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Design Evaluation of Biological Unit as a Basic Consideration to Determine the Design Criteria of Domestic Wastewater Treatment Plant at 1st Zone, Jakarta

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Abstract. The evaluation of existing Wastewater Treatment Plant (WWTP) is doing by evaluate the performance and design of biological unit. On design planning of WWTP, the biological process unit is the key role to reach the target of pollutant removal efficiency. The optimum design parameter of biological process unit could be attained from the real condition by doing evaluation of existing WWTP as a comparison. The selection of an appropriate existing WWTP is based on the similarity of region characteristic, typical activities of people who use the water and wastewater quality and characteristic, and it match to Tana Tinggi WWTP. Tana Tinggi WWTP has capacity 63.8 L/s that already serve 2785 home connections system or 77% of serving area of Tangerang City. The process and operation units are consist of screening, activated sludge, clarifier and sludge handling system. The evaluation of activated sludge gives the data that BOD loading rate is 0.32 Kg/m^3.day, MLSS is 3920 mg/L, F/M ratio is 0.036 kg BOD/kg MLSS.day, hydraulic retention time (HRT) is 6.78 hours and sludge age is 5.16 days. From the evaluation results there are three parameters that can be determine as design criteria and will be apply for design of biological process unit. The parameters are MLSS 3900 mg/L, HRT 6 hours and sludge age 5 days. In otherwise, the F/M ratio doesn't prove the appropriate value and it show that the activated sludge of existing WWTP is leak of nutrition that is necessary for microorganism metabolism.

1. Introduction

Design of Waste Water Treatment Plant (WWTP) has to recognize some points, they are (1) the quality and flow of wastewater that will be service by WWTP (2) the quality of wastewater influent before the treatment (3) data to make design of the quality of wastewater effluent that must be reach. The quantity of wastewater is one of the important point to make a design because the number of wastewater will determine the size of every single units processes and operation and also hydraulic design of WWTP [1].

Tana Tinggi WWTP, that located in Tangerang City – Indonesia is one of domestic WWTP will be comparison design for WWTP 1st Zone Jakarta. Tana Tinggi WWTP is domestic scale with the off-site system and the facilities of wastewater treatment lies outside of percil or divided by the distance between pipe systems and houses then together deliver to WWTP. The service of Tana Tinggi WWTP is specific for Sukasari Village and Babakan Village of Tangerang City. The wastewater capacity is 230m³/hour

(63.8L/sec). Nowadays Tana Tinggi WWTP service of 2758 house connections or 10646 people (77%), 1154 house connection of Sukasari Village and 1204 house connection of Babakan Village.

The total of length pipe system from Sukasari Village to WWTP is 20.9km with total manhole is 525 and Babakan Village only has 1.8km of pipe systems with 62 manhole.

The Tana Tinggi WWTP is being one of comparison WWTP because of the level activities is similar with 1st Zone DKI Jakarta. The level activities of the city is categorized as metropolitan city so that the quality and the fluctuation of wastewater are similar between Tangerang City and 1st Zone of DKI Jakarta.

Activated sludge is the most used as biological processes to remove carbon and nitrogen [2]. Because of that, activated sludge has the large number of existing facilities, and need research effort to be focused on optimizing the operation strategies or improve the plant design. Some cases the WWTP treat high level of wastewater poorly because of the poor design, operation or maintenance of treatment units [3].

That's why on this research will be focused on evaluation the biological unit as the main process unit to remove the organic pollutant from domestic wastewater and find the ideal criteria to design the WWTP.

2. Materials and methods

In this design the collecting data will be get from direct observation to the Tana Tinggi WWTP of Tangerang City (-6.174735, 106.647593). There are 3 main point of data that will be taken from comparison WWTP:

- The Quality of Wastewater
- Fluctuation of the Concentration BOD dan TSS
- Variable Design of Biological Units

The analysis of design variable of existing biological units aims to know the design parameter is meet the standard of design criteria as the consideration to choose the proper value, and as the evaluation of existing WWTP efficiency to find the best alternative of design WWTP 1st Zone DKI Jakarta.

Table 1. Design variable analysis of biological units.

Design Variable	Analysis Data
BOD and TSS Loading Rate	- Inlet flow of wastewater - Inlet concentration of BOD and TSS - Volume of reactor
Mix Liquor Suspended Solids (MLSS)	The mass of total suspension solid in aeration tank
Mix Liquor Volatile Suspended Solids (MLVSS)	The mass of total suspension solid that will volatile
Food-to-Microorganism Ratio (F/M)	- Inlet flow of wastewater of aeration tank - Inlet concentration of BOD and TSS - Outlet concentration of BOD and TSS from aeration tank - Volume of reactor - The mass of total suspension solid in aeration tank
Hydraulic Retention Time (HRT)	- Inlet flow of wastewater of aeration tank - Volume of reactor
Hydraulic Recycle Ratio	- Sludge that recirculate to aeration tank - Inlet flow of wastewater of aeration tank

Table 1. Cont.

Design Variable	Analysis Data
Sludge Age	• The mass of total suspension solid in aeration tank • Effluent solid suspension • Sludge solid suspension • Influent flowrate • Effluent flowrate • Volume of reactor

3. Results and discussion

3.1. Analysis data of wastewater quality of tana tinggi WWTP

The source of wastewater that will be treated in Tana Tinggi WWTP is come from houses type of medium to low income. The distribution of wastewater in piping systems was separated from drainage system. The wastewater come to inlet of Tana Tinggi WWTP consist of grey water and black water from Sukasari Village and Babakan Village. Those wastewater will be collected in collection tank equipped bar screen to screen the course materials such as garbage. Then the wastewater will be pump using 2 submersible pump and the capacity 38L/sec (136.8m^3/hour) and 44L/sec (158.4m^3/hour) to WWTP units of treatment by pipe 1.5km length. The analysis of wastewater quality will be done by laboratory analysis of 9 parameter of wastewater and 3 of them are temperature, pH and Dissolve oxygen (DO) in situ analysis. The results of wastewater analysis can be seen in Table 2.

Table 2. Wastewater quality of inlet tanah tinggi WWTP.

Parameter	Units	Quality of Wastewater				Quality Standard
		09.10	12.35	16.00	Average Concentration	
pH	-	7.02	6.98	6.98	6.99	*6-9
Temerature	°C	29	31	29	30	-
DO	mg/L	1.9	1.9	1.9	1.9	-
TSS	mg/L	32	28.6	36	**32.20**	*30
COD	mg/L	88.61	109.06	95.42	**97.70**	**80
BOD$_5$	mg/L	43.40	53.40	48.40	**48.40**	*30
Oil/Grease	mg/L	1.25	0.44	0.37	0.69	*5
Surfactant	mg/L	0.34	1.70	2.60	1.55	**2
Ammoniac	mg/L	0.35	0.24	0.25	0.28	*10

Regulation of Environmental Ministry 68/2016

*** Regulation of Governor DKI Jakarta 122 /2005* [4]

From **Table 2**, it can be concluded that some parameters are above the quality standard, such as TSS, COD and BOD$_5$ so that it become the concern of treatment and design. The ratio of BOD/COD wastewater influent is 0.49, it is describe that typical of wastewater is biodegradable and the wastewater could be treat by biological treatment unit [5].

Table 3 show that the characteristic of domestic wastewater as generally in Indonesia, especially Jakarta. By making the comparison of wastewater quality from Table 2 and Table 3 the characteristic of wastewater that will be used is show by Table 3 from BPPT (2011). It because of the Tana Tinggi wastewater quality is too low for the high activities as metropolitan city. And perhaps the sampling just doing once in one time, the safety factor is to low and make the meaning difference.

Table 3. Characteristic of the wastewater.

No	Parameter	Units	Average Concentration	Quality Standard
1	TSS	mg/L	119.25	*30
2	COD	mg/L	615.01	**80
3	BOD$_5$	mg/L	353.43	*30
4	Oil/Grease	mg/L	63.00	*5
5	Surfactant	mg/L	5.73	**2
6	Ammoniac	mg/L	84.76	*10

3.2. Analysis data of flow rate, and concentration of BOD and TSS fluctuation

The data of flow rate fluctuation of influent with the concentration of BOD and TSS fluctuation will be used to design the equalization tank. These unit is important to handle the fluctuation condition so that could be increase the performance of treatment process and could be decrease the cost of operation. The main function of equalization tank is to prevent shock loading condition for biological treatment.

The waste water will deliver to sewerage system to WWTP as final. The fluctuation of waste water has unstable of flow and concentration of the characteristic because of the human activities that always different by the time. The factor that will be effect of mass loading of wastewater are (1) repeating activities by the people (2) the seasonal condition that lead long term, and (3) activities of industry around the service area that cause the short term or long term has different mass loading variation [6].

Table 4. Fluctuation of flow rate, BOD5 and TSS.

Time (Hours)	Q Inflow (%)	BOD mg/L	BOD %	TSS mg/L	TSS %
07.20 - 08.20 am	5.54%	353.4	4.17%	106.4	3.72%
08.20 - 09.20 am	4.40%	385.5	4.55%	106.4	3.72%
09.20 - 10.20 am	5.64%	417.7	4.92%	162.4	5.68%
10.20 - 11.20 am	6.53%	353.4	4.17%	145.6	5.09%
11.20 - 12.20 am	5.82%	289.2	3.41%	173.6	6.07%
12.20 - 01.20 pm	5.42%	321.3	3.79%	151.2	5.28%
01.20 - 02.20 pm	4.87%	321.3	3.79%	173.6	6.07%
02.20 - 03.20 pm	5.19%	353.4	4.17%	100.8	3.52%
03.20 - 04.20 pm	4.15%	257.0	3.03%	184.8	6.46%
04.20 - 05.20 pm	3.27%	257.0	3.03%	173.6	6.07%
05.20 - 06.20 pm	5.18%	353.4	4.17%	207.2	7.24%
06.20 - 07.20 pm	5.50%	321.3	3.79%	212.8	7.44%
07.20 - 08.20 pm	3.46%	642.6	7.58%	240.8	8.41%
08.20 - 09.20 pm	2.85%	610.5	7.20%	112.0	3.91%
09.20 - 10.20 pm	2.66%	610.5	7.20%	84.0	2.94%
10.20 - 11.20 pm	3.67%	642.6	7.58%	67.2	2.35%
11.20 - 00.20 am	2.91%	546.2	6.44%	56.0	1.96%
00.20 - 01.20 am	2.26%	546.2	6.44%	56.0	1.96%
01.20 - 02.20 am	2.26%	160.7	1.89%	50.4	1.76%
02.20 - 03.20 am	2.37%	160.7	1.89%	39.2	1.37%
03.20 - 04.20 am	2.50%	128.5	1.51%	61.6	2.15%
04.20 - 05.20 am	2.90%	160.7	1.89%	67.2	2.35%
05.20 - 06.20 am	4.50%	160.7	1.89%	72.8	2.54%
06.20 - 07.20 am	6.15%	128.5	1.51%	56.0	1.96%
TOTAL	100.00%	8482.3	100%	2862.0	
Average		353.4		119.3	

3.3. Analysis data of variable design of the activated unit

The design of variables of biological processing in Tana Tinggi WWTO will be used as reference for design criteria of IPAL Domestic Planning in Zone 1st of DKI Jakarta. The following design of process variables modification of active sludge in the form of aeration tank used:

1) BOD Loading Rate

- Flowrate = 430 m^3/hours
- Concentration of BOD inlet (S$_o$) = 48,4 mg/L   = 48.4 × 10^{-3} kg.BOD/m^3
-
- Volume of reactor   = 1560
- $BOD \ Loading \ Rate = \dfrac{Q \times S_o}{V}$ $0,32 \ \dfrac{kg}{m^3} days$

2) Mix Liquor Suspended Solids (MLSS)
   MLSS (total of suspension solid organic matter + minerals + microorganisme) [7].

   MLSS *inlet clarifier*   = 3920mg/L

3) Mix Liquor Volatile Suspended Solids (MLVSS)
   MLVSS contain of organic matter not microorganisme + life microorganisme + dead microorganisme + dead cell [7].

   MLVSS *inlet clarifier* = 3054 mg/L

4) MLVSS/MLSS

   MLVSS/MLSS *inlet clarifier* = 0.78
   The standard value of ratio MLVSS/MLSS is 0.8 [8].

5) Food-to-Microorganism Ratio (F/M)
   Flow rate = 230 m^3/hours = 5520 m^3/days
   Concentration of BOD *inlet* (S$_o$) = 48,4 mg/L = 48,4 × 10^{-3} kg.BOD/m^3
   Concentration of BOD *outlet* (S) =8,74 mg/L = 8,74 × 10^{-3} kg BOD/m^3
   Volume of reactor = 1560 m^3
   MLSS   = 3920 mg/L = 3,92 kg MLSS/m^3

   $$= \frac{5520 \ \frac{m^3}{hari} \left(48,4 \times 10^{-3} \frac{kg \ BOD}{m^3} - 8,74 \times 10^{-3} \frac{kg \ BOD}{m^3}\right)}{3,92 \ \frac{kg \ TSS}{m^3} \times 1560 \ m^3}$$

   $$= 0,036 \ \frac{kg \ BOD}{kg \ MLSS} \ day^{-1}$$

6) Hydraulic Retention Time (HRT)
   HRT   = V/Q = 1560 m^3/ 230 m^3/jam
   HRT = **6.78 hours**

7) Hydraulic Recycle Ratio

   $$= \frac{volume \ of \ sludge \ recirculation}{volume \ of \ wastwater \ oxidation \ pond \ inlet}$$

   $$= \frac{187 \ m^3/hours}{230 \ m^3/hours}$$

   $$= 81\%$$

8) Sludge Age
   Q *effluent*   = 240 m^3/jam = 5760 m^3/day
   Q *wasting*   = 190 m^3/jam = 72 m^3/day
   SS$_{effluent}$ = 4,30 mg/L = 4,30 × 10^{-3} kg/m^3
   SS$_{waste}$ = 16100 mg/L = 16,1 kg/m^3

Volume reactor = 1560 m^3
MLSS   = 3920 mg/L = 3,92 kg/m^3

$$Sludge\ Age = \frac{MLSS \times V}{(SS_{eff} \times Q_{eff}) + (SS_{wa} \times Q_{wa})}$$

$$= \frac{3,92\ \frac{kg}{m^3} \times 1560\ m^3}{(4,30 \times 10^{-3}\ \frac{kg}{m^3} \times 5760\ m^3/day) + (16,1\ \frac{kg\ BOD}{m^3} \times 72\ m^3/day)}$$

$$= 5.16\ days$$

From the analysis of the calculation data above, there are 2 (two) parameters that theoretically did not meet the design criteria criterion that is the ratio of F / M and the sludge age, but actually the effluent of Tana Tinggi WWTP has meet the quality standard. Theoretically the value of the F/M ratio is too low describes there are too much nutrients consumed by microbes per unit time. The sludge age will affect the duration of deposition of the sludge. To obtain effective sedimentation, generally the age of sludge is designed 20-30 days for oxidation ditch [9].

4. Conclusions

The evaluation of activated sludge gives the data that BOD loading rate is 0.32 Kg/m^3.hari, MLSS is 3920 mg/L, F/M ratio is 0.036 kg BOD/kg MLSS.day, hydraulic retention time (HRT) is 6.78 hours and sludge age is 5.16 days. From the evaluation results there are three parameters that can be determine as design criteria and will be apply for design of biological process unit. The parameters are MLSS 3900 mg/L, HRT 6 hours and sludge age 5 days. In otherwise, the F/M ratio doesn't prove the appropriate value and it show that the activated sludge of existing WWTP is leak of nutrition that is necessary for microorganism metabolism.

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