provided the requested information to ICEH.

- Incomplete details regarding assessing and managing "abnormal operation" conditions (Kamrava *et al.*, 2015), in which all project's EHIA, failed to mention their control/damage minimizing protocols during abnormal conditions, only providing operation protocols for normal operation.

- Alternative options for projects. In other words, "If there is no such project, what would happen?" Thisincludes all projects that blatantly disregard any decommissioning protocols (Ragaišis *et al.*, 2016). This is especially an issue in the Map ta phut area when a project had been constructed but the factory was shut down and its machinery got dismantled. Several abandonedplants have had looters in their premises and property stolen, causing toxic materials to contaminate the local environment.

- Monitoring and Auditing efforts (Swangjang, 2006; Shafiea *et al.*, 2013) are probably the most important, and the most problematic, since they can no longer be relied to ensure the local communities are going to be safe from adverse effects due to the lack of proper and efficient investigation methods.

- Threat analysis done by projects often avoids the discussion of "worst case scenarios" (Karl *et al.*, 2011). In the Map ta phut area, for example, disasters occurred there are often products of such neglect. Several EHIA reports submitted by several projects stated that the Rayong Provincial Hospital can accommodate the necessary amount of patients in the event of a "worst case scenario". However in reality, the hospital is already overwhelmed with the usual daily amount of patients it receives, let alone having the capacity to care for additional patients in the case of a worst case scenario.

- Current information regarding pollution and natural resources is an ongoing issue. On several occasions, what we have discovered is completely different to what was stated in the EHIA report. In addition there are also cases of incomplete data in the EHIA reports regarding effected natural resources. For instance, an EHIA report did not include a nearby water resource which is also used for local consumption of nearby communities. Thus, no efforts were made to determine the impacts of the project to the water resource.

- The 5 kilometer radius assessment done by the projects. Where the 5 kilometer radius comes from is a source of debate as the ONEP stated they never had put down any such requirement (Amornpitakbhand, 2015). Nonetheless, the 5 kilometer radius assessment only includes the local population that resides in this radius, but doesnot include anyone who uses the resources within the radius. Thus, no studies were conducted to assess the impacts of the project on these people.

- Inadequate damage control protocols (Rechak *et al.*, 2013), this includes the training for carrying out the protocols which are usually not strictly conducted. This caused damage control efforts to be inefficient as seen from what happened on the 5th May 2012 (more detail is available at http://www.bangkokpost.com/learning/learning-news/292077/factory-blast-at-map-ta-phut).

- Public hearing/participation (as called Kor1 and 3) (Salonons *et al.*, 2014) conducted by the project's consultant were simply ceremonial as required by the ONEP, not actually taking what was mentioned in the hearings to improveor solve concerns of the projects. Furthermore, some of affected people were not invited to attend the hearing.

- The willingness of project directors to solve issues regarding to their projects is always an ongoing issue. During hearing sessions held to take in opinions from the public, IECH often found that only junior officerswere present on behalf of the project administrators. However, they have no authority to make decisions or conduct any major changes regarding the project.

- All EHIA reports stated that the projects submitted their Material Safety Data Sheet (MSDS) to the local Departments of Health. However, the local departments declared on public participation held by ICEH that they received no MSDS from the projects. (MSDS is a formal document containing important information about the characteristics and actual or potential hazards of all chemical substances used in the projects. This document is very important for aiding emergency.)

- Impact assessments on health, community, and natural resources in EHIA sometimes do not cover the concerns of local communities.

- Inadequacy of basic information (Kagstrom, 2016), which is the most problematic when doing EHIA in Thailand. ICEH have encountered several cases in which the EHIA makers have to start their EHIA from scratch even though those information are available. This is due to the fact that the information available is hard to access or the company does not know of its existence. Thus, the author recommendsto set up a central/national environmental database where anyone canaccess anduse the data for assessing the environmental impacts of large scale projects. With this, the EHIA process will be sped up andcan be therefore easily verifiedsince the data will come from the same source.

- The contents of the EHIA reports should be easy to understand for local people (Werner *et al.*, 2015). Some local people had stated that "Why does the EHIA have an Executive summary report but not a community report which would be easier for communities to understand?"
- The pollution carrying capacity is data showcasing the ability of an environment to "accept" pollution (Rega and Baldizzone, 2015). At this point, there is no EHIApresentingthis data, though it is the duty of the state to present such information. In addition to the SEA study, it hasnot been conducted seriously.
- Ecological assessment methods are outdated, unreliable and unscientific, making it almost impossible to accurately gauge the impacts of a project (Treweek, 1996; Wathern, 1999; Swangjiang *et al.*, 2004).

5. Conclusions

EHIA in Thailand still contains several serious defects which may cause severe conflicts among its stake holders. Even though EHIA is a good tool to optimize and balance development and quality of life for people living in or nearby the proposed project, however, poor EHIA may cause or expand conflicts among stake holders. Local government offices related to any community's concern must attend EHIA's public participation and have an open mind to contribute academic information to the public. Nonetheless, the most important approach is that study of EHIA must be performed sincerely and academically.

One possibility of improving the quality of the EHIA is to have several EHIA reports on the same project; one made by the project owner and one by the local community or a third party. As long as all versions are using up-to-date information and reporting on the same area that a project is going to effect, even though they use different methods to assess the affected area, it is acceptable. This would cut down the time to review EHIA significantly, as well as being more efficient.

Finally, the expectations of the author for the EHIA are as follows:

1) Academic information stated in the EHIA reports regarding the projects should be accurate and up-to-date.
2) A central data base for all up-to-date information on the environment be set up. This will speed up the EHIA making process and the information used would be easily traceable.
3) Pollution containment and eradication efforts should be revised to be more strict and efficient.
4) Closer cooperation between the companies, local community, and the government, as per the Thai constitution.
5) Environmental laws be more strictly enforced

6) Better court prosecution regarding environmental cases, or better yet; set up a separate court to deal with environmental cases specifically.

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Appendix I

Type, size and implementing procedure of project or activity that may cause a severe impact on the quality of environment, natural resources, and health of a community that requires a government agency, a state enterprise, or a private enterprise to prepare an environmental impact assessment (ONEP, 2010)

No.	Type of Project/Activity	Size	Criteria, Implementing Procedure
1	Land reclaimed from sea or lake off the existed coastal area, excluding a land claimed for beach rehabilitation	300 rai	To be submitted during the project approval or permission process.
2	Mining according to the Mining Act as follows:		
	2.1 Underground mining, only that its supported structure is designed to subside after mining without using any supporters or substitute material to prevent a subsidence.	All sizes	To be submitted with the application during the mining permit process.
	2.2 Lead mining, zinc mining, or other metal ore mining that uses cyanide or mercury or lead nitrate in a process, or other metal ore mining having arsenopyrite as an associated mineral	All sizes	To be submitted with the application during the mining permit process.
	2.3 Coal mining, only the case that coal is transported out of the mining area by land vehicle	≥ 200,000 ton/month or ≥ 2,400,000 ton/year	To be submitted with the application during the mining permit process.
	2.4 Sea mining	All sizes	
3	Industrial estate as defined by the industrial estate laws; or other projects with similar features of industrial estate, as follows:		
	3.1 Industrial estate or its similarity established for facilitating more than 1 factory of petrochemical as specified in No. 4 or iron smelting industry as specified in No. 5.1 or 5.2 as the case maybe.	All sizes	To be submitted during the project approval or permission process.

No.	Type of Project/Activity	Size	Criteria, Implementing Procedure
	3.2 Industrial estate or its similarity that is expanded to facilitate petrochemical industry as specified in No. 4 or iron smelting industry as specified in No. 5.1 or 5.2	All sizes	To be submitted during the project approval or permission process.
4	Petrochemical industry as follows:		
	4.1 Upstream petrochemical industry	All sizes or All sizes or production capacity is expanded by ≥ 35%	To be submitted with the application during the process for a construction permit or a factory operation permit, or a factory expansion permit, as the case maybe.
	4.2 Intermediate petrochemical industry, as follows:		
	4.2.1 That produces Group 1 carcinogens or that uses Group 1 carcinogens as raw material	Production capacity of ≥100 ton/day or Total expansion of ≥ 100 ton/day	To be submitted with the application during the process for a construction permit or a factory operation permit, or a factory expansion permit, as the case maybe.
	4.2.2 That produces Group 2A carcinogens or that uses Group 2A carcinogens as raw material	Production capacity of ≥700 ton/day or Total expansion of ≥ 700 ton/day	To be submitted with the application during the process for a construction permit or a factory operation permit, or a factory expansion permit, as the case maybe.
5	Ore or metal smelting industry, as follows:		
	5.1 Iron smelting industry	Having input capacity of ≥ 5,000 ton/day or Having total input ≥ 5,000 ton/day	To be submitted with the application during the process for a construction permit or a factory operation permit, or a factory expansion permit, as the case maybe.

No.	Type of Project/Activity	Size	Criteria, Implementing Procedure
	5.2 Iron smelting industry having coke production process or sintering process	All sizes	To be submitted with the application during the process for a construction permit or a factory operation permit as the case maybe.
	5.3 Copper, gold, or zinc smelting	Having input capacity of ≥ 1,000 ton/day or Having total input ≥ 1,000 ton/day	To be submitted with the application during the process for a construction permit or a factory operation permit, or a factory expansion permit, as the case maybe.
	5.4 Lead ore smelting	All sizes	To be submitted with the application during the process for a construction permit or a factory operation permit as the case maybe.
	5.5 Metal smelting (except iron and aluminum)	Having capacity of ≥ 50 ton/day or Having total capacity of ≥ 50 ton/day	To be submitted with the application during the process for a construction permit or a factory operation permit, or a factory expansion permit, as the case maybe.
	5.6 Lead smelting	Having capacity of ≥ 10 ton/day or having total capacity of ≥ 10 ton/day	To be submitted with the application during the process for a construction permit or a factory operation permit, or a factory expansion permit, as the case maybe.
6	Production or disposal or treatment of radioactive substances	All sizes	To be submitted with the application during the process for a factory operation permit.
7	*Central waste treatment plant, landfill or incinerator according to the factory law, having incinerated or landfilled hazardous waste, except when hazardous waste is	All sizes	To be submitted with the application during the process for a construction permit or a factory

No.	Type of Project/Activity	Size	Criteria, Implementing Procedure
	used as a substitute raw material or fuel in a cement kiln		operation permit as the case maybe.
8	Air transportation system	Runway is constructed or expanded ≥ 3,000 m.	To be submitted during the project approval or permission process.
9	*Port	1) Berth length ≥ 300m or Port area ≥ 10,000 sqm; excluding port for daily life transportation or tourism	To be submitted during the project approval or permission process.
		2) With channel dredging of ≥ 100,000 m3	To be submitted during the project approval or permission process.
		3) Where hazardous substances or hazardous wastes considered as Group 1 carcinogens is transshipped in total quantity of ≥ 25,000 ton/month or ≥ 250,000 ton/year	To be submitted during the project approval or permission process.
10	Dam or reservoir	1) Storage volume of ≥ 100 million m3, or	To be submitted during the project approval or permission process.
		2) Storage area of ≥ 15 sq. km.	To be submitted during the project approval or permission process.
11	Thermal power plant as follows:		
	11.1 Coal power plant	Total capacity of ≥ 100 MW	To be submitted with the application during the

No.	Type of Project/Activity	Size	Criteria, Implementing Procedure
			process for a construction permit or a factory operation permit as the case maybe.
	11.2 Biomass power plant	Total capacity of ≥ 150 MW	To be submitted with the application during the process for a construction permit or a factory operation permit as the case maybe.
	11.3 Natural gas power plant, which is combined cycle or cogeneration power plant	Total capacity of ≥ 3,000 MW	To be submitted with the application during the process for a construction permit or a factory operation permit as the case maybe.
	11.4 Nuclear power plant	All sizes	To be submitted with the application during the process for a construction permit or a factory operation permit as the case maybe.
12	Coking coal industry	All size	To be submitted during the project approval or permission process

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The "Fishing for Litter Programme", an Example of a Practical Policy and Management Tool Applied on the International Level to Address the Extensive Environmental Problem of Plastic Pollution in the Marine Environment

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Abstract

Plastic pollution in the marine environment is an extensive problem on a global scale with a large number of environmental impacts, with adverse effects on e.g. the ecosystem, fisheries and tourism. KIMO is a local authorities international environmental organisation designed to give municipalities a political voice at regional, national and international level. For almost 15 years, the organisation coordinates a project called Fishing for Litter — an imaginative yet simple initiative that aims to reduce marine litter by involving one of the key stakeholders, the fishing industry. The initiative not only involves the direct removal of litter from the sea, it also raises awareness of the problem in the fishing industry. On the policy level this included extensive lobbying on the local, national, European and international level. As a result Fishing for Litter is currently operating in the UK, the Netherlands, Sweden and the Faroe Islands and has been endorsed by OSPAR as a model for their members to adopt. Thus, it evolved from a locally oriented project to an initiative that influences international maritime environmental policy and decision making processes. The past 15 years over 4500 tonnes of marine litter have been collected by fishing vessel in the countries where the project has been implemented.

Keywords: Fishing for Litter; marine pollution; plastic soup

1. Introduction

Plastic pollution in the marine environment is an extensive problem on a global scale with a large number of environmental impacts, with adverse effects on e.g. the ecosystem, fisheries and tourism. Each year, at a minimum 8 million tonnes of plastics end up in the ocean. There is estimated that there are over 150 million tonnes of plastics in the ocean today. In a business-as-usual scenario, the ocean is expected to contain 1 tonne of plastic for every 3 tonnes of fish by 2025 (World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, 2016). KIMO (Kommunenes Internasjonale Miljøorganisasjon) was founded by local municipalities with a shared concern for the state of the environment, in response to a series of emerging environmental threats. KIMO is a local authorities international environmental organisation designed to give municipalities a political voice at regional, national and international level. It has over 70 municipal members in Belgium, Denmark, The Faroe Islands, Germany, The Netherlands, Sweden and the United Kingdom. Over the past 25 years KIMO has become a pioneering environmental force which has contributed to a steady reduction in marine pollution in Europe's seas.

For almost 15 years, the organisation coordinates a project called Fishing for Litter — an imaginative yet simple initiative that aims to reduce marine litter by involving one of the key stakeholders, the fishing industry. KIMO provides fishing boats with large bags to collect marine litter. When the fishing boats come into port, they can unload the bags of litter. These bags are collected regularly and the rubbish is recycled or disposed of on land. This reduces the volume of debris washing up on our beaches and the amount of time fishermen spend untangling their nets. The initiative not only involves the direct removal of litter from the sea, it also raises awareness of the problem in the fishing industry. Fishing for Litter is currently operating in the UK, the Netherlands, Sweden and the Faroe Islands and has been endorsed by OSPAR as a model for their members to adopt. OSPAR is the mechanism by which 15 Governments and the European Commission cooperate to protect the marine environment of the North-East Atlantic. The past years over 4500 tonnes of marine litter have been collected that way.

2. Materials and Methods

In the North Sea and North Eastern Atlantic, fishermen quite often collect marine litter during their daily fisheries operations. In most cases that litter was thrown overboard again, but caught in the nets not too soon after. This led to the idea that somehow marine litter could be removed from the sea during daily operations of fishermen. But how? That was one of the questions that needed to be addressed during the start of the programme, which was an EU funded project at first, in 2002. Since fisheries communities are part of coastal municipalities the link between them is evident and cooperation between KIMO and the fisheries organisations was established. To address the complex and extensive issue of plastic soup effectively, one needed to assess the waste value chain and a four pronged approach was needed to establish the programme and to create support. This meant extensive lobbying and fundraising. The lobbying to remove litter from the seas by means of fisheries vessel included addressing four levels of organisations: at the local level, the national level, the European level and international level. Because of its practical appeal, this initially small scale initiative could link at a later stage to the environmental policy cycle (Jann & Wegrich, 2007) and one was able to become an agenda setting issue that even became part of environmental policy formulation for countries which cooperate within the OSPAR convention.

3. Results and Discussion

At the local level, organisations that needed to be contacted included: crews of fisheries vessels that collect waste, port authorities of ports that receive waste, and the management of waste collection and processing companies that process the litter. A lot of extensive and lengthy lobbying was needed to convince fishermen to join the programme. Next, negotiations with port authorities who are legally responsible for waste reception by means of OSPAR and IMO regulations was done. However, "Fishing for Litter waste" was not a kind of waste that ports had to acceptlegally, since this was a new kind of waste. This meant negotiations with ports on how to deal with this. In addition, the waste needed to be processed as well, which meant involvement of the waste collection and processing sector. During the project's implementation, it became apparent that the problem was extensive and funding and political support on a higher level would be needed to make it a success. Thus, negotiations with national governments of coastal European Member States were started. A number of Member States where willing to support the programme, including the United Kingdom and the Netherlands. Since the value of the programme was acknowledged, national governments also supported a more international approach for the seas do not know boundaries. That was why the Oslo Paris Convention (OSPAR for short) was contacted. As a result OSPAR adopted Fishing for Litter actions in the Regional Action Plan for the North East Atlantic. At a next stage lobbying with the European Commission was started. This led, only recently, to discussions on the possible alteration of environmental maritime legislation with regard to waste reception of ports on the pan European level.

4. Conclusion

In conclusion, a locally oriented initiative to remove marine litter from the seas by means of fishermen, was framed in such a way that it was adopted by national and international authorities to addressing plastic pollution of the seas. The idea is adopted in the North East Atlantic region. The prevention of the dumping of litter into the oceans would be better, but this practical approach leads to results as well, e.g. appr. 4500 tonnes of waste have been removed in 15 years.

Acknowledgements

The authors express their thanks to all those who funded and/or participated in the programme, local and national authorities, port authorities, waste processors; but above all the fishermen who do all the work, to remove litter from the seas.

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EnvironmentAsia

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How to Actively Engage Society in Environmental Policy and Management: the Dutch "Green Deal Approach" as an Example of Addressing Effectively the Prevention of Littering and the Removal of Litter in the Coastal and Marine Environment

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Abstract

Environmental problems are vast and addressing these by imposing legislation and law enforcement alone does often not solve the problem effectively. Another option is present: engage the stakeholders who are either responsible for the pollution and those who could help prevent or cure this and thus making them part of the Environmental Policy Cycle process. This is what is practiced in the Netherlands for a number of years, the so called "Green Deal Approach". In this approach the National government with stakeholders are linked to an environmental problem and together solve that problem. Three maritime Green Deals, are presented in this article: Green Deal Fisheries for a Clean Sea, Green Deal Ship Generated Waste and the Green Deal Clean Beaches. In these Green Deals stakeholders participate actively, which creates support for this policy approach. It also leads to new insights and ideas for environmental measures. The Green Deal approach is an innovative way to include society to solve environmental problems. In this initiative, the national government is no longer the manager of the environmental policy processes but fosters a bottom up approach, allowing society to participate and to act and address environmental issues. This approach, together with communication, economic and legal environmental instruments that are in place, addresses environmental problems on a more acceptable and effective way.

Keywords: environmental policy; public participation; network management; Green Deal Approach; Green Deal Fisheries for a Clean Sea; Green Deal Clean Beaches; Green Deal Ship Generated Waste; marine pollution; plastic soup

1. Introduction

Environmental problems can be caused by market failures, linked to negative externalities (Löfgren, 1998). Apart from this awareness and mentality play also an important role. To a large extent this also applies to pollution of the coastal and marine environment with adverse effects on the ecosystem, fisheries and tourism. Each year, at a minimum 8 million tonnes of plastics end up in the world's oceans. It has been estimated that there are over 150 million tonnes of plastics in the ocean today. In a business-as-usual scenario, the ocean is expected to contain 1 tonne of plastic for every 3 tonnes of fish by 2025 (World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, 2016). However, this is a global problem with large regional differences in abundances being present. How to prevent and address such pollution in an effective way? Policy instruments that could be applied to solve the issue can be divided into three main groups: communication, economic and legal instruments (Van den Heuvel, 2001). National governments often define legislation and impose regulations to prevent pollution of all kinds or allocate funds for subsidies to address the issue. Of course this is important and needed, but additional environmental and economic benefits can be reached by making use of the positive energy and initiatives in society. This involves a combination of communication and economic instruments with some legal actions. A network management approach could be applied: engage the stakeholders who are either responsible for the pollution or could help prevent or cure this, thus making them part of the Environmental Policy Cycle process (Jann & Wegrich, 2007). This is what is applied in the Netherlands for a number of years, the so called "Green Deal Approach". An essential aspect of this approach is that there is a shared ownership. The stakeholders are the "owners" of the initiative and therefore responsible for its outcome. A small group of frontrunners can create a transition in society, of which awareness and the will to take responsibility are key elements. About 180 Green Deals have been launched so far of which 3 address the marine environment including: the Green Deal Ship Generated Waste, the Green Deal Fisheries for a Clean Sea and the Green Deal Clean Beaches, the last two are discussed in this article. Apart from the Green Deals there is the Plastic Value Chain Agreement as well, a wider Dutch initiative that fosters the cooperation between all kinds of stakeholders in the Netherlands that are involved in plastic production, consumption and clean up of plastic waste. Green Deals are targeted to specific sectors.

2. Materials and Methods

For a Green Deal approach one needs a well defined organisational structure and a proper approach that appeals to the stakeholders to work on the problem. It is a kind of network management for which in general are needed (Glasbergen, 1995):

1. The creation of an organisational framework for guidance of the processes of interaction and communication;
2. Methodological supervision of the processes of interaction and communication.

Regarding the organisational framework the structures that are applied to the Green Deals include, are 1) a secretariat to guide the process, 2) a steering committee made up of the stakeholder groups 3) the national government to solve legal obstacles when needed, and 4) the group of stakeholders itself. The methodological framework and its supervision includes an accepted agreement in which common objectives are defined, and planned meetings and events. In addition, the interaction and progress should be monitored and observed, the agreements should be kept. Important is that stakeholders are both being informed and able to discuss their views in the meetings. These meetings have a decisive role as well: the group has to decide on the practical measures that will be applied and the roles of every participant in the implementation process. There should be room for launching project proposals by the stakeholders themselves, which helps to support the initiative. A small annual budget for that is available. The Green Deal Clean Beaches includes 40 stakeholders and stakeholder groups, representing: beach pavilion owners, coastal municipalities, national NGO's, local action groups, the Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs. In this Green Deal there is a role for start-ups that could become the driving force for new business models on the application of waste as a resource. In the Green Deal Fisheries for a Clean Sea, apart from the Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs 20 stakeholders and stakeholder groups participate, including: port authorities, coastal municipalities, fishermen and Fisheries Associations, waste collectors and processors and national NGO's.

3. Results and Discussion

The latter two Green Deals described started in November 2014 and already reached interesting results. These include: the implementation of pilot projects launched in several ports to collect waste dolly rope (parts of nets), thus preventing this to end up into the sea. Another result is improved collection of fisheries related wastes in ports like waste nets, dolly rope, galley waste, oily waste and waste collected during fisheries activities (the so called "Fishing for Litter waste"). Easy accessible disposal of these wastes in the ports is key. On beaches new ways of litter prevention have been launched for beach visitors. Well sited new types of waste bins encourage the public to deliver and separate waste. Beach pavilion and restaurant owners take responsibility for the litter on their terrace and the surrounding beach . In addition, the Green Deal links all kind of initiatives to clean up beaches and to recycle or reuse materials. The Green Deal concept, leads to enthusiastic response and activation of the stakeholders, thus creating support for this kind of environmental policy. The participating stakeholders always look for ways to find an answer to the challenges that are met during the process. Stakeholders meet on a regular basis, develop new approaches and business models hence mutual trust increases. It leads as well to the implementation of environmental measures and solving legal barriers when needed.

4. Conclusions

The Green Deal approach is an innovative way to enable society to solving environmental problems. It is a kind of network management approach in which the stakeholders are owners of the environmental management process and its outcomes. The national government is no longer the manager of and responsible for environmental policy processes. Instead it sets preconditions and helps stakeholders to build up a resilient community (and ecosystem) that solves their environmental issues.

Acknowledgements

The authors express their thanks to those who participate in the Green Deal Ship Generated Waste, Green Deal Fisheries for a Clean Sea and the Green Deal Clean Beaches.

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A Powerful Research Tool for Screening and Development of Solid-state Catalysts Building up the Environment Harmless Chemical Technologies

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Abstract

Environmentally harmless technologies are essential for the global environmental protection. However, most of chemical processes in chemical industries still remain low efficient and environmentally harmless; where E-factor (kg waste/kg product) of small chemical processes remains generally 5 – 100. In addition, conventional chemical processes involve the usage of organic solvents and toxic materials so that these processes would be replaced with environment friendly materials. To improve or replace such inefficient and harmless processes with more efficient and environmentally friendly processes, the development of recyclable and environmentally friendly solid-phase catalysts without using organic solvents is a key approach. In the present study, the potential of hydrothermal flow reactors, which would be useful for development of solid-state catalysts in hydrothermal conditions, will be described.

Keywords: research tool, solid-state catalyst; liquid-solid phase reaction; classical inefficient industrial chemical processes, high temperature; hydrothermal reaction

1. Introduction

Development of environmentally harmless technologies without toxic environmentally safe materials would be a key approach for the global environmental protection. Alternatively, the improvement of efficiency in such chemical processes is also required. Recently, organic reactions in aqueous solutions, especially hydrothermal reactions, have been focused as more environmentally friendly chemical medium by replacing conventional organic synthetic processes involving the use of organic substances and solvents. Different applications under hydrothermal conditions have been focused for providing potentially efficient and rapid alternative pathways instead of synthetic processes in organic reactions at low temperatures (Schmieder *et al.*, 2000; Sanchez-Oneto *et al.*, 2007; Jin and Enomoto, 2008). However, many of conventional (or classical) industrial chemical processes still remain environmentally unfriendly with low efficiency. The E-factor (kg waste/kg product) of such small chemical processes is generally 5–100, especially for the fine chemical and pharmaceutical processes (Poliakoff *et al.*, 2002; Constable *et al.*, 2002).

This fact would also contribute to rising up the price of the products, such as medicines, which would lead the inequality in consumption. Improvement of efficiency of industrial productions is one of the main approaches for the global environmental protection as well as the reduction of consumptions. According to these reasons, the research tools for improvement of such hydrothermal processes are highly desirable from different viewpoints (Kawamura, 2016; 2017).

On the other hand, the development of recyclable and environmentally friendly solid- phase catalysts, which are active in liquid-phase reactions, is a key approach (Sheldon, 1997; Rinaldi & Schüth, 2009) to improve the efficiency of the low efficient chemical processes. Here is a general problem that in situ and real time monitoring of such reaction processes at the millisecond to second time scale is difficult, although the importance of analytical measurements of solid-state catalysts is well known (Weckhuysen, 2003; 2004; Weckhuysen & Keller, 2003). The fact that such liquid phase processes frequently proceed at high temperatures and pressure make the real-time and in situ monitoring more difficult (Kawamura, 2011a). The development of the solid-phase catalysts is normally carried out indirectly by analyzing samples after the reactions, which are exposed at high temperatures. Thus, an efficient research tool for screening and development of solid-state catalysts is desired to improve the quality of such classical chemical processes. The importance of solid-state catalysts for replacing conventional inefficient chemical processes with efficient ones is illustrated in Figure 1. In the present paper, I summarize the usefulness and scope of our techniques as the research tools for improvement of solid-state catalysts.

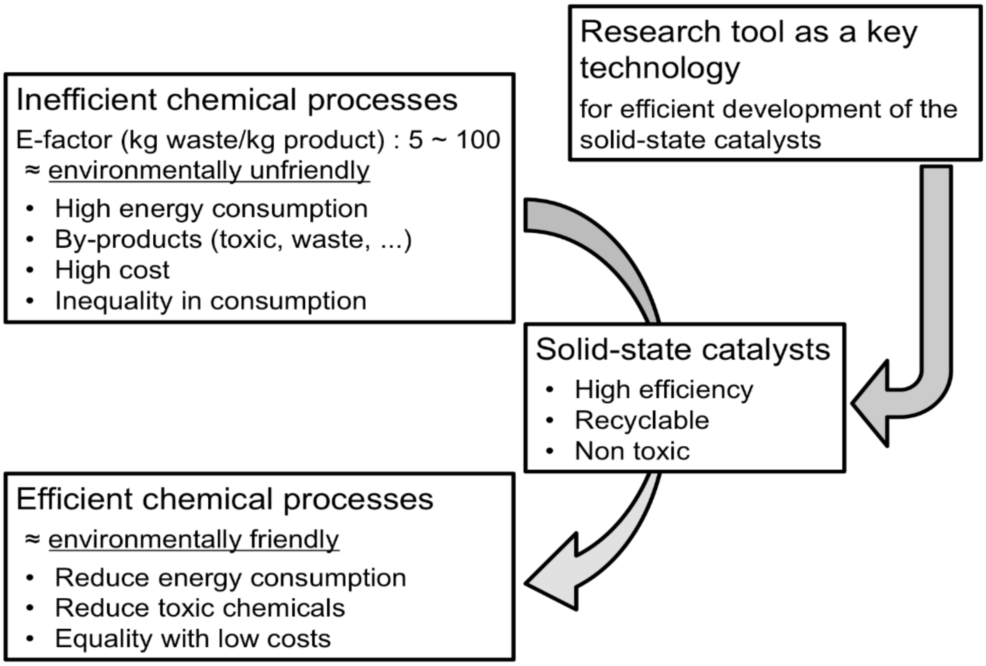

Figure 1. Role of the research tool as a key technology for improvement of chemical industrial processes, where the development of solid-state catalysts is essential.

2. Development of Hydrothermal Micro-flow Reactor Systems

2.1. Real-time Monitoring within the Millisecond to Second Time Scale and in situ Monitoring of Absorption Spectra at UV-visible Region

Originally, we started to develop hydrothermal flow reactor systems to investigate a fundamental study that is chemical evolution processes in relation to the origin of life problem. These reaction rates become fast with increasing of temperature so that the reaction behaviors cannot be monitored directly and in real time using conventional batch reactors. By using a conventional high temperature and pressure resistant batch reactor, a sample is putted in the batch reactor, heated for a certain reaction time, and then the sample is taken out for analysis of the products. The batch reactor possesses several disadvantages including that this cannot perform to analyze rapid reactions since heating time for the batch reactor itself is required for a several minutes at shortest, 100 – 10000 mL of sample volume is frequently required, time-consuming, it is sometime dangerous if the batch reactor size is large. We have successfully developed a hydrothermal flow reactor (HTFR), and HTFR solved most of disadvantages, which appeared in the conventional batch reactors. HTFR enables to monitor the chemical reactions under the extreme earth environments in relation to the chemical evolution of biomolecules. The principle is already described in our previous studies (Kawamura, 1998; 1999a; 1999b; 2000). The hydrothermal flow reactor consists of a water reservoir, a high-pressure pump, a sample injector, a high-temperature, high-pressure resistant reactor, a temperature controller, a cooling bath, a pressure regulator, and a sampling port. Modifications for the reactions in the presence of solid particles and for the in situ monitoring of absorption spectra within UV-visible-NIR region have been made continuously to fit fundamental and practical requirements. The development of hydrothermal flow reactor systems is summarized in Table 1. In principle, if the size of flow reactor tubing, that is, its inner diameter and its length is reduced, the residence time, of which the sample solution is exposed at high temperature, can be decreased (Kawamura, 1999b; 2011a). A typical flow reactor system for screening solid-state catalyst with in situ absorption spectrophotometer, which is described in a later section (Kawamura, 2017), is illustrated in Figure 2. The minimum residence time samples exposed at high temperature reactor tubing can be decreased down to 2 milliseconds, at which a fused-silica capillary tubing of inner diameter 0.025 mm and 5 cm length was applied (Kawamura, 1999a; 2000). This is a shortest residence time among the different types of flow type reactors (Masten *et al.*, 1993; Kieke *et al.*, 1996). The decrease of viscosity of water with increasing temperature notably contributes the success of this technology. The reason from the viewpoint of hydrodynamics why such a short time monitoring time was achieved was also quantitatively described in previous publications. The rate of heat transfer is also important factor to determine the success of this technology (Kawamura, 1999b).

Since fused-silica capillary tubing was used in HTFR for the millisecond scale of reaction monitoring, we found that this system can be readily applied for in situ measurements of absorption spectra if the polymer coating of fused-silica capillary is removed or capillary tubing covered with transparent polymer coating is used (Kawamura, 2002). An optical window, which was made on the fused-silica capillary tubing, was connected with a pair of optical fibers and then the UV-visible detection signals can be obtained, namely, the capillary flow hydrothermal reactor system for the UV-visible spectrophotometric detection system (CHUS) (Kawamura, 2002; 2003a; 2003b; 2005). Recently, it was confirmed that transparent polymer coated fused-silica capillary can be more easily used for CHUS.

Table 1. Improvement of hydrothermal flow reactor systems

Type of flow reactor	Method	Improvement	References
Real time monitoring of hydrothermal reactions using narrow tubing	HTFR	Monitoring at 0.002 – 200 sec, at 400 ºC, at 30 MPa.	Kawamura, 1999a; 1999b; 2000
In situ monitoring of hydrothermal reactions with UV-visible absorption spectrophotometer	CHUS	In situ measurement of UV-visible-NIR absorption spectra at 200 – 600 nm, at 0.3 – 60 sec, at 400 ºC, at 30 MPa	Kawamura, 2002; 2003a; 2003b; 2005; Kawamura *et al.*, 2010
Mineral-mediated hydrothermal flow reactor	MMHF	High temperature reactor column packed with mineral particles at 0.3 – 60 sec, at 300 ºC, 30 MPa.	Kawamura, 2011a; 2011b
Flow injection analysis for high temperatures with hydrothermal flow reactor	HT-FIA	Reactions are accelerated with high temperature reactor at temperatures up to 400 ºC	Kawamura *et al.*, 2011b; 2012
In situ monitoring in the presence of solid-state-catalysts with UV-visible-NIR spectrophotometer	SSCM-SP	High temperature reactor column packed with solid-state catalysts and in situ analysis at UV-visible-NIR region.	Kawamura *et al.*, 2016; 2017

HTFR and CHUS are used for hydrothermal reactions at temperatures up to 400 ºC at the millisecond to second time scale. We have successfully demonstrated the usefulness of these techniques for the study on chemical evolution and the origin of life problem, especially on the reaction behaviors of amino acids, peptides, nucleotides, and RNA molecules (Kawamura, 2000; Kawamura & Yukioka, 2001; Kawamura, 2003c; 2003d; Kawamura *et al.*, 2005; 2009; El-Murr et al., 2012). Furthermore, we showed that these techniques are useful for measuring biologically important weak interactions, that is hydrogen bonding and hydrophobic interactions. That is to say, CHUS can be readily applied to use for thermodynamic measurements as the conventional UV-Visible spectrophotometer is used for thermodynamic measurements (Kawamura, 2003a; 2005; Kawamura & Nagayoshi, 2007; Kawamura *et al.,* 2010).

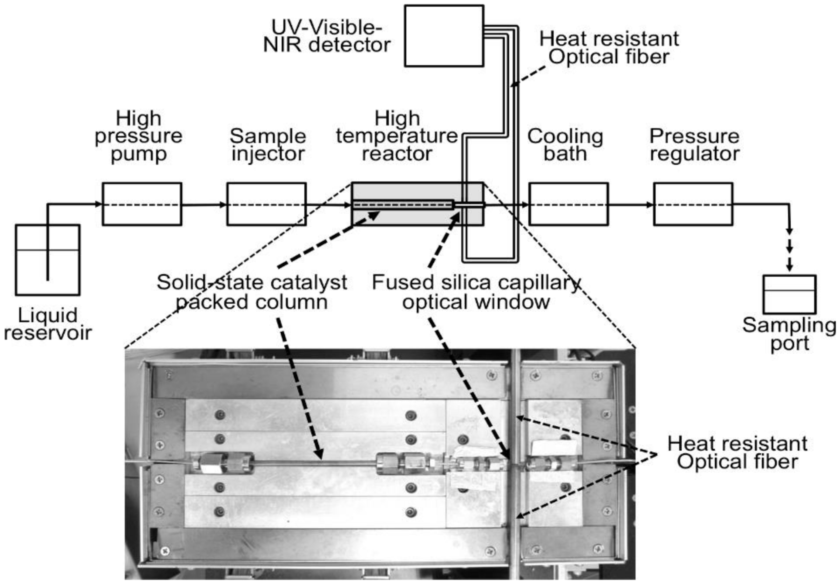

Figure 2. Components of the flow reactor system for the investigation of hydrothermal reactions (Kawamura *et al.*, 2017).

2.2. Application of Hydrothermal Flow Reactor Systems for Heterogeneous Reactions

On the other hand, it is known that real hydrothermal system in submarine hydrothermal vent systems involve dynamic interactions between seawater and minerals while our hydrothermal flow reactor systems are normally used for monitoring homogenous hydrothermal reactions without solid phases. Thus, we attempted to develop a new type of hydrothermal reactor, which simulates more realistic natural hydrothermal systems in the presence of solid-state mineral particles. We attempted to use a narrow column, of which naturally occurring minerals are packed, settled in a block heater of the hydrothermal flow reactor system. This attempt was succeeded for monitoring heterogeneous hydrothermal systems involving solid-phase and water-phase, namely mineral-medicated hydrothermal flow reactor (MMHF) (Kawamura, *et al.*, 2011a). By using MMHF, we succeeded to discover the mineral enhancement for spontaneous oligopeptide elongation under hydrothermal conditions by carbonate minerals. Furthermore, we applied to connect

MMHF to a UV-visible-NIR spectrophotometer with a pair of optical fibers at the downstream of the high temperature reactor column according to the similar principle designed for CHUS. These techniques are also useful for the studies on chemical evolution and origin of life problem.

3. Application of Hydrothermal Reactors for Green Technologies

3.1. Application to Green Analytical Methods

Nowadays, many types of analytical techniques are quickly developed. These methods are frequently based on the improvement in the fields of technologies in physics, electronics, mechanics, and sometime biotechnologies. Naturally, these methods are useful for quantitative and qualitative analysis. For instance, the detection limits of physical analytical techniques have been improved quickly. However, this strategy causes problems on the high costs, such as the price of instrument itself, high running costs, and high investment for instrumentation. In other words, these technologies would not be assigned as environmental friendly technologies. In addition, these advanced technologies are not widely used, because of some reasons. For instance, high quality of maintenance is required, but this is not always available except for highly developed countries. The trend would reflect the problem on the excessive technical progress and the big science since the stream for development of high-cost analytical instruments seems to be strongly related with the rapid developments societies.

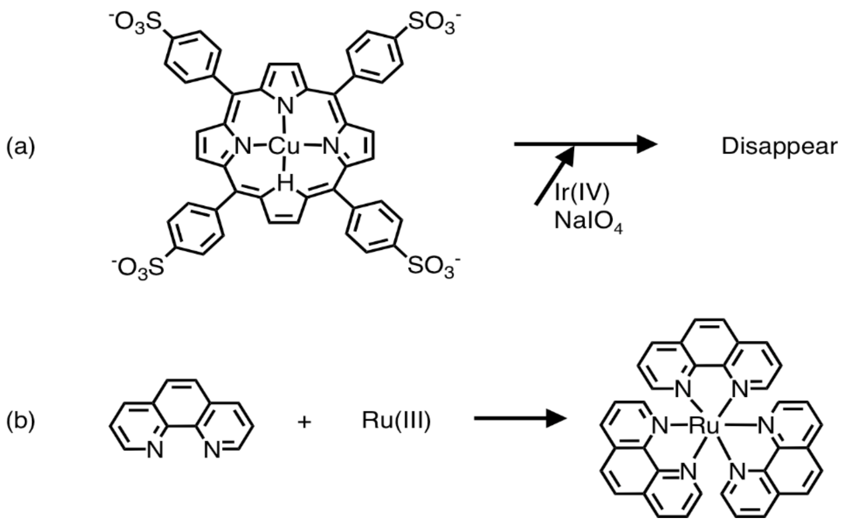

Figure 3. Chromogenic reagents and the principle of trace analysis of Ir(IV) and Ru(III). (a) Ir(IV) is analyzed indirectly using catalytic indicator reaction of the decomposition of water-soluble porphyrin. (b) Ru(III) is analyzed using chromogenic reaction with 1,10-phenanthroline which reactions normally require 2 hours for the complex formation

On the other hand, analytical methods based on chemical phenomena would be regarded as complementary to the analytical methods based on physical phenomena. Although so many types of analytical chemical reactions with chromogenic reagents have been developed until today, only selected methods and reagents are being utilized in practical fields. At the same time, this fact indicates that many of chromogenic reagents have been already forgotten instead of the advantages of the classic that the safety for organisms and environment, and characteristics of these materials are well known. By these reasons, we demonstrated some applications of hydrothermal flow systems for designing a new type of flow injection analysis (FIA) attached with a hydrothermal reactor for metal ions, namely hydrothermal flow injection analysis (HT-FIA) (Kawamura *et al.*, 2011b). HT-FIA would be an attempt to be replaced with high cost analytical techniques based on physical phenomena and refocus the importance of classical chromogenic reagents. The roles and advantages using HT-FIA for these two cases are summarized in Figure 3. As an advantage of HT-FIA, it enables high-throughput analysis since the labeling reactions with chromogenic reagents are highly accelerated at high temperatures. In our previous study for Ir(IV) analysis, 10^{-8} M level of Ir(IV) analysis can be indeed carried out and the detection limit reaches to 10^{-9} M level using a catalytic determination using water-soluble porphyrin in the presence of $NaIO_4$ at temperatures 100 – 150 ºC (Kawamura *et al.*, 2011b). In our another example study for Ru(III) analysis, a sufficient amount of complex formation of Ru(III) with 1,10-phenothroline with heating time of 5 s was achieved for the detection of Ru(III) with detection limit of 5.3×10^{-7} M Ru(III) although the complex formation reaction requires 2 h at room temperature. This enables a high throughput analysis (at least 10 samples per 10 min) of Ru(III) with small sample volume, such as 100 μL sample (Kawamura *et al.*, 2012).

3.2. Application to Green Research Tool in Screening Soli-State Catalysts for Liquid-Phase Reactions

As the importance of solid-phase catalysts was described in introduction, both inefficient chemical processes and environmentally harmless chemical processes should be replaced with efficient and environmentally friendly chemical processes. The development of recyclable solid-state catalysts is a strong strategy to solve these problems (Thomas, 1999; Beale & Sankar, 2003; Mallat & Baiker, 2004; Nakai & Kawamura, 2010; Buuramans & Weckhuysen, 2012; Sheldon, 2015). The illustrated flow shows how the development of solid-state catalysts affects the efficiency of chemical processes. On the other hand, replacing organic processes with organic solvent-free processes, such as hydrothermal processes is also strongly desired. However, there are limited cases that the hydrothermal reactions were successfully applied for organic synthesis as practical industrial chemical processes. From this viewpoint, the development of solid-state catalysts is an important approach to spreading widely the environmental friendly chemical processes.

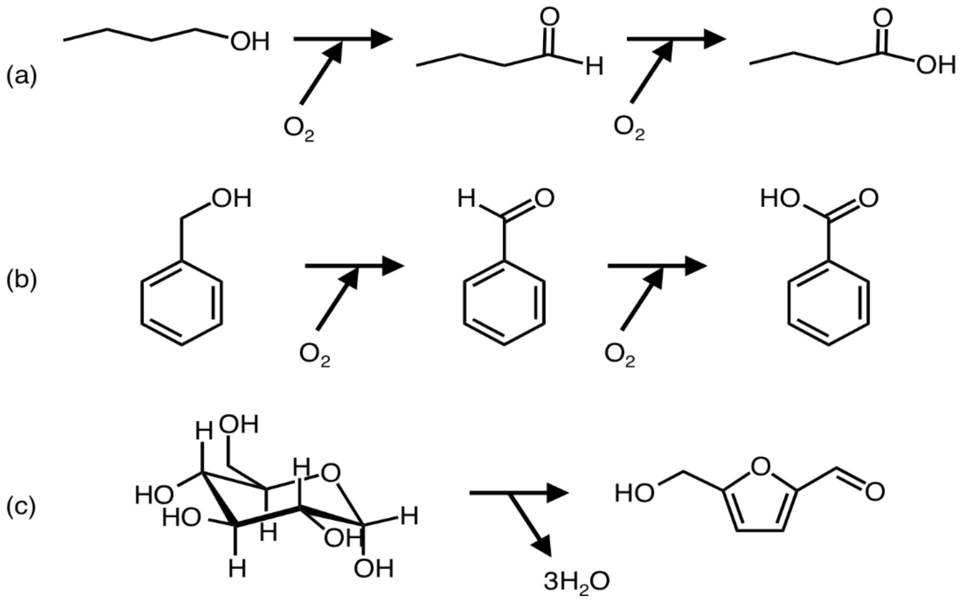

Figure 4. Reactions adapted for screening of solid-state catalysts using SSCM-SP. (a) oxidation of aliphatic alcohol (methanol, ethanol, 1-propanol, 1-butanol) (Kawamura *et al.*, 2016), (b) oxidation of benzyl alcohol (Kawamura *et al.*, 2016), (c) dehydration from glucose to form 5'-hydroxymethylfurfural (Kawamura *et al.*, 2017).

MMHF with or without in situ absorption spectrophotometer at the UV-visible-NIR region is unique technique for monitoring and investigation of chemical processes consisting of solid and liquid phases. Although conventional batch reactors would be used to monitor such reactions, real-time and in situ monitoring of reaction behaviors in millisecond to second time scale was not possible. In our previous papers, we demonstrated two examples of industrial related chemical process in aqueous phases, which are, the oxidation of alcohols (Kawamura, *et al.* 2016) and the formation of 5'-hydroxymethylfurfural (HMF) from glucose and cellulose (Kawamura, *et al.* 2014; 2015; 2017). The reactions are summarized in Figure 4. Actually, these processes have been widely investigated as an important future chemical process (Hasegawa *et al.*, 2011). First, the oxidation of alcohols by dissolved oxygen in aqueous phase or hydrogen peroxide is carried out in aqueous solution at high temperatures. Second, HMF is strongly expected as a green starting material for medicines and polyethylene terephthalate, etc. Since HMF can be produced from sugars and cellulose containing materials, several types of waste containing cellulose and sugar, such as clothes, woods, foods wastes, are potentially supplied for the formation HMF in the chemical recycling process. Although the principle and general strategy for recycling of these natural products is not yet completely established, these processes would be helpful for reducing the amount of wastes.

MMHF consists of basically the same instrument components as HTFR combining with a reactor column, of which particles as solid-state catalyst are packed in the reactor column. The inner diameter of reactor column from 0.7 mm – 1.5 mm with 10 cm in length was examined for screening of solid-state catalysts. In our previous study, naturally occurring minerals were examined as catalysts for prebiotic formation of oligopeptides. This attempt was succeeded, but showed some problems, which should be improved. One problem is that mineral-particle packed column results in clogging of flow even though the mineral particles are grinded and filtrated with particular size of metal mesh before packing.

This problem was solved by using solid-state catalysts deposited on homogeneous beads, such as silica gel and aluminum beads with 0.075 - 0.15 mm diameter. The influence of catalysts on the surface of these particles is readily observed. If the reactor columns packed with silica or alumina beads coated with different types of catalysts are prepared, the flow reactor system readily can be performed to analyze the efficiency of the catalyst coated on the beads. This type of flow reactor would be named as solid-state catalysts (solid-state-catalyst-mediated hydrothermal flow reactor: SSCM-HF). According to our experiences, packing of beads in such narrow tubing column with inner diameter 0.7 – 1.5 mm is easily and accurately carried out and the clogging of solvent flow is not observed as long as catalyst coated homogeneous beads are used. SSCM-HF with absorption spectrophotometer (SSCM-SP) showed in situ monitoring absorption spectra and the residence time, where the reaction solution is exposed in the reactor column is readily controlled at the time range 7 – 118 s by changing the flow rate at the high pressure pump. Thus, the screening of catalytic effect is performed very efficiently. These results clearly demonstrated the usefulness of SSCM-SP for screening of solid-state catalysts.

4. Conclusion

In the present paper, a brief history for the development of a series of hydrothermal flow reactor technologies and the environmental friendly applications was described. However, it is not so easy to replace the conventional processes with newly developed processes. Consumption of organic solvent and materials would not be readily reduced unless the central material stream within the present industrial civilizations will be changed according to the principle on the relationship between human and civilization. Nevertheless, at the same time, the development of highly efficient catalysts, which act in environment friendly solvents, would be attractive and valuable approach for the global environmental protection the since these materials directly contribute the cost of chemical processes as well as the efficiency.

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