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The Appropriate Biochemical Oxygen Demand Concentration for Designing Domestic Wastewater Treatment Plant

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Abstract

Majority of Wastewater treatment plants in Thailand faces the problem of over design, as this is based on the Biochemical Oxygen Demand (BOD) content of the inputted wastewater having a lower concentration than the efficiency of the design system. To meet the purpose of this study the findings of the optimum recommended BOD concentration for the effectiveness of the treatment and high operating costs. Water samples were collected from January 2009 to December 2017 (N = 90). The results showed that the BOD concentration differ shows an inconsistence variation over time as this is due to the wide range of wastewater sources from various activities. The results of this paper showed that the recommended BOD concentration for the wastewater treatment plant should be 80 mg/L in the vicinity of the city, while 60 mg/L is the recommended concentration for wastewater that has been transited for over 5 hours into the treatment plant system away from the city, as the transferring processes of the wastewater through the close pipeline resulted in an anaerobic treatment which reduces the BOD concentration. Thus, the overall concepts suggested that the BOD concentration entering the wastewater treatment plant of 80 and 60 mg/L respectively falls under the 80% confident range.

Keywords: Domestic wastewater; BOD concentration; Wastewater treatment; Self-purification; Sewer system

1. Introduction

With the sewer system is intended to drain the wastewater from the point sources to the wastewater treatment plants. The wastewater will be trapped and drained in the sewer system with a retention time depending on the form and length of the sewer system, as this would result on the changes in the physical, chemical and biological composition (Hvitved-Jacobsen *et al.*, 1999; Konnerup *et al.*, 2009; Qteishat *et al.*, 2011; Poommai *et al.*, 2013; Jinjaruk *et al.*, 2018). Regarding the lifestyle of Thai people, domestic wastewater that are generated in the country composes of organic matters and nutrients with high nitrogen and phosphorus levels as this composition gave the right proportions for a natural degradation of bacteria while the wastewater flows through the sewer. Besides, the temperature of the wastewater also falls within the mesophilic temperature ranges as this lead to a high metabolic rate for biodegradable or-

ganic matter in wastewater from point sources (residentials, commercials and governmental units) to the central wastewater treatment plant having an efficiency of 95% Biochemical oxygen demand (BOD). (Jinjaruk *et al*., 2018) However, based on the self-purification in the drainage pipeline the BOD concentration of the wastewater treatment plants often have their design process over design as this factor would eventually lead to problems concerning the efficiency of mineral nutrients and higher costs due to the need to add carbon sources for use in the treatment. (Noophan *et al*., 2009; BMA, 2012).

There are several factors to consider when choosing a wastewater treatment system, as this includes the cost, location, effluent composition, system administrator, etc. While in designing the treatment system, one can easily find a cost-effective oxidation pond system for the parameters that are used to calculate the area of the wastewater treatment system is BOD concentration, wastewater flow rate and BOD surface loading as shown equation (1)

The importance of this equation is to calculate optimum treatment efficiency, where if the BOD concentration is too high, it will result in large wastewater treatment which will cost a higher budget. If the BOD is too low, it will not be able to treat wastewater according to the wastewater standard. Therefore, this research aims to determine the appropriate BOD recommendations for use in calculating the size of the community wastewater treatment system in Thailand as this is to save on the cost of construction and effective treatment.

$$A = \frac{QS_o}{L_a} \qquad \text{Equation 1}$$

A = surface pond area (m^2)
Q = wastewater flow rate (m^3/day)
S_0 = BOD concentration of wastewater (mg/L)
La = BOD surface loading rate (g BOD/m^2/day)

2. Materials and methods

This research was carried out by the collection wastewater samples in the Phetchaburi municipality wastewater system transferring to the equalization pond (Klongyang collection ponds) and throughout the 400 millimeters 18 km HDPE pipeline to the treatment ponds of The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project (LERD) (Figure 1). The LERD Project was established by King Rama the 9th treating wastewater in 4 different system of the oxidation ponds system, plants filtration, constructed wetland and mangrove forest under the royal initiatives of the nature by nature process, simple technology and low cost (LERD, 2017).

The water sampling was taken from two points of the Klongyang collection ponds (WW1) at the outlet and the wastewater en-

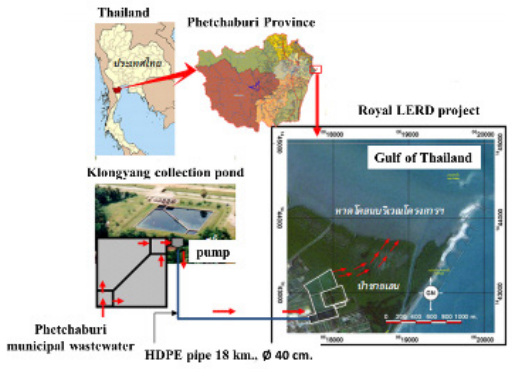


Figure 1. The Location of Phetchaburi and LERD project site (Source: Jinjaruk *et al*. 2018)

trance point of the sedimentation pond (WW2) (Figure 2). The general scheme in designing a wastewater treatment plant, includes a collection pond for retaining wastewater for 24 hours is necessary. Where this would enable for a constant flow rate into the treatment plant for further biological treatment (Metcalf and Eddy, 2004). The Klongyang collection pond consisted of 4 connecting ponds including an initial wastewater inlet pond, two resting ponds and one terminal wastewater outlet pond. The retention time within the Klongyang collection pond is designed to hold the total volume of 7,200 m^3 of wastewater for 29 hours. Where besides its function of a collection pond, Klongyang also serves as a filter for sediments and biological rehabilitation as this decreases the BOD concentration (Jinjaruk *et al*., 2018). Through this, the outlet of the Klongyang collection pond makes for a necessary sampling point (WW1) in which the BOD concentration will determined the capacity of the biological treatment for the treatment system that can be located in city.

On the other hand, the LERD Project which is located 18 km away from Phetchaburi municipal requires wastewater to be transfer into the sedimentation pond through a 400 millimeters diameter, 18-km length HDPE pipeline by 3 alternating pumps, 1 working and 2 on standby as the purposes of these pumps are to increase head water, making the wastewater flowed constantly and continuously. While inside the HDPE pipeline, there is an anaerobic digestion process that reduces the BOD concentration (Poommai *et al*., 2013; Jinjaruk *et al*., 2018). Therefore, taking BOD samples from the inlet sampling point of the LERD project at the sedimentation pond (WW2) would be an essential indicator for the biological treatment of the wastewater treatment plant which is constructed outside of the city center.

Wastewater samples were collected through the method of grab sampling once a month, during the time that ranges from 1.00-2.00 pm of the day, from January 2009 to December 2017 where the samples are kept at 4°C in PE 1-liter bottle during its transfer to the laboratory. The analysis of Biochemical oxygen demand (BOD) of wastewater are taken under the Standards Methods for the Examination of water and wastewater (1998).

3. Results and discussions

3.1. The BOD concentration Suitable for designing wastewater treatment systems

The water samples collected from January 2009 to December 2017 (N=90) showed the BOD value in Figure 3 found that the concentration of the Klongyang wastewater outlet (WW1) ranges from 16.2-108.0 mg/L, averaging in 67.5 mg/L with the standard deviation of 17.9, while the average BOD concentration at the inlet of the sedimentation pond (Pond 1) of the LERD project (WW2) ranges from 6.6-70.5 mg/L with an average of 45.9 mg/L with the standard deviation of 13.5. The BOD concentration of both points does follow the same trends yet shows high variations as the source of the wastewater in the Phetchaburi municipal was based on the fact that the city has different activities during different times of the day as the example would

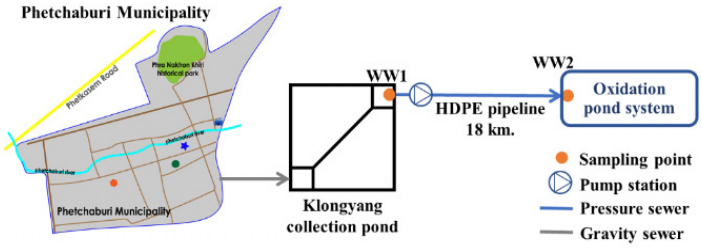


Figure 2. Schematic diagram of the Phetchaburi municipal sewer system and sampling points.

When depicting on the wet seasons (May till November) of the Phetchaburi province (highlighted section of the figure 3), it is found that the BOD concentration tends to be lower than that of the dry season as this is because the dilution from the rainwater. This is especially seen through the sampling trail 20 (n=20) where the BOD concentration is found to be 16.2 (WW1) and 6.6 mg/L (WW2) respectively. Extrapolating on the explanation, it is during the flooding period of the Phetchaburi city where the sampling point was taken.

The compositions of domestic wastewater from Phetchaburi municipal can be easily treated by both anaerobic and aerobic biological process because it comprises of easily biodegradable organic matter and is very abundant in nutrients, nitrogen and phosphorus. The wastewater is pumped through 18-km HDPE pipeline from Klongyang collection pond to the treatment system at Laem Phak Bia Project with a 7.5 hours transporting time that directly affect only the anaerobic biodegradation process and decreases the BOD concentration. The BOD digestion rate trend to constant at 12 km, 5 hours, from the collection pond (Jinjaruk *et al*., 2018). The efficiency of the BOD from WW1 to WW2 was found to be 32%.

When taking a long-term phenomenon, it is found that both of the sampling points showed that the BOD concentration is increasing as this is affected by the increasing amount of fresh markets, malls, tourist attractions and governmental/administrative buildings caused by the increase in population following the process of the city growth and expansion. Moreover, due to the increase in the total population, it is that the quantity of the wastewater outputted from the city increases as well. This then reduce the wastewater retention time resulting in the decrease in efficiency of the self-purification process.

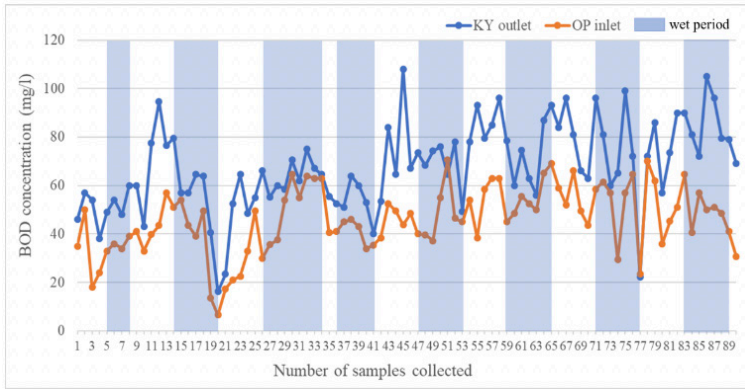
Due the concentration of the BOD at WW1 and WW2 conveying a large variation over time, the average BOD data that was used to calculate the area of wastewater treatment may not be appropriate as this is because the under design of the system, as this study, the aim was to determine the BOD concentration as we arrange the BOD concentration at WW1 and WW2 in ascending order, as shown in Figure 4.

The high BOD value falling within the 80% confident interval found that at the outlet of Klongyang collection pond and inlet of oxidation pond system has a BOD concentration around 80 and 60 mg/L respectively. However, it is also necessary that when considering the BOD concentration covering 90% of all the data, which was found to be 93 and 65 mg/L respectively. This comparison between the maximum data that covers 80 and 90 percent is not significantly different, the application in Thailand, a developing country, can use the 80% BOD concentration (with 20% being probability that the BOD values of wastewater exceeding the design value) for the design values as this would reduce the cost of construction. Therefore, in the designing process of the wastewater treatment plant adjacent to the collection pond in the vicinity of the city, the BOD loading concentration should be adjusted to 80 mg/l. While for treatment plants located more than 5 hours transiting time away from the municipal the loading value of 60 mg/L can be applied since the pumping of wastewater through a close system pipeline provides anaerobic treatment (Jinjaruk *et al*., 2018).

3.2. The comparison of the wastewater system area to the BOD concentration

Generally, large-scale urban wastewater treatment systems in Bangkok and large municipals are designed using a BOD concentration of 150 mg/L, conversely, based on the water quality data from the Department of Drainage and Sewer, Bangkok, as shown in Table 1. The data provide points out that the BOD of wastewater entering treatment during January to October 2017 was lower than the expected design parameters. Where the wastewater treatment in the city has an on-site treatment such as septic tank, oil and grease trap as well as pretreated in the sewer system prior to entering the biological wastewater treatment system.

In the designing processes of the oxidation pond to allow self-purification system for the wastewater, equation (1) can be applied to determine the size of the surface area of



Remarks:
- KY outlet is WW1 (Klongyang collection pond outlet)
- OP inlet is WW2 (Oxidation pond inlet)
- October 2011– July 2012 and January 2013-May 2013 data not available due to the maintenance of the treatment system of the LERD project.

Figure 3. BOD concentration of Phetchaburi municipal wastewater of WW1 and WW2

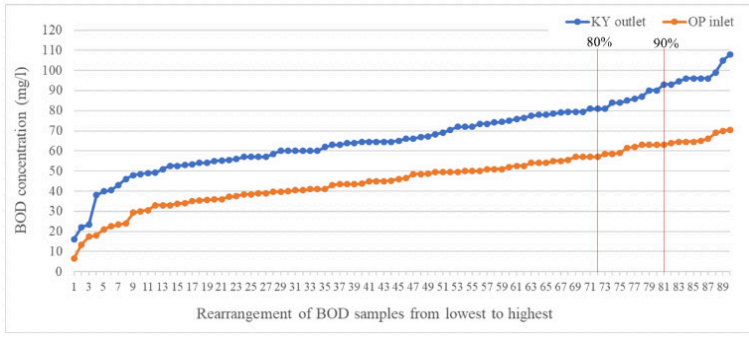


Figure 4. The BOD concentration of the sampling point WW1 and WW2 that are arranged from the lowest to higher values.

Table 1. BOD concentration values used in wastewater treatment plants (WWTPs) in Bangkok, Thailand.

WWPTs	Year	BOD design (mg/L)	BOD inlet (mg/L)
Si Phaya	1994	150	62.8-42.0
Rattanakosin	2000	200	58.5-49.7
Chong Nonsi	2000	150	33.5-30.4
Nong Khaem	2002	150	57.8-38.8
Tung Khru	2002	150	34.6-30.6
Din Daeng	2004	150	42.2-34.1
Chatuchak	2006	150	37.5-31.2
Bang Sue	2015	100	37.0-29.0

Remarks: Data from January-October 2017

Table 2. The oxidation pond area base on the BOD concentration.

BOD design (mg/l)	Total area		Area difference compare with BOD 150 mg/l			Area difference compare with BOD 80 mg/l		
	m^2	rai	m^2	rai	%	m^2	rai	%
150	55,318	34.6	-	-	-	-	-	-
80	29,503	18.4	25,815	16.1	47	-	-	-
60	22,127	13.8	33,191	20.7	113	7,376	4.6	25

Remarks: BOD surface loading rate = 25 g BOD/m^2/day (lowest temperature of 25°C)

oxidation pond of the wastewater treatment system. In this study, the surface area of the oxidation ponds (A) was determined using a BOD concentration (S0) of 150 mg/L as this represents the value of the suggested typical system, 80 mg/L for treatment system inside the municipal and 60 mg/L for the treatment plants away from the municipal. Where the 80 and 60 mg/L are the comparison of BOD concentration to the typical value of 150 mg/L as this was adjusted according to the flow rate of wastewater from the Phetchaburi municipality at 5,910 m^3/day. The BOD surface loading rate that is suitable for Thailand is 25 g BOD/m^2/day for the design of wastewater with a minimum temperature of 25°C (Pollution Control Department (PCD), 2010). (Table 2)

In general, the design of the wastewater treatment system for oxidation pond system consisting by three consecutive ponds are recommended to have the efficiency is adjusted to 60%. Where in setting the BOD values to 150, 80 and 60 mg/L it is calculated that the spaces that the treatment pond requires with the different BOD concentration are 55,318, 29,503 and 22,127 m^2 respectively. In using the BOD concentration of 80 mg/L as the new design wastewater inlet of the treatment system for sites near the city and comparing it with the general value of 150 mg/L, we could reduce the area of the treatment pond by 47% and thus still able to achieve the wastewater outlet understand the PCD standards. While in the model of wastewater treatment system in Phetchaburi municipality, which uses wastewater for treatment away from city, we can use BOD 60 mg/L for the design, which reduces the size of the area of the treatment plant by 113% when compared the old 150 mg/l and 25% for the BOD concentration of 80 mg/L.

This model may have the disadvantage in leading to a higher cost of building a sewer system. However, it can help reduce the size of the area, and the sensitivity of the potential environmental impacts to the city, as the outlet treated wastewater can also be used in agriculture. In comparing the efficiency of oxidation pond system to the area has now been reduced, when calculating the size of the area with other treatment plants such as the aerated lagoon with a higher BOD surface loading rate, it was found that the size of the treatment area was smaller than that of the oxidation pond system but the BOD loading concentration is still the same.

4. Conclusion

This study was conducted in January 2009 to December 2017 (N = 90) for the determination of the appropriate BOD concentration in the long-term municipal wastewater drainage system and wastewater treatment pond design. The results of the study showed that the BOD concentration was significantly fluctuated at different times as this is mainly because of the source of wastewater, that originated from various activities at different times for example, houses, bazaars, government offices and commercial zones, etc. have different operation activities/hours throughout the year. However, in the long run, the BOD concentration in the wastewater is likely to increase due to the increasing amount of wastewater from the city's

growth (population). As a result, the retention time in the sewer system will be decreased.

Where in this study, the surface area of the oxidation pond was calculated to the recommended BOD as this can be divided into two types, according to the location of the wastewater treatment plant, in and away from the city. For wastewater treatment plant is located next to the collection pond in the vicinity of the city, the BOD loading value of 80 mg/L is recommended for used in the design, as this would result in a 47% reduction in area compared to the conventional BOD 150 mg/L as thus the results remain the same. Conversely, for the wastewater treatment plant is built in the area away from city and requires an airless pump with an overhead of over 5 hours, the BOD loading concentration are expected to be 60 mg/L as this would reduce the size of the area by 113% compared to the design value of 150 mg /L BOD and 25% reduction compared to BOD 80 mg/L.

Acknowledgements

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References

Bangkok Metropolitan Administration (BMA). Bangkok State of the Enviroment 2012 (Revised Edition). Bangkok, Thailand. 2012.

Hvitved-Jacobsen T, Vollertsen J and Tanaka N. Wastewater quality changes during transport in sewers – An integrated aerobic and anaerobic model concept for carbon and sulfur microbial transformations. Water Science and Technology 1999; 38(10): 257-64.

Jinjaruk T, Chunkao K, Pongput K, Choeihom C, Pattamapitoon T, Wararam W, Thaipakdee S, Srichomphu M and Maskulrath P. HDPE pipeline length for conditioning anaerobic process to decrease BOD in municipal wastewater. EnvironmentAsia 2018; 11(1): 31-44.

Konnerup D, Koottatep T and Brix H. Treatment of domestic wastewater in tropical, subsurface flow constructed wetlands planted with canna and Heliconia. Ecological Engineering 2009; 35: 248-57.

LERD. Annual report year 2017. The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, The Chaipattana Foundation, Thailand. 2017.

Metcalf and Eddy. Wastewater engineering treatment and reuse. 4th (ed.). McGraw-Hill, New York, USA. 2004.

Noophan P, Paopuree P, Kanlayaras K, Sirivethayapakorn S and Techkarnjanaruk S. Nitrogen removal efficiency at centralized domestic wastewater treatment plants in Bangkok, Thailand. EnvironmentAsia 2009; 2: 30-35.

Qteishat O, Ayszograj S and Suchowska-Kisielewicz M. Change of wastewater characteristic during transport in sewers. Waste Transactions on Environment and Development 2011; 11(7): 349-58.

Pollution Control Department (PCD), Ministry of Natural Resources and Environment. Announcement from the Pollution Control Department, Thailand, on domestic wastewater collection pond and treatment plant standards. Bangkok, Thailand. 2010.

Poommai S, Chunkao K, Dumpin N, Boonmang S and Nimpee C. Determining the in-pipe anaerobic processing distance before draining to oxidation pond of municipal wastewater treatment. Environmental Science and Development 2013; 4(2): 157-62.