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Alum Dosage Reduction and Sensitivity Analysis in Water Treatment System using Data Mining Software: Case study of Provincial Waterworks Authority, Udonthani, Thailand

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Abstract

This research applied Rapid Miner V.9.2 for alum dosage reduction and sensitivity analysis in water supply system of PWA, Udonthani, Thailand. The input parameters were pH and turbidity of raw water, pH and turbidity of pre-filtered water. The output parameter was alum dosage. The data were used from October, 2004 to April, 2019 that collected 5,118 records. The theory used W-Linear Regression W-MLP W-REPTree W-M5P W-M5Rules and GBT for modeling, alum dosage prediction, apply to alum dosage reduction and sensitivity analysis. From all 24 scenarios experiment, in conclusion, 10 models could be the alum dosage prediction. When applied to reduce the alum using dosage and sensitivity analysis, it was found model can the most alum reduction was model in summer by W-M5P theory and model in winter by GBT. All two models were used in Banthon WTP to reduce the alum dosage up to 21.69 percentage per year or 243,230 baht per year. The input parameters affected the most sensitive model that were pH and turbidity of raw water, pH of pre-filtered water. Therefore, this model could be applied to reduce cost of alum for PWA, Udonthani.

Keywords : Prediction; Raw Water Quality; Alum; Chemical; Water Treatment System; Sensitivity

Introduction

Tap water has a need for our daily life such as consumption, using tap water in product process, cleaning of raw material, so tap water has increase demand every day. Consequently, tap water has important in every section. Water supply system includes raw water source, water treatment system, water transportation system and water distribute system [1]. In Thailand, the most water supply system includes coagulation, flocculation, sedimentation, filtration and disinfection. For Provincial Waterworks Authority, Udonthani, it is the surface water supply system (conventional) that it is used commonly in large community [2, 3]. Raw water source uses from river, canal, reservoir or dam because there is more water volume for the water demand. Most of the raw water is high turbidity; then, the water treatment system uses alum for turbidity reduction of raw water [3-5]. The data of Provincial Waterworks Authority, Udonthani is collected from October, 2013 to April, 2019. It finds that much volume of alum using in water treatment system because the pre-filtered water was 0.5 to 6.5 NTU. Most of pre-filtered water was 0.5 to 2 NTU (65% of all data) which the alum using was over necessary. The pre-filtered water criteria of Provincial Waterworks Authority must be less than 10 NTU [6]. If Provincial Waterworks Authority, Udonthani must reduce the volume of alum using, they will must control the pre-filtered water approximately 10 NTU. As a result, this research aimed to alum dosage reduction and sensitivity analysis in water treatment system using data mining software: Case study of Provincial Waterworks Authority, Udonthani by using RapidMiner V.9.2.

Previous research tried to use the WEKA program to predict alum concentration demand. The study used four prediction methods namely Multilayer Perception, M5P, M5Rules, and REPTree with six parameters as an input including turbidity, water hardness, pH, electroconductivity, color, and, total suspended solids. The best result from the research was the M5Rules method, which was then used to create an alum concentration predicting model that helped reduced time used and limitations in jar test [7]. Another research study the relationship between pH and the amount of lime used using Regression theory, which was done using pH as an input into the Matlab program. The result was an 89 percent effective correlation equation between pH and the amount of lime used [8]. Moreover, researcher studied the weight-based growth model for Nile tilapia in waste water treatment pond without feeding. It was growth model for forecasting of tilapia weight and sensitivity analysis of model for change the recording of important information. The result was that most sensitivity variables was pH value [9]. Consequently, from literature review, it was found that parameters that affect alum dosage, Modeling methods, and the sensitivity analysis of the model.

Methodology

Searching, collecting and requesting information

This research's data was data of Provincial Waterworks Authority, Udonthani from October, 2013 to April, 2019 included 1) daily report of raw water quality 2) daily report of process water quality and 3) daily report of jar-test.

The input parameters, output parameters and data preparation

From research review about the chemical dosage prediction and the coagulation process, it was found that the coagulation process was to remove turbidity from raw water. The coagulation process occurred that the pH after the coagulation process was neutral [1]. In this research, the researchers considered pH and turbidity of pre-filtered water. So, the researcher had determined the input parameters which were pH of raw water, pH of pre-filtered water, turbidity of raw water (NTU) and turbidity of pre-filtered water (NTU). The output parameter was alum dosage (mg/l). Data preparation was two excel files, as follows.

The set data 1st was used for parameter adjustment each theory, modeling for alum dosage prediction in 24 cases that consideration was overall of three WTP, each WTP, each raw water source and each season. The set data 1st was 4,029 data since October, 2013 to April, 2018.

The set data 2nd was used for the alum dosage prediction verification in water supply system in 24 cases. The set data 2nd was 1,089 data since May, 2018 to April, 2019. In both excel data file, the researchers cut the set data that some input parameters were distorted or missing. In addition, the data set couldn't have all data for reduction the bias that would occur [10-11, 14].

Theory of experiment

There are six theories in total. W-Linear Regression is a linear relationship between input and the modeled parameters where the output is continuous [12]. W-Multilayer Perceptron is a multilayer perceptron where the first layer received and calculated the input and weight of the incoming data, then transfer it to the next layer [13]. W-REPTree create a tree-like structure from information gained, variance, and cutting, which is similar to the C4.5 theory, but REPTree is less prone to errors and faster [14]. W-M5P is also a tree-like structure, but with linear regression function replacing the last leaf of the model. W-M5P is a way to predict numerical data. The value of the node weighs less than the variable resulting in a reduced error rate, which makes this theory the most popular. Lastly, W-M5Rules, based on the M5 theory, is a theory where a regression term in the form of If-Then Rules is created. [15] Gradient boosted trees (GBT) is a boosting algorithm using decision tree as weak learners. So, the best of GBT is the ability to learn from both discrete and continuous data due to its tree-based structure. [16]

Experiment

First, this research used the Rapid Miner V.9.2 program to adjust parameter each theory such as W-Linear Regression, W-MLP, W-REPTree, W-M5P, W-M5Rules and gradient boosted tree (GBT), so considered each of all 24 cases. Second, the optimal parameter each theory was applied to model creation for alum dosage prediction. Then, the model was adjusted parameter each theory to the operator addition, such as Retrieve, Filter example, Select attributes and Apply model. As show in Figure 1, for alum dosage prediction, alum dosage reduction and sensitivity analysis in water treatment system of Provincial Waterworks Authority, Udonthani.

After that, we applied all model for alum dosage reduction in Provincial Waterworks Authority, Udonthani, which turbidity of pre-filtered water was selected that is 2 to 6.5 NTU. Finally, sensitivity analysis of all four parameters would have an effect that how much alum was change (mg/l). This consideration would change each parameter to ±5 ±10 ±20 ±50 and ±90 percent respectively, so the result was measured from MAE of decreased variable, increased variable and total. If the average of MAE is high, the model is very sensitive. Nevertheless, if the average of MAE is low, the model is less sensitive.

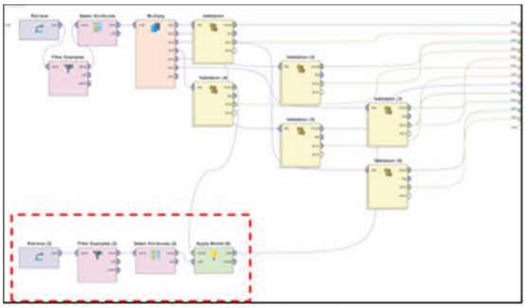

Figure 1 The model for alum dosage prediction, alum dosage reduction and sensitivity analysis

Matrix in determining the effectiveness of the model

1. Root Mean Square Error is a value of error or difference between the predicted data and the actual data. The closer the RMSE is to 0 the more accurate the model is. The equation for the RMSE is shown in equation (1) [15].

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(x_i - x)^2}{n}} \quad (1)$$

2. Mean Absolute Error is a mean value of the absolute error value of the predicted data. The closer it is to 0, the more accurate the model is. The equation to calculate MAE is shown in equation (2) [14].

$$MAE = \sum_{i=1}^{n}\frac{|x_i - x|}{n} \quad (2)$$

x_i = Actual alum (mg/l)
x = Predicted alum (mg/l)
n = Number of data

3. Consider the amount of predicted values set within the error ±5 mg/l more than 80% in both parts. Consideration of the best model is the least RMSE and MAE from all six theories of each case. Unless it has not the best model, we must consider the amount of predicted values set within the error ±5 mg/l more than 80% in both parts.

Results and Discussion

From modeling and the optimum alum dosage prediction, all 24 formats (1,440 cases), the best efficiency model for each format was showed in table 1. The result was found that 10 models had passed the criteria and the best qualities each case.

From Figure 2, these was turbidity of pre-filtered water in Provincial Waterworks Authority, Udonthani from May, 2018 to April, 2019 that turbidity of pre-filtered water was 0.5 to 6.5 NTU. Most of turbidity of pre-filtered water was 0.5 to 2 NTU that was 65 percent of all data, so these was the overdose alum using in coagulation, flocculation and sedimentation. Since Provincial Waterworks Authority defined criteria for turbidity of pre-filtered water less than 10 NTU [6]; therefore, 10 models were applied for alum dosage reduction in Provincial Waterworks Authority, Udonthani. Turbidity of pre-filtered water was selected that was 2 to 6.5 NTU, which was approximately 35 percent. So, it was not to affect the model efficiency.

Table 1 The model was passed the criteria each case

Model	Condition	Theory	RMSE	MAE
1	Banthon WTP (Format 1-3)	GBT	4.784	3.259
2	Bannikom WTP (Format 1-4)	GBT	3.949	2.751
3	Raw water from Huailuang dam (Format 1-5)	GBT	4.886	3.338
4	3 WTP (summer) (Format 1-7)	W-M5P	5.407	4.015
5	Banthon WTP (summer) (Format 1-13)	W-M5P	4.140	3.208
6	Banthon WTP (rains) (Format 1-14)	W-M5P	3.651	1.642
7	Banthon WTP (winter) (Format 1-15)	GBT	3.306	2.797
8	Bannikom WTP (summer) (Format 1-16)	GBT	2.049	1.264
9	Bannikom WTP (winter) (Format 1-18)	GBT	3.351	2.286
10	Raw water from Huailuang dam (winter)	W-M5P	4.615	1.968

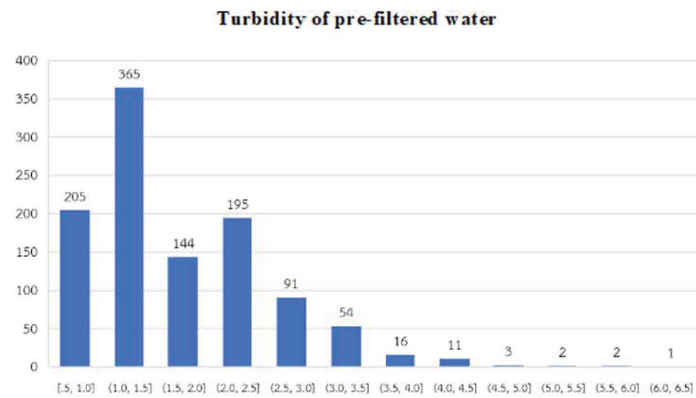

Figure 2 The turbidity graph of pre-filtered water (May, 2018 to April, 2019)

Table 2 Comparison between the actual and predicted alum dosage

Model	Actual Alum			Alum Prediction			±Price (Baht)	± percent
	Dosage (kg.)	Avg. per day (kg./day)	Price (Baht)	Dosage (kg.)	Avg. per day (kg./day)	Price (Baht)		
1	305,339	843	1,885,255	269,703	745	1,665,227	-220,028	-11.67
2	290,094	795	1,791,126	263,613	722	1,627,628	-163,498	-9.13
3	621,408	667	3,836,758	591,937	635	3,654,794	-181,964	-4.74
4	152,505	571	941,613	145,568	545	898,783	-42,830	-4.55
5	74,782	840	461,724	62,121	698	383,554	-78,170	-16.93
6	123,695	825	763,730	163,335	1,089	1,008,477	244,747	32.05
7	106,862	869	659,801	80,129	651	494,743	-165,058	-25.02
8	65,674	738	405,489	73,042	821	450,981	45,492	11.22
9	91,394	743	564,293	87,035	708	537,380	-26,913	-4.77
10	203,356	711	1,255,582	199,548	698	1,232,070	-23,513	-1.87

Annotation: Price of Aluminium Sulphate was 6,174.30 baht per metric ton (excluding vat)

From table 2, comparison between the actual alum dosage and the predict alum dosage showed that.

- Model 1st used Banthon WTP data that alum dosage reduced 11.67 percent per year or 220,028 baht per year.
- Model 2nd used Bannikom WTP data that alum dosage reduced 9.13 percent per year or 163,498 baht per year.
- Model 3rd used raw water data from Huailuang dam that alum dosage reduced 4.74 percent per year or 163,498 baht per year.
- Model 4th used all three WTP (summer) data that alum dosage reduced 4.55 percent per year or 181,964 baht per year.
- Model 5th used Banthon WTP (summer) data that alum dosage reduced 16.93 percent per year or 78,170 baht per year.

- Model 6th used Banthon WTP (rains) data that alum dosage increased 32.05 percent per year or 244,747 baht per year.
- Model 7th used Banthon WTP (winter) data that alum dosage reduced 25.02 percent per year or 165,058 baht per year.
- Model 8th used Bannikom WTP (summer) data that alum dosage increased 11.22 percent per year or 45,492 baht per year.
- Model 9th used Bannikom WTP (winter) data that alum dosage reduced 4.77 percent per year or 26,913 baht per year.
- Model 10th used raw water data from Huailuang dam (winter) that alum dosage reduced 1.87 percent per year or 23,513 baht per year.

In summary, Model 1st, 2nd, 3rd, 4th, 5th, 7th, 9th and 10th can reduce the actual alum dosage. Model 5th uses Banthon WTP (summer) data that uses W-M5P theory to modeling and Model 7th uses Banthon WTP (winter) data that uses GBT theory to modeling. Consequently, both the model is used in Banthon WTP that can reduce the most actual alum dosage 21.69 percent per year or 243,230 baht per year. However, Model 10th uses raw water data from Huailuang dam (winter) that uses W-M5P theory to modeling, so Model 10th can reduce the least actual alum dosage 1.87 percent per year or 23,513 baht per year. On the other hand, Model 6th and 8th cannot reduce the actual alum dosage.

Table 3 Sensitivity Analysis each model

Model	Input parameters	MAE		
		Decreased parameter	Increased parameter	Total
1	pH of raw water	11.14	22.44	16.79
	pH of pre-filtered water	16.64	6.06	11.35
	Turbidity of raw water	5.25	6.98	6.11
	Turbidity of pre-filtered water	2.71	2.42	2.57
2	pH of raw water	1.59	6.52	4.06
	pH of pre-filtered water	5.35	28.41	16.88
	Turbidity of raw water	6.45	7.20	6.83
	Turbidity of pre-filtered water	3.69	8.60	6.14
3	pH of raw water	5.64	8.75	7.20
	pH of pre-filtered water	11.59	4.66	8.12
	Turbidity of raw water	3.58	4.66	4.12
	Turbidity of pre-filtered water	3.89	4.24	4.07
4	pH of raw water	4.93	21.03	12.98
	pH of pre-filtered water	7.43	38.85	23.14
	Turbidity of raw water	2.18	5.84	4.01
	Turbidity of pre-filtered water	0.89	0.70	0.80
5	pH of raw water	16.09	16.66	16.38
	pH of pre-filtered water	16.51	16.09	16.30
	Turbidity of raw water	17.11	11.62	14.36
	Turbidity of pre-filtered water	16.94	14.69	15.82

Model	Input parameters	MAE		
		Decreased parameter	Increased parameter	Total
6	pH of raw water	36.13	99.00	67.57
	pH of pre-filtered water	18.95	37.02	27.99
	Turbidity of raw water	34.51	47.25	40.88
	Turbidity of pre-filtered water	35.59	36.33	35.96
7	pH of raw water	14.69	40.54	27.61
	pH of pre-filtered water	9.30	6.36	7.83
	Turbidity of raw water	13.59	10.85	12.22
	Turbidity of pre-filtered water	11.91	9.56	10.73
8	pH of raw water	9.35	8.97	9.16
	pH of pre-filtered water	7.68	9.82	8.75
	Turbidity of raw water	10.34	10.50	10.42
	Turbidity of pre-filtered water	9.75	9.39	9.57
9	pH of raw water	3.15	2.58	2.87
	pH of pre-filtered water	16.62	13.30	14.96
	Turbidity of raw water	0.66	0.46	0.56
	Turbidity of pre-filtered water	2.26	7.23	4.75
10	pH of raw water	4.14	20.77	12.45
	pH of pre-filtered water	12.24	13.67	12.96
	Turbidity of raw water	21.26	13.20	17.23
	Turbidity of pre-filtered water	17.64	8.91	13.27

From table 3, sensitivity analysis uses 10 models that is the best performance in each case. To sum up, the pH of raw water is the most sensitive to model 1st, 5th, 6th and 7th. The pH of pre-filtered water is the most sensitive to model 2nd, 3rd, 4th and 9th. Moreover, the turbidity of raw water is the most sensitive to model 8th and 10th.

Conclusion

Model can use to alum dosage prediction in water supply system of Provincial Waterworks Authority, Udonthani. So, from all 24 formats (1,440 cases), the best efficiency model for each format. The result finds that 10 models have passed the criteria and the best qualities each case. For the alum dosage reduction in water treatment system of Provincial Waterworks Authority, Udonthani using data mining software, the result finds Model 5th uses Banthon WTP (summer) data that uses W-M5P theory to modeling and Model 7th uses Banthon WTP (winter) data that uses GBT theory to modeling. Consequently, both the model is used in Banthon WTP that can reduce the most actual alum dosage 21.69 percent per year or 243,230 baht per year. For the sensitivity analysis, the result finds three parameters that are the most sensitive to model, such as pH of raw water, pH of pre-filtered water and turbidity of raw water. As a result, the operator must accurately record data and verify the accuracy of water quality instruments every six months to data isn't error.

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Site Assessment for Large Scale Organic Agriculture Plot using Integrated Geoinformatic and Sub-Global Assessment Case Study of Nong Wang Sok Phra, Phon District, Khon Kaen, Thailand

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Abstract

Organic agriculture has been currently promoted by the governmental policy to meet sustainable agriculture development. To enhance organic agriculture, Nong Wang Sok Phra, Phon District, Khon Kaen, Thailand has designated organic agriculture plot covering the area of 2,000 rai (320 hectare) along the creek. It is necessary to identify boundary of organic agriculture plot with land use and perception of organic agriculture plot member. The objective of this research, thus, was to assess the large scale of organic agriculture plot by integrating Geoinformatic together with Unmanned Arial Vehicle and Sub-global Assessment (SGA). The study steps and results are as follows. Firstly, creating the study area and land use map with physical characteristics identified by photography and video record. Secondly, establishing the systematic maps of large scale of organic agriculture. by criteria weighting and rating scale for analysis of land suitability, using Geoinformatic and UAV Arial Photography of 7 factors consisting of land use, soil suitability, water resource, transportation, average debt of village, acceptation of member, organic agriculture plot definition. Social study using SGA approach was carried out after getting systematic by focus group interview on debt of farmers and acceptation of organic agriculture plot's members. Thirdly, Arial Photography taken from Unmanned Aerial Vehicle (UAV) for the potential large organic agriculture plot covering many land parcels. Again, SGA identified the suitable plot ranked from the potential large organic agriculture plot. Finally, with the overlay technic with processing UAV Imagery and parcel maps, the output was the map of suitable organic agriculture plot, located at Ban Kok Lam Village no.3, covering plot of 129 rai (20.64 hectare), where the agriculture parcels were belonged to 25 owners. With technical and social acceptance would identify the actual organic agriculture area.

Keywords : Organic Agriculture plot; UAV Arial Photography; Sub-Global Assessment

Introduction

The promotion of large scale agriculture plot is the agriculture preferment system on plot based approach by integration of the line agencies and managing the plot along the supply chain by the plot manager. The purpose of the large scale agriculture plot is to enhance collaboration of farmers and co-managing in order to co-production, co-sale with the known market. With the large scale agriculture promotion project, the farmers can reduce production cost, increase product/unit as well as qualified products under integration of governmental and private sectors [1]. However, the conventional agriculture both small and large scales have still used chemical fertilizer and pesticides which are potentially impacted on soil and water ecosystem as well as health of farmers. Data of illness induced by chemical pesticides reported in 2017 was 10,312 patients being equivalent to 17.12 to 100,000 people, which increased from 8,689 patients (14.47 to 100,000 people) recorded in 2016. The highest illness rate was found in Satoon province (144.06 to 100,000 people) followed by Prae Province (127.26 to 100,000 people) and Uttaradit Province (116.98 to 100,000 people), respectively. Based on the number of patients, three provinces had the highest number of patients were Phrae Province (572 patients), Uttaradit Province (536 patients) and Buriram Province (533 patients), respectively. Khon Kaen Province (the study area) had 478 patients being equivalent to 26.53 to 100,000 people [2].

Therefore, organic agriculture is the solution of agriculture practice that is safe to human health and ecosystem. The government has policy on organic agriculture enhancement by setting the target of increasing organic agriculture plot and farmers, increasing the ratio of organic agriculture market within the country as well as leveraging the local wisdom organic agriculture group toward the development of organic agriculture of Thailand, as the regional leader of production, consumption, marketing and service of organic agriculture on the sustainable concept and international acceptance following the National Organic Agriculture Development Strategy 2017-2021 [3].

In addition, it is still questionable to identify the large scale of agriculture organic plot in terms of land use map with boundary and acceptance of farmers. In order to enhance organic agriculture which is safe to human health and environment, it requires an integration of spatial data and Sub-Global Assessment (SGA which is the social study to get the scientific information toward decision making) which reflect the spatial planning map with acceptance of farmers. Consequently, this study focused integration of Geoinformatic, Sub-Global Assessment [4] in order to select the large scale of organic agriculture plot.

Objective

The objective is to assess the site for large scale organic agriculture plot using Integrated Geoinformatic and Sub-Global Assessment.

Materials and Methods

Study area is organic agriculture pilot area designated in 4 year Development Plan (2017-2021) of Nong Wang Sok Phra Sub-District Administration Organization, Phon District, Khon Kaen Province (Figure 1) [5]. Study methodology consisted of following steps as subsequently described (Figure 2).

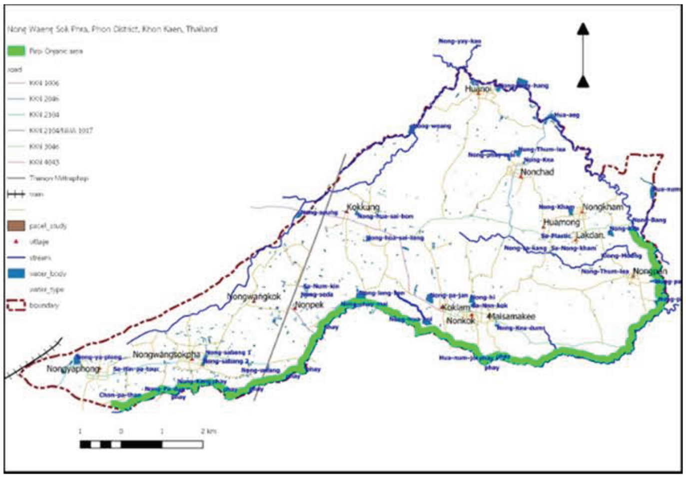

Figure 1 Study Area on Organic Agriculture Pilot Area Designated in 4 year Development Plan (2017-2021) of Nong Wang Sok Phra Sub-District Administration Organization, Phon District, Khon Kaen Province

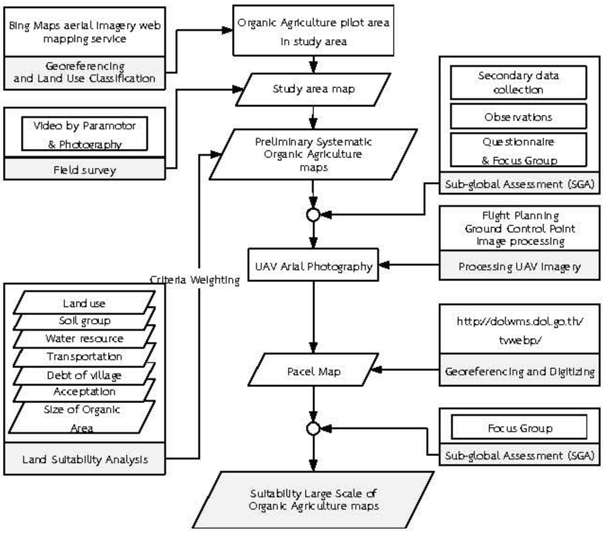

Figure 2 Study Steps

1. First step was to create study area and land use map by following sub-steps.

1) Creating the study area and land use map by geo-referencing of Bing Maps Aerial Imagery Web Mapping service and classify land use on the organic agriculture pilot area.

Checking the study area through field survey with video record and photography by camera equipped paramotor to illustrate physical characteristics of the study area.

2. Second step was to establish the preliminary systematic maps of large scale

of organic agriculture plot which included following sub-steps.

1) Establishing the preliminary systematic maps of large scale of organic agriculture by criteria weighting and rating scale to analyze for land suitability. The criteria consisted of land use, soil suitability, water resource, transportation, average debt of village, acceptation of member, organic agriculture plot defined by the Ministry of Agriculture and Cooperation [4].

2) Collecting secondary data and field survey by observations and photography to define the physical characteristics of the study area. In the meantime, SGA had been employed to collect agricultural data and information through focus group and questionnaire in order to perceive and understand the large scale organic agriculture plot.

3. Third step was to check the preliminary systematic maps of large scale of organic agriculture by

3.1 Recording image with UAV and processing UAV Imagery by

1) Site selected for fight recording

2) Ground control point [6] by creating ground control targets [7].

3) Recording geographic coordinate systems at ground control point with GNSS.

4) Flight planning through flight control program of UAV DJI GO.

5) UAV image processing by Agisoft PhotoScan 1.4.5 Professional Edition software with geometric correction and image to map rectification.

3.2 Establishing suitable large scale of organic agriculture maps by

1) Creating parcel maps of the study area and digitized imagery parcel owner on web mapping service form Department of Lands Headquarters, Ministry of Interior.

2) Overlay technic with processing UAV Imagery and parcel maps to get the suitable large scale of organic agriculture maps) of the study area.

Results and Discussion

Regarding the land use map created from study steps 1 and 2, land use of organic agriculture plot is defined in Figure 3. It is classified as shown in Table 1, of which paddy field was the most occupied area and forest plantation was the lowest occupied area. With the largest paddy field area, it is beneficial to large scale organic rice field.

Based on the field survey with video and photography with camera equipped at Paramotor (Figure 4), physical characteristics of the study area existed in May 2017, the creek namely Huai Luek fulfilled with water along the stream for 22 km distance. It covered cultivation area of 7 villages with an area of 2,000 rai (320 hectare). Through social approach (preliminary SGA) by questionnaire interview to collect data of the land owner and agriculture data/information, the existing large scale of organic agriculture area had 210 members, cultivation area of 1,310 rai (210 hectare), rice product of 459,000 kg with an average of 350 kg/rai or 2,186 kg/ha, classified as sticky rice as RD 6 / RD 12 and jasmine rice 105. Soil conditioning was mostly used manure of cow and composting fertilizer averagely 100 kg/rai or 625 kg./ha, as presented in Table 1.

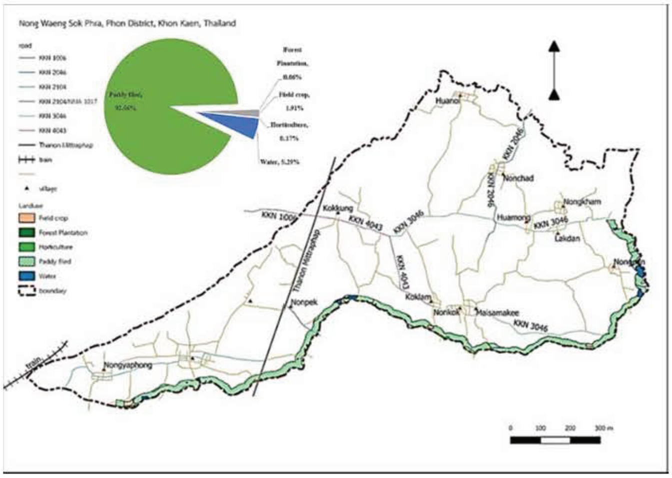

Figure 3 Land use of Organic Agriculture Pilot Area

In order to analyze for land suitability, it is to create systematic maps of large scale of organic agriculture by criteria weighting and rating scale. Factors, index, and criteria for large scale organic agriculture plot are presented in Table 2. With overlay technic, it produced the preliminary of systematic maps of large scale and organic Agriculture as presented in Figure 5 indicating land suitability of organic agriculture area.

Then, using SGA approach (SGA 1) with such preliminary of systematic maps to find out the perception of members through focus group. Based on discussion with the members, they had still used both compost/manual fertilizer and chemical fertilizer. Of 2,000 rai (320 hectare) could be finally classified for organic agriculture 129 rai (20.64 hectare), which was only 15.50% of total organic pilot area, as shown in Figure 6. In order to present the existing status of the suitable area for large scale organic agriculture, two more steps were performed by using UAV for the background and parcel map of land owner (data taken from Land Use Department) as the foreground as exhibited in Figure 7. Then, this suitable organic agriculture with parcel map was shown to the organic agriculture members for deep perception and understanding (SGA2). Analysis results of the suitable area for large scale organic agriculture plot were evident to all members. It enables acceptance of the members towards organic agriculture development including practice in terms of meeting the criteria leading to increasing organic agriculture members. This integration of technical mean (GIS and UAV) and social mean (SGA) can be used for expansion of organic agriculture plot to meet the target of 2,000 rai (320 hectare) as designated plan.

Table 1 Organic Agriculture Rice Types (from questionnaire)

Rice seed	Member	Area		Product	Average Product	
	(person)	(rai)	(Ha)	(Kg)	(Kg./rai)	(Kg/ ha)
RD 6	163	957	153.12	335,450	350.52	2,190.75
RD12	1	5	0.8	1,750	350	2,187.50
Jusmine105	46	348	55.68	121,800	350	2,187.50
Total	**210**	**1,310**	**209.6**	**459,000**	**350.38**	**2,189.88**

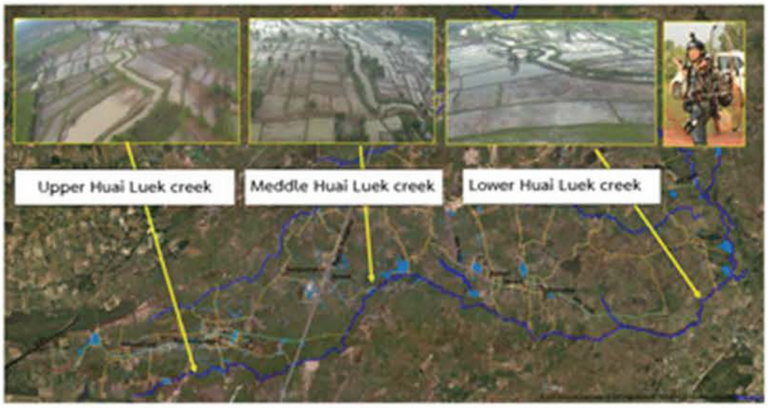

Figure 4 photography with camera equipped at Paramotor

Table 2 Factor, Index, and Criteria for Large Organic Agriculture Area

Factor	Index	Criteria	Data used
Landuse	Suitable level taken from land use	Suitable score taken from land use	Landuse map
Soil	Suitable level of soil	Suitable score taken from soil series	Soil series map
Water resource	Catchment area	Score of catchment area	Water resource map
Transportation	Distance access to main road and minor road, railway line	Score of distance (near or far) access to road	Road map
Organic area	Size of organic area of Ministry of Agriculture.	Score based on size of organic area	Organic Area map
Average debt of village	Average debt/year	Score of average debt/year	Debt map
Acceptation of member	Acceptation for adjustment of organic agriculture to large scale	Score along with acceptation	Accept map

Table 3 Rating and Scaling

Factor	Review			Researcher	Member	Rating Scale
	(1)	(2)	(3)	(4)	(Organic) (5)	(6)
1.Landuse (P1)	0.09	-	0.130896	0.16	0.15	0.11
2.Soil (P2)	0.01	0.25	0.326998	0.20	0.11	0.18
3.Water resource (P3)	0.25	-	0.296936	0.27	0.27	0.22
4.Transpotation (P4)	-	-	0.035088	0.08	0.08	0.04
5.Organic Area (P5)	-	0.1	-	0.27	0.27	0.15
6.Debt of village (P6)	-	-	-	0.50	0.05	0.20
7.Acceptation (P7)	-	0.15	-	0.20	0.15	0.10

(1) Liu W, 2019 [8].
(2) Vogdrup-Schmidt M et al., 2019 [9].
(3) Sarath Midatana, Saran S, Ramana KV, 2018 [10].
(4) Researcher form average of (1), (2), (3), (5), survey and observation
(5) Questionnaire
(6) Average of (1) – (5)

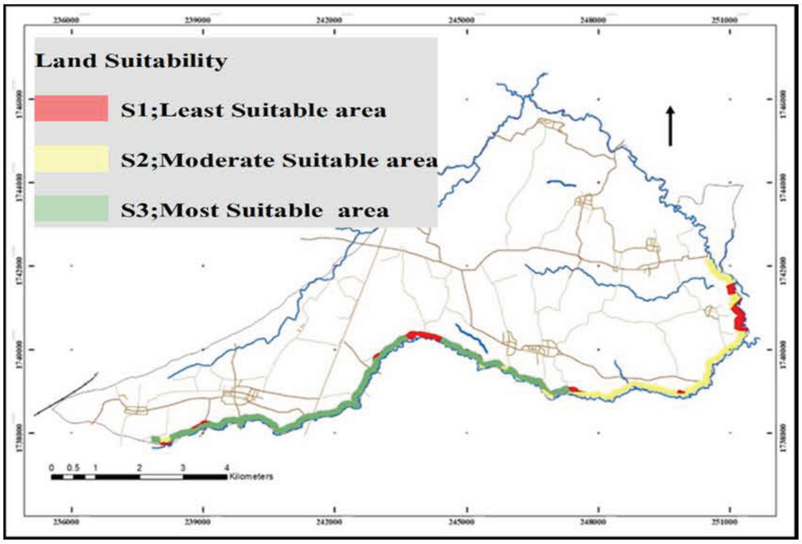

Figure 5 Systematic maps of Large Scale and Organic Agriculture

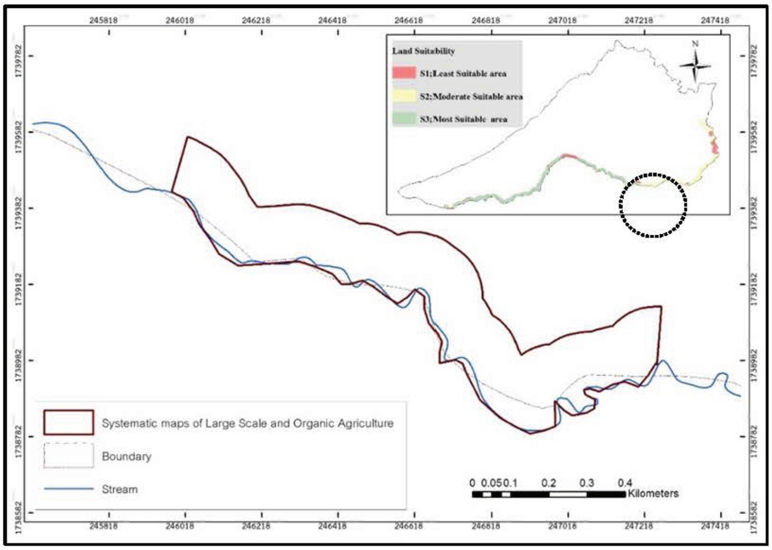

Figure 6 Systematic maps of Large Scale and Organic Agriculture through SGA approach

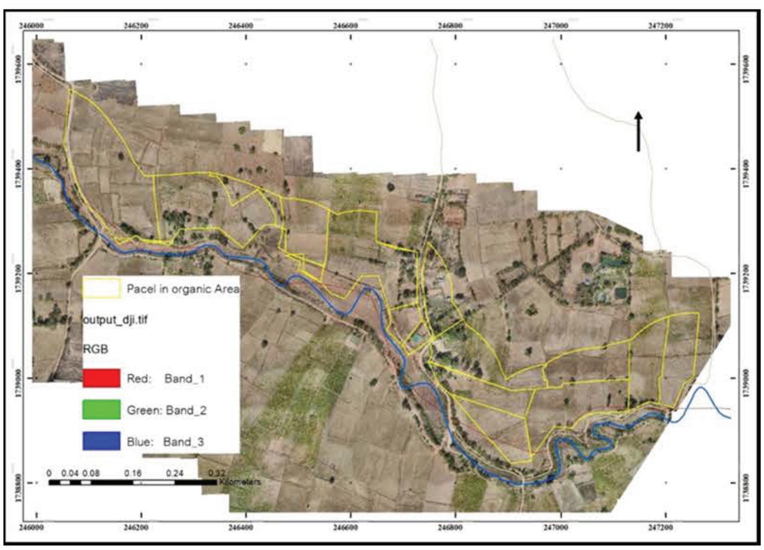

Figure 7 Suitability Large Scale of Organic Agriculture Maps

Conclusions

In accordance with the large scale of organic agriculture plot promoted on the sustainable agriculture concept and international acceptance following the National Organic Agriculture Development Strategy 2017-2021, the organic agriculture pilot plot has been designated in 4 year Development Plan (2017-2021) of Nong Wang Sok Phra Sub-District Administration Organization, Phon District, Khon Kaen Province. However, it is necessary to identify the large scale of agriculture organic plot in terms of land use map with boundary and acceptance of farmers.

This study focused integration of Geoinformatic and Sub-Global Assessment in order to assess the large scale of organic agriculture plot. The study process included 3 main steps; (1) creating the study area and land use map by geo-referencing and classifying land use on the organic agriculture pilot area, as well as confirming through field survey with video record and photography, (2) establishing the preliminary systematic maps of large scale of organic agriculture by criteria weighting and rating scale to analyze for land suitability. The criteria consisted of land use, soil suitability, water resource, transportation, average debt of village, acceptation of member, organic agriculture plot definition. This step consisted of characterizing the physical characteristics and carrying out SGA through focus group and questionnaire, (3) checking such preliminary systematic maps by UAV/ UAV Imagery, and creating parcel maps, then overlay UAV Imagery and parcel maps to establish the suitable large scale of organic agriculture maps.

The existing agriculture organic pilot area of 2000 rai (320 hectare) was downsized to and downsized to 129 rai (20.64 hectare), which was only 15.50% of total organic pilot area. The organic agriculture map created through digital technology (GIS and UAV) and SGA (social mean) has enable acceptance of the members towards organic agriculture. This can be used for expansion of an organic agriculture to meet the designated target of 2,000 rai (320 hectare) of the 4 year plan.

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Effects of Salinity and Nitrate on Coral Health Levels of *Acropora sp.*

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Abstract

Changes of marine environmental conditions such as low salinity and nutrient enrichment in seawater can be mainly affected on coral health levels or can adversely cause mass coral bleaching. According to these unsuitable conditions, leading to the objective of this study is to study the effect of salinity and nitrate on coral health levels in branching coral (*Acropora sp.*) at the salinity vary in 15, 20, 25, and 30 psu, the concentration of nitrate vary in 20, 60, and 100 μg-N/l with triplicate experiments. The experimental results showed that 30 psu of salinity at 96 hours was unable to calculate LC_{50} (Lethal Concentration) because of insufficiently lower in declining coral health level or lower in motility percentage. However, the results showed that 15 psu of salinity at 96 hours was able to calculate LC_{50} using Probit analysis, LC_{50} 15 psu of salinity at 96 hours was equally to 89.50 μg-N/l Moreover, high nitrate concentrations showed more paling color and stimulating to release mucus in *Acropora sp.*

Keywords : salinity; nitrate; coral health levels; coral bleaching; LC_{50}

Introduction

Corals and coral reefs play an important role both direct and indirect way as providing vital ecosystem services as a mainly source of food and habitation, protecting the shoreline from storms and wave action and conducting economically valuable as tourist attractions, fishing and generating coastal developments for the purpose of tourism that increasingly revenue to government and private sector. In contrast, human activity by expanding in coastal development is the main threat of coral, leading to discharge wastewater into the sea, and overfishing. The status of coral reef in Thailand in 2015, was continually declining in both the Gulf of Thailand and Andaman side. In 2015, the percentage of live coral cover was 28.3% remarked on high damage level and 50.0% in live coral cover remarked on vary high damage level, while the previous status in 2008 was 19.1% and 18% in live coral cover respectively. Moreover, there are various factors, caused declining coral health as low salinity events, inducing salinity stress in coral by losing control processes for homeostasis which leads to the reduction of the zooxanthellae and chlorophyll concentration, to against growth and reproduction, and to severely result in coral bleaching [1]. Others declining coral health's factor as nutrient enrichment, including dominantly nitrate and ammonia from nutrient runoff from human activities on coastal or directly discharge untreated wastewater. Nutrient enrichment can increasingly promote the growth rate of coral reef organisms. The other studies also found that high ammonia or nitrate concentrations, resulting in loss of zooxanthellae in coral from an imbalance between coral and zooxanthellae [2]. Therefore, this study is focused on the effects of salinity and nitrate on the health status of branching coral (*Acropora sp.*) with acute toxicity test. Coral health evaluation conducted coral health chart, used for calculating health status and mortality percentages and conducted photographic assessment, used for analysis of the active polyp percentages of *Acropora sp.* [3]. The acute toxicity of nitrate concentrations resulting in bleached coral at more than 50% (50% Lethal Concentration: LC50) was calculated by Probit analysis, in order to use as baseline information for monitoring nitrate concentration in seawater that adversely effects on coral health which can result in coral bleaching.

Methodology

Acute Effects of Salinity and Nitrate

Branching coral or *Acropora sp.*, colony size 15 centimeter or more, was kept in a filtered seawater pond with continuous water flowing for 7 days for acclimation. Then the selected corals were checked its color by using coral health chart in the level of 6 and were cut into 3-4 centimeters from the tip of coral. Settling 3 pieces of selected coral into a chamber, sizing of 14x22x16 centimeter. Salinity was varied at 15 20 25 and 30 psu by mixing between filtered seawater (30 psu) and filtered water (0 psu). After that, adding potassium nitrate (KNO_3) to get the various concentration of nitrate at 20 60 and 100 µg-N/l respectively as shown in Figure 1. Temperature and pH were constantly controlled at 30°C and pH 8. In monitoring, coral health status was recorded and photographed by using Olympus stylus TG-4 in Macro mode at 0 12 24 48 72 and 96 hours. After that, replacing seawater with regular seawater without adding nitrate. Coral health status was recorded at 24 and 48 hours with the aim of monitoring coral health recovery which was lower than Level 3 or corals with bleaching on both pieces and parts.

Figure 1 Experiment kit example

Active Polyp Percentages

Converting the pictures, photographed in macro mode at 0, 12, 24, 48, 72 and 96 hours from true color (RGB color) into grayscale. The extend polyps or active polyps obviously appear white spots in grayscale. Counting the active polyps in fixed coral's areas and calculating active polyp percentages [3] using the equation (1) below. Its percentage can be comparable to coral health status, shown in Table 1.

$$\text{Active polyp percentages} = \frac{\text{Number of active polyp} \times 100}{\text{Total of polyp counted}} \quad (1)$$

Table 1 Active polyp percentages and health status

Active polyp percentages	Remark
> 50	Good health
25-50	Decline health
< 25	Poor health

Coral Health Status Evaluation

Evaluation of coral health status in *Acropora sp.* could apply Coral Health Chart [4] in Figure 2 to estimate its health status. The color of each side was divided into 4 groups and classified into 6 levels in each side [5]. In level 6 is the representative of coral in good health (best health) and level 1 is representative for declining coral health (worst health). After evaluating the coral health status based on colors, these statuses were calculated into percentages as shown in Table 2.

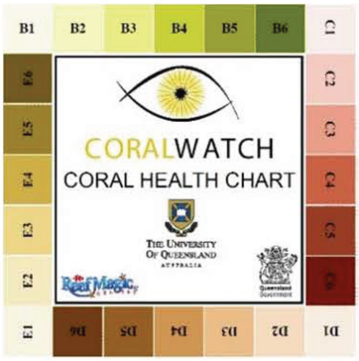


Figure 2 Coral health chart [5]

Data Analysis

Pictures and amounts of color at 0, 12, 24, 48 and 96 hours were used for converting into health status and mortality percentages with Table 2. The corals with health status lower than level 3 or having a mortality percentage higher than 50 would be inducted to calculate the acute toxicity test (LC_{50}) by using Probit analysis [6].

Table 2 Health status and mortality percentages from the coral health chart

Level	Remark	Health status percentages	Mortality percentages
1	Worst health	16.67	83.33
2	Poor health	33.33	66.67
3	Declining health	50.00	50.00
4	Fair health	66.67	33.33
5	Good health	83.33	16.67
6	Best health	100.00	0.00

Results and Discussion

The result in Table 3 found that coral at salinity 30 psu at 24 and 96 hrs showed in health status levels 4 to 5 (72.22-83.33% in health status) as remarked on fair to good health. The lowest mortality percentage was found in nitrate concentration at 20 µg-N/l which had 16.67% in health status. Salinity at 15 psu at 72 hrs, showed in health status level 3 to 4 as remarked on declining to fair health. The lowest health status percentage was found in nitrate concentration at 100 µg-N/l at 72 hrs which had 55.56% in health status or which it was lower than 50% in mortality. Mortality percentages lower than 50 would prevent the calculation of nitrate concentrations and their effects on coral bleaching or LC50. Therefore, at 72 hrs with 44.44% in mortality could not be calculated into LC_{50}.

Table 3 Health status and mortality percentages at salinity 15, 20, 25 and 30 psu.

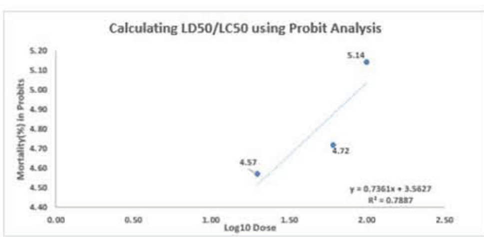
Salinity 15 psu	Healthy Status (%)						Mortality (%)
Nitrate (µg-N/l)	0 hr.	12 hr.	24 hr.	48 hr.	72 hr.	96 hr.	96 hr.
20	100.00	83.33	83.33	83.33	77.78	66.66	33.33
60	100.00	83.33	83.33	83.33	72.22	61.11	38.89
100	100.00	83.33	83.33	83.33	55.56	44.44	55.56
Salinity 20 psu							
Nitrate (µg-N/l)	0 hr.	12 hr.	24 hr.	48 hr.	72 hr.	96 hr.	96 hr.
20	100.00	83.33	83.33	83.33	83.33	72.22	27.78
60	100.00	83.33	83.33	83.33	72.22	66.67	33.33
100	100.00	83.33	83.33	83.33	66.67	50.00	50.00
Salinity 25 psu							
Nitrate (µg-N/l)	0 hr.	12 hr.	24 hr.	48 hr.	72 hr.	96 hr.	96 hr.
20	100.00	83.33	83.33	83.33	83.33	77.78	22.22
60	100.00	83.33	83.33	83.33	77.78	77.78	22.22
100	100.00	83.33	83.33	83.33	83.33	83.33	16.67
Salinity 30 psu							
Nitrate (µg-N/l)	0 hr.	12 hr.	24 hr.	48 hr.	72 hr.	96 hr.	96 hr.
20	100.00	83.33	83.33	83.33	83.33	83.33	16.67
60	100.00	83.33	83.33	83.33	83.33	77.78	22.22
100	100.00	83.33	83.33	83.33	72.22	72.22	27.78

Whereas, at salinity 15 psu and 96 hrs, the coral showed in health status levels 2 to 3 (44.44-66.66% in health status) as remarked on poor to declining health. The lowest health status percentage was found in nitrate concentration at 100 µg-N/l which had 44.44% in health status or 55.55% in mortality that it was higher than 50% in mortality. Therefore, at 96 hrs with 55.55% in mortality could be calculated into LC_{50} using Probit analysis. Nitrate concentrations that affected on coral bleaching or 50-percent coral mortality at 96 hrs was equal to 89.50 µg-N/l, shown in Figure 3.

In table 3, the results showed the effect of salinity on the coral separately. In constant nitrate concentration, the lowest concentration of nitrate at 20 μg-N/l at salinity 15, 20, 25 and 30 psu at 96 hr had mortality percent as 33.33, 27.78, 22.22 and 16.67 respectively. It can be concluded that mortality in *Acropora sp.* was dominantly caused by lower salinities (15, 20 and 25 psu) than normal salinity (30 psu). Mortality in corals after exposure to low salinity was influenced by tissue sloughed-off [7]. Moreover, the result also showed that the coral at same salinity (15, 20, 25 and 30 psu) had the lowest mortality percentages, showed in nitrate concentration at 20 μg-N/l while highest mortality percentages showed in nitrate concentration at 100 μg-N/l (in salinity 15, 20 and 30 psu). Indicating that stressed in *Acropora sp.* in salinity between 15-30 psu was also caused by higher nitrate concentration (100 μg-N/l). Also, stressed in coral, caused by nitrate has the effects of decreasing the Zooxanthellae density and chlorophyll in the coral tissue [8]. Even if, nitrate can increase Zooxanthellae density and chlorophyll in the coral tissue at first [9, 10]. Different coral species have individual resistance and response for nitrate concentration differently, for example, *Pocillopora damicornis* mainly affected by nitrate while *Porites lobate Dana* can resist temperature and nitrate concentration in 232.4 μg-N/l. However, *Acropora sp.* also responses to ammonia which is an important form of nitrogen in seawater. There was research confirmed that LC_{50} of ammonia concentration at 0.054 mg-N/l can cause coral bleaching or 50-percent coral mortality in 48 hrs. [11].

Dose Units= microg-N/l

	Dose/Conc.	Total	Dead
Control	0.00	100	0
2	20.00	100	33.33
3	60.00	100	38.89
4	100.00	100	55.56
5			



LD/LC (%)	LD/LC microg-N/l	95%Fiducial CI Lower	Upper
LD46	65.352	15.736	271.398
LD47	70.709	17.026	293.645
LD48	76.493	18.419	317.668
LD49	82.743	19.924	343.622
LD50	89.499	21.551	371.679
LD51	96.806	23.311	402.026
LD52	104.716	25.215	434.873
LD53	113.282	27.278	470.450
LD54	122.568	29.514	509.013
LD55	132.642	31.940	550.847
LD56	143.579	34.573	596.269
LD57	155.466	37.436	645.633

(Scroll down for LC/LC values)

Figure 3 Calculating LC_{50} using Probit analysis at salinity 15 psu.

According to Figure 4 a), the highest active polyp percentages at salinity 30 psu and 0 hr in nitrate concentrations of 20, 60 and 100 μg-N/l were equal to 70 74 and 43% in active polyp. Similarly, at salinity 15 psu and 0 hr, Figure 4 b) had the highest active polyp percentages which were respectively equal to 85 75 and 95% in active polyp.

Next more hour, between 24 and 96 hrs at salinity both 15 and 30 psu found decreasing of active polyp percentages. At salinity 15 psu in Figure 4 b) showed decreasing with rapid in 48 hr, unlike at salinity 30 psu showed decreasing with slightly. Likewise, at salinity 15 psu and 48 hr, the coral started releasing mucus in Figure 5. Also, the lowest active polyp percentages were found in salinity 15 psu and 96 hr, Figure 4 b), including 0, 2 and 0% in active polyp that correlated with the highest mortality percentages in Table 3, ranged between 33.33-55.56% in mortality.

Moreover, in testing at salinity 15 psu with a nitrate concentration of 100 µg-N/l found that *Acropora sp.* released mucus coat themselves at first time in 48 hours, shown in Figure 5 and its mucus increasingly thicker in 72 and 96 hrs respectively. Releasing mucus in coral is affected by living in severe environmental conditions that triggered defence mechanism of coral to against exposing severe environment.

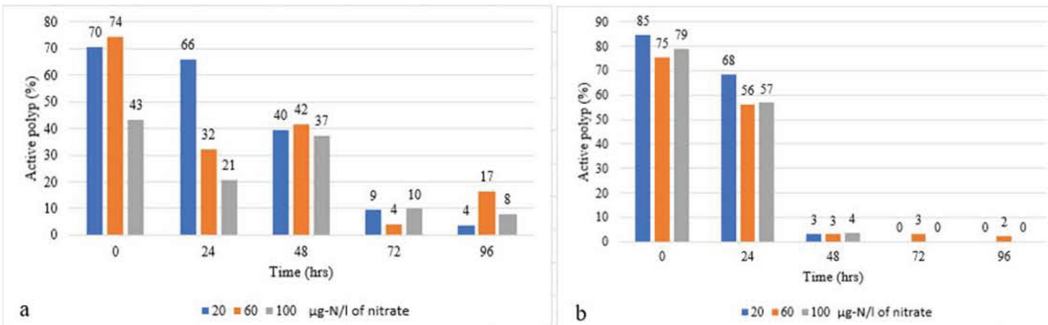


Figure 4 Active polyp percentages for *Acropora sp.* a) Salinity at 30 psu b) Salinity at 15 psu

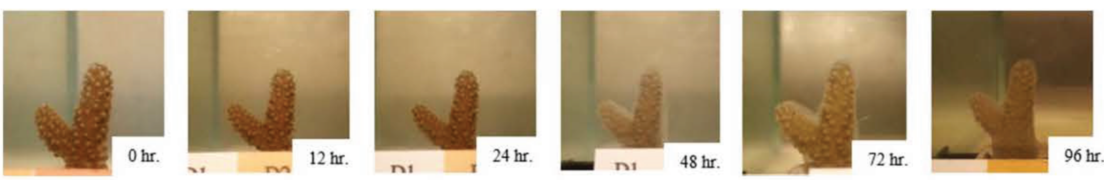


Figure 5 *Acropora sp.* at nitrate concentrations of 100 µg-N/l with salinity 15 psu in 0 to 96 hrs

Though, extremely releasing mucus can cause to tissue sloughed-off which coral can unable to recovery themselves in natural seawater, unlike to paled coral which can recovery themselves completely under natural condition [12] shown in 72 and 96 hour relating with color health level into poor to fair health (in levels of 2 and 3) or healthy status percent in 44.44 to 77.78 which shown in Table 3. Thus, nitrate is one of the severe factors that threatening coral health.

Conclusion

In this study, the result of the salinity and nitrate effects on the coral health status of branching coral (*Acropora sp.*) at the salinity varied in 15, 20, 25, and 30 psu and the concentration of nitrate varied in 20, 60, and 100 µg-N/l, during 0-96 hrs. the result showed that at salinity 15-30 psu along with nitrate concentrations increasingly caused mortality or trigged to bleaching coral. Mortality in coral related to higher nitrate concentrations, affected on more paling color and stimulating to release mucus. At salinity 15 psu with a nitrate concentration of 100 µg-N/l and 96 hrs, coral had the highest mortality percentages (33.33-55.56% in mortality) which contrarily related to the lowest active polyp percentages (0-2% in active polyp). Indicating that coral has a defense mechanism, trigged from stress or irritating in severe environmental conditions by reduced polyp activity and using mucus to cover itself to unexposed these conditions. Therefore, at salinity 15 psu with a nitrate concentration of 100 µg-N/l and 96 hrs had the highest mortality percentages, more than 50% in mortality, which could be calculated into LC50 using Probit analysis. Then, nitrate concentrations that effect on coral bleaching or 50-percent coral mortality at 96 hrs was equal to 89.50 µg-N/l.

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Reduction of Methane and Nitrous Oxide from High Strength Municipal Solid Waste Leachate by Sequencing Batch Reactor with *Alcaligenes faecalis* No.4

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Abstract

This research investigated the performance and greenhouse gas emission from high strength municipal solid waste (MSW) leachate by sequencing batch reactor(SBR) with *Alcaligenes faecalis* No.4 (*A. faecalis* No.4). The SBR was carried out by anaerobic reactor followed by aerobic reactor. The system was operated at hydraulic retention times (HRT) of 2 days during 130 operating days (Run 1) and 45 days with *A. faecalis* No.4 (Run 2). At steady state, the organic removal efficiencies were found to be 62.7% for (Run 1) and 86.7% for (Run 2). The organic carbon and nitrogen were mainly removed in aerobic reactor. The surface emission rates of methane and Nitrous oxide in aerobic reactor were reduced 35% and 14%, respectively with *A. faecalis* No.4.

Keywords : *Alcaligenes faecalis* No.4; Municipal Solid Waste Leachate; Greenhouse gas emission; Sequencing batch reactor

Introduction

Leachate pollution from solid waste disposal is receiving more attention as the increase in the amount of solid waste collected from urban areas is dumped into landfills or open dumpsites, especially in developing countries. More stringent regulations on leachate control have been put forward for a better management of solid waste disposal sites. Municipal solid waste leachate contains other compounds, including organic substances and toxic substances.

Sequencing batch reactor (SBR), which is widely used for biological nutrient removal (BNR) in municipal and industrial wastewaters [1]. Sequencing batch reactor (SBR) has become a global researcher's focus to optimize operational flexibility, space saving, and operating costs [2, 3].

This study aims to develop a two-step SBR process. However, greenhouse gases (GHGs) can be produced significantly from biological activity during treatment because methane (CH_4) can be produced under anaerobic conditions in the initial stages of treatment [4]. Significant CH_4 emissions can occur at non-oxygenated areas of the leachate system under high loading [5]. In addition, the appearance of high levels of nitrogen in the leachate can cause the emission of N_2O significantly soon after the raw leachate is aerated [6]. N_2O is released during nitrogen removal since N_2O is produced by autotrophic nitrifying bacteria, most of which are ammonia oxidation bacteria [7] during the nitrification, but most of them would be produced during denitrification [8].

In order to overcome limitation of indigenous nitrifying microorganisms, microorganisms that have heterotrophic nitrification and aerobic denitrification abilities such as *Paracoccus denitrificans*, *Pseudomonas stutzeri* and *Alcaligenes feacalis* have been introduced as potential microorganisms that may be used to overcome problems inherent in the conventional method [9]. Among them, *Alcaligenes faecalis* No.4 (*A. faecalis* No.4), has several advantages over other microorganisms such as (1) procedural simplicity, where nitrification and denitrification can take place simultaneously, (2) shorter acclimatization period, (3) lesser buffer quantity needed because alkalinity generated during denitrification can partly compensate for the alkalinity consumption in nitrification. *A. faecalis* No.4, was used to treat concentrated organic and nitrogenous wastewater such as anaerobic digester, coking wastewater, cattle wastewater (12,000 mgCOD/L) as well as high strength ammonium wastewater (5,000 mgN/L) from chemical companies [10]. In greenhouse gas emission perspective, *A. faecalis* No.4 were found to contribute to reduce methane production whereas this specific microorganism can remove 40-50% of ammonium through denitrification and 90% of denitrified products was in the form of N_2 [11, 12]. The rest of removed ammonium was convert to intracellular nitrogen thus producing less N_2O during its process.

To explore the possibility in enhancing of treatment performance of two-stage SBR through bio-augmentation of *A. faecalis* No.4, an experimental study was carried out to investigate the organic and nitrogen removals and greenhouse gas (CH_4 and N_2O) emission from the two-stage SBR system. Specific objective of this study was to determine appropriate operating condition of two-stage SBR to achieve high treatment efficiencies while producing low greenhouse gas emission.

Methodology

Lab-scale SBR unit with capacity of 5 l/d was used in this study. The schematic diagram of the experimental system is shown in Figure 1. The system consisted of two treatment steps. The anaerobic and aerobic reactor, each has 0.010 m^3 working volume. The aeration was continuously supplied to the aerobic reactor which maintained DO level of 3-4 mg/l (Controlled by aeration pump).

Hydraulic retention time (HRT) in both tanks was kept at 2 days. The study was conducted in two experimental systems. Run 1 (without *A. faecalis* No.4, 130 days) and 2 (with *A. faecalis* No.4 in aerobic tank, 45 days), are operated continuously from anaerobic (Stage I) to aerobic reactors (Stage II). The two run have been used to provide stable conditions in terms of water quality and emissions.

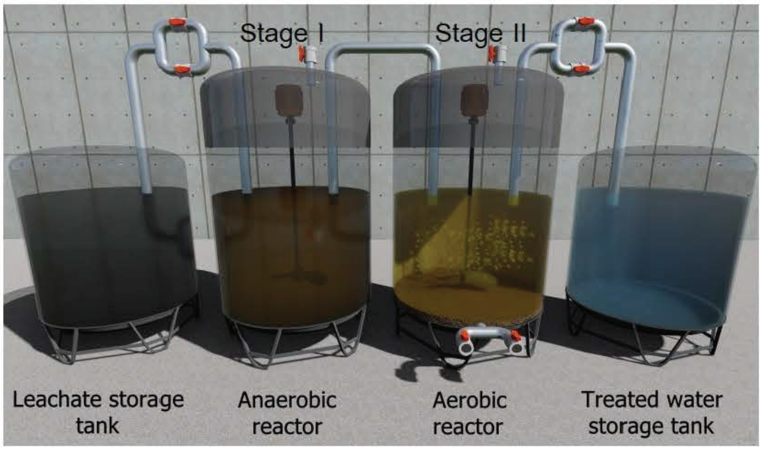

Figure 1 Schematic of two-stage SBR system

Leachate preparation and water quality analyses

Raw leachate was obtained from solid waste collection trucks into waste disposal area, collected at the station every week. Wastewater samples were kept in a glass container and stored at 4°C. All leachate analysis was performed according to the standards for water and wastewater [13]. The water parameters used in the analysis include pH, DO, BOD, COD, TOC, SS, NH_3, TKN, NO_2 and NO_3. In the reactor, MLSS concentrations were monitored. Total viable cell numbers in aerobic tank (expressed as cell per ml.) was counted on L agar plates [14], while greenhouse gases include CH_4 and N_2O. Chemical characteristics of leachate are shown in Table 1. The leachate used exhibited high organic concentrations in terms of BOD, COD and TOC and was acidic in nature. SBR was prepared by mixing fresh leachate and tap water at a ratio of 1: 3 v/v to maintain a constant COD concentration in leachate feed. The average concentration was 8,050 mg COD/L and was to be consistent in feed water.

Table 1 Chemical characteristics of raw and feed leachate

Parameters	Raw leachate		Diluted leachate used in the experiment	
	Range	Average(SD)	Range (System I & II)	Average (System I & II)
pH	3.2-5.1	4.25(0.82)	4.8-5.9	5.24(0.73)
BOD(mg/l)	58,520-70,500	62,050(5,210)	5,150-5,530	5,240(210)
COD(mg/l)	72,400-84,200	74,320(5,260)	7,500-8,560	7,840(340)
TOC(mg/l)	16,550-23,540	19,870(2,210)	2,580-3,380	2,890(310)
SS(mg/l)	410-1,420	680(32)	82-550	235(120)
NH^{+}_{3}-N(mg/l)	2,480-3,350	2,800(290)	730-850	770(51)
TKN(mg/l)	2,620-3,530	3,220(310)	820-1,130	905(80)
NO^{-}_{2}-N(mg/l)	0.4-0.9	0.6(0.40)	0.3-0.6	0.4(0.05)
NO^{-}_{3}-N(mg/l)	0.9-2.8	2.0(0.60)	0.3-2.3	1.7(0.8)

Note: The numbers show avg. (SD) values

Determination of greenhouse gas emission

During the operation, a closed-flux chamber was occasionally placed on top of anaerobic and aerobic reactors to determine greenhouse gas emission from the system. Close flux chamber is a chamber made of plastic plate with 150-mm in diameter and 100-mm in height. During the measurement, special care was taken to make sure that there were not any gas leakages. The reactor surface area which covered the chamber was 0.018 m^2. In order to determine the emission rate, gas samples from the closed-flux chamber were collected into a 9-ml vial by a gas-tight syringe at different time intervals (e.g. every 30 minutes) up to 120 minutes. Then, gas composition in a vial was analyzed by using a gas chromatograph (GC) for CH_4 and N_2O analysis. Closed flux chamber operated by allowing upward diffusive gas to accumulate in the chamber. As the area of flux chamber and reactor was equal, the increasing rate of gas in the chamber was used to determine the mass of emitting gas as follows.

$$F_{AN} = \frac{V\Delta C(298)}{A\Delta t(273+T)} \quad (1)$$

Where F_{AN} = Mass of gas emitted from anaerobic ($g/m^2.d$) at 25°C ; V =volume of chamber (m^3); $\Delta C/\Delta t$ = gas concentration gradient ($g/m^3.d$); T = temperature measured in degree: Celsius (°C). The gas emission was measured from anaerobic reactor at different times during the operation period. For the determination of gas emission from aerobic reactor, gas samples were collected from the cover chamber equipped with gas outlet port. The size of cover chamber was identical to that used in anaerobic reactor. The gas emission was determined from supplied air flow rate and measured outflow gas concentration using the following equation.

$$F_{AE} = Q_{air}\, C/A \quad (2)$$

Where F_{AE} = Flux of gas emitted from aerobic reactor ($g/m^2.d$), Q_{air}= supplied air flow rate (m^3/d), C = outflow gas concentration (g/m^3) and A= area of the cover chamber (m^2).

Results and Discussion

Treatment performance of SBR

During the 1st run (W/O *A. faecalis* No.4), the BOD and COD efficiencies in the SBR system were 64.5% and 51.3%, respectively. NH_3 and TKN removals were also higher than 50% as shown in Table 2. Most of nitrified nitrogen was denitrified resulting in low concentrations of oxidized nitrogen. In the 2nd run (With *A. faecalis* No.4), slightly higher BOD COD and TKN removal efficiencies of 80.1% 67.8% and 75.1%, respectively were obtained but changed to indicating. At with *A. faecalis* No.4 conditions, much higher biodegradable organic (BOD) concentrations were detected in the effluent of aerobic reactor even though the effluents from first stage anaerobic reactor were only moderately elevated.

Figure 2 shows the variation of biomass (MLSS) concentrations in anaerobic and aerobic reactors as well as *A. faecalis* No.4 population. In Run 1, MLSS in aerobic reactor gradually increased from 7.1 to 9.2 gl^{-1} at an increasing rate 0.017 $gl^{-1}d^{-1}$ while MLSS in the anaerobic reactor were kept relatively constant at about 4.2 gl^{-1}. When *A. faecalis* No.4 was introduced in the aerobic reactor in Run 2, MLSS was continuously increased to 13.3 gl^{-1} having higher biomass increasing rate of 0.095 $gl^{-1}d^{-1}$. This significant increase in biomass concentration in the aerobic reactor was possibly associated with the growth of *A. faecalis* No.4. The results indicate that the *A. faecalis* No.4 could utilize carbon and nitrogen compounds presented in the leachate efficiently for their growth under aerobic condition. Their cell concentrations were increasing from $6.5x10^8$ to $5.3x10^9$ cells ml^{-1} during that period. Naturally, the growth of *A. faecalis* No.4 were also found associated with elevated pH condition as the pH was found increase from 8-9 on day 132 and up to more than 10 during initial period (day 141-145) of Run 2 during which a decrease in *A. faecalis* No.4 population was observed. Subsequent operation with pH control (day 146-175) between 8 and 9 led to more stable operation and steadily growth of *A. faecalis* No.4. Extremely high pH condition, e.g. more than 11, was also reported to inhibit the growth of *A. faecalis* No.4 in previous study [14]. These results suggested that with *A. faecalis* No.4 had insignificant effect on the SBR performance on organic and nitrogen removals.

Table 2 Effluent qualities from SBR during steady operation

Parameters	Without *A. faecalis* No.4			With *A. faecalis* No.4		
	Eff. (An-SBR)	Eff. (Ae-SBR)	% Removal	Eff. (An-SBR)	Eff. (Ae-SBR)	% Removal
pH	6.4(0.3)	7.3(0.2)	-	6.5(0.2)	9.5(0.6)	-
DO	0.0(0.02)	4.1(0.5)	-	0.2(0.1)	2.1(0.3)	-
BOD	3,915(137)	1,860(138)	64.5	4,035(154)	803.0(206)	80.1
COD	6,482(94)	3,157(151)	51.3	6,540(101)	2,106(345)	67.8
TOC	2,006(140)	750(91)	62.7	2,098(140)	279(432)	86.7
NH^+_3-N	615(42)	300(30)	50.2	624(33)	619(126)	77.9
TKN	642(32)	285(14)	55.5	701(26)	175(62)	75.1
NO^-_2-N	0.16(0.06)	0.08(0.07)	48.3	0.21(0.11)	0.05(0.12)	72.5
NO^-_3-N	0.64(0.16)	0.3(0.09)	55.4	0.88(0.3)	0.2(0.13)	77.3

Note: The numbers show avg. (SD) values

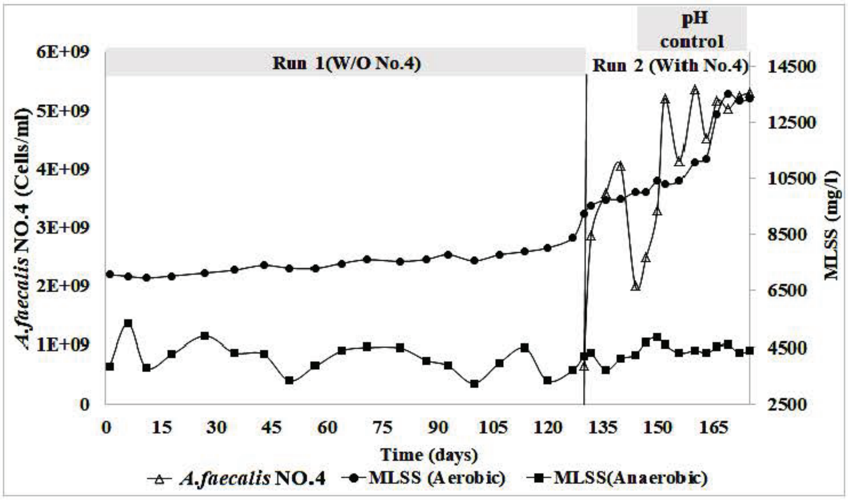

Figure 2 Characteristic of *A. faecalis* No.4 and biomass concentration

Measurements of greenhouse gas emissions from SBR

Table 3 presents surface emission rates of CH_4 and N_2O from anaerobic and aerobic reactors during leachate treatment. During the 1^{st} run (W/O *A. faecalis* No.4), average CH_4 emission rate from anaerobic and aerobic reactors was 0.195 and 0.013 $g/m^2.d$. This is equivalent to CH_4 mass of 0.0035 and 0.0003 g/d. Meanwhile, N_2O emission rate was 0.0217 and 0.0022 $g/m^2.d$. These results show that both greenhouse gases were mainly emitted from the anaerobic reactor. When put *A. faecalis* No.4 operated in the 2^{nd} run, CH_4 and N_2O emission rates were found decreasing in aerobic reactors. These results show that both GHG were mainly emitted from the anaerobic reactor. Similar observation on the CH_4 emission trend during the treatment process was reported in [1]. The major source of CH_4 emission came from the first reactor which was favorable for methanogens. Meanwhile, Anaerobic reactor N_2O production could take place where DO was maintained at about 0.5 mg/l. In previous research, it was reported that high N_2O production was observed under a DO level less than 2 mg/l [5, 7] as N_2O was produced from denitrification instead of N_2 in low oxygen condition [15].

Table 3 CH_4 and N_2O emission from anaerobic and aerobic reactors of SBR system

Conditions	GHGs	Anaerobic($g/m^2.d$)		Aerobic($g/m^2.d$)	
		Range	Avg	Range	Avg
W/O *A. faecalis* No.4	CH_4	0.127-0.297	0.195	0.012-0.018	0.0132
	N_2O	0.004-0.024	0.022	0.0020-0.0028	0.0022
With *A. faecalis* No.4	CH_4	0.142-0.267	0.209	0.007-0.012	0.0086
	N_2O	0.006-0.037	0.023	0.0017-0.0022	0.0019

Conclusion

An experimental study on greenhouse gas emission from two-stage SBR treating highly concentrated leachate suggested CH_4 gas were mainly emitted from first anaerobic stage at an average rate of 0.195 and 0.209 $g/m^2.d$ at Run I and Run II. Meanwhile, the emissions from second aerobic reactor were 0.0132 and 0.0086 $g/m^2.d$, respectively. Decreases in Run II in aerobic reactor, decreased CH_4 emission by 35%. Based on this conclusion, it is recommended to run the system at a very high storage capacity, which will improve the efficiency of wastewater treatment and reduce greenhouse gas emissions. *A. faecalis* No.4 with heterotrophic nitrification and aerobic denitrification abilities was bio-augmented in two-stage SBR yielding improved organic carbon and nitrogen removals. High organic carbon (86.7%) and nitrogen (75%) removals were achieved even the system was operated with *A. faecalis* No.4.

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Hazardous Waste Management of Establishments Motorcycle Repair Shop in the Phuket Municipality Area Mueang District, Phuket Province

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Abstract

Hazardous waste management of establishments motorcycle repair shop in Phuket municipality area, Mueang district, Phuket province has the objective to study on types, quantity, and methods in managing hazardous waste from motorcycle repair shop, as well as on problems, obstacles, and suggestions for hazardous waste management. In this study, record forms were used to collect data on type and quantity. Interview, observation, and taking photos were used to record on methods on storing hazardous waste from 10 motorcycle repair shops. Questionnaire was used to study on hazardous waste management, problems, obstacle, and suggestions from 55 motorcycle repair shops. The data was collected from August - October 2018.

The result shows that in 100 percent of hazardous waste consists of the following types: 1) engine oil, 2) tyre, 3) inner tube, 4) grease can, and 5) engine oil can. In terms of quantity of hazardous waste, engine oil, gear oil, and lubricant oil are 443.80 liters in total. The total amount of tyre is 624 pieces and 2,431 pieces for total amount of inner tube. The result of the study on hazardous waste management found shows that used oil buckets are used for storing engine oil, which is a good way to reduce contamination. For used tyre and inner tube are stacked up in the shop without any containers, which need to be improved in order to reduce contamination. Regarding the methods for hazardous waste management, the most used method is waste buying companies, which is accounted for 100 percent including engine oil, metal parts, chains, lubricant oil, and gear oil. Items that are most disposed to municipality's bin are gloves with engine oil stain and used face masks, which accounted for 100 percent. Re-use is accounted for 90.90 percent, which include clothes with engine oil stain. Selling is accounted for 21.82 percent and the items that most sold are lubricant and engine oil cans. Other methods like putting in closed garbage bags and lay by municipality bins accounted for 74.55 percent on waste that contaminated with engine oil. The study on problems and obstacles found that the lack of discipline in managing hazardous waste is the major cause of improper hazardous waste management, which is accounted for 85.47 percent. The study on suggestion for hazardous waste management found that most of the operators suggest that there should be bins for each type of hazardous wastes specified clearly. This suggestion is accounted for 89.10 percent.

Keywords : Motorcycle repair shop; hazardous waste; hazardous waste management

Introduction

In Thailand nowadays, there is high expansion of economy, which the government imposed development policies and improved infrastructure system in all forms of transportation in order to increase the capacity in traveling and goods shipment for both domestic and international movements to be more convenient, secure, and faster [1]. There are many formats of transportation in the transportation system such as ships are used for water transportation, planes are used for air transportation, and for land transportation different types of cars are used. However, the most used transportation format is land transportation by using cars, which is easy and convenient for public transportation or transport of goods. For this reason, people are more prefer to use cars in traveling more and more. A smaller vehicle like motorcycle becomes another alternative for working people because it is flexible, can travel quickly on the road, low maintenance cost, and its gas price is not too expensive when comparing to public transportation or private car. This makes the number of motorcycles increases rapidly.

The continual use of motorcycle in traveling causes deterioration, which repair or change of vehicle parts like engine oil, tyre, bulbs, battery, and lubricant are needed to be done in motorcycle repair shops. If these hazardous wastes are not manage properly and disposed to environment with community wastes, it will leak out or spread to the environment and affect people's health. Moreover, it can cause the destruction of ecosystem, antique objects, and landscape [2].

Tourism development in Phuket has been improved rapidly. In the area of Phuket municipality, Mueang district, Phuket province is the heart of the city, which consists of 2 sub-districts: Talad Nue and Talad Yai. These two sub-districts are considered to be the center of many important governmental and private organizations and tourist attractions like schools, municipality office, banks, shopping malls, old town, and hotels. In each day, there are many people including tourists and working people come to use services from these places. For this reason, the number of tourist and latent population in Phuket increase a lot. Hence, the use of motorcycle for traveling increases. This causes those who have knowledge in motorcycle repairing make it a profession by operating motorcycle repair shop. From this, the number of motorcycle repair shops also increases. According the list of registered motorcycle repair shops, there are 25 shops registered [3]. The additional survey was conducted by purposive sampling due to there are many unregistered operators in the area of study. Therefore, the researcher is required to conduct a survey, which found that there are another 34 shops in Phuket municipality area, Mueang district, Phuket province. In total, there are 58 shops spread in all area of Phuket municipality. Motorcycle repair shops are the source of important hazardous waste incurring from repairing or changing parts services after the use of motorcycle. From the problems mentioned above, it makes the researcher became interested in studying on hazardous waste management of motorcycle repair shops in Phuket municipality area, Mueang district, Phuket province in order to learn on the types and quantity of hazardous wastes, methods in managing hazardous waste in motorcycle repair shops.

Materials and Methods

This research is conducted as a survey research by using tools and methods in collecting data, and duration of data collecting as follow:

1. Tools, sample groups, and duration of research

In this research, outcome record and questionnaire are used as tools in collecting data as follow:

1.1 Data on types and quantity were collected from 10 motorcycle repair shops, which randomly selected from purposive sampling because these 10 shops corporate in hazardous waste management that can be good for the study. Moreover, there are similar services provide in these 10 shops. The data is collected by using outcome record once a week for the duration of 3 months within the area of Phuket municipality, Mueang Phuket district, Phuket province.

1.2 Interview, observation, and taking photos are used in collecting information on storing hazardous waste in 10 motorcycle repair shops, which randomly selected from purposive sampling because these 10 shops corporate in hazardous waste management that can be good for the study.

1.3 For methods in hazardous waste management, problems, obstacles, and suggestions of motorcycle repair shops in Phuket municipality area, Mueang district, Phuket province, the data was collected by using questionnaire. The questionnaire was divided into 3 parts: Part 1 collects general information of respondents, which includes gender, age, level of education, length of operation time, average number of motorcycles receiving services per day, and type of services provided. Part 2 collects information on methods of hazardous waste management (methods include using municipality services, reuse, storing in container to be disposed later, sell, buying companies, or other methods). Part 3 collects information on problems, obstacles, and suggestions of motorcycle repair shops in managing hazardous wastes.

The study on problems, obstacles, and suggestions of motorcycle repair shops in managing hazardous wastes, purposive sampling was used to collect information from 55 shops. There are 25 shops from the list of registered motorcycle repair shops of municipality office and another unregistered 34 shops from self survey within the studied area. In total, there are 59 shops in Phuket municipality, Mueang district, Phuket province. The duration of data collection started from August to October 2018. Moreover, the data was collected from 55 shops because the other 4 shops were not available willing to corporate in responding to the questionnaire.

2. Equipment used in collecting information include gloves, weighing scale, face mask, garbage bag, sticky tape, pens, and outcome record form.

3. In analyzing data, studying on types and quantity of hazardous wastes in motorcycle repair shops, the results were used to analyzed by using basic statistics include percentage and average value. Then, display the data in table. Moreover, data from the study of methods in hazardous waste management of motorcycle repair shops was used to analyzed in terms of narrative analysis in order to find a conclusion.

Results and Discussion

1. The result of the study on types of hazardous wastes incurring from motorcycle repair shops

Types of hazardous wastes incurring from motorcycle repair shops include used engine oil, tyre, inner tube, lubricant can, and engine oil can, which accounted for 100 percent due to a motorcycle requires to discharge engine oil every 1,000-4,000 kilometer of riding in order to maintain the capacity of engine to function well always. This is relevant to the study of Suparat Chanpetch [4] on hazardous waste management of auto service centers in Phuket, which found that the type of hazardous waste that can be found the most is used engine oil.

2. The result of the study on quantity of hazardous wastes incurring from 10 randomly selected motorcycle repair shops is displayed in table 1.

Table 1 shows the total quantity of hazardous waste incurring in 3 months in 10 randomly selected motorcycle repair shops

Rank	Type of Hazardous Waste	Quantity	Unit
1	Oil - used engine oil - Gear oil - Lubricant oil	443.80	Liter
2	Tyre	624	Piece
3	Inner tube	2,431	Piece
4	Metal remains such as bearing, chain, screw, spark plug, and brake lining	270.30	Kilogram
5	Aluminum can - Rustproof Spray can - Paint can	63.10	Kilogram
6	Plastic can - Grease can - Engine oil can	163.40	Kilogram
7	Electrical wire	6.10	Kilogram
8	Light	629	Bulb
9	Battery	225	Unit

The study of quantity of hazardous waste incurring in 10 randomly selected motorcycle repair shop in the area of Phuket municipality, Mueang Phuket, Phuket province found that the amount of used engine oil, gear oil, and lubricant oil is 443.80 liters in total. The operators of motorcycle repair shops provided information that a motorcycle should discharge and change engine oil once reached 1,000-4,000 kilometers of usage in order to maintain the capacity of engine for the effective functioning [5]. The second highest amount of hazardous waste is tyre, which there are 624 tyre in total. The total amount of inner tube is 2,431 tubes due to the usage of motorcycle caused fast deterioration of tyre and inner tube. In terms of metal remains like bearing, chain, screw, spark plug, and brake lining, the total amount is 270.30 kilograms. Plastic cans for grease and engine oil in total are 163.40 kilograms, which is higher that the to amount of aluminum cans, 63.10 kilograms, of rustproof and paint spray [6]. The total amount of electrical wire is 6.1 kilograms, motorcycle lights is 649 bulbs, and battery is 225 pieces.

3. Results from the study of hazardous waste management of motorcycle repair shops

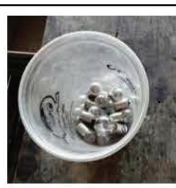
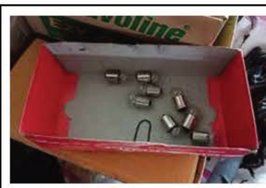
3.1 Results from the study of hazardous waste storing of motorcycle repair shops

From the study on hazardous waste storing of motorcycle repair shops by using interview, observation, and taking photos of 10 random selected motorcycle repair shops from purposive sampling, the results displayed in table 2.

Table 2 shows the results on storing methods hazardous wastes incurring in 10 samples of motorcycle repair shops, which are correctly and incorrectly according to academic theories (require improvement)

Correct storaging method according to academic theory		Incorrect storaging method according to academic theory (Require improvement)	
Engine oil, gear oil, lubricant oil		Tyre, inner tube	
 Oil bucks for storing engine oil, gear oil, and lubricant oil	 Oil bucks for storing engine oil, gear oil, and lubricant oil	 Used tyre and inner tubes of motorcycle are stack up in front of the shops	 Used tyre and inner tubes of motorcycle are stack up in front of the shops

Table 2 shows the results on storing methods hazardous wastes incurring in 10 samples of motorcycle repair shops, which are correctly and incorrectly according to academic theories (require improvement) (con't)

Rustproof and paint spray can		Electrical wire	
 Paper box for storing rustproof and paint stray cans	 Sack for storing rustproof and paint stray cans	 Paper box for storing wasted electrical wire	 Metal bucket for storing wasted electrical wire
Motorcycle light		**Metal remain**	
 Plastic cup for storing decayed and unusable motorcycle lights	 Paper box for storing decayed and unusable motorcycle lights	 Metal bucket for storing metal remains like chains, bearing, and screw	 Paper box for storing metal remains like chains, bearing, and screw
Engine oil and lubricant can		**Battery**	
 Storing engine and lubricant oil can	 Storing engine and lubricant oil can	 Storing unused battery in a paper box and placed in the shops without any container	 Storing unused battery in the shops without any container

The results from the study of methods in storing hazardous waste from motorcycle repair shop shows that a strong closed container for each type of hazardous wastes is required in order to prevent spilling, leakage, and contamination to environment. In case of clothes contaminated with oil stains must be disposed of properly by sending to the factory that receives hazardous waste disposal to be burned in a high temperature incinerator.

3.2 The study of hazardous waste management of motorcycle repair shop

1) The study of respondents' general information

From the study on respondents' general information, it shows that there are more male respondents than female ones, which is accounted for 85.45 percent of all respondents. The age of respondents between 40-49 years is accounted for 50.9 percent due to the suitability of men in serving in motorcycle repair shops than women and right age for owning a business. The level of education of most respondents are in Vocational Certificate and High Vocational Certificate level, which are accounted for 45.45 percent, as providing motorcycle repair services requires specific knowledge. Therefore, choosing to study in Vocational Certificate and High Vocational Certificate levels is more suitable for working in his field. The length of business operation mostly between 11-15 years, which accounted for 32.73 percent. Mostly, the average number of motorcycles to repair is 16-20 motorcycles a day. Most of the shops provide services for motorcycles including changing tyre, changing inner tube, discharging engine oil, changing brake lining, battery, lights, spark plug, brake oil, ring, gear oil, stretching and changing chain, and changing bearing the most, which accounted for 100 percent.

2) Results from the study of methods in hazardous waste management of motorcycle repair shops

Methods in managing hazardous waste of 55 motorcycle repair shops in Phuket municipality area, Mueang Phuket, Phuket province, we found that eliminating hazardous waste by selling to waste buying companies is the most used method for used engine oil, metal remains, chain, lubricant oil, and gear oil, which is accounted for 100 percent. This is due to used engine oil, lubricant oil, and gear oil can be sold to decrease quantity of waste. For metal remains, there are garbage sorters come to buy at the shops because metal remains can be melt to produce the same or different product. This is relevant to the study of Jintana Petchwang [7] who conducted a study on hazardous waste management of garages in Mueang district, Phuket province. The study shows that selling to waste buying companies is the most used method for hazardous waste management of garages in Mueang district, Phuket province. The items with highest sales are engine oil, lubricant oil, and metal remains.

3) The study of problems, obstacles, and suggestions in managing hazardous waste of motorcycle repair shops

The study of problems, obstacles, and suggestions in managing hazardous waste of motorcycle repair shops shows that most of the respondents do not have any problems in managing hazardous waste, which accounted for 83.64 percent. The problems that found the most in managing hazardous waste in motorcycle repair shops are lacking of bin for hazardous waste, which accounted for 52.73 percent. This is due to hazardous waste management in most shops do not have bin for hazardous waste. If the municipality or related organizations provide bins for hazardous wastes to these shop, it can reduce contamination, spilling, and leakage, as well as it can be disposed correctly and not contaminate the environment.

The study on the causes of incorrect methods of hazardous waste management shows that most of the respondents think that the lack of discipline is the major cause of incorrect methods of hazardous waste management, which accounted for 85.47 percent. This is relevant to the study of Chainarong Phanomtheerakiat. In managing hazardous wastes, it is required to classify the type of hazardous waste in order to make it easier for disposal. The disposal can be complicated for operators. So, most of the operators dispose hazardous waste with other wastes like plastic bags and papers. From these reasons, it caused operators to become lacking of discipline in managing hazardous waste.

Suggestions from motorcycle repair shop operators

1) For managing hazardous waste of motorcycle repair shops in Phuket municipality area, Mueang district, Phuket province, there should be specific bins to classify the type of hazardous waste.

2) Phuket municipality in Mueang district, Phuket province should take a serious action in managing hazardous waste.

3) All operators request for related organizations to provide knowledge for managing hazardous waste from motorcycle repair shops, as some of the operators still lack of knowledge and understanding in managing hazardous waste from their shops.

4) Motorcycle repair shop operators should participate in responsible for disposal of hazardous waste and be disciplined in working on classifying type of wastes to ease the disposal process.

5) In buying hazardous waste from operators, buying companies should be legally registered. Moreover, the companies should concern on safety in collecting and transporting hazardous waste to prevent leakage and contamination to the environment.

Conclusion

The study on hazardous waste management of motorcycle repair shop in Phuket municipality area, Mueang district, Phuket province shows that the types of hazardous waste mostly found are 1) engine oil, 2) tyre, 3) inner tube, 4) grease can, and 5) engine oil can, which accounted for 100 percent. Quantity of hazardous waste consists of engine oil, gear oil, and lubricant oil in total 443.80 liters, tyre in total 624 pieces, and inner rubber in total 2,431 pieces. In terms of methods in managing hazardous waste, we found that for storing hazardous waste, used oil bucket are used to store engine oil, which is the best method to reduce contamination. For used tyre and inner tube, they are stacked up in the shops without any container, which this method needs to be improved in order to reduce contamination. For types of waste that are mostly eliminated by selling to waste buying companies are engine oil, metal remains, chain, lubricant oil, and oil. Type of wastes disposed to municipality bins the most are loaves with engine oil stain and used face mask. The most reused wastes are working cloth with engine oil stain. The most sold wastes are lubricant can and engine oil can. Wastes disposed by putting in closed garbage bags and placed by with engine oil. The study on problems and obstacles shows that lacking discipline in managing hazardous waste is the main cause of incorrect hazardous waste management. The study on suggestions for hazardous waste management shows that most operators suggest to have specific bins to classify hazardous wastes.

In this study, it is a collection of hazardous waste from motorcycle repair shops once a week for 3 months, which is the amount of accumulated waste per cycle. And the researcher did not collect the number of customers who came to use the service Therefore can not compare the proportion of customers who use motorcycle repair service with the amount of waste from motorcycle repair shops that occurred.

Acknowledgement

I would like to thank all respondents at motorcycle repair shops in Phuket municipality area, Mueang district, Phuket province who sacrificed their time to participate and provide very useful information for this research.

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Site Selection for Special Economic Zone using Spatial Planning with Strategic Environmental Assessment Application Case Study of Nongkai Province

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Abstract

This article presents site selection for special economic zone (SEZ) development at Nong Khai Province, and appropriate industrial type for the selected suitable SEZ site. The study steps consisted of spatial planning for site selection and industrial type by strategic environmental assessment (SEA). Spatial planning was started with 11 SEZ potential sites previously declared by Nong Kai Province. Then, 11 potential SEZ sites were screened out by excluding the area where have already been designated for other uses, including commercial area, tourism area, and industrial area; and with the criteria of industrial estate; 11 SEZ potential sites was cut down to 7 and 3 SEZ potential sites, respectively. Finally, overlaying of 3 SEZ potential sites on town planning map, only one SEZ site was classified as suitable SEZ site. It is Animal Raising Public area, Chai Ya Village, no 4, Sra Kai Sub-district, Sra Kai District, Nong Kai Province, covering total area of 718 rai or 115 hectares. Later, SEA was applied to assess the industrial alternatives proposed to such suitable site. Alternatives included no development of industrial (no action), all types of industries permission, only eco-industrial type permission. Impact assessment was performed through 3 implys; check list multi-criteria analysis indicators, impact matrices analysis for assessing impact score of alternatives. The maximum assessed impact score was calculated. With the maximum assessed impact score, eco industry was proposed to such defined suitable SEZ site

Keywords : Special Economic Zone; Spatial Planning; SEA; Eco-industry

Introduction

Sustainable Development Goals (SDG) are the world development framework after 2015. SDG has been continually designated by the United Nation after ending of the Millennium Development Goals (MDG). In accordance with the 70th session of the United Nations General Assembly, the 2030 Agenda for Sustainable Development and SDGs have been endorsed for the countries to implement and meet the sustainable development; economic, social and environmental perspectives for 15 years (September 2015- August 2030) [1]. Currently, Strategic Environmental Assessment (SEA) is the significant tool to drive the country to accomplish the SDG of the strategic level. SEA alleviates effectively systematic decision making for considering policy, plan and programs [2].

Under the 12^{th} National Economic and Social Development Plan 2017-2021), SEA is considered as the major tool for Special Economic Zone (SEZ) defined in Strategy 9, Regional, Town and Economic Area Development [3]. National Economic and Social Development Board (NESDB) has initiated the SEZ particularly at the border area since 2000. SEZ has been established in order to develop the area in conformance with the potential area and the need of people as well as the good governance that will increase the economic competitiveness of the country.

Under the Committee of Social Economic Zone Policy, SEZ phase 1 has been designated for the area of Tak, Sra Kaew, Mukdahan, Trad and Songkla Provinces (declared on Jan 19, 2013); and SEZ phase 2 has been designated for Nongkai, Narathiwas, Chiangrai, Nakokn Panom and Kanchanaburi Provinces(declared on April 24, 2013) [4]. Although, SEZ is proposed to enhance the economy of the provinces along the border area, site selection of SEZ might not cover all concerning perspectives. It might consider only economic concern and geographical factors, but not social and environmental concerns. For geographical base, SEZ sites are considered in terms of advantageous toward transportation, border crossing, access to production factors, marketing, potential and readiness area for development, standing out production base, expansion opportunity, available infrastructures, finance, labor, no disaster, no stability effect, necessity or urgent need, memorandum of agreement of the countries. Along with SEZ development, particularly with the industrial estate development, site selection, raw material procurement, production, transportation, waste management are noted to cause environmental impacts that further impact to people living nearby relate social aspect or quality of life value. The suitable location for SEZ is primary need followed with the appropriate industrial type (environmental friendly industry) on the basis of sustainable considered as the balancing of three major pole; economic, social and environmental dimensions.

Regarding with SEZ plan, Nong Kai Province is the place designated for SEZ establishment. SEZ sites were firstly considered basing on the area of the state property or public area together with industrial estate criteria, the potential area located in 5 districts of 559,614 rai or 89,538 hectare. However, on the basis of sustainable development, the eco-SEZ (environmental and social friendly SEZ) is needed to re-consider for Nong Kai Province. In the implytime, the governmental policy has recently declared for application of SEA to SEZ. The concept of spatial planning (one of the SEA tools) proposed to identify the suitable SEZ site for Nong Kai Province, and appropriate industrial type using SEA approach (consisting of alternative and participation) are therefore studied and presented herein.

Objective

The objectives of this work is to identify the suitable sites for SEZ using spatial planning approach and appropriate industrial type using SEA approach.

Methodology

Research methodology is as following

1. **Preliminary study**

1) Studying and reviewing secondary data of various documents including Policy of National Economic and Social Development, Environmental Quality Management Plan, Strategic Environmental Assessment, Policy of Special Economic Zone Development, National Logistic Policy and Strategic Plan, Socio Economic and Environment Status, and, Provincial and Provincial Cluster Development Plan; as well as relevant literature reviews and theories.

2) Reviewing 11 SEZ potential sites located in 5 districts previously declared by the Province.

2. **Research study**

1) Spatial planning for 11 SEZ potential sites with GIS application was performed as follows.

(1) Primary screening out against the criteria of excluding the area have already been designated for other uses, including commercial area, tourism area, and industrial area, called as the primary SEZ potential sites,

(2) Secondary screening out against the criteria of industrial estate (see below) for the primary SEZ potential sites; called as the secondary SEZ potential sites

Physical

- sufficient water quantity for water uses
- Soil is not suitable soil for agriculture
- area located near to the main road and readily access to road network

Environment

- area should locate far away water sources, for this study it should be away of the Mekong river, at least 200 meters.
- area is not located in the national park and wildlife sanction area, and conservative forest area
- area is not in the reserve wildlife habitat
- area is not at the crowded community area
- area (is not located near the conservative water resources and valuable ecosystem.

(3) Thirdly, overlaying of the secondary SEZ potential sites on town planning map, only one SEZ site was identified as suitable SEZ site.

2) SEA application

Assess the impact of the industrial type alternatives by SEA approach with following steps.

(1) Setting the indicators of economic, social and environmental dimensions by formal and informal check list for industrial type alternatives selection. This step included following sub-steps.

- proposing such mentioned indicators.
- consulting with the experts of economic, social and environmental indicators.

- collecting primary data (if needed) and secondary data for completeness of the indicators.
- consulting with the line agencies in the area for additional comments quality of data.

(2) Weighting the dimension and indicators using multi criteria analysis.

(3) Assessing impact of each alternative by impact matrices analysis as following calculation.

For each dimension of each alternative:

- multiplying weight score with impact score of each indicator, the result was impact assessed score
- Combining each impact assessed score to be sub-total impact assessed score of each dimension.

For three dimensions of each alternative

- Combining sub- total impact assessed score of each dimension to be total impact assessed score.

(4) Comparing total impact assessed score of each alternative, the output was the appropriate alternative site by considering the maximum total impact assessed score

Results

As declared by Nong Kai Province, 11 SEZ potential sites are presented in Table 1 and Figure 1. Such potential sites were res-studied to identify the suitable SEZ site.

Table 1 Preliminary Potential SEZ Using and Size of State Property Area or Public Area Industrial Estate Criteria

Name of Public Area	Location in Nong Kai Province			
	Sub-District,	District	Area (Rai)	Area (Ha)
1. Nata railway station	Nhong Kom Koa	Muang	219	35
2. Nong Kai railway station	Nhong Kom Koa	Muang	152	24
3. Nong Kai railway station (old)	Meechai	Muang	100	16
4. Animal raising area Koke Nong Pung, Pone Tan Village no 3	Kai Bok Whan	Muang	201	32
5. Industrial Estate	Kai Bok Whan	Muang	2,960	474
6. Pa Koke Yai Public Area (Plot 1)	Wat Luang	Pone Pisai	401	64
7. Pa Koke Yai Public Area (Plot 2)	Wat Luang	Pone Pisai	166	27
8. Animal raising area , Chai Ya Village, no 4	Sra Kai	Sra Kai	718	115
9. Koke Soke Dindang	Sra Kai	Sra Kai	700	112
10. Nong Mung, Ban Pone Sa	Ban Pone Sa	Ta Bo	259	41
11. Animal raising area, Tha Kathin Village, no 4	Ban Mho	Sri Chiang Mai	462	74

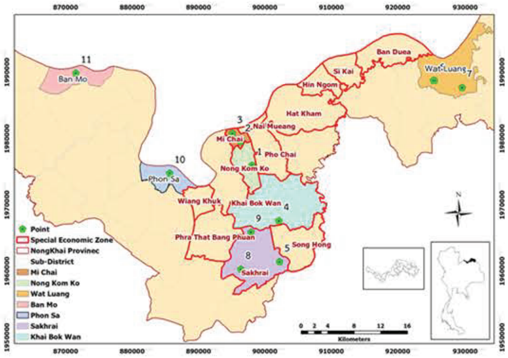
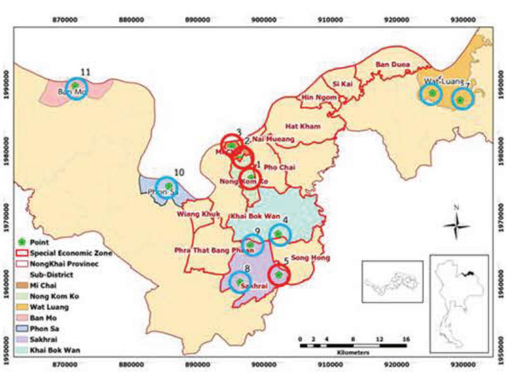


Figure 1 Eleven Potential SEZ Using State Property or Public area together with Industrial Estate Criteria

3. Study results

1) Spatial planning for the suitable SEZ site. This section is re-studied of such 11 potential SEZ site, which are subsequently described.

The first step was preliminary screening out the area have been already designated by the Provincial Development Plan for future use including commercial area, industrial area, tourism area; the output of this screening out was 7 screened feasible ZES potential sites (Figure 2).



Remark: The sites where were cut out

Figure 2 Seven screened SEZ Potential Sites

The second step was screening out the feasible SEZ potential sites to be the feasible alternative SEZ sites. With using industrial criteria with some modification and GIS application, 7 SEZ potential sites were cut down to 3 SEZ potential as shown in Figure 3.

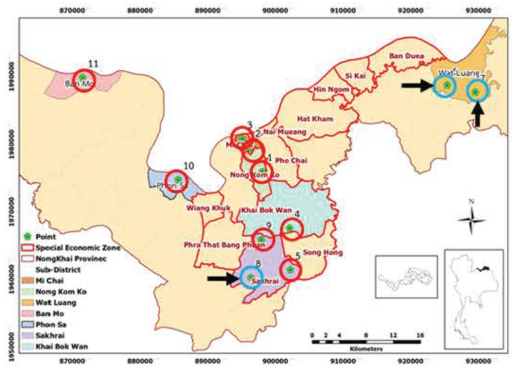


Figure 3 3 SEZ potential sites

Finally, overlaying of 3 potential SEZ sites on the town planning map, only one site was defined to be the suitable SEZ zone, which was Animal Raising Public area, Chai Ya Village, no 4, Sra Kai Sub-district, Sra Kai District, Non Kai Province, covering total area of 718 rai or 115 hectare. (Figure 4)

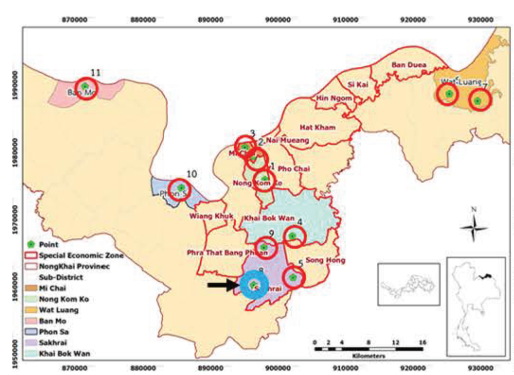


Figure 4 Sustainable SEZ site

2) SEA approach for appropriate industrial type.

Although the suitable SEZ site was accomplished, industrial types have to be considered as well. SEA tool (balancing of economic, social and environment dimension; alternatives, participation) was used on the principle of sustainable development. Three alternatives were proposed to carry out in such suitable SEZ site as follows; no industrial estate development (no action), all industrial types permission, and only eco-industry permission. Then, SEA approach with expert judgement carried out along SEA process was employed for assessing to appropriate industrial type as follows.

Firstly, indicators of each economic, social, and environmental dimensions were listed by formal and informal check list with expert comments [4, 5], indicators are listed in Table 2.

Secondly, weighting of each economic, social and environmental dimension, and weighting of indicators under each dimension were made by using MCA [6]. Weight of each dimension was assessed on the sustainable development concept which is the balancing of economic, social and environmental dimensions. In the other hand, weight score of each dimension can be evaluated by MCA with pairwise comparison as follows.

- Weight of column-indicator which is the same as row- indicator, the score was 0.
- Weight of column-indicator was higher than row- indicator, the score was 3.
- Weight of column-indicator was equal as row- indicator, the score was 2.
- Weight of column-indicator was lower than row- indicator, the score was 1.

For each dimension, weighting of all indicators was calculated using MCA based on pairwise comparison, as presented below, which is the example of environmental dimension presented herein.

- Weight of column-indicator which is the same as row- indicator, the score was 0.
- Weight of column-indicator was the highest compared to the row- indicator, the score was 5.
- Weight of column-indicator was higher than the row- indicator, the score was 4.
- Weight of column-indicator was equal as row- indicator, the score was 3.
- Weight of column-indicator was lower than row- indicator, the score was 2.
- Weight of column-indicator was the lowest compared to the row- indicator, the score was 1.

Weighting score of all indicators under each dimension are summarized in Tables 5-1, 5-2 and 5-3, respectively.

- Thirdly, impact assessment of the alternative based on matrices analysis, the assessed impact score are calculated as exampled for environmental dimension shown in Table 6, of which the impact score is assessed as below. Impact score 0.00-0.20 imply the positive impact is the lower level
- Impact score 0.21-0.40 imply the positive impact is low positive
- Impact score 0.40-0.60 imply the positive impact is moderate level
- Impact score 0.61-0.80 imply the positive impact is higher level
- Impact score 0.81-1.00 imply the positive impact is the highest level

Total assessed impact score of alternatives are presented in Table 7.

Table 2 List of Indicators of Each Dimension

Economic Dimension	Social Dimension	Environmental Dimension
1. National GDP	1. Ratio of non-registered population	1. Sufficient water use for all sectors
2. Provincial GPP	2. Workers with social security	2. Surface water quality
3. Inflation rate	3. GINI coefficient	3. Groundwater quality
4. Tax collected by Revenue Department	4. Average household debt	4. Air quality
5. Unemployment rate	5. Ratio of illness	5. Capability to traffic accommodation
6. Economic growth of industrial sector	6. Adequacy and access to education	6. Sufficient of electrical service/energy
7. Economic growth of agriculture sector	7. Average education year of people	7. Capability of domestic solid waste management
8. Economic growth of service sector	8. Number of crimes against property	8. Capability of industrial waste
9. Economic value	9. Recreation area	
	10. Number of complaints to environment	

Table 3 Weighting of Economic, Social and Environmental

Dimension	Economic	Social	Environment
Economic	0	2	2
Social	2	0	2
Environment	2	2	0
Total	4	4	4
100	33.33	33.33	33.33

Table 4 Example of Weighting Score of Indicator Under Environmental Dimension

Indicators	1. Sufficient water use for all sectors	2. Capability of industrial waste	3. Groundwater quality	4. Air quality	5. Capability to traffic accommodation	6. Sufficient of electrical service/energy	7. Capability of domestic solid waste management	8. Capability of industrial waste
1. Sufficient water use for all sectors	0	2	2	2	2	2	3	3
2. Surface water quality	4	0	2	2	2	2	4	4
3. Groundwater quality	4	4	0	2	2	2	3	3
4. Air quality	4	4	4	0	3	2	4	4
5.Capability to traffic accommodation	4	4	4	3	0	2	4	4
6.Sufficient of electrical service/energy	4	4	4	4	4	0	5	5
7. Capability of domestic solid waste management	3	2	3	2	2	1	0	4
8.Capability of industrial waste	3	2	3	2	2	1	2	0
Total weight of each indicator	26	22	22	17	17	12	25	27
Weight of each indicator for social dimension score of 33.33	5.2	4.4	4.4	3.4	3.4	2.4	5.0	5.4

Remark Weight of each indicator = Total weight of each indicator/ Total weight of all indicator

Ex: Non-registered population indicator,

Total weight of each indicator = 26

Total weight of all indicator = 26+22+22+17+17+12+25+27 = 168

Weight of non-registered population = (26/168) x 33.33 = 5.2

Table 5-1 Indicators and Weighting of Economic Dimension

Economic Dimension	
1. National GDP	2.1
2. Provincial GPP	3.5
3. Inflation rate	3.2
4. Tax collected by Revenue Department	3.2
5. Unemployment rate	3.0
6. Economic growth of industrial sector	3.7
7. Economic growth of agriculture sector	3.5
8. Economic growth of service sector	3.2
9. Economic value	2.4

Table 5-2 Indicators and Weighting of Social Dimension

Social Dimension	
1. Ratio of non-registered population	3.2
2. Workers with social security	3.3
3. GINI coefficient	2.6
4. Average household debt	3.0
5. Ratio of illness	4.3
6. Adequacy and access to education	4.2
7. Average education year of people	4.1
8. Number of crimes against property	2.6
9. Recreation area	2.6
10. Number of complaints to	3.5

Table 5-3 Indicators and Weighting of Environmental Dimension

Environmental Dimension	
1. Sufficient water use for all sectors	5.2
2. Surface water quality	4.4
3. Groundwater quality	4.4
4. Air quality	3.4
5. Capability to traffic accommodation	3.4
6. Sufficient of electrical service/energy	2.4
7. Capability of domestic solid waste management	5.0
8. Capability of industrial waste	5.4

Table 6 Example of Impact Assessment of Alternatives Under Environmental Dimension

Indicator	weighting	alternative 1		alternative 2		alternative 3	
	Weighting Score	impact	score	impact	score	impact	score
1. Sufficient water use for all sectors	5.20	0.70	3.64	0.35	1.82	0.80	4.16
2. Surface water quality	4.40	0.55	2.42	0.40	1.76	0.80	3.52
3. Groundwater quality	4.40	0.55	2.42	0.40	1.76	0.70	3.08
4. Air quality	3.40	0.40	1.36	0.30	1.02	0.80	2.72
5. Capability to traffic accommodation	3.40	0.60	2.04	0.50	1.70	0.70	2.38
6. Sufficient of electrical service/energy	2.40	0.70	1.68	0.50	1.20	0.80	1.92
7. Capability of domestic solid waste	5.00	0.50	2.50	0.40	2.00	0.70	3.50
8. Capability of industrial waste	5.40	0.50	2.70	0.40	2.16	0.70	3.78
total	33.6		18.76		13.42		25.06

Table 7 Total Impact Assessment of Alternatives

Dimension	Weight	Alternative 1	Alternative 2	Alternative 3
Economic	33.33	16.30	19.80	19.81
Social	33.33	19.98	19.58	20.28
Environmental	33.33	18.76	13.42	25.06
Total	100	55.04	52.80	64.97

Conclusion

With spatial planning approach by GIS application on the designated criteria step by step; 11 SEZ potential sites preliminary declared by the Province had been cut down to one suitable SEZ site. Animal Raising Public area, Chai Ya Village, no 4, Sra Kai Sub-district, Sra Kai District, Non Kai Province, covering total area of 718 rai or 115 hectare. In order to accomplish the sustainable development for the suitable SEZ site, SEA approach for the proposed alternatives including no industrial development (no action), all industrial type permission, eco-industrial type permission. Academically, eco-industry is advantageous to the environment and social aspects but might not be economic aspects. With SEA tool, it has proved that eco industry is kind of balancing such three dimensions. Suitable SEZ with eco-industry would be the most important path of sustainable development.

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Kinetics of Organic and Inorganic Degradation in Biofilter Using Isolated Bacteria from Petrochemical Wastewater Treatment Plant

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Abstract

The objective was to study the kinetics of the degradation of hydrogen sulfide, benzene and xylene in a lab-scale biofilter. Pseudomonas aeruginosa S19 and Bacillus cereus O5-1/1 were fixed on the surface of plastic pall rings and used as media in the lab-scale biofilter. Synthetic polluted air contained hydrogen sulfide, benzene and xylene was generated and introduced into the 106-liter lab-scale biofilter. Various concentrations of hydrogen sulfide, benzene and xylene in the synthetic polluted air were adjusted and introduced into the biofilter. The inlet flowrate of the synthetic polluted air was controlled about 5.0 liters/minute. The concentrations of hydrogen sulfide, benzene and xylene were measured at the inlet and also after passing through the media layers in the biofilter at the heights of 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50 meters. Flowrate, temperature and humidity were recorded.

The retention time of the synthetic polluted air in the biofilter (EBRT) was calculated at each efficiency, inlet and outlet concentration. Results data of each pollutant from the experiment were plotted to determine the correlation according to the various kinds of the kinetic equations. From the results of the study can be concluded that the degradation of hydrogen sulfide, benzene and xylene in the biofilter were zero-order reaction limited by bacterial degradation. The kinetic equations were C_0-C = k_0t. The zero order reaction rate constants (k_0) of these kinetic equations were:

- Hydrogen sulfide, k_0 = 0.0159 ppm. s^{-1}
- Benzene, k_0 = 0.0219 ppm. s^{-1}
- Xylene, k_0 = 0.0458 ppm. s^{-1}.

Keywords : Biofilter; Kinetics; EBRT

Introduction

Polluted air may be treated by biotechnology technique that microorganisms degrade some air pollutants to become non-toxic or odorless gases. Biofilter is an air pollution control system using this technique highly effective in controlling mostly volatile organic compounds and some inorganic compounds. In the case of petrochemical wastewater treatment plant usually emitted volatile organic compounds (VOCs) and hydrogen sulfide gas (H_2S). Biofilter can be used with fluctuate air flow, very low concentration with low operation and installation costs [1, 2]. Biofilter has been used in various industry, such as, wastewater odor control, rubber industry, paint and surface coating industry. Natural materials such as wood chip, compost, soil have been used as media for microorganisms in the nature. The disadvantages of using natural material as media is that it takes rather long time to start up the system (about 1-2 weeks), difficult to scaling up from lab-scale to actual scale, its pressure drop will get higher and the efficiency will decrease when the natural media deteriorate [3]. These disadvantages may lower If synthetic media are applied [4-7].

Materials and Methods

Material Synthesis [8, 9]

Pseudomonas aeruginosa S19 and Bacillus cereus O5-1/1 bacteria were isolated from a petrochemical industry wastewater treatment plant could effectively degrade volatile compound BTEX group [10]. *P.aeruginosa S19* and *B.cereus O5-1/1* were cultured in nutrient broth at 37 degrees Celsius for 48-72 hours. The bacteria were prepared in a solution in a laboratory. Then prepare a container for infusion of material with a capacity of 200 liters. Which contains 120 liters of bacteria mixed and using distilled water to dilute the solution to flood all media materials. The bacteria were immobilized on the media at room temperature for 3 days continuously [10]. These bacteria were fixed on the surface of pall ring plastic media (Figure 1). Vapor of benzene and xylene were generated by passing cleaned air on the surface of liquid benzene and xylene. Hydrogen sulfide was synthesized by a chemical reaction between sodium sulfide and hydrochloric acid. Synthetic polluted air used in this experiment was produced by mixing benzene, xylene vapor and hydrogen sulfide gas with cleaned air in a mixing chamber to control the inlet concentrations and fed into the 106-liter lab-scale biofilter contained the media fixed with bacteria. The inlet flowrate of the synthetic polluted air was controlled about 5.0 liters/minute. The concentrations of hydrogen sulfide, benzene and xylene were measured at the inlet and also after the polluted air passing through the media layer in the biofilter at the height of 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50 meters. Flowrate, temperature and humidity were recorded. The figure of the lab-scale biofilter is shown in Figure 2. The schematic of the lab-scale biofilter experimental system is shown in Figure 3.

Figure 1 Pall ring plastic media fixed with bacteria on the surface

Figure 2 The lab-scale biofilter

The study of the kinetic of the degradation was done by analyzing the efficiency of the system and the retention time of synthetic polluted air in the biofilter (EBRT). Inlet (C_0) and outlet (C) concentrations of hydrogen sulfide, benzene and xylene at each height of the lab-scale biofilter were calculated for the efficiencies (Eff) of the system. EBRT at each efficiency was calculate according to the volume flowrate of the polluted air and the volume of the media (height of the media bed x cross-sectional area of the lab-scale biofilter). C_0, C, Eff and EBRT were selected to plot to determine the correlation among these parameters according to various kinetic equations.

The Models of the kinetic of the degradation of air pollutants [11-14]

The kinetic of the degradation of air pollutants in a lab-scale biofilter according to microorganisms can be classified into 2 categories:

1. Zero order reaction [23]

1) Zero Order Reaction Limited.

The zero order with reaction limited is the kinetic of the degradation of air pollutant in a biofilter where the rate of reaction (biological degradation) is slower than the rate of the diffusion of the air pollutants to the biofilm. The process would be reaction limited. The kinetic can be written as the following equation:

$$C_0 - C = k_0 t \qquad \text{(Eq.1)}$$

Where C_0 = Inlet concentration of pollutant (ppm)

C = Outlet concentration of pollutant (ppm)

k_0 = zero order reaction rate constant (reaction limited) ($ppm.s^{-1}$)

t = EBRT (s)

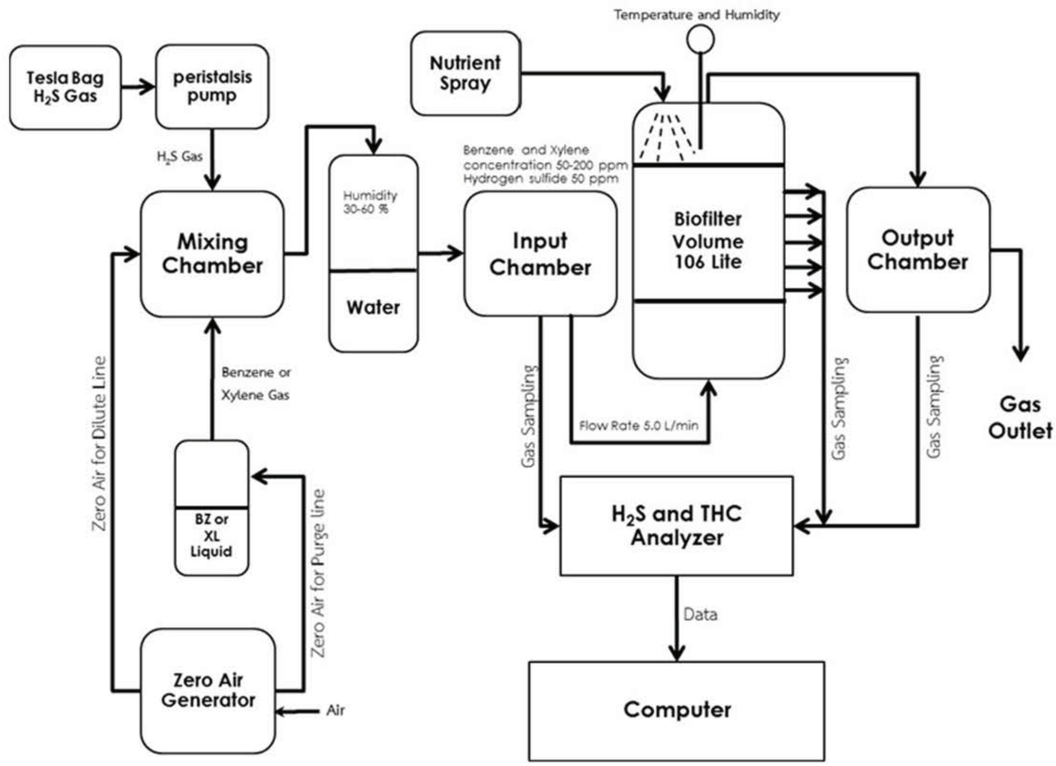

Figure 3 Schematic of the lab-scale biofilter system

2) Zero order Diffusion limited.

The diffusion limited model occurs when the pollutant reaches its maximum degradation ability in the biofilm at a depth that is less than the actual biofilm thickness. In this case, the diffusion limits the overall removal in the biofilm. The equation for this type of the kinetic is given by:

$$C = C_0\left(1 - \beta_1 \frac{t}{\sqrt{C_0}}\right)^2 \qquad \text{(Eq.2)}$$

$$\beta_1 = A_s\sqrt{\frac{k_0\, f(X_V).D}{2m}}$$

Where t = EBRT (s) ($ppm^{0.5}.s^{-1}$)

As = biofilm surface area per unit volume of biofilter (m^{-1})

k_0 = zero order reaction rate constant (Zero Order Diffusion Limitation) ($ppm.s^{-1}$)

D = Diffusivity of the pollutant in water ($m^2.s^{-1}$)

M = Henry's Constant of the pollutant

$f(X_v)$ = ratio of diffusivity of a compound in the biofilm to that in water (dimensionless)

2. First Oder Reaction [23]

First Order Reaction is the reaction where the degradation of the pollutant in the biofilter depends on the inlet concentration of the pollutant. The first order reaction model equation is given by:

$$\ln \frac{C}{C_0} = -k_1 t \quad \text{(Eq.3)}$$

Where k_1 = first order reaction rate constant (s^{-1})

Results and Discussions

Kinetics of the degradation of hydrogen sulfide, benzene and xylene in the lab-scale biofilter were studied according to the kinetic equation in the form of 1) zero order reaction with reaction limited (Plotting C_0-C vs EBRT) 2) zero order with diffusion limited (Plotting $(1-(C/C_0)^{0.5}) \times (C_0^{0.5})$ vs EBRT), and, 3) first order reaction (Plotting ln (C/C_0) vs EBRT). The results are summarized as follows.

For hydrogen sulfide, the tests for kinetic equations are as shown in Figure 4, Figure 5 and Figure 6. Considering the determination coefficient (R^2), the kinetic equation model of hydrogen sulfide degradation in the Lab-scale biofilter was found in zero-order with reaction limited. The determination coefficient (R^2) was 0.4512 with the first order reaction rate constant (k_1) of 0.0006 s^{-1}.

The tests for the kinetic equations for benzene are as shown in Figure 7, Figure 8 and Figure 9. Considering the determination coefficient (R^2), the kinetic equation model for the degradation of benzene was found in zero-order with reaction limited. The determination coefficient (R^2) was 0.4512 with the first order reaction rate constant (k_1) of 0.0006 s^{-1}.

For xylene, the tests for the kinetic equations are as shown in Figure 10, Figure 11 and Figure 12. The kinetic equation model of the degradation of xylene was found in zero-order with reaction limited with the determination coefficient (R^2) of 0.2575 and the zero order reaction rate constant (k_1) of 0.0006 s^{-1}.

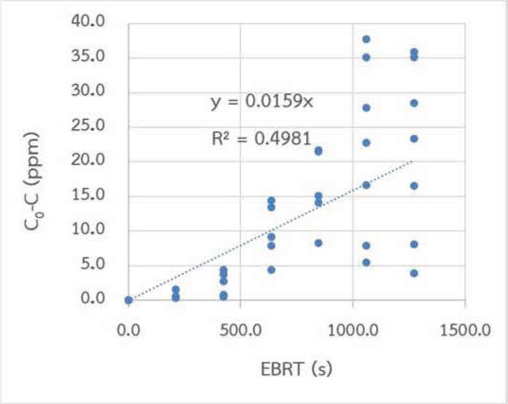

Figure 4 Plotting C_0-C vs EBRT for testing the kinetic on zero order with reaction limited of hydrogen sulfide

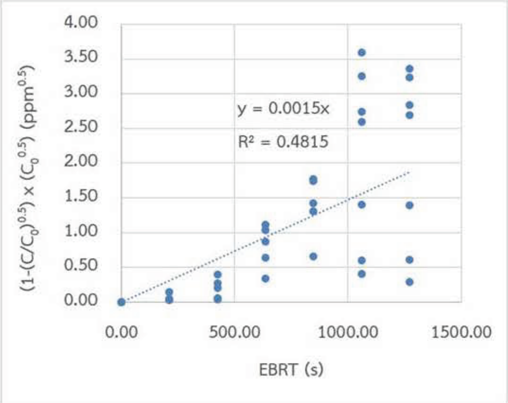

Figure 5 Plotting $(1-(C/C_0)^{0.5}) \times (C_0^{0.5}))$ vs EBRT for testing the kinetic on zero order with diffusion limited of hydrogen sulfide

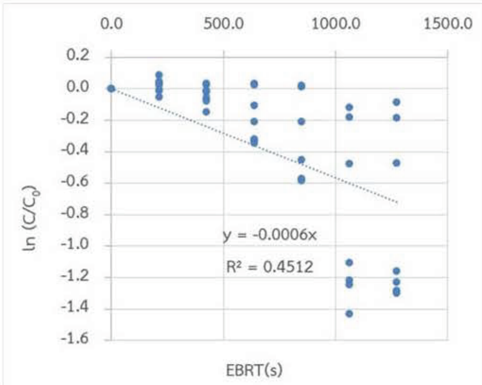

Figure 6 Plotting $\ln(C/C_0)$ vs EBRT for testing the kinetic on first order of hydrogen sulfide

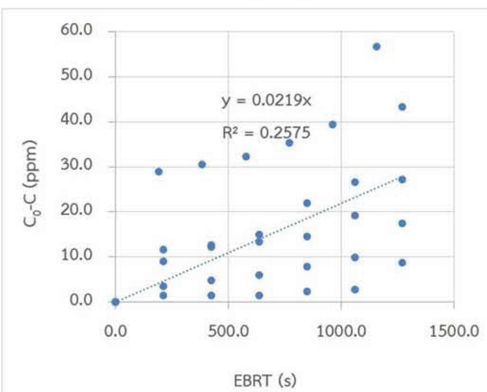

Figure 7 Plotting between C_0-C vs EBRT for testing the kinetic on zero order with reaction limited of benzene

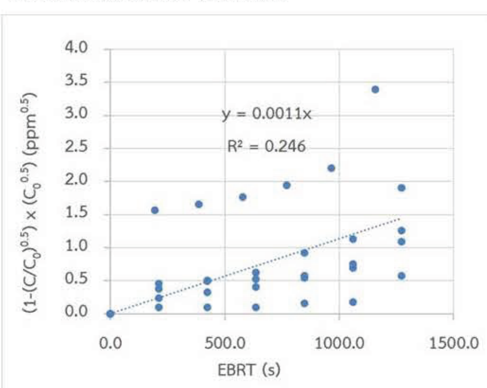

Figure 8 Plotting $(1-(C/C_0)^{0.5}) \times (C_0^{0.5})$ vs EBRT for testing the kinetic on zero order with diffusion limited of benzene

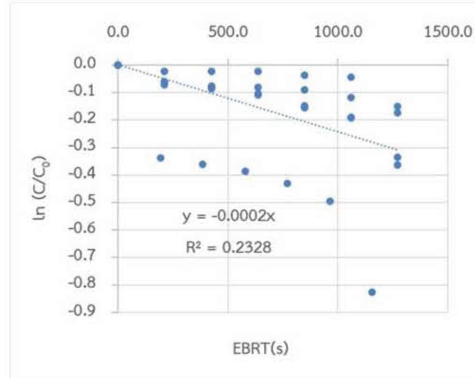

Figure 9 Plotting between $\ln(C/C_0)$ vs EBRT for testing the kinetic on first order of benzene

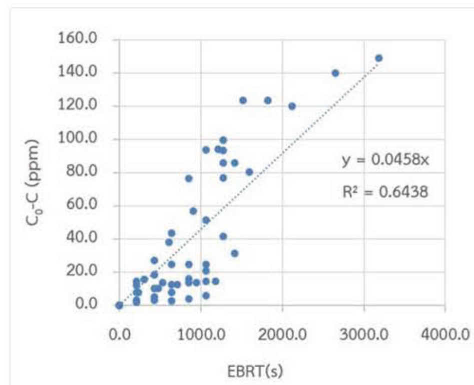

Figure 10 Plotting between $(1-(C/C_0)^{0.5}) \times (C_0^{0.5})$ and EBRT for testing the kinetic on zero order with diffusion limit of hydrogen sulfide

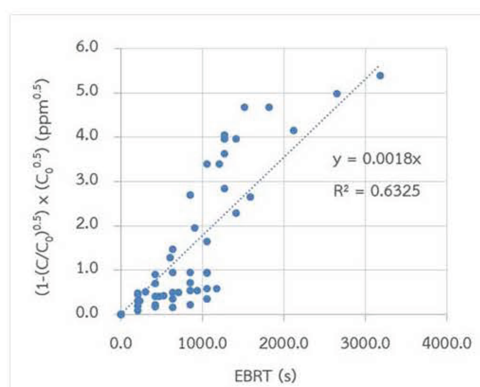

Figure 11 Plotting between $(1-(C/C_0)^{0.5}) \times (C_0^{0.5})$ and EBRT for testing the kinetic on zero order with diffusion limited of hydrogen sulfide

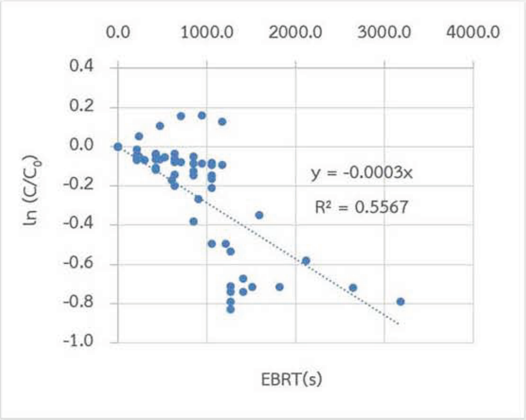

Figure 12 Plotting between ln(C/C0) and EBRT for testing the kinetic on first order of hydrogen sulfide

Table 1 Summary of the study of the degradation kinetic of hydrogen sulfide, benzene and xylene

Degradation Kinetic	Equation	k	Determination coefficient, (R^2)
Hydrogen sulfide			
Zero order reaction limited	C_0-C = k_0t	k_0 = 0.0159 ppm. s^{-1}	0.4981
Zero order diffusion limited	$(1-(C/C_0)^{0.5}) \times (C_0^{0.5}) = \beta_1 t$	β = 0.0015 $ppm^{0.5}.s^{-1}$	0.4815
First order reaction	ln (C/C_0) = -k_1.t	k_1 = -0.0006 s^{-1}	0.4512
Benzene			
Zero order reaction limited	C_0-C = k_0t	k_0 = 0.0219 ppm. s^{-1}	0.2575
Zero order diffusion limited	$(1-(C/C_0)^{0.5}) \times (C_0^{0.5}) = \beta_1 t$	β_1 = 0.0011 $ppm^{0.5}.s^{-1}$	0.2460
First order reaction	ln (C/C_0) = -k_1.t	k_1 = -0.0002 s^{-1}	0.2328
Xylene			
Zero order reaction limited	C_0-C = k_0t	k_0 = 0.0458 ppp. s^{-1}	0.6438
Zero order diffusion limited	$(1-(C/C_0)^{0.5}) \times (C_0^{0.5}) = \beta_1 t$	β_1 = 0.0018 $ppm^{0.5}.s^{-1}$	0.6325
First order reaction	ln (C/C_0) = -k_1.t	k_1 = -0.0003 s^{-1}	0.5567

From the results of the kinetic study of hydrogen sulfide gas degradation and benzene, xylene in the lab-scale bio-filter using bacteria isolated from the wastewater treatment plant of a petrochemical industry in the group P. aeruginosa S19 and B. cereus O5-1 / 1 found that the kinetics of hydrogen sulfide, benzene and xylene was a zero order reaction which was limited by the degradation reaction of bacteria which can be summarized as in Table 1.

The study of kinetic decomposition of hydrogen sulfide, benzene and xylene in a lab-scale bio-filter using bacteria (P. aeruginosa S19 and B. cereus O5-1 / 1) isolated from the wastewater treatment plant of a petrochemical industry were studied. Synthetic polluted air were generated by mixing cleaned air with hydrogen sulfide, benzene and xylene. According to the result of the study, the kinetic of the degradation of hydrogen sulfide, benzene and xylene in the biofilter were zero-order reaction which was limited by bacterial degradation reaction. The kinetic equations were C_0-C = k_0t. The zero order reaction rate constants (k_0) for these kinetic equations were:

- Hydrogen sulfide, $k_0 = 0.0159$ ppm. s^{-1}
- Benzene, $k_0 = 0.0219$ ppm. s^{-1}
- Xylene, $k_0 = 0.0458$ ppm. s^{-1}.

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Environmental Impact of Solid Wastes Generated from Land use Change in Highland Tourism : A case study of Pai District, Mae Hong Son province

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Abstract

Increasing amount of solid wastes due to land use change has been resulted by the intensive tourism services in Pai District, Mae Hong Son Province. It has consequently affected the ecosystem, especially in the highland area, where are natural tourist attractions. The aims of this study are: (1) to assess the environmental impact of the solid wastes generated from the generated point as well as from the disposal point, and (2) to assess the environmental impact of land use change for tourism sites in mountain areas or tourist attraction highlands, using the Geographic Information System (GIS). GIS is an assessment tool for land use planning in accordance with sustainable urban development. The study results presented that 6.07 tons/day being the amount of wastes generated by tourists of urban areas. An average of 52.25 kg/sampling spot/day generated from various hotel sizes, while an average of 66.63 kg/sampling spot/day generated from the tourist sites. There were 32 wastes disposal points, using the Trench Method, Open dump and Open burning where are spatially distributed at different areas and at different heights. Many areas are classified as sensitive areas, contamination risk areas, spreading to other nearby areas. Conclusively, if wastes management is in conformance with land use planning, legally wastes disposal to the right spots with academic performing, it would be possible to minimize the environmental impact possibly occurred in the short and long term. This could also lead to urban planning that promotes tourism while maintaining a balanced environmental and ecological status.

Keywords : Highland tourism attractions; Solid wastes; Environmental impact; Land use

Introduction

Tourism is considered as service industry, consisting of hotels, resorts, travel agencies, restaurants, shops and currency exchange businesses that are continuously growing, constituting an important source of income for many countries [1]. When tourism occurs in any area, especially if it attracts heavy tourist traffic, the amount of solid wastes will increase rapidly [2]. Such wastes have a negative impact on humans and on the environment [3]. When tourism occurs at the mountains, such as the highland adventures, there are difficulties in managing the environmental impact. Spatial management is therefore an important factor in solving environmental problems [4]. The problem has begun to intensify.Consequently, there have been studies of wastes management models, predicable systems and future trend estimation of wastes, and network collaboration, which can lead to creating strategies related to wastes management in each area [5]. Mountain tourism areas or highland tourism have been experiencing problems in management of wastes from tourism or various related activities. In particular, such establishments often dispose of wastes by the Open dump method, resulting in direct and indirect water pollution in the environment [6]. Popular activities for tourists in mountain areas or during highland tourism are trekking, mountain climbing and camping. Most of these activities cause pollution in various ways, such as water pollution and soil pollution. The most obvious thing about tourism is the occurrence of wastes. At present, several studies investigate the impact of wastes generated from various sources. There have also been modern and accurate technological developments for measuring pollution. For example, Geographic Information System (GIS) is one tool that can be used for assessing the environmental impact along with mapping and mathematical models; for example, a study by Davide (2009) using GIS to study wastes disposal and its location in the Ladakh region in India found that dumping directly affects surface water and groundwater [7]. Using Spatial Autoregression (SAR), Geographically Weighted Regression (GWR), or Ordinary Least Squares Regression (OLSR) with spatial data from local to national levels assists in the analysis and assessment of the problem of wastes, for the purpose of policy formulation [8]. In addition, the application of indicators is one of the tools that has received attention, because it is a tool for analysing spatial data and works well on mountains, in cities, local areas, and beaches; it is called the ISOST index. There are interesting environmental indicators such as energy consumption, utilisation, wastes generation, utilisation area and distribution of tourist spots, which may affect the environment [9]. There are other tools also which help to assess the environmental impact caused by the increasing number of tourists in an area, such as assessment of the environmental impact that may occur from tourism, in order to protect the Natural Protected Areas (NPA) or areas with specific characteristics landscape (Protected Landscape)using the method of impact tourism, the Tourism Impact Assessment (TIA) from the activities of tourists.Evaluated results prove that the number of tourists who have stayed overnight in urban areas that have the infrastructure, accommodation and services with high growth rates directly affect the environment [10, 11]. In addition to other activity forms according to tourists' preferences, it is important to identify increase in certain types of wastes that come from purchasing goods and services as well as staying in hotels [12]. Apart from the satisfaction from tourism activities, it is also found that tourists, especially foreign tourists, have a positive attitude towards the environment, as do the people who own the area and resources [13]. Due to the increasing popularity of ecotourism, in the years 2011-2012 the Ministry of Tourism has begun to implement policies to attract tourists and promote tourism that is environmental friendly [14]. Later, many tourists travelled to the area and caused a noticeable negative physical change, especially due to the construction of accommodation and services, as well as various establishments that relate to the tourism business [15]. The environment is considered as one of three main points in assessing the carrying capacity of the pollution in an area [16]. The environmental analysis system based on sustainable development consists of 3 groups, which are Initial Environmental Examination : IEE, Environmental Impact Assessment : EIA, and Environmental Health Impact Assessment : EHIA. This analysis show that there are ecological issues that have been considered in the EHIA by taking ecological information together with general plan and land use plan which is one of the ways that economic, social, and environmental issues can be linked [17]. The aims of this research are: 1) assessing the environmental impact of solid wastes at generating point and disposal point, which is the destination; and 2) assessing the environmental impact due to land use of tourism sites at the mountain areas or highlands, by using the Geographic Information System (GIS) as an impact assessment tool.

Material and Methods

1. Study Area

Pai District is 1 of 7 districts in Mae Hong Son Province, covering an area of 2,244.7 square kilometres. It corresponds to the boundary between Thai and Myanmar border, and its territory is adjacent to the neighbor districts as follows: North is bordered by Spin City, Tongki Province, Shan State, Republic of the Union of Myanmar; South, next to Samoeng District Mae Chaem and Kalayaniwattana Districts; East of Chiang Mai, adjacent to Wiang Haeng District Chiang Dao District and Mae Taeng District Chiang Mai Province; West, next to Muang Mae Hong Son District and Pang Mapha District. Mae Hong Son province with a population of 38,786 people (2562 B.E.). Pai District covers 7 sub-districts with 66 villages, including Wiang Tai Sub-district, Wiang Nuea Sub-district, Mae Na Toeng Sub-district, Mae Na Toeng Sub-district, Mae Hi Sub-district, Thung Yao Sub-district Chapin and for Pong.Pai Province lies in the contact zone between the mountainous regions of Laos to the north and the Thongchai Road mountains to the east and south. The average height above sea level ranges from 470 metres to 2,005 metres. There are narrow plains of the Pai River, which have a height above mean sea level of between 470 to 650 metres. The Pai River flows through Mae Hong son province and down into the Sal River. The Win river flowing from Kayah State, Myanmar, has a length of 135 kilometres in Thailand, with water flowing all year round; there are also many branch streams (Figure 1) Pai District has the highest proportion of land use for forestry in 2010, at 2,176.26 sq. Km., representing 95.27 percent of the total area, followed by rice fields 2.6 percent, Shifting cultivation 1.09 percent, 0.54 percent farmland, 0.49 percent urban area, and 0.047 percent fruit trees. When separating land use by sub-district, it is found that Mueang Paeng Sub-district has the highest proportion of land use, which is 509.50 square kilometres or 22.29 percent. The sub-district with the highest proportion of forest area is Mueang Paeng Sub-district, at 494.19 square kilometres, representing 19.03 percent of the total forest area. The sub-district with the highest proportion of urban areas is Mae Hi Sub-district, which is 2.39 square kilometres or 21.2 percent of the total urban area.

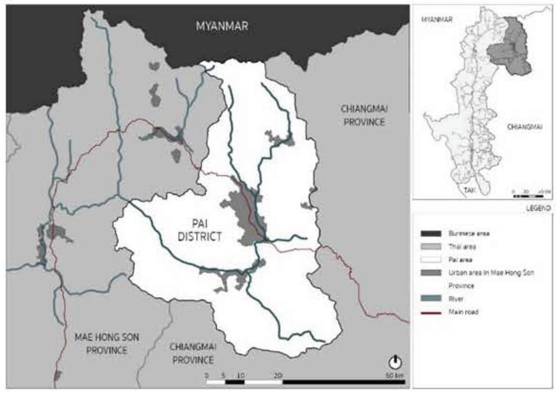

Figure 1 Study area

Determining future utilization area: the country's economic and social systems according to the National Economic and Social Development Plan No. 11 have a transportation network policy to support the expansion of Pai District in the future and promote this district as an ecotourism centre of Mae Hong Son Province. This involves promoting service and tourism activities in the cultural and culture conservation areas as well as supporting the expansion of the commercial area in the centre of the city. Department of Public Works and Town and Country Planning shown the projected improvements in the land use from 7 categories to 13 categories, which are: (1) Reserves for living, (2) Less dense residential areas, (3) Moderately dense residential areas, (4) Commercial areas and very densely residential, (5) Rural and agricultural areas, (6) Rural and agricultural conservation areas, (7) Agricultural land reform areas, (8) Open space for recreation and protecting the environment, (9) Forest conservation areas, (10) Educational institution areas, (11) Conservation areas for the promotion of Thai art and culture, (12) Religious institution areas, and (13) Government institutions, public utilities and utilities with use areas. Later, there were announcements of changes to the content of the ministerial regulations. According to the Government Gazette 2015, the Pai Town Community Plan was enforced in Mae Hong Son province for 5 years in the area of Mae Na Toeng sub-district, Wiang Nuea sub-district, Wiang Tai sub-district, Mae Hi sub-district and Thung Yao sub-district, to guide the development and maintenance of cities and related areas or the rural areas. Land use would be in accordance with the development and maintenance of cities and related areas or rural areas, the use of property, transportation utilities, public service and the environment. One passage states the use areas for hotel construction, because there is a tourism industry in the area.

The beginnings of Pai tourism lay in its use as a trading route in the past and a military route from Chiang Mai to Burma during the Lanna Kingdom. Later, during World War 2 (1939-1945), Japan created a way to transport soldiers from Mae Taeng (Chiang Mai Province) to the Union of Myanmar. This route was developed and improved by the Office of Rural Development in Thailand in 1962 to allow motor vehicles to traveling. In 1977, tourists began to go hiking in Pai. Therefore, the road was developed from Mae Taeng to Mae Hong Son between 1978-1987. Transportation became easier, resulting in tourists arrual for rest and recuperation, and after that the tourism business grew accordingly. From the summary of the situation of tourist stays during the year 2018, Mae

Hong Son had 1,004,967 visitors, with an increase of 0.027 percent, and a tourism revenue of 4,980.71 million baht, an increase of 2.40 percent (Statistical data for tourism, Mae Hong Son Province).

2. Study of waste data and final disposal methods

1) Wastes quantity analysis by weighing wastes from the garbage collection trucks to find the total amount of wastes is divided between 2 areas: (1) urban area, including Pai Sub-district municipality, and (2) outskirts of the city, i.e., the Thung Yao Sub-district Administration Organization. The urban area is a big tourist attraction. Therefore, we managed to save wastes data divided into 2 types, which were hotels and accommodations and tourist attractions which were 4 types: natural tourist attractions, cultural attractions, historical attractions and ecotourism. The wastes weighing was divided into 2 periods, one during the tourist season (Nov-Feb) and the other during the non-tourist season (Mar-Oct), in order to check the different amounts of wastes generated by tourists.

2) Study of the final wastes disposal model was carried out in 8 administrative districts, including 1 Pai Sub-district Municipality and 7 Sub-District Administrative Organizations, by surveying the disposal sites in the area as well as recording geographic coordinates for the study as displayed on the map using GIS.

3. Land use of tourist attractions in mountainous regions or highland tourism

Pai District maps from Satellite imagery interpretations from 2015, Google Earth, together with the Land Development Department's land use map were employed as base maps to show the final wastes disposal sites. The height of the garbage collection point, surface water and groundwater resources are scoped throughout the conservation forest areas and village locations.

4. Environmental Impact Assessment from the interaction of wastes data and land use

All garbage and spatial data were displayed with ArcGis to show the likelyhood of the areas that may be especially affected, in order to lead to the EIA and propose management guidelines.

5. Research tools

This study employed weighing methods to quantify wastes survey data. Data and geographic information systems (GIS) were employed to store geographical coordinates by GPS (Global Positioning System) and the data display program ArcGis.

Results and Discussion

1. Wastes study results

1) Total wastes from the study using the weighing method was equal to 6.07 tons/day (Low Season) and 6.68 tons/day (High Season) in Wiang Tai Sub-district. The total amount of wastes outside the city was 1.90 tons/day in Thung Yao Sub-district.

2) Amount of wastes from urban areas This includes wastes from various sized hotels and the wastes from all 4 types of tourist attractions during the high season and low season. It was found that there was an increase solid wastes from hotels of various sizes in high season during Nov-Feb, although without any statistically significant differences in T-test (T-Value = 1.15 P-Value = 0.34). From the observation, it was seen that 15-30 room hotels' rooms generate the highest quantity of wastes. This showed that hotels of this size were popular with tourists. Therefore, the local authorities in the area should focus on the supervision of medium-sized hotels, in the area of wastes management. (Table 1)

Table 1 Hotel wastes

Hotel size classified by number of rooms	Solid waste (Kg)	
	High Season	Low Season
Less than 15 rooms	47.03	11.30
15-30 rooms	72.34	50.70
More than 30 rooms	37.38	40.60
Average	52.25	34.2

As for wastes from all 4 types of tourist attractions, the amount of increase in the High Season was not statistically significant from the test : T-test (T-Value = 1.04 P-Value = 0.35). However, data show that natural attractions have the highest amount of wastes, and therefore the authorities should first pay attention and promote the wastes management policy in such types of tourist destinations. (Table 2)

2. Final wastes management model

As for the final form of wastes management in all 8 areas, almost all are open dump and open burning. Only Pai Sub-district Municipality uses the Trench Method. However, it still lacks a complete waterproofing system Therefore, the wastes may leak out into natural resources. The most common problem is that open dumping lacks writing systematically because of the conditions in hilly area. Therefore, there may be a problem of washing the garbage in the rainy season, resulting in soil and water pollution and also the probability of wastes entering the agricultural areas. (Table 3) Open burning will cause a lot of problems during January-February, because the fumes from the burning will not rise and instead will fall into the basin, causing the problem of burning haze, which has adverse effects on health. (Figure 2)

In addition, for other departments in the study area such as Pai Hospital located in the municipal area of Wiang Tai Sub-district, there was a form of wastes management which can be divided into general wastes and hazardous wastes, i.e., infectious wastes. There was general wastes being sent to the community for disposal in the municipal area. Infectious wastes was disposed by the legal private company. Although the hospital has a wastes incinerator to eliminate infectious wastes, as it is located in the centre of the community it is not possible to use the incinerator and it is currently inactive. Huai Nam Dang National Park is a popular tourist destination with wastes management systems where valuable wastes was separated first and wastes disposal is done by incinerator.

3. Some types of land use in Pai District

Although the garbage disposal model is similar in each area, but the distribution characteristics of wastes collection points in each sub-district might have differences in area height and community proximity. One problem occurred regularly in the area is that junk cars cannot reach the disposal point in the rainy season due to road surface problems. From the geographic coordinates of the total 32 collection points in the area, it was found that the highest wastes collection point is Huai Nam Dang National Park With a height of 1,649 metres above sea level, where as the lowest is Ban Huai Bon, which is in the administrative district of Muang Pang Sub-district, at a height of 436 metres above sea level. In order to see the relationship of some important land use in the area of Pai District.

Table 2 Amount of wastes from all 4 types of tourist attractions

Type of tourist attraction	Solid waste (Kg)	
	High Season	Low Season
Natural attractions	110.20	84.23
Cultural attractions	86.73	22.13
Historical sites	37.83	40.60
Ecotourism	31.77	19.17
average	66.63	37.18

Table 3 Final wastes management model

Area	The final form of disposal waste	Issues
Pai Sub-district Municipality	Trench Method	No waterproofing system
Wiang Tai Sub-district	Open Dump, Open Burning	There is only one disposal site
Wiang Nuea Sub-district	Open Dump, Open Burning	There is only one disposal site
Mae Hi Sub-district	Open Dump	There is only one disposal site
Mae Na Toeng Sub-district	Open Dump, Open Burning	Many places scattered in the village area
Thung Yao Sub-district	Open Dump, Open Burning	There is only one disposal site
Mueang Pang Sub-District	Open Dump, Open Burning	There is only one disposal site
Pongsa Sub-district	Open Dump, Open Burning	There is only one disposal site

Figure 2 Various methods of wastes disposal

1) Characteristics of community housing distribution

Figure 3 shows the distribution of housing in various communities in Pai District. Community distribution follows the same pattern as the layout of water resources. There will be only some areas that are far away from water sources because water is a natural resource that is vital to life and is important for agricultural activities.

2) Characteristics of surface water sources and groundwater sources

The nature of the upstream area affects the surface water flow and the location of the groundwater. Figure 4 shows the direction of water flow from the upstream area to the Pai River and shows the location of groundwater sources. As mentioned previously, human settlement is closely tied to water sources, and so the map positioning with the ArcGis can show the likelihood of a particular area being affected by the wastes.

3) Scope of natural forest area

The green colour in Figure 5 shows the natural forest areas and the forest areas. From the statistics of the Royal Forest Department for 2015, Mae Hong Son Province has a total forest area of 11,103.93 square kilometres or 6,939,953.28 rai, which is 86.99 percent of the total area. The province consists of national forest reserves and a permanent forest zone. According to the resolution of the Cabinet in 1966, the national park, wildlife sanctuary, forest park and arboretum were established in the Pai Basin wildlife sanctuary in the area of Mae Na Toeng sub-district, Thung Yao sub-district, Wiang Tai sub-district, Mueang Paeng sub-district, Pai District, Som Pong sub-district, Tham Lod sub-district, Pang Mapha sub-district, Na Pu Pom sub-district, Pang Mapha District, Pang Mu sub-district, Huai Pha sub-district, Mok Champae sub-district, Mueang District and Mae Hong Son Province cover an area of 738,195 rai or 1,181 square kilometers.

4. Environmental impact assessment

Information related to land use characteristics is mentioned in section 3.3 once overlapped with the disposal point, the possibility of contamination or impact on surface water and groundwater resources might be considered, causing the spread of pollution to other areas which are unavoidably close, both directly and indirectly. The scope of the final stage of wastes management points has been spatially distributed in various parts of the study area. There are different elevations from the sea level and there is an EIA from various points of origin at a radius of 10 kilometres from the source. Some points have a radius overlay, indicating that the area being affected by neighbor sources, (Figure 6) depending on other factors related to the promotion of fragmentation or the increased severity of effects. Therefore, if wastes management is ineffective, it will have a widespread impact. The area within the radius is an area where a public awareness campaign should be carried out. In particular, communities that are isolated on the high ground should be cultivated and made aware, not only about managing household wastes but also for preserving the natural resources of upstream forests.

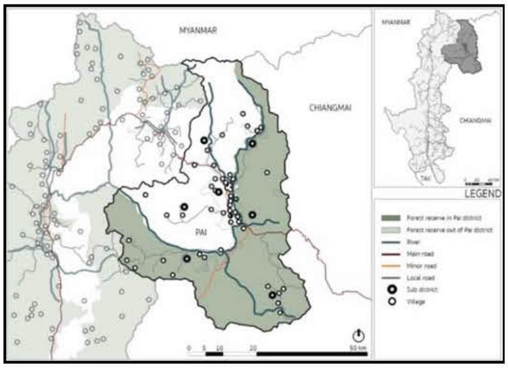

Figure 3 Characteristics of community housing distribution

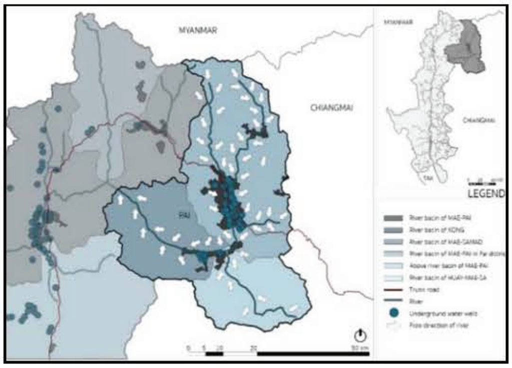

Figure 4 Characteristics of surface water sources and groundwater sources

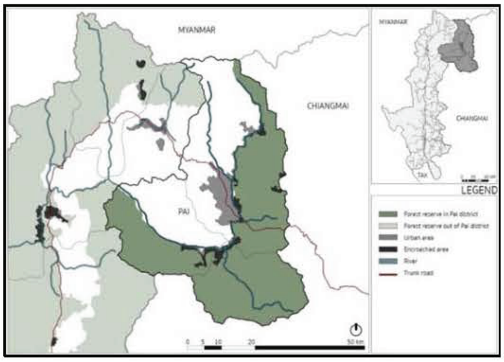

Figure 5 Characteristics of forest boundary

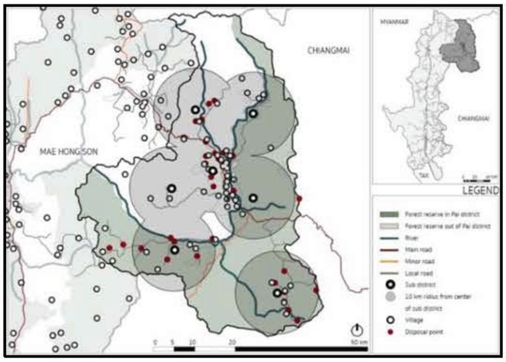

Figure 6 Characteristics of environmental impact from wastes disposal sites

Conclusions

The study results from the environmental impact assessment of the land use plan in the study area show the boundaries of various areas that are a source of pollution and also show the scope of those areas that might be affected. One of the aims of the research is to propose guidelines for sustainably managing wastes from tourism to solve the environmental issues in Pai district at the present and also in the future. These suggestions will be useful for the consideration of the agency in charge at their discretion, they are 1) To stipulate the policy to use areas differently from general area, in the form of special economic zones or specially controlled zones that are able to effectively manage wastes from tourist attractions, and to limit the number of tourists staying in the area, especially in sensitive areas such as national parks and cultural attractions. 2) To support the establishment of a centre for buying recyclable wastes or recyclable junk in the area in the form of private enterprises or with financial support from the government, to stimulate the economy in the community and encourage people to understand and participate in wastes segregation activities. To develop garbage collection areas for separation, such as temporary buildings of separated wastes at high volume disposal points or spaces to engage communities in the wastes separation activities. To acknowledge people and stimulate their responsibility as well as promote sustainable community cooperation such as through a recycling wastes fund, a bank for recycling wastes, or other activities for motivating the community to continuously participate in short and long term activities including regular follow-up and evaluation of activities 3) To encourage local governments to provide suitable wastes disposal areas and to eliminate existing wastes disposal points that may carry the risk of environmental contamination. To determinate the form of wastes management in each area to be consistent in order to preserve the environment of the upstream areas that are important areas of the country. However, the determination of land use in tourist areas needs to be actualised in order to limit the expansion of the hotel business, since it can cause spatial problems and have an environmental impact.

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[1] Inthorn, D., Sidtitoon, N., Silapanuntakul, S. and Incharoensakdi, A. 2002. Sorption of mercury, cadmium and lead in aqueous solution by the use of microalgae. Science Asia. 28 (3): 253-261.

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