The Coastal Water Quality Change by Effluent Discharging from Phetchaburi Municipal Wastewater Treatment System: The King's Royally Initiated Environmental Research and Development Project, Phetchaburi province, Thailand

Sateinpong Khowhit[1*], Wasin Inkapatanakul[2], Onanong Phewnil[1], Anukorn Boutson[3], and Kasem Chunkao[1,4]

[1] Department of Environment Science, Faculty of Environment, Kasetsart University, THAILAND
[2] International College, Silpakorn University, Taling chan, THAILAND
[3]Department of Marine Science, Faculty of Fisheries Kasetsart Univeristy, THAILAND
[4] Director of the King's Royally Initiated Environmental and Development Project.(LERD), Phetchaburi province, Thailand.

Abstract

The research entitled "The Coastal Water Quality Change by Effluent Discharging from Phetchaburi Municipal Wastewater Treatment System: The King's Royally Initiated Environmental Research and Development Project, Phetchaburi province, Thailand" has been focused on examinating and monitoring of water quality in the coastal area receiving effluent from Phetchaburi Municipal Wastewater Treatment System. The King's Royally Initiated Environmental Research and Development Project (the LERD project) has been operating based on "nature heals nature" by applying natural mechanisms of constructed wasteland and stabilization ponds for sedimentation and bio-mechanism of aquatic plants. After the treated municipal wastewater has been released into the coastal area, the water quality has been shown in three different zones, as follows : zone A: 200 meters from the coast, zone B: 600 meters from the coast and zone C: 1,000 meters from the coast. Water quality has been sampled and analyzed during August 2012 (rainy season), December 2012 (winter) and March 2013 (summer). Six parameters have been identified as follows : Temperature, pH, Dissolved Oxygen (DO), Phosphate, Nitrate and Ammonia. The study expresses that the average levels at different distances from the coastal target areas of the LERD project have been 31.84±1.73°C ,8.18±0.12, 6.14±0.82 mg/L, 0.25±0.21 mg/L, 0.12±0.05 mg/L and 0.04±0.03 mg/L, respectively**.** By comparing with the standard water quality from the Ministry of Natural Resources and Environment (2004), the results of the study have been consistant with the original standards.

Keywords: Coastal Water Quality/Effluent Discharging/Wastewater Treatment

1. Introduction

Water pollution has been accepted as one of the most important environmental problems in Thailand. Main sources of polluted water are from communities in municipal areas, which are composed of household and business sectors. Wastewater from daily community activities, especially showering, cleaning, cooking, washing, have been considered to be the main cause of water pollution. Wastewater from different municipalities has different characteristics and volumes. Thus, many organizations had to find apply urgent measures in order to solve the mentioned problem. Nevertheless, wastewater treatments did not achieve their goals because of their high costs and complex management and process, as well as the requirement for experienced system controllers (LERD, 1999; LERD, 2000; Kasem *et al*., 2012; Kasem *et al*., 2012). The Phetchaburi municipality has been considered as a big municipality that covers an area of 5.4 square kilometers or about 3,375 rai. This area is a plain river bank of the Phetchaburi River that flows through the center of the municipality area.center of the municipality area.

The problem of municipality wastewater has been occurring regularly over many years. Direct impacts from municipality wastewater compose of the obstruction and deterioration of natural water resources, while indirect impacts have been on wildlife and other natural resources. According to Phetchaburi Municipality, the amount of daily water consumption has been estimated and recorded at 60.55 liters per person and 95.06% of the wastewater has been released into the public waterways of the municipality. This is the main cause of pollution in the Phetchaburi River. (LERD, 2011; Jittisa *et al*., 2012; Satreethai *et al.*, 2013; Thanit *et al*., 2013) In order to improve water quality, His Majesty the King initiated the Laem Phak Bia Environmental Research and Development Project in 1990. By applying the nature heals nature principle, it was decided that wastewater from the municipality would be treated by using stabilization ponds for sedimentation and aquatic plants for water purification. The project used simple and economical methods according to the principle of letting nature heal itself. (Orathai *et al*., 2013; Penha-Lopes *et al*., 2012; Satreethai *et al*., 2012; Watanabe *et al*., 2013). The objective of this study is to examine the water quality in the coastal area receiving effluent from Phetchaburi municipal wastewater treatment system.

*Corresponding author:
E-mail: puiku_1213@hotmail.com

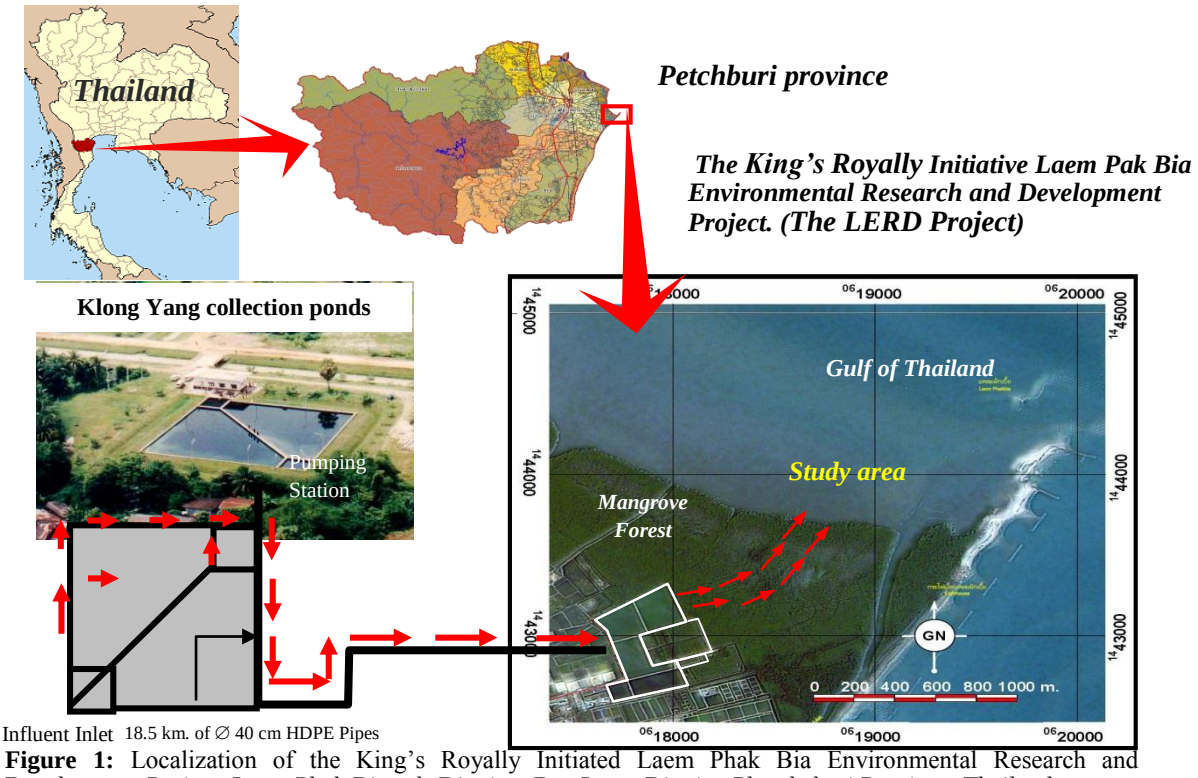

Figure 1: Localization of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Laem Phak Bia sub-District , Ban Laem District, Phetchaburi Province, Thailand.

2.2 Experimental design and collection of water samples

In the LERD Project, 15 water samples have been collected in 3 zones from the coastline. Zone A: 200 meters from the coastline (A1 - A5), Zone B: 600 meters from the coastline (B1 - B5), and Zone C: 1,000 meters from the coastline (C1 - C5) (Figure 2). The water sample collection was done at the time of which the water level reached its highest level in rainy season (August 2012), winter season (December 2012), and summer season (March 2013). Water samples have been tested according to the standard methods for the Examination of Water and Waster (APHA,AWWA, and WF, 2005). Morever,1-liter Bottles of samples would be stored in a refrigerated tank at temperature lower than 4 °C. Six parameters of water quality would be tested, i.e. temperature, pH, Dissolved oxygen (DO), phosphate, nitrate and ammonia. (Ministry of Natural Resources and Environment, 2004).

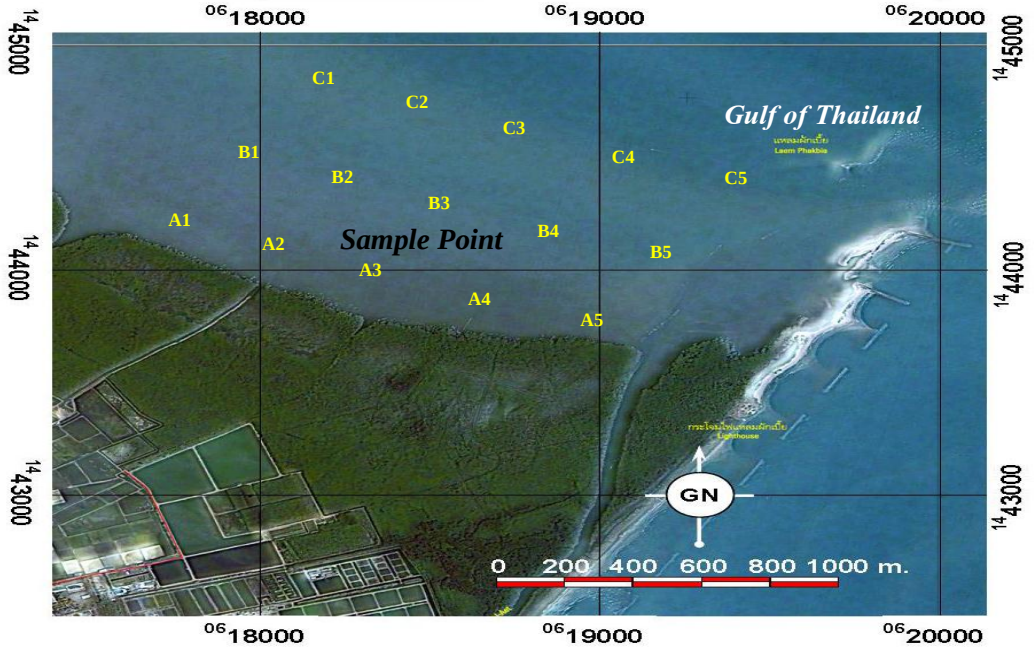

Figure 2: Sample point of water quality at the LERD Project.

2.3 Statistical analysis

The mean values of each point after months of water sampling were calculated and then compared with effluent standards for coastal aquaculture safety. (Ministry of Natural Resources and Environment, 2004) in table 1.

Table 1: Parameters and Analytical method

Parameters	Material and Method
Temperature (°C)	Thermometer
pH	pH Meter
DO (mg/L)	DO Meter
Phosphate (mg/L)	Ascorbic Acid Method
Nitrate (mg/L)	Cadmium Reduction Method
Ammonia (mg/L)	Phenate Method

3. Results and Discussion

3.1 Temperature

The average temperature of the water at the coastal area of the LERD Project at zone A, B, C and the total average have been 32.08±1.77, 31.84 ±1.70 ,31.59±1.72 and 31.84±1.73°C, respectively. The recorded temperatures have been higher than the standard temperatures of coastal water)28 °C(and the coastal area of reference as shown in Table 2 and Figure 3. These results have been consistent with the study of Wutichi (2000). Comparing between temperatures of the water at the coastal of the LERD Project, Ban Laem, Pak Thale ,Bang Kaew and Had Leam Lueng have been 28.78, 29.23, 29.39, 29.04 and 28.91 °C respectively, while the latter area has been 29.90 °C (Ratana, 2009). Suwat (2011) found that the water temperatures at the coastal areas of the Palian estuary were recorded at 27.58 - 31.18 °C. It could be stated that there is no significant difference between the water temperatures at the coastal area of the LERD Project and any other areas recorded in the test results.

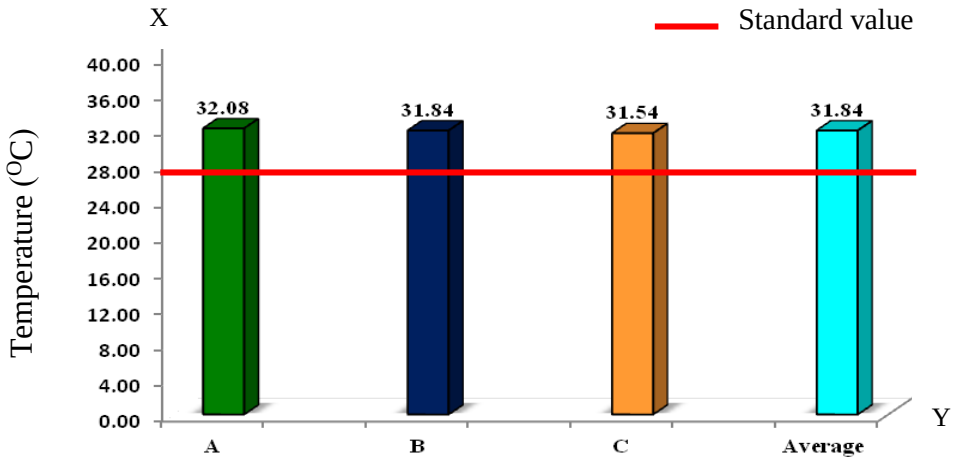

Figure 3: Temperature at sampling zone compared with standard value.

3.2 PH

The average pH values of the water at the coastal area of the LERD Project at zone A, B, C and the total average have been 8.18±0.28, 8.17±0.16, 8.18±0.07 and 8.18±0.12 respectively. The different seasons have been significant (p>0.05) in the following recordings, the pH values of each point has been in line with the standard pH value of coastal water as shown in Table 2 and Figure 4. These results have been consistent with Wutichi (2000). After comparing the pH values of the water at the coastal area receiving wastewater from the municipality and area at the normal coastal areas, it showed that the pH values at the coastal areas of the LERD Project, Ban Laem, Pak Thale, Bang Kaew and Had Leam Lueng have been 0.02, 8.04, 8.08, 8.07 and 8.08, respectively. Ratana et al. (2009) found that the pH value of the water at the coastal area of Laem Klat was recorded at 8.20. Suwat (2011) found that the pH values of the water at the coastal areas of the Palian Estuary was recorded at 6.14 – 7.46. It could be stated that there is no significant difference between the pH values of the water at the coastal area of the LERD Project and other areas.

3.3 Dissolved Oxygen

The average dissolved oxygen values at the coastal area of the LERD Project at zone A, B, C and the total averages was 5.89±0.80, 6.13±1.03, 6.39±0.65 and 6.14±0.82 mg/L respectively. The dissolved oxygen values of different seasons showed significant (p>0.05) results also. The dissolved oxygen values were higher than the standard dissolved oxygen value of the coastal waters as shown in Table 2 and Figure 5. These results were consistent with Ratana (2009). The findings of dissolved oxygen values within the water at the coastal area of Laem Klat (6.1 mg/L) and 4.81-7.31 mg/L values of the coastal areas of Palian Estuary (Suwat, 2011). By comparing the dissolved oxygen values of the water at the coastal areas receiving wastewater

from the municipality in the LERD Project and comparing to the normal coastal areas, it can be stated that there is no significant difference between the dissolved oxygen values. The dissolved oxygen values were higher if the sampling points were further away from the coast because the effect from the waves and winds at the time increased the values. .

Table 2: Water quality of Temperature, pH, Dissolved Oxygen, Phosphate, Nitrate and Ammonia Compared with Standard Values.

Parameters	Standard	Season	A	B	C	Average
Temperature (°C)	Less than 28	Rainy	33.36±0.03^{b}	32.18±0.59^{b}	32.34±0.68^{b}	32.63±0.52^{b}
	Less than 28	Winter	29.72±0.39^{a}	29.94±0.30^{a}	29.36±0.09^{a}	29.67±0.26^{a}
	Less than 28	Summer	33.16±0.30^{b}	33.40±1.40^{b}	33.08±0.47^{c}	33.21±0.77^{c}
	Less than 28	**Total**	**32.08±1.77**	**31.84±1.70**	**31.59±1.72**	**31.84±1.73**
pH	7.0-8.5	Rainy	8.26±0.02^{b}	8.29±0.06^{a}	8.26±0.02^{c}	8.27±0.03^{c}
	7.0-8.5	Winter	8.21±0.08^{ab}	8.13±0.12^{a}	8.21±0.02^{b}	8.18±0.74^{b}
	7.0-8.5	Summer	8.06±0.17^{a}	8.10±0.21^{a}	8.09±0.01^{a}	8.08±0.13^{a}
	7.0-8.5	**Total**	**8.18±0.28**	**8.17±0.16**	**8.18±0.07**	**8.18±0.12**
Dissolved Oxygen (DO)(mg/L)	More than 4	Rainy	6.58±0.79^{b}	6.61±0.11^{b}	6.68±0.15^{b}	6.62±0.35^{b}
	More than 4	Winter	5.96±0.28^{b}	6.60±0.13^{b}	6.82±0.49^{b}	6.46±0.30^{b}
	More than 4	Summer	5.14±0.47^{a}	5.19±1.41^{a}	5.66±0.46^{a}	5.33±0.78^{a}
	More than 4	**Total**	**5.89±0.80**	**6.13±1.03**	**6.39±0.65**	**6.14±0.82**
Phosphate (mg/L)	Less than0.045	Rainy	0.54±0.29^{b}	0.40±0.09^{b}	0.33±0.11^{c}	0.42±0.16^{c}
	Less than0.045	Winter	0.36±0.15^{ab}	0.25±0.34^{ab}	0.15±0.04^{b}	0.25±0.18^{b}
	Less than0.045	Summer	0.12±0.03^{a}	0.08±0.01^{a}	0.03±0.01^{a}	0.08±0.02^{a}
	Less than0.045	**Total**	**0.34±0.25**	**0.24±0.23**	**0.17±0.14**	**0.25±0.21**
Nitrate (mg/L)	Less than 0.06	Rainy	0.23±0.07^{b}	0.18±0.07 ^{c}	0.11±0.01 ^{b}	0.17±0.05^{c}
	Less than 0.06	Winter	0.14±0.04^{a}	0.12±0.05 ^{ab}	0.10±0.02^{b}	0.12±0.03^{a}
	Less than 0.06	Summer	0.09±0.01^{a}	0.07±0.02 ^{a}	0.06±0.01 ^{a}	0.07±0.01^{b}
	Less than 0.06	**Total**	**0.15±0.07**	**0.12±0.06**	**0.09±0.02**	**0.12±0.05**
Ammonia (mg/L)	Less than 0.1	Rainy	0.07±0.03^{b}	0.06±0.01^{b}	0.07±0.01^{c}	0.07±0.02^{c}
	Less than 0.1	Winter	0.04±0.02^{ab}	0.02±0.01^{a}	0.04±0.02^{b}	0.03±0.02^{b}
	Less than 0.1	Summer	0.02±0.02^{a}	0.01±0.01^{a}	0.02±0.01^{a}	0.02±0.01^{a}
	Less than 0.1	**Total**	**0.04±0.03**	**0.03±0.02**	**0.04±0.03**	**0.04±0.03**

Remarks: The Standard of Effluent Standard for Coastal Aquaculture from Ministry of Natural Resources and Environment (2004), Thailand. (p>0.05).

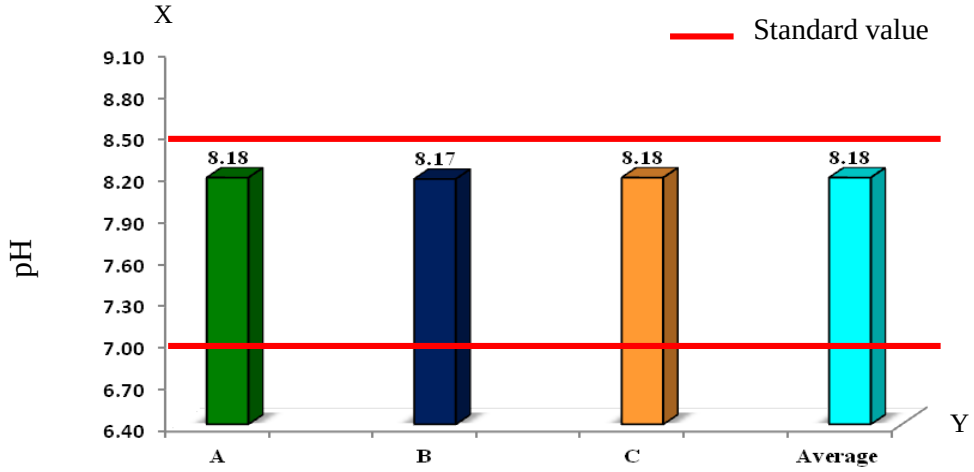

Figure 4: pH at sampling zone compared with standard value.

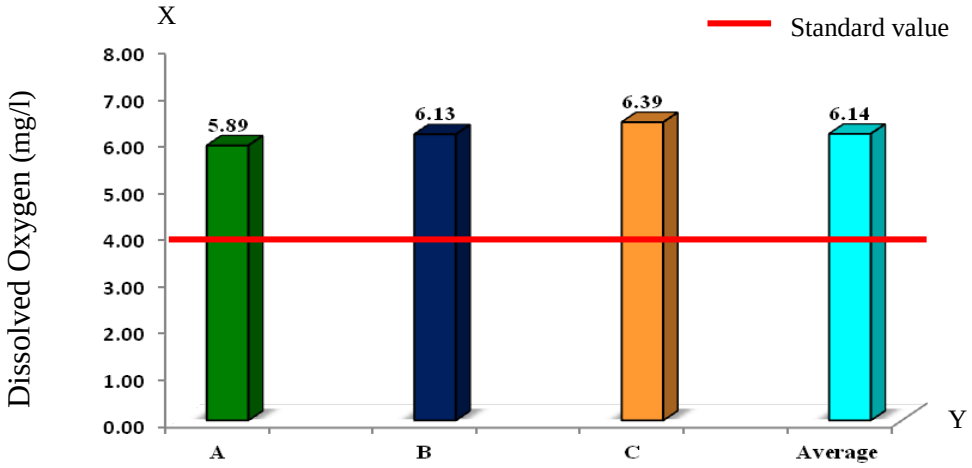

Figure 5: Dissolved Oxygen at sampling zone compared with standard value.

3.4 Phosphate

The average phosphate values of the water at the coastal area of the LERD Project at zone A, B, C and the total averages were 0.34±0.25, 0.24±0.23, 0.17±0.14 and 0.25±0.21 mg/L respectively. The phosphate values of different seasonal changes showed a significant ($p>0.05$) difference also. The phosphate values were higher than the standard phosphate values of coastal water as shown in Table 2 and Figure 6. These results were consistent with that of Wutichi (2000). After comparing the phosphate values of the water at the coastal area receiving treated wastewater from the municipality in the LERD Project and that of normal coastal areas, it was found that the phosphate values of the water at the coastal areas of the LERD Project, Ban Laem, Pak Thale ,Bang Kaew and Had Leam Lueng were 0.024, 0.037, 0.021, 0.021 and 0.017 mg/L respectively. Ratana (2009) found that the average phosphate value of the water at the coastal area of Laem Klat was 0.0020 mg/L. Suwat (2011) found that the phosphate values at the coastal areas of the Paliane estuary were 0.009 - 0.013 mg/L. The phosphate values of the water at the coastal area of the LERD Project and other areas were different, because the first area received wastewater a the large municipality, the Phetchaburi town municipality, which included many purification processing activities (e.g. washing and cleaning things as well as wastewater from cleaning markets) using powered detergent that caused a high level of phosphate in the treated water (Janon, 2009).

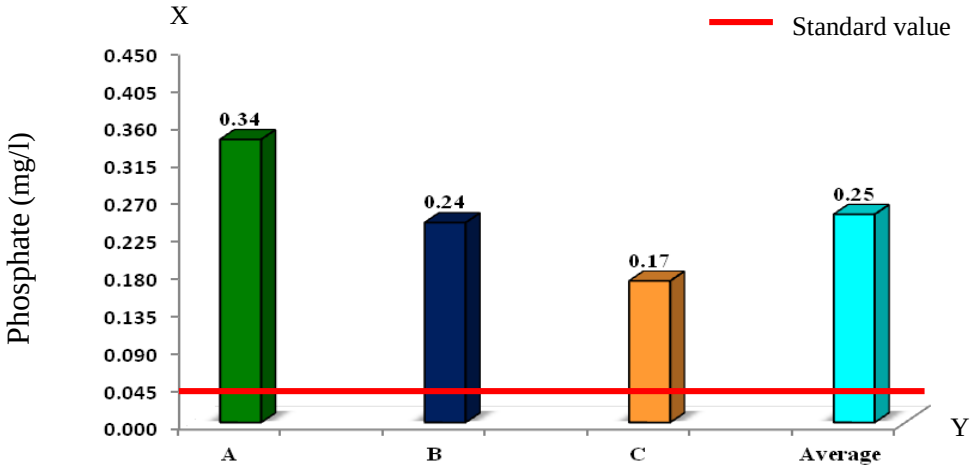

Figure 6: Phosphate at sampling zone compared with standard value.

3.5 Nitrate

The average nitrate values of the water at the coastal areas of the LERD Project zone A, B, C and the total averages were 0.15±0.07, 0.12±0.06, 0.09±0.02 and 0.12±0.05 mg/L, respectively. The nitrate values of each different season showed significant ($p>0.05$) changes, the nitrate values were higher than the standard nitrate value of the coastal waters as shown in Table 2 and Figure 7. Wutichi (2000) compared the nitrate values of the water at the coastal area receiving wastewater from the municipality in the LERD Project and that of the normal coastal areas, it was recorded that the nitrate values of the water at the coastal areas of the LERD Project, Ban Laem, Pak

Thale, Bang Kaew and Had Leam Lueng were 0.05, 0.04, 0.03, 0.05 and 0.04 mg/L, respectively. Ratana et al. (2009) found that the average nitrate value of the water at the coastal areas of Laem Klat was 0.0034 mg/L. The nitrate values of the water at the coastal areas in the LERD Project higher than that of normal coastal areas, because the former are municipality, the Phetchaburi town municipality where is densely populated. Therefore, the nitrate values of the treated water were higher because of human waste, differing activities, as well as additional rain water levels (Barnes, 1982 ; Tharaporn 1998).

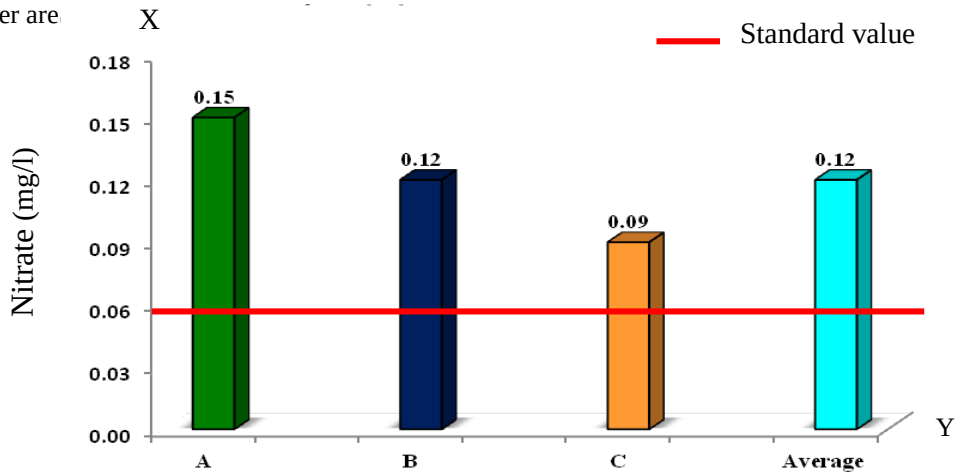

Figure 7: Nitrate at sampling point compared with standard value.

3.6 Ammonia

The average recorded ammonia values of the water, at the coastal area of the LERD Project at zone A, B, C and the total averages were 0.04±0.03, 0.03±0.02, 0.04±0.03 and 0.04±0.03mg/L respectively. The ammonia level and value of each different season held a significant ($p>0.05$) change. The ammonia values were in line with the standard ammonia value of coastal water as shown in Table 2 and Figure 7. Wutichi (2000) compared the ammonia values of the water at the coastal area receiving wastewater from the municipality in the LERD Project and that of normal coastal areas, it was found that the ammonia values of the water at the coastal areas of the LERD Project, Ban Laem, Pak Thale, Bang Kaew and Had Leam Lueng were 0.18, 0.20, 0.15, 0.17 and 0.17 mg/L,respectively. Ratana (2009) found that the average ammonia value of the water at the coastal area of Laem Klat was 0.0043 mg/L. The ammonia values of the water at the coastal area in the LERD Project were higher than that at normal coastal areas because the first area received wastewater from the large municipality, the Phetchaburi town municipality, where it is densely populated this therefore caused the ammonia values of the treated water want to be higher, because of the many different uses of the water from the Phetchaburi river for showering, cleaning vegetables and fruits, cooking, and other activities. In other words, the water resource was recently contaminated before the water sampling (Tharaporn, 1998).

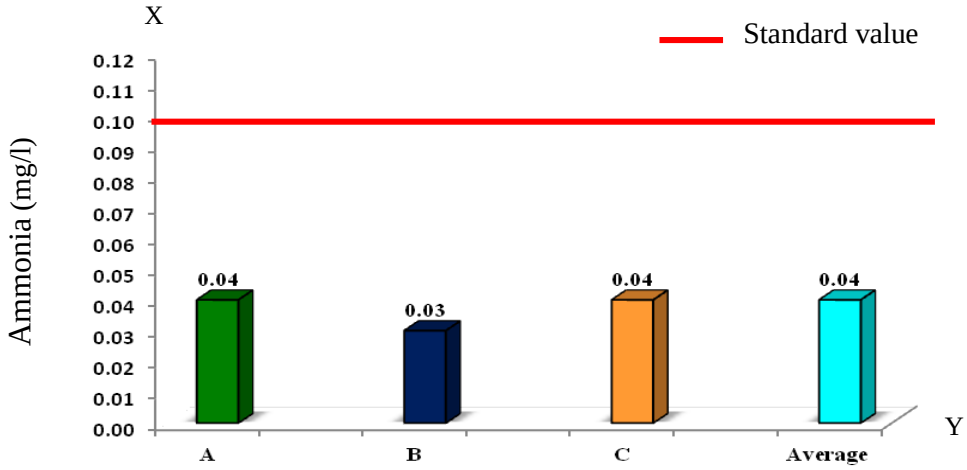

Figure 8: Ammonia at sampling zone compared with standard value.

4. Conclusion

From the examination of water qualities around the coastal areas receiving effluent from Phetchaburi Municipal Wastewater Treatment System, with simple technology by using aquatic plants, constructed wasteland and stabilization ponds and the nature-by-nature process, it was found that the municipal wastewater treatment system could control the water qualities at the coastal area in the LERD Project: Water quality parameters applied in this research have been Temperature, pH, Dissolved Oxygen (DO), Phosphate, Nitrate and Ammonia. The study expresses that the average levels at different distances from the coastal target areas of the LERD project have been 31.84 ±1.73°C, 8.18±0.12, 6.14±0.82 mg/L, 0.25±0.21 mg/L, 0.12±0.05 mg/L and 0.04±0.03 mg/L, respectively. This is in accordance with the standard of quality within coastal areas (Ministry of Natural Resources and Environment, 2004). The system prevented pollution problems affecting the coastal areas, public health and aquatic animals. Water quality in coastal area has created an appropriate environmental condition for macrobenthos, especially Hard clams (*Metetrix* spp.). Good quality of water in coastal areas has been one of the most important conditions for growth, reproduction, cell development, and induced spawning (Sateinpong *et al*., 2015). At least 64 fishermen per year in the area and others have harvested 262 tons per year of Bivalvia. They could receive an income of approximately 185.49 Baht per day or 18,400 Baht per year or 22 million Baht annually (Ranida, 2012). This system also benefited the coastal area in the LERD Project because it improved the quality of the water by increasing the phosphate and nitrate values to be higher than that of any of the other coastal areas. Perceived differently, the system provided more minerals and organic matter for the wastewater released into mangrove forests and coastal ecosystem to consume, feed and at the same time filter, in this coastal area, than any other coastal area. Due to the fact that this coastal area received wastewater from Phetchaburi town municipality, which is a large and densely populated municipality with a lot of human waste, plus other activities, e.g. washing and cleaning, as well as wastewater from cleaning markets using powdered detergent, the phosphate and nitrate values of the treated water at this coastal area were higher than that of any other coastal area. Nutrients have been affected by the primary production of water resources, food chain, and ecology of 45 general and 94 species of micro-organisms. The density at 85.04 cells per litre of *Coscinodiscus* sp. Was the highest density among micro-organisms in the area. Because *Coscinodiscus* sp. has been the main source of food for Hard clams, therefore, Hard clams has been found mostly in the study area (Ekachai, 2014; Sateinpong *et al*., 2015).

5. Recommendation

Because of the limited research, concerning the quality of treated water in coastal areas of Thailand, recommendations have been focused mainly on comparison studies and monitoring the water quality as follows:

1) The comparison study of water quality in different where areas should be implemented, especially the areas that Hard clams have been found, completely wiped out, or are very scarce.

2) Water quality among the municipal untreated water areas, industrially untreated water areas and the natural coastal have been significantly different, the monitoring of water quality should be encouraged.

6. Acknowledgement

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