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The effects of domestic wastewater effluent on the Mangroves Forest of the King's Royally Initiated Laem Phak Bia environmental Research and Development project, Thailand

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ABSTRACT

This study aims to examine to relationship between the mangroves forest that was influenced but the output of a nature by nature wastewater treatment system (W transect) to a natural control site (T transect) at the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, in Phetchaburi Province Thailand. The methods used in comparing these two sites were having each site be placed into the transect and dividing them into 3 zone as there are 250-meter distance correlated with tidal flooding's between 25 - 30 days, 20 - 25 days or less than 18 days. The Mangroves water and soils parameters physical and chemical parameters were then collected as the period in which the measurement took place was from August and September of 2018 and January of 2019. With the effluent water from the oxidation pond system during the experimental period containing 4.40 and 0.06 mg/l of available N and P respectively. The results were that there was a significant difference in the mangroves density of the wastewater effluent site has a lower tree density in the W transect of 1.17, 1.32 and 0.50 tree/m^2 while in the T transect densities were 1.27,1.60 and 1.15 tree/m^2 respectively, as this was in relation to the higher nutrient content. The results also showed that the Diameter (DBH) were also higher transect larger as the averages were 23.6974, 23.1333 and 34.3680 while in the reference transect were 21.7622, 21.8994 and 24.2539 cm respectively. In explanation to this results it was suggested that there were a higher concentration of phosphorus and nitrogen availability as the treated domestic wastewater from the treatment system was found to be the addition sources for these nutrients as they promote a higher growth for the mangroves forest.

Key words : *Mangroves, Avicenna marina, Wastewater, Nature by nature*

Introduction

Mangroves forest have over the recent years becoming effected by the rising environmental concerns generated by the Anthropocene, with pollution and land use changes prompting the decline in the forest area along the coast lines. While regarded as forests located in the intertidal zone of tropical and subtropical regions, are known as specific ecological habitats, as their key role are structural for maintaining the coastal ecological balance. With the prevention of costal erosion being the factor that recent adaptations of climate change mitigation methods being the focus on. Together with its position in the mouth of river and an ecosystem mangroves forest as the transitional/intertidal zones from the fresh water to the salt water ecosystem. (Cheong *et al.,* 2013)

With regards to tropical area being populated with the human's environment, the adaptation of mangroves ecosystem in used for the benefits of the growing demands have been used as a natural treatment system for wastewater especially domestic wastewater. With adaptation made at The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project (LERD), Phetchaburi Province, Thailand, the mangroves of the project have over the years become one of the prominent nature by natural methods that has been depicted by tropical communities as they are phytoremediators for heavy metals and organic compounds.

Receiving wastewater from Phetchaburi municipality located in Phetchaburi province, it covers an area of 5.4 km^2 and has population 123,767in 2018. The sources of wastewater are generated from households, fresh-food markets, schools, shopping malls and offices as this is classified as domestic wastewater which is then drained to sewer system flowing into Klongyang collection ponds (Equalization pond), with the general design scheme of the collection pond compromise of 2 small and 2 big ponds with the holding the total volume 7,200 m^3. This collection pond acts as anin town storage for wastewater before pumping into the LERD project through a 400 millimeters diameter, 18-km length HDPE pipeline to the sedimentation pond, the first pond of oxidation pond system in the LERD project (Jinjaruk *et al.,* 2019) and (Khowhit, 2014). Upon entering the oxidation treatment system, the wastewater undergoes the process of aerobic digestion by microorganism digesting organic materials in which the examples of organic compounds such as ammonia are nitrified making them suitable of release into a mangroves site of the LERD dominated by species of *Avicenna marina*.

Methods and Materials

Site of the Study

This research was conducted out at The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project (LERD), Phetchaburi Province, Thailand where the site has been known for its nature by natural initiatives of treating domestic wastewater set by King Bhumibol Rama the 9th of Thailand. With the treatment technologies adapting into oxidation pond treatment system, the wastewater is received from the municipally of the Phetchaburi province collected at the collection pond within the city center. Upon collecting the wastewater, the transferring process is then done through the 400 millimeters 18 km HDPE pipeline into the treatment ponds (Figure 1). At the LERD Project wastewater the wastewater then undergoes 4 different treatment system consisting of the oxidation ponds system, plants filtration, constructed wetland and mangrove forest (Jitthaisong, *et al.,* 2012). With the main processes of these treatment being focused on the addition of oxygen allowing for bacterial activities converting organic substances into inorganic substance and later being uptake by phytoplankton or plants.

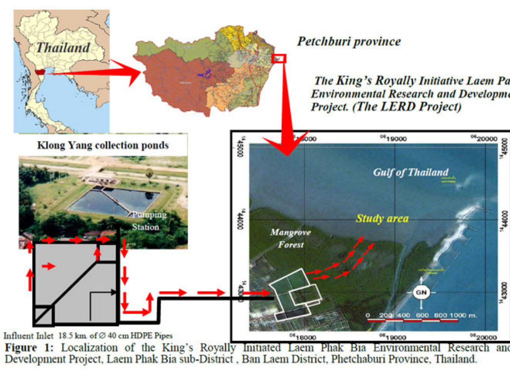

Fig. 1. Study area of The King's Royally Initiated Laem Phak BiaEnvironmental Research and Development Project (LERD), Phetchaburi Province, Thailand (Kasem Chunkao, 2014)

In regards with this study on the effects of mangroves it is that the selected site of the study was the effluent of the oxidation ponds (5 consecutive oxidation ponds), where through the nature by natural method of domestic wastewater treatment, the treated water condition was below the Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand, Total Phosphorus, Electrical Conductivity, Total Dissolve Solids, pH, Hardness, Nitrate, Temperature and Total Kjeldahl Nitrogen (TKN).

This research focused on the mangroves filtration system that aims to study on the effects of the mangroves forest filtration system towards the well-being of the mangroves species as the project mangroves forest were used for the treatment of wastewater and to also serves as final treatment factor to the oxidation ponds system, receiving the effluent water before releasing out into the gulf of Thailand.

Mangroves Species

Having the establishment of the LERD project in 1991, the recovering mangroves from salt and shrimp has been growing at the 10% rate per year for the past 30 years. The diversity of the species of the mangroves forest are dominated by three different tropical mangroves species. The *Avicennia marina*, *Rhizophora apiculta* and *Rhizophora mucronata.* With these mangroves especially the *A. marina* being known for its high level of environmental tolerance levels in its capacities to survive in a wide range of salinity and pH, absorbs a high quantity of nutrients, low oxygenated sediments, intermittent flooding, sustaining osmotic balance and metal pollutants (Hossain and A, 2016). Further Emphasis on the *Avicennia marina* has been depicted for its complex root system, as the species are categorized by the classification of its roots functions that are used for oxygen/ gas exchange, nutrients and anchor roots, as these functions are in support for their adaptive trails for different environmental changes. Where this behavior, the specie was also known for its status as the pioneer species for the mangroves forest.

Area of data Collection

This research has scope itself to compare the effects of treated domestic wastewater effluent on the mangroves forest before entering the gulf of Thailand. As the aim to indicate on effects of wastewater effluent on the mangroves as different field parameters have been establish to monitor and evaluate for the well-being the diversity of the mangroves ecosystem depicting on the growth feature of the mangroves species. With regards to the mangroves ecosystem being in dynamics with the intertidal ecosystem, the selection of the LERD Project area/site was based on the prior research that was separated by different tidal sea water that have intruded into the forest. Where following works of (Orathai, 2014) that the separation of these mangroves was divided into 3 zone as there are 250-meter distance between the 25 - 30 days, 20 - 25 days or less than 18 days of flooding, so, the transects were divided in three stations according to the tide level. To sum up, there are six stations: (i) three stations in the control transect (T1, T2, T3), (ii) three stations in the transect treated by the wastewater (W1, W2, W3), as presented in figure 2. The sampling parameters selected are 1) Soil sampling 2) Water sampling and 3) Mangroves samplings. (Orathai, 2014)

Fig. 2. Collection area

In conduction two lines of sampling were selected as one control area for natural reference and the other area receiving the effluent from the wastewater oxidation treatment system.

Mangroves Sampling

Mangorves specices, Diameter at brest height (DBH), Height, Trees, Sampling, Seeding roots density and physical measurement were taken on August 2018. With the expiremntal plots depicting the 10x 10 meters for mangroves tree measurement, 2 x 10 meters for sampling measrement and 1 x1 meter for the seedling and roots measurement with 3 replications that are located along 3 different zones separeated by monthy tidal depths (Federation & APH Association American Public Health Association : Washington, 2005)

The expermenital plots were divided into the two distinct lines as one being the mangroves forest reciving direct effluent from the domestic wastewater treatment system, while the other being the control or referenece site of natural forest. The classification used for the distiction that are used referd to the seedlings height, less than 1.3 meters, the saplings are higher than 1.3m, and seeding less than 1.3m in height (Orathai, 2014).

Soil Sampling

The soils samples were taken in August and September of 2018 during the lowest with six parameters have been taken for one in the area where the wastewater is treated by the mangroves forest (W) and the second in a reference area (T). The sam-

Table 1. Mangroves Parameters

Parameter	Sampling Plot (m)	Repetition
Species proportion / Number of species	10 x 10	3
Tree density / Height / DBH	10 x 10	3
Sapling density	2 x 10	3
Seedling density	1 x 1	3
Root density / Height / Diameter	0.5 x 0.5	8

Fig. 2. Mangroves sampling

pling was done with a core sample using the adapted 20 cm diameter. The Six parameters have been measured in the soil were temperature, pH, bulk density, texture, available phosphorus and available nitrogen as the methods water and wastewater set by Thailand's Pollution Control Department.

Water Sampling

Water samples were taken in August and September of 2018 and January of 2019 as this was taken during the high tide where the aims were to take when water levels were highest in the mangroves flooding. There were 10 parameters that were taken at the site as these selected parameters were taken for the sampling of physical, biological and chemical characteristics effecting the forest. As their parameters are pH, temperature, salinity, Electrical conductivity (EC), Total Suspended Solids, Total dissolve solids, Total Kjeldahl nitrogen (TKN), Nitrate, total Phosphorus, Biochemical oxygen demand (BOD) and Dissolved Oxygen (DO) as the methods for analysis follows the Standard method set by Thailand's Pollution Control Department.

Results and Discussion

From the remaining effluent of the oxidation system still containing the sufficient amount of nitrogen and high dissolved oxygen concentration enabling for the process of nitrification producing nitrogen in available forms for plants uptake (Table 2).

From this observation, this research was based on the effects of treated domestic wastewater effluent towards the density, diameter, height of all trees, sapling seeding and roots. The results of the study was computed under the analysis of variance (ANNOVA) as the two zones of mangroves receiving effluent of the oxidation ponds wastewater treatment system and the other being the natural site, the results of the T-test for the tress physical character of height, diameter at breast height (DBH), root height and diameter under the 95% confident interval found that the p-values were less than 0.05, as this concludes that the two zones were significantly different from one another.

Establishing that they were different from one another, the statistical analysis were then taken to look at each individual sections within the zones. As the comparison of each zones were taken into the Duncan's test and grouped for each physical parameters measured as shown in Table 3. From the Duncan's analysis of the physical parameters separation that the groupings were divided into groups that represented their statistical differences. From the diameter at breast height of the sampling plots were divided into 3 major groups as in line T (the natural/ reference site) consist of smaller DBH, tree height and root diameter. While density wise, the natural reference line is much denser when grouped against the wastewater effluent line. While it was

Table 2. Mangrove Parameters

Date	Parameters				
	pH	BOD (mg/L)	DO (mg/L)	Total P (mg/L)	Total N (mg/L)
Aug2018	8.8	10.8	8.1	0.04	4.8
Sept 2018	8.8	7.8	10.2	0.04	3.1
Dec 2018	8.6	9.6	4.6	0.074	5.5
Jan 2019	8.2	10.2	6.8	0.066	4.2
Average	8.6	9.6	7.425	0.055	4.4

seen that within the mangrove forest of both the reference and the wastewater effluent site, 3 mangroves species were found, however, when taken the sampling points of the experiment, the area is dominated by *Avicennia marina* with 100% of this species along the two transects. However, the **Error!** Reference source not found. shows that the dark green zones which corresponds to the *Rhizophoramucronate* or *R.apiculata* species which are present in the area.

Height, Density and Diameter at breast height of Mangroves

The suggested findings in the Marine Nation National Park and Sanctuary of Eastern India that he height of *A.marina* ranged from 55.052 ±3cm to 554.28±60cm (0.5 m to 5.5 m) (Yadav *et al.,* 2017). The mangroves that were measured in the LERD project site corresponds to the heights with averages ranging from 4.97 to 7.63m respectively.

The trends of height were also grouped by the Duncan statistic that in the reference line where the overall tree height was found that be higher in average in the W transect, as this could refer to the levels of nutrients phosphate and nitrate that was found in both the water and soil samples that were collected. Where cloud cover of the two transects was higher in the W transect than that of the T transect as this was 93.81% and 75.13% respectively. (Orathai, 2014).

In comparing the density of the two lines, it was found that density in the references line were significantly higher than that of the wastewater effluent line. supported by significant differences (p-value = 0.01) of the lower tree density was found to be in the W transect of 1.17, 1.32 and 0.50 tree/m^2 while in the T transect densities were 1.27,1.60 and 1.15 tree/m^2, respectively. This was suggesting that due to growth competition, the mangroves in the reference transect where found the be much denser as the results of density (Alongi, 2002). That the higher density of *A marina* are results for the entire mangroves ecosystem competition for nutrients and survival. Thus to add to this point the slopes measurement were 1:80 as this represent the mild slop gradient meaning that the nutrient were kept in place (K G, 2017).

The results for diameter at breast height (DBH) confirms that when the tree density is high, height and diameter are low, and this relation is observed in both the transects. With the results showing that mangrove in the W transect larger in the significant of (p-value > 0.05) on averages as the results were that the grouping 23.6974, 23.1333 and 34.3680

Table 3. Duncan's Statically of mangroves parameters

Zones	Parameters						
	Tree Density (Tree/m^3)	Sapling Density (Sapling/ m^3)	Seeding Density (Seeding/ m^3)	Diameter at Brest Height (DBH) (cm)	Tree Height (m)	Root Diameter (cm)	Root Height (cm)
T1	1.27^b	2.10^c	0.00^a	21.76^a	5.66^{b,c}	0.59^b	24.68^c
T2	1.60^c	1.65^b	20.00^b	21.90^a	5.32^{a,b}	0.53^a	17.36^a
T3	1.15^b	0.35^a	40.00^c	24.25^b	5.89^c	0.66^c	28.78^d
W1	1.17^b	0.90^{a,b}	0.00^a	23.70^{a,b}	6.65^d	0.65^c	27.30^d
W2	1.32^b	2.10^c	40.00^c	23.13^{a,b}	4.97^a	0.63^c	28.19^d
W3	0.50^a	0.30^a	24.00^b	34.37^c	7.63^e	0.65^c	20.76^b

Table 4. Soil Samples Results

Parameters	Station					
	T1	T2	T3	W1	W2	W3
T (°C)	29.5	30	31	29	29.5	28.5
pH	7.5	7.7	7.8	7.6	7.2	7.2
Bulk density (g/cm^3)	1.26	0.91	0.95	1.29	0.93	0.89
Available P (mg/l)	78.5	85.9	115.2	118.75	86.45	113.75
Available N (mg/l)	1.43	0.67	0.26	0.29	0.63	0.04
Texture	clay	clay loam	silt loam	clay loam	clay loam	silt loam

while in the reference transect were 21.7622, 21.8994 and 24.2539 respectively. This differences can be explained by the discharge of the wastewater in the W area which brings more nutrients to the trees and so increase their height and width. In addition, the results already observed that the discharge of moderate sewage loadings results in enhanced growth of trees (Penha-Lopes *et al.,* 2010).

Linking with the soil phosphorus availability in the first station is higher in the area treated by the wastewater were, 113.75, 86.45 and 118.75 mg/l while 115.2, 85.9 and 78.5 mg/l in the reference (T) transect. With the reason for the higher levels of phosphorous in the W transect being the effluent from the fifth pond (last oxidation pond) has been already pre-treated and so, it has a high phosphorus availability before being discharged into the mangrove forest. The levels of available phosphorus decreases because the trees consume it, and this is related to the tree density, height and diameter, this is due to a concentration of high phosphorus availability, as there is less competition for the nutrients and so the tree density is higher. While at W3, the levels increase due to because the tide brings a high nutrient sea water into the forest rising the levels. Conversely, the references transect have a significantly lower levels of available phosphorus yet follows the same trends. With The Available P is considerably higher than the available Nitrogenas the *A. marina* absorbs nitrogen during their growth period during the wet season (July to November) while the higher absorbance of than phosphorus is found during the flowering period (Reef *et al.,* 2010). With this, the study on the impacts of crown cover also plays an important role in shaping the uptake in the levels of nitrogen where from the data (Jitthaisong *et al.,* 2012) it has been suggested that the mangroves (*A.marina*) contains a larger crown cover (sky view) than that of the reference site. From this reasoning, it can be suggested that that amount of nitrogen that was inputted from the effluent of the oxidation pond system has been deposited into the soils as the tress are able to oxidize the nitrogen creating a nitrification and ammonification process generating nitrite and ammoniaas the dissolve oxygen is enough within thewater, in which mangroves are able uptake. (Xiao *et al.,* 2018) (Figure 3).

The bulk density increases with the distance from the sea, so the soil compaction increases. This is related to density of seeding and sapling that alsofollows the trends, with research suggesting that lower bulk density will allow for younger growth forest to strived. (Hossain, 2016). This is also represented in the roots height, diameter and density. However, there is no significant differences on the root density (p-value > 0.05) between the T and W transects with an average of 6.6 roots/m^2 and 6.4 roots/m^2 in the W transects as there is no significant. Suggested that as a pioneer forest, the *A.marina* found itself facing lots of competition between them and therefore a small root network per tree. Then, the release of the wastewater into the mangrove forest has selected the trees and decreased their density.

Table 5. Water Samples Results

Parameters	Station						
	Average Effluent (August 2018 to January 2019)	T1	T2	T3	W1	W2	W3
pH	8.60	7.70	7.53	7.77	7.66	7.83	7.96
T (°C)	-	28.43	28.40	29.10	28.27	28.67	28.83
Salinity (ppt)	-	27.40	28.00	28.63	26.43	26.60	27.27
EC (mS/cm)	-	1,304	1,290	1,281	1,382	1,321	1,290
TSS (mg/l)	-	228	156	158	149	155	166
TDS (mg/l)	-	3,106.6	3,0733.3	3,020.0	3,283.3	3,143.3	3,090.0
TKN (mg/l)	-	1.867	1.867	2.100	0.933	1.307	0.747
Nitrate (mg/l)	4.40	0.033	0.045	0.050	0.020	0.051	0.087
Total P (mg/l)	0.055	0.152	0.170	0.176	0.170	0.067	0.049
BOD (mg/l)	9.6	2.25	2.45	2.9	3.1	4	3.95
DO (mg/l)	7.46	5.45	5.25	5.80	5.62	6.20	6.29

Remarks: W: Wastewater effluent Transect
T: Control area effluent Transect

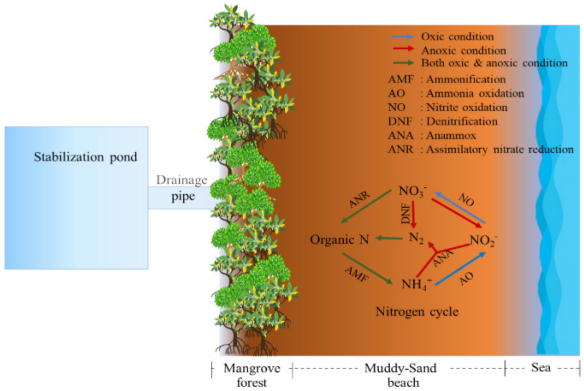

Fig. 3. Nitrogen cycle within the mangrove forest ecosystem.

Ground levels also plays an important role in the heights of the roots with reported data suggested that with uneven ground levels to roots levels of the *A. marina* have the tendency to adapt their roots height in accordance to tidal levels. (Dahdouh-Guebas, Kairo, De Bondt, & Koedam, 2007). Where the additional factor would be in relation with the slopes where in relation to the 1km stretch of the mangroves forest.

The water quality shows a clear evident that the W transect represented the treated domestic wastewater with the BOD concentration ranging from3.10 to 4.00, while 2.25 to 2.90mg/L were the concentration in the natural reference site. Along with this the salinity ranges from 26.45 to 26.43 ppt, temperature 28.5-31.0, and pH 7.2-7.8 are the qualities found throughout both of the transects as this meets with the brackish salinity of 0.5 to 35 ppt, the temperature ([20-40] °C) and pH ([7-8]) which are optimum for the bacteria activity which treat the wastewater. The TKN in both transects 1.867, 1.867, 2.100mg/l in the T reference transect and 0.933, 1.307, 0.747mg/l in the W transects, as this can be explained through conversion of organic into inorganic as in W transects the uptake of nitrogen are being used up by mangroves in the area.

Having the BOD concentration is lower than the 20.0 mg/l expected by the PCD in both the areas. The higher concentration in the W transects (3.10, 4.00 and 3.95 mg/l) than in the T transects (2.25, 2.45, and 2.90 mg/l) is simply because the aerobic bacteria tendency to requires more oxygen to breakdown the organic matter into inorganic matter from the wastewater. As expected, the DO is higher when the BOD is low because the low oxygen demand by the bacteria it due to a high oxygen concentration in the water (Peralta *et al.*, 2020). In addition, the breaking down into inorganic matter are often refers to as phosphate and nitrate which then deposit in water and later into soils and becoming available for mangroves uptake. The TSS, EC and TDS are of the water quality were explained by their values being in representing the sea water effects in the mangroves forest.

Conclusion

From the effluent of the domestic wastewater that have been treated by the oxidation pond treatment technology under the King's Royally Initiated Laem Phak BiaEnvironmental Research and Development Project (LERD), Phetchaburi Province, Thailand. Comparison between mangroves forest of a natural reference site and the wastewater effluent site, it was seen through that in the mangroves trees receiving the effluent of the wastewater treatment system were lower in density per square meter but were larger in diameter and height which can conclude that the effects that were observed with higher concentration of nutrients promotion of mangroves *(A. Marina)* growth in treated wastewater effluent were much more efficient than that of a reference site.

Acknowledgments

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