Evaluation of the Operational and Structural Design of Sewage Treatment Plant of Muara Fajar (IPLT Muara Fajar) Pekanbaru City, Riau Province, Indonesia

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Keywords: Evaluation, Performance, Sewage Treatment Plant, Structural Design

Abstract: Sewage Treatment Plant of Muara Fajar (IPLT Muara Fajar) was conventional and biofilter system designed to treat municipal sewage from Pekanbaru City. The system was built in 2006 and has been operated for 2 years. Today the system was no longer operating due to lack of maintenance and the high operational cost. Implementation of sewage treatment plant was urgently required to treat municipal sewage, thus the plant was evaluated. The performance of the plant was evaluated for three months. Evaluation of IPLT includes calculation of a number of population, Actual BOD Load, Operation Efficiency, and Evaluation of Structural Design. Laboratory Results from influent concentrations of BOD, COD and TSS were 3.500 mg/L, 5.300 mg/L and 100 mg/L respectively. Design calculation compares to Indonesian National Standard. Design calculation showed that two-stage anaerobic unit with dimension @ 7 x 3 x 3,3 m^3 can be operated by re-painting the unit, aerobic biofilter with the dimension 9,6 x 4 x 2 can be operated by replacing new media and re-painting the unit, two-stage facultative basin with the dimension 35 x 19 x 1,5 m^3 must be re-built on the second basin due to hard damage in the building structure. Meanwhile maturation basin with the dimension 17 x 5 x 1 m^3 must be re-built due to heavy damage to the building structure. With these volumes, the IPLT system can treat municipal sewage with capacity of 40 m^3/day from selected areas in Pekanbaru City, that are Rumbai District and Senapelan District, with the population about 21,900 inhabitants.

1 INTRODUCTION

In general, municipal waste from households that do not have access to wastewater treatment plant is a major source of environmental pollution which can cause serious impacts because it can easily enter the water body or seep into the soil body. Every year, the average citizen of a developed country produces about half a tonne of waste (Jouhara, 2017).

Without a good system of wastewater management, it will have an impact on environmental pollution and a decrease in the quality of water, such as rivers, reservoirs, and others.

This will cause a number of problems, such as damage to the ecological balance in the river flow, health problems leading to increasing mortality from water-related infectious diseases (such as dysentery and cholera) (William and Henry, 2007), from Norovirus in wastewater (Shinobu, *et.al*, 2015), and from chemical and microbiological risks in River Rurh (Martin, *et.al*, 2016).

One of the domestic wastewater is sewage sludge. Most urban communities have equipped their homes with septic tanks. The community paradigm considers that septic tanks are the last treatment of their wastewater so that they are not carried out regularly. This approach is not a sustainable use of septic tanks.

The city of Pekanbaru has a Sewage Treatment Plant (here in after referred as IPLT). IPLT Muara Fajar was conventional and biofilter system designed to treat municipal sewage from Pekanbaru City. The system was built in 2006 and had been operated for 2 years. Today the system was no longer operating due to lack of maintenance and the high operational cost. Implementation of sewage treatment plant is urgently required to treat municipal sewage, thus the plant was evaluated.

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2 MATERIALS AND METHODS

The performance of the plant was evaluated for three months. Evaluation of existing IPLT includes evaluation of Building Structure, Actual BOD Load, Actual Volumetric Load, and Operation Efficiency. Here are several steps of the research:

A. Determination of the Area Service

IPLT planning depends on determining the area of the service. For this purpose data collection and review of the master plan for handling the wastewater system in the relevant area and other data was explained previously. IPLT only processes sludge that comes from residential area and does not process liquid waste from industries, hospitals, or laboratory waste.

B. Determination of IPLT capacity

The capacity of the IPLT can be determined by calculating the number of septic tank facilities in the area. This data can be obtained from health centres. Furthermore, the calculation of IPLT capacity also requires information on the estimated number of occupants or users of the septic tank and the period of drainage of the sludge from the septic tank.

IPLT Capacity can be determined by the equation below:

$$\text{Capacity } (m^3/\text{day}) = \text{The number of population} \times \text{sludge volume} \quad (1)$$

C. Criteria of Design

Actual BOD Load can be determined by the equation below:

$$\text{Actual BOD load} = \frac{\text{Influent concentration of BOD} \times \text{WWTP capacity}}{\text{WWTP volume}} \quad (2)$$

Actual Volumetric Load can be determined by the standard which is about: 40 – 60 gram BOD/m^3.day

D. Structural Evaluation

There are several forms of testing methods that can be used, including local tests that are non-destructive such as ultrasonic and hammer tests, and tests that are semi-destructive to the overall components of the building being tested in the form of loading tests.

Non-Destructive Test is a material testing technique without damaging the test object. This test is carried out to ensure that the material we use is still safe and has not exceeded the damage tolerance limit.

3 RESULTS

IPLT Muara Fajar, in Pekanbaru City was built in 2006, with a capacity of 40 m^3/day. Location of the IPLT is in Muara Fajar Village, Rumbai Sub-district, Pekanbaru City, with Coordinates: 0 ° 38'43 "N 101 ° 26'31" E (BPS, 2016).

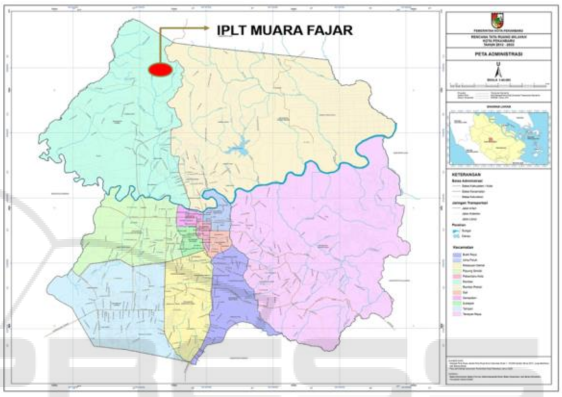

Figure 1. IPLT Muara Fajar Location

Figure 2. IPLT Muara Fajar Situation

This system of treatment plant was used a series of ponds; anaerobic pond, facultative pond, maturation pond and sludge drying bed. The anaerobic process at IPLT Muara Fajar was in the form of two enclosed anaerobic ponds built in 2012. These were the first processing units.

Figure 3. Anaerobic pond

Sewage treatment by high-rate anaerobic processes has been widely reported over the last decades as an attractive method for providing a good quality effluent. Anaerobic treatment owes to attractive advantages of energy saving, biogas recovery, and lower sludge production (Valentina & Maria, 2018). Another substrate for anaerobic co-digestion with sewage sludge may increase biogas production (Richard *et.al*, 2018). One of the most important factors which influence the sludge degradation efficiency of an anaerobic pond is the local climatic conditions (Mende, *et.al*, 1995). Temperature, in particular, plays a key role in the performance of such a system, since physicochemical and biological processes are greatly dependent on it.It is generally accepted that very little anaerobic degradation occurs at temperatures below 15ºC, since, at such temperatures, bacterial growth and metabolism are reduced (Tebbut, 1992; Lens, *et.al*, 2001). The types of bacteria involved in the anaerobic processes, namely the acidogenic and methanogenic bacteria, become more active under warm conditions.The optimum temperature range for mesophilic anaerobic degradation is considered to be between 30ºC and 35ºC (Tchobanoglous & Schroeder, 1987).

The aerobic process at IPLT Muara Fajar is in the form of an enclosed aerobic pond with an aerator to supply oxygen and is equipped with wasp nests as a medium for bacteria. Bacteria may live in wastewater and use wastewater for their nutrient for living and degrading the wastewater or sewage sludge. The bacterial diversity in landfill leachate showed the presence of *Planctomycetales*, *Verrucomicrobiales*, some *Desulfovibionaceae* sulfate-reducing bacteria and *Pseudomonas sp* (Heloisa *et.al*, 2012). Bacteria will be capable to store energy compounds if there is a proper feast in aerobic granular sludge reactors (Santo, *et.al*, 2016).

Figure 4. Aerobic pond

Facultative ponds function to decompose and reduce the concentration of organic matter in the treated wastes in anaerobic ponds. The process that occurs in this pond is a mixture of anaerobic and aerobic processes. In general, the facultative pond is stratified into three zones that have different degradation conditions and processes.

Figure 5. Facultative pond

The maturation pond is used to treat wastewater from facultative ponds and is usually referred to as maturation ponds. This pond is the final step of aerobic process of sewage so that it can reduce suspended solids (TSS) and BOD that remain from the previous processing unit.

The maturation pond results in dried sewage sludge that can be reused as compost. Sewage sludge is a by-product generated during wastewater treatment. Due to its high content of organic matter (OM) and plant nutrients (nitrogen, phosphorus, etc.), sewage sludge can be considered as a soil modifier or fertilizer (Dorota and Sandra, 2018).

Figure 6. Maturation pond

A. Analysis of IPLT Muara Fajar Service Area

The population of Pekanbaru City and its projections can be calculated with three general methods of analysis of population growth. They are arithmetic method, geometric method and least square method. Based on the results of a linear regression analysis of the three methods, the projection approach of population growth was geometrical with the correlation coefficient R2, which was 0.94. This is the basis of the population calculation until 2022, then the results will be the basis for calculating the intake of sewage waste for the IPLT Muara Fajar.

Based on the wastewater map in the city of Pekanbaru, the service area with of IPLT Muara Fajar covers a radius of 10-15 km from the IPLT facility itself. However, the service area must be described again to obtain the number of potential customers that can be served by the IPLT Muara Fajar. The following is an analysis of the area using the calculation method through satellite imagery with a radius limit starting from 0 - 5 kilometers then it is continued to a service area calculation with radius of 5-10 km.

Table 4. The number of potential customers based on the IPLT distance radius

No.	Distance from IPLT (km)	Consumers
1	0 – 1	139
2	1 - 2	200
3	2 - 3	542
4	3 - 4	660
5	4 - 5	835
6	5 - 6	1045
7	6 - 7	794
8	7 - 8	530
9	8 - 9	887
10	9 - 10	1154
Total		6786

We found that the number of potential customers based on the IPLT distance radius were 6,786 inhabitants, then these numbers were calculated to determine the IPLT capacity.

B. Determination of IPLT capacity

IPLT Capacity can be determined by the equation below:

Capacity =
The number of population x sludge volume (1)

$$\text{Capacity} = \frac{6{,}786 \times 2\ m^3/day}{3\ year \times 365\ day/year} = 12.39\ m^3/day$$

The IPLT capacity of 12.39 m^3/day can be used to treat municipal waste from potential costumers (see Table 4). Meanwhile, the initial IPLT Capacity was 40 m^3/day, so the population can be added to this IPLT, yielding 21,900 inhabitants.

$$\text{Capacity} = \frac{21{,}900 \times 2\ m^3/day}{3\ year \times 365\ day/year} = 40\ m^3/day$$

C. Criteria of Design

Laboratory Results of influent concentration BOD, COD and TSS were 3,500 mg/L, 5,300 mg/L and 100 mg/L respectively. From the Criteria of Design calculation, we found the appropriate dimension for these IPLT (table 5).

Table 5. Dimension of IPLT

Unit	Long (m^3)	Wide (m^3)	Deep (m^3)
First-stage anaerobic	7	3	3.3
Two-stage anaerobic	7	3	3.3
Aerobic biofilter	9.4	4	2
First-stage facultative basin	35	19	1.5
Two-stage facultative basin	35	19	1.5
Maturation basin	17	5	1

On table 6 we can see the result of laboratory test of inlet sludge :

Table 6. Laboratory Result

Parameters	Unit	Result	Methods
Physical			
Temperature	ºC	29	SNI-06-6989-23-2005
BOD	Mg/L	3,500	APHA 5210 B-2012
COD	Mg/L	5,300	APHA 5210 B-2012
TSS	Mg/L	100	APHA 2540 D-2012
Chemical			
Cadmium	Mg/L	<0.0001	APHA 311 B & 3030 F-2012
Chromium Hexavalent	Mg/L	0.0001	APHA 3500-Cr-B-2012
pH	-	5.9	APHA 4500 H* B-2012

Source : Health Agency of Pekanbaru City, 2016

Previous study showed that an effective first stage treatment process in waste stabilization ponds (WSP) systems is the low-rate anaerobic one in deep ponds with average hydraulic retention time of 1–4 days. The main advantage of a WSP system with a deep anaerobic pond is that it takes less area than systems without one, resulting in a considerable reduction in project expenditure (Loeh, 1974; Mara,et.al,197; Pecsod, 192). In the anaerobic pond, part of the suspended solids (SS) settles to the bottom, thus forming a sludge zone where it undergoes anaerobic degradation (Saqqar & Pescod, 1995).

D. Structural Evaluation

Design calculation showed that two-stage anaerobic unit with dimension of 7 x 3 x 3.3 m^3 can be operated by re-painting the unit, aerobic biofilter with the dimension of 9.6 x 4 x 2 can be operated by replacing new media and re-painting the unit. Two-stage facultative basin with the dimension of 35 x 19 x 1.5 m^3 must be re-built on the second basin due to heavy damage in the building structure. Meanwhile, maturation basin with the dimension of 17 x 5 x 1 m^3 must be re-built also due to heavy damage to the building structure. Based on the Criteria of Design calculation and Evaluation of the IPLT System, here are the designs of New IPLT of Muara Fajar:

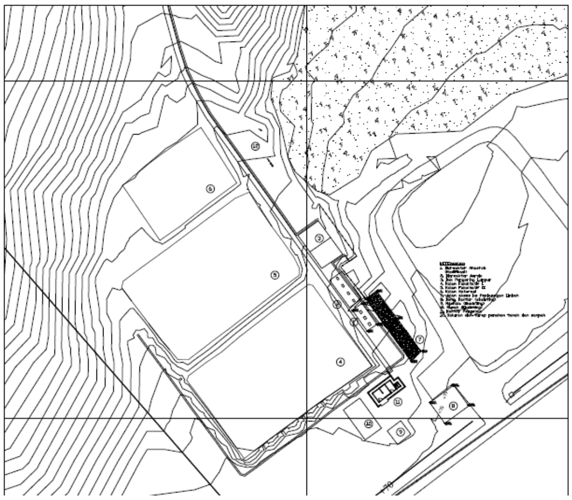
Figure 9. Lay Out of IPLT Muara Fajar

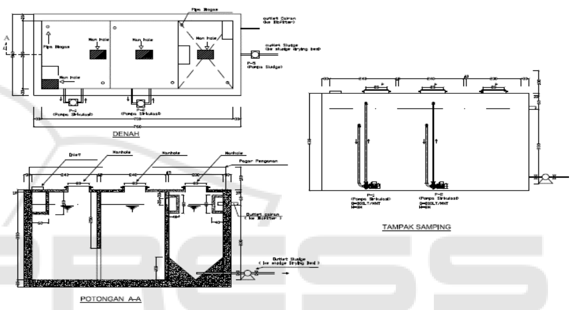

Figure 10. Anaerobic Pond

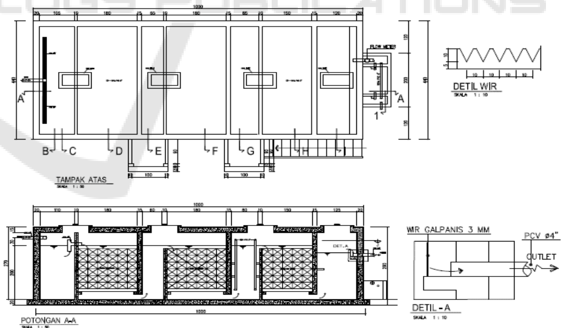

Figure 11. Aerobic Pond

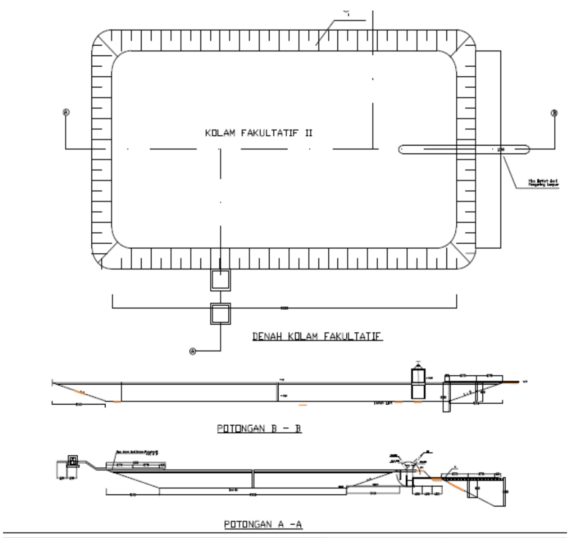

Figure 12. Facultative Basin

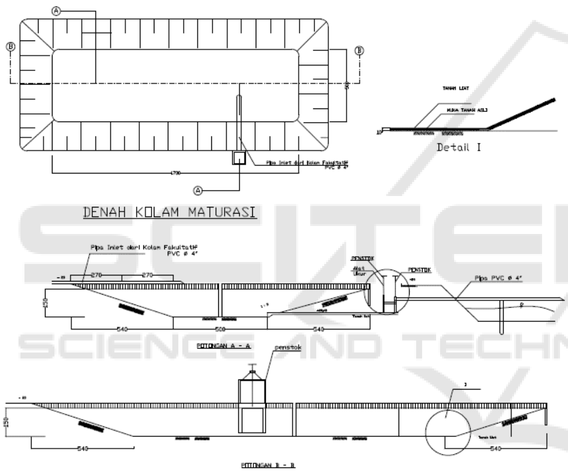

Figure 13. Maturation Basin

4 CONCLUSIONS

Design calculation showed that two-stage anaerobic unit with dimension of 7 x 3 x 3.3 m^3 can be operated by re-painting the unit, aerobic biofilter with the dimension of 9.6 x 4 x 2 can be operated by replacing new media and re-painting the unit. Two-stage facultative basin with the dimension of 35 x 19 x 1.5 m^3 must be re-built on the second basin due to heavy damage in the building structure. Meanwhile, maturation basin with the dimension of 17 x 5 x 1 m^3 must be re-built also due to heavy damage on the building structure.

With these volumes, the system can treat municipal sewage with capacity of 40 m^3/day from selected areas in Pekanbaru City, that are Rumbai District and Senapelan District with the population about 21,900 inhabitants.

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