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Primary Sedimentation Unit Design at the Glycerin Production Wastewater Treatment Plant at PT X

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Abstract.
PT X needs Waste Water Treatment Plant (WWTP) to reduce the high value of TSS and organic matter levels for the wastewater of glycerin production. The objective of the experiment is to design the dimensions of the primary sedimentation unit at PT X. This design is expected to reduce wastewater TSS levels up to 50 to 70 percent and BOD levels up to 25 to 40 percent. The design method in this experiment include determining the quantity of wastewater discharged by PT X per day through production operations, quality testing wastewater, and designing primary sedimentation units. PT X wastewater quality testing includes measuring pH, ammonia, TSS, COD, BOD, oil & grease. The parameters are determined based on the basic oleochemical industry quality standard. The primary sedimentation unit design in WWTP PT X was rectangular. The quantity of discharge of wastewater entering the primary sedimentation tank of 0.00139 m^3/second and the detention time is designed for 4 hours. Sedimentation tank volume is based on the calculation of 10 m^3 with a multiplier of 1.1 so that the actual volume of the sedimentation tank is 11 m^3. The result of this design experiment are the length of the tub is 4 m, the width of the tank is 1.1 m, 2.5 m deep, and 0.5 m freeboard. TSS level allowance and BOD that occurs in the primary sedimentation unit are the TSS level of 62.99% and BOD levels of 40.82%.

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1 Introduction

PT X has now built a new production plant, namely the manufacture of glycerin, so this plant does not have a WWTP. Glycerin waste generated from this plant is only accommodated in a tub. The resulting waste contains high organic matter and Total Suspended Solid (TSS) and has a strong foul odor. The high content of TSS and organic matter if it enters the environment will damage the aquatic ecosystem. High levels of TSS can cause water turbidity caused by the addition of solid materials, both organic and inorganic materials found in wastewater without treatment. Turbidity in these waters will block the entry of sunlight which will reduce the ability of aquatic plants to carry out the photosynthesis process which has an impact on decreasing oxygen content in the aquatic environment. The content of organic matter and TSS needs to be reduced in the WWTP system before being discharged into water bodies. One of the processes that can reduce the high levels of TSS and organic matter is primary sedimentation in the physical treatment process. Primary sedimentation can reduce TSS levels up to 50 to 70 percent and Biochemical Oxygen Demand (BOD) levels up to 25 to 40 percent [1].

This experiment aims to design the dimensions of the primary sedimentation unit at the WWTP at PT X. The design in this experiment was made based on the quantity and quality of the wastewater produced. This design is expected to reduce the TSS content of PT X's wastewater by 50 to 70 percent and BOD levels by 25 to 40 percent.

2 Method

The design stages in this research included testing the quantity, testing the quality of wastewater, and designing the primary sedimentation unit. The quantity of PT X's wastewater was the amount of wastewater released by PT X per day through production operations. Tested the quality of PT X wastewater including measured pH [2], ammonia [3], TSS [4], COD [5], BOD [6] and oil & fat testing [7].

2.1 Wastewater Quantity Test

Data on the quantity of discharge of PT X's wastewater per day was converted into units of m^3/second by multiplying the wastewater discharge by the conversion factor and peak factor to determine the peak discharge. The formula for determining the conversion of discharge to m^3/second and peak discharge was as follows:

Discharge conversion:

$$Q_{average}\ (m^3/seconds) = Q_{average}\ (m^3/day)\ x\ 1\ day/86400\ seconds \quad (1)$$

Peak discharge

$$Q_{peak}\ (m^3/seconds) = Q_{average}\ x\ peak\ factor \quad (2)$$

Notes:

$Q_{average}$ = Debit rata-rata air limbah (m^3/hari) / (m^3/detik)

Q_{peak} = Peak discharge (m^3/detik)

2.2 Wastewater Quality Test

The tested wastewater quality parameters are determined based on the basic oleochemical industry quality standards according to the Regulation of the Minister of Environment Number 5 of 2014 [8].

2.2.1. pH measurement

The electrodes were cleaned using dry tissue, then electrodes were rinsed with distilled water. The electrode is immersed in the test sample until the pH meter shows a constant reading.

2.2.2. Ammonia Measurement

The visible light spectrophotometer was turned on and the HR TNT ammonia program was selected. A total of 0.1 mL of distilled water was added for blank measurement and 0.1 mL of filtered sample for measurement of test samples into a tube containing reagents for ammonia testing. The solid reagents of ammonia salicylate and ammonia cyanurate were added to the test tube. The tube was tightly closed and shake until all solids were completely dissolved. The sample/blank to be tested is stored on a test tube rack for 20 minutes. The outside of the tube containing the blank sample was cleaned with dry tissue and inserted into the sample holder on a visible spectrophotometer. Then the zero button is pressed until the screen shows the number 0.0 mg/L NH3-N. The procedure is repeated for sample measurement and the read button is pressed until the display shows the sample NH3-N value.

2.2.3. TSS Measurement

The visible light spectrophotometer is turned on and the 630 Suspended Solids program is selected. The sample to be tested is shaken first. A total of 10 mL of distilled water was added for blank measurement and 10 mL of test sample for sample measurement into a 10 mL cuvette bottle. The bottle is tightly closed and cleaned using a tissue. The bottle containing distilled water was put into the sample holder on the spectrophotometer and the zero button was pressed until the screen showed the number 0.0 mg/L TSS. The procedure was repeated for sample measurements.

2.2.4. COD Measurement

The sample of PT X wastewater to be tested is filtered first and 0.2 mL pipetted into a reflux tube containing High Range Plus (HR+) reagent. Wipe the outside of the reflux tube with a paper towel, then invert it several times to ensure that the tube is tightly closed. The sample was heated for 2 hours in a COD reactor at a temperature of 150^{o}C. The reactor was turned off after the heating ended and the sample was left for approximately 20 minutes until the sample temperature was less than 120^{o}C. The sample is taken after the temperature drops and is homogenized (some samples will produce a precipitate). The sample is stored on a test tube rack until the sample temperature reaches room temperature. COD levels were measured using a visible spectrophotometer. The spectrophotometer is turned on and the program is selected according to the range of COD levels to be measured. The tube containing the blank sample was cleaned from the outside with dry tissue and inserted into the tube holder. The zero button is pressed until the display shows the number 0 mg/L COD. The procedure is repeated for sample testing and the read button is pressed until the screen shows the COD content of the sample being tested. For the use of the HR+ range, the value of the COD content obtained is multiplied by 10 as the final value of the sample COD content. The description of the range of COD levels can be seen in Table 1.

Table 1. Range of COD Content Values

No	Range of COD. Content Values (mg/L)	Add sample/blank (mL)	Wavelength (nm)
1	LR (3 – 150)	2	420
2	HR (20 – 1500)	2	620
3	HR^{+} (200 – 15000)	0,2	620

Source: HACH Method 8000 Reactor Digestion, 2014.

2.2.5. Determination of BOD

The test sample solution was conditioned at a temperature of 20 $^{o}C \pm 3\ ^{o}C$, then pH measurements were carried out, if the pH value of the solution was not in the range of 6.0 - 8.0 then the test sample solution was added with a solution of H_2SO_4 or NaOH so that the pH of the solution was within that range. If the solution contains interfering compounds such as chlorine, hydrogen peroxide, supersaturated dissolved oxygen, and other toxic compounds, it is necessary to remove them first using the procedure stated in SNI 6989.72:2009. The test sample solution was diluted by adding each 1 mL of phosphate buffer solution, $MgSO_4$, $CaCl_2$, $FeCl_3$, and microbial seeds. The solution was calibrated using oxygen-saturated mineral-free water up to a volume of 1 liter. The number of dilutions of the BOD test sample can be seen in Table 2.

Table 2. Total Dilution of BOD Test Samples

Type of test sample	Concentration of test sample (%)	Dilution factor
Highly concentrated industrial	0,01-1,0	10000-100
Precipitated waste	1,0-5,0	100-20
Effluent from biological processes	5,0-25	20-4
River water	25-100	4-1

Source: Standard Methods for the Examination of Water and Wastewater 21st Edition, 2005; Biochemical Oxygen Demand [9].

Based on Table 2, the number of dilutions of the BOD test sample used is a very concentrated industrial waste because the waste produced by PT X contains high pollutants and includes concentrated waste. The diluted sample was poured into two BOD bottles for DO0 and DO5 testing to overflow, then the bottles were closed carefully to avoid the formation of air bubbles. The bottle is shaken several times and mineral-free water is added around the closed mouth of the bottle. DO5 bottles were stored in an incubator at a temperature of 20°C ± 1°C for 5 days. Dissolved oxygen was measured in DO0 bottles using a calibrated DO meter and DO5 which had been incubated for 5 days. Sample blanks were tested using a diluent without a sample and the same procedure was carried out with the sample test. The BOD5 value of the test sample can be calculated as follows

$$BOD_5 = \frac{(DO_0 - DO_5) - \left[\frac{(B_0 - B_5)}{V_b}\right] V_c}{P}$$

Notes:

BOD_5= BOD_5 value of the test sample (mg/L);

DO_0 = dissolved oxygen content of the test sample before incubation/0 days (mg/L);

DO_5 = dissolved oxygen content of the test sample after incubation/5 days (mg/L);

B_0 = blank dissolved oxygen level after incubation/5 days (mg/L);

B_5 = blank dissolved oxygen level after incubation/5 days (mg/L);

V_b = Volume of microbial suspension (mL) in blank DO bottles;

V_c = Volume of microbial suspension in the test sample vial (mL);

P = Comparison of the volume of the test sample (V_1) per total volume (V_2).

2.2.6. Testing for Oil and Fat Content

The test sample solution was put into a separatory funnel of as much as 250 mL. After that, 30 mL of n-hexane was added to the separating funnel. The sample was shaken vigorously for 2 minutes and allowed to separate the layers. If a clear (translucent) solvent layer is not obtained and there is an emulsion of more than 5 mL, then centrifugation is carried out for 5 minutes at 2400 rpm. The centrifuged material was transferred to a separatory funnel and the solvent layer was dried through a funnel with filter paper and 10 g Na_2SO_4, both of which had been previously washed into a clean, weighed flask.

The aqueous layer and the residual emulsion or solids in the separatory funnel were combined and extracted 2 times with 30 mL solvent for each repetition. The procedure is repeated if there is still an emulsion in the next extraction step. The extraction results were combined into a distillation flask and distillation was carried out with a water bath at a temperature of 70°C. The distillation process was stopped when it was seen that the solvent condensation had stopped. The distillate was transferred to a cup and dried in an oven at a temperature of (70±2)°C for 30-45 minutes. The cup was transferred to a desiccator for approximately 15 minutes, then weighed using an analytical balance until a constant weight was obtained. The results of the calculation of the determination of oil and fat content are obtained through the equation:

$$\text{Oil and fat content (mg/L)} = \frac{(A-B) \times 1000}{\text{mL of test sample}}$$

Noted:

A = cup weight + extract (mg);

B = weight of empty cup (mg).

2.3 Designing Primary Sedimentation Unit

The primary sedimentation unit in the PT X WWTP system was designed after the chemical process that occurred in the equalization tank, namely the neutralization process. The design carried out refers to the method of designing a wastewater treatment plant [10], and a thesis on the design of a wastewater treatment plant [11] and also the journal on the design of rectangular sedimentation units in wastewater treatment plants [12].

The stages of the primary sedimentation unit design are as follows:

1. Determination of the quantity and quality of the study of industrial wastewater as described in the previous point.
2. Determination of mass balance and hydraulic flow based on the journal Concept of Mass Balance and Hydraulic Flow to determine flow rate, substrate concentration, and solids concentration entering the primary sedimentation tank.
3. Calculating the dimensions of the primary sedimentation unit based on the quantity and quality of wastewater that has been analyzed through mass balance and hydraulic flow.

The design of the dimensions of the sedimentation tank unit refers to several criteria that have been regulated or determined by experts. These criteria are useful as a basis for designing so that the expected processing effectiveness can be achieved.

Sedimentation tank design criteria can be seen in Table 3.

Table 3. Sedimentation Tank Design Criteria Parameters Symbol Unit Quantity

No	Parameters	Symbol	Unit	Quantity
A	Sedimentation			
1.	decrease in SS efficiency		%	30 - 70
2.	decrease in BOD efficiency		%	30 - 40
3.	Detention time	Td	hour	1,5 – 2,5
4.	Overflow rate	Vo	m^2/m^3.hour	30 – 50
5.	Overload			
	For Qr 44 l/s	Qr	m^2/m^3.day	124
	For Qr > 44 l/s	Qr	m^2/m^3.day	186
6.	The ratio of length: width		M	4:1 - 6:1
7.	Ratio	M		4,2-25

No	Parameters	Symbol	Unit	Quantity
	Width: depth			
8.	Depth	D	M	3 - 4,5
9.	Length	P	M	15 – 90
10.	Width	L	M	3-24
11.	Base slope	S	%	1-2
12.	Inlet speed	V	m/s	0,3

Source: Asmadi & Suharno, 2012

In designing a sedimentation tank, it is necessary to understand the zones in the sedimentation tank. There are 4 zones in the primary sedimentation tank, namely the inlet, Transition, Sludge, and outlet zones. The four zones need to be calculated separately so that the deposition process is not disturbed. The primary sedimentation tank sketch can be seen in Figure 1.

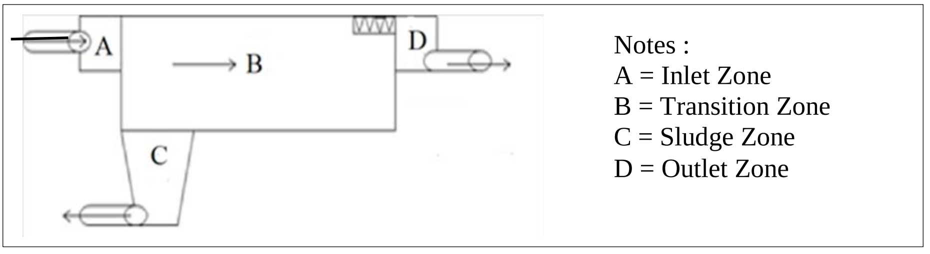

Fig. 1. Sketch of the Primary Sedimentation Tank

The zones are calculated sequentially starting from the inlet zone, deposition zone, mud zone, and outlet zone to facilitate the planning of sedimentation unit dimensions.

3 Results and Discussion

The primary sedimentation unit is designed to reduce TSS concentrations by 50 to 70 percent and BOD levels by 25 to 40 percent through a physical process without the addition of chemicals. In designing the primary sedimentation unit, several factors need to be considered as the basis for designing and determining the dimensions of the unit. These factors include the quantity and quality of wastewater discharge.

The quantity of PT X's wastewater is known from the average discharge of 60 m3/day = 0.000694 m^3/second. The peak discharge is assumed to be twice the average discharge = 0.00139 m^3/second.

The results of the wastewater quality test can be seen in Table 4.

Table 4. Data of PT X. Wastewater Quality Test Results

No.	Parameters	Test Result Value	Quality Standards
1.	BOD (mg/L)	5160	125
2.	COD (mg/L)	11680	250
3.	TSS (mg/L)	448,3	150
4.	Oil & Grease (mg/L)	0,7912	15
5.	Ammonia (NH_3-N) (mg/L)	4,4	10
6.	pH	2,59	6 – 9

Table 4. shows that several parameters such as pH, COD, BOD, and TSS have exceeded the quality standard values stipulated by the Regulation of the Minister of the Environment Number 5 of 2014 concerning the quality standards of industrial wastewater so that treatment processes need to be carried out to reduce the high content. One of them is by making a primary sedimentation unit. The process in the primary sedimentation unit designed is an anaerobic process using the Internal Circulation UASB (IC reactor) followed by an anaerobic process using activated sludge. In the mass balance calculation, there are two parameters are used as a reference, namely the BOD parameter which is used to represent the content of organic matter in wastewater, and TSS as an indicator of the presence of suspended solids.

The configuration design of the PT X treatment unit consists of an inlet tank, equalization, primary sedimentation, anaerobic, aerobic, secondary sedimentation, and disinfection, as well as a thickener sludge treatment unit and filter press. The sedimentation tank in this experiment is designed to be rectangular because it has several advantages over the circular basin, including the rectangular basin requires less land area than the circular basin and the surface area of the sedimentation tank is larger than the circular basin which allows higher processing efficiency. The effectiveness of the sedimentation process in separating solid particles is influenced by the Reynolds number and Froude number [10]. The Reynolds number to achieve the best conditions in the sedimentation process is < 2000 or in laminar conditions, while the Froude number for sedimentation is > 10-5. In addition, the effectiveness of the sedimentation process can also be increased by adding a plate settler [1].

The top view of the design of the primary sedimentation tank that has been made can be seen in Figure 2.

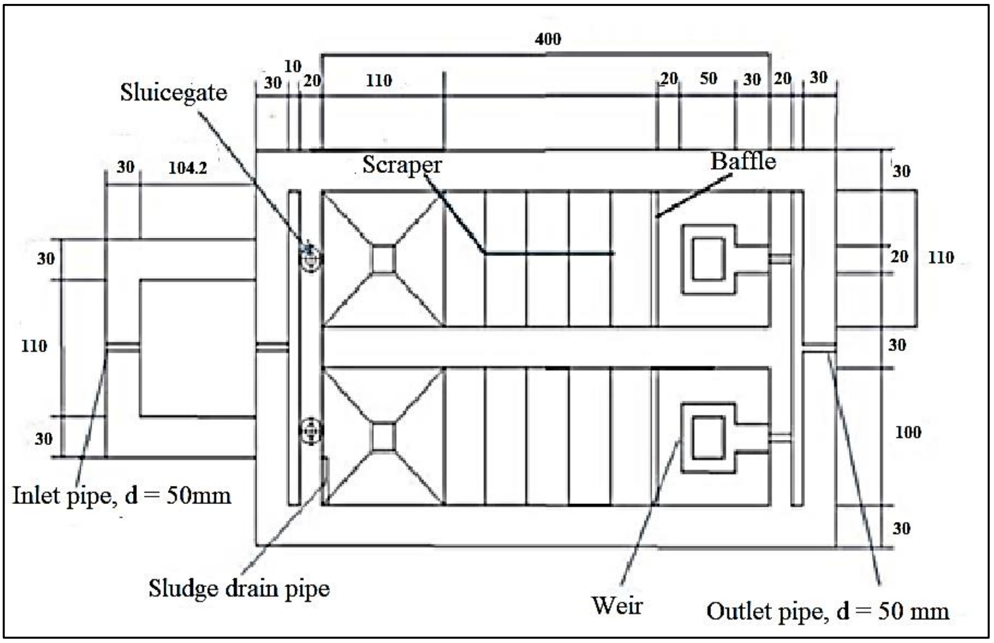

Fig. 2. Top View of Primary Sedimentation Tank Design

Based on Figure 4. it is clear how wastewater flows from the inlet zone to the outlet zone. The depth of each zone and the shape of each zone can be seen in the side view of the primary sedimentation tank presented in Figure 3.

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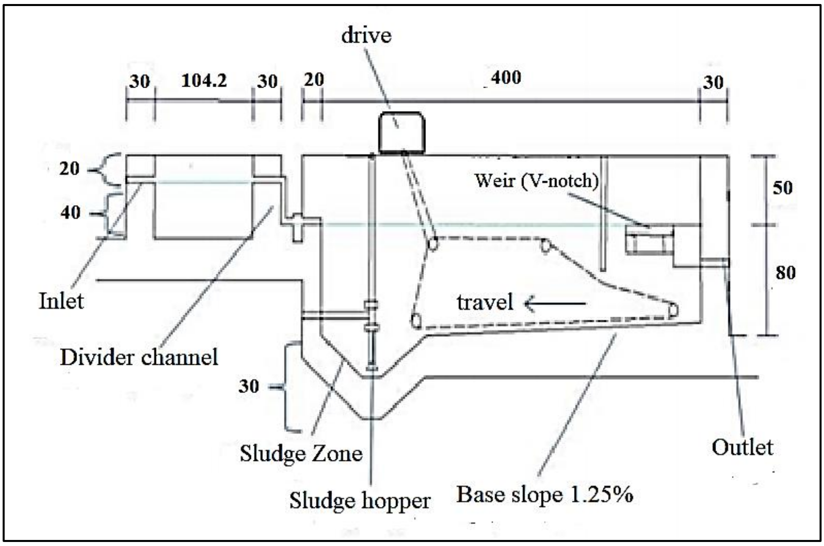

Fig. 3. Side View of Primary Sedimentation Tank

The primary sedimentation unit consists of 4 zones, namely the inlet zone, sedimentation zone, sludge zone, and outlet zone, each designed based on each zone and calculated separately.

3.1 Inlet Zone

The inlet zone consists of a Transitional/Gathering Tub, Dividing Channel, and Sluice gate. Based on the calculation results, the values of Nre and Nfr have met the criteria, namely Nre<2000 and Nfr>10-5. The Nre value in the <2000 deposition zone indicates laminar flow conditions, while the Nfr value >10-5 indicates no short flow in the transition tank. The sketch of the Inlet zone can be seen in Figure 4.

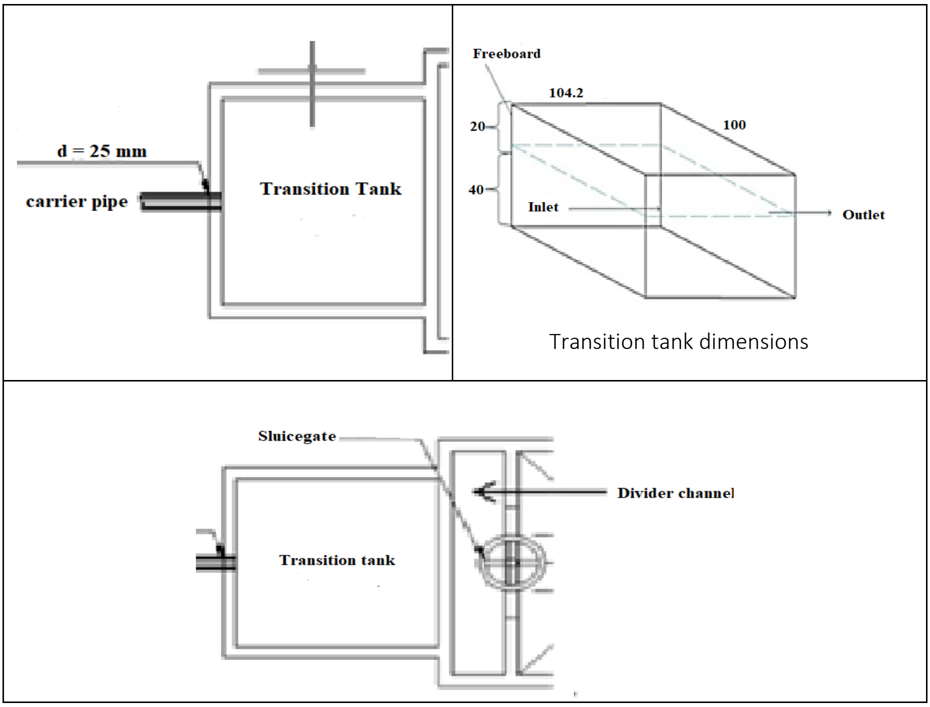

Fig. 4. Inlet Zone

3.2 Sedimentation Zona

Based on the calculation results, the Nre and Nfr values have met the criteria, so the perforated baffle does not need to be installed at the channel inlet. The value of Nre at deposition < 2000 indicates laminar flow conditions. Meanwhile, the Nfr value > 10-5 indicates that there is no short flow in the primary sedimentation tank.

A sketch of the design of the sedimentation basin zone can be seen in Figure 5.

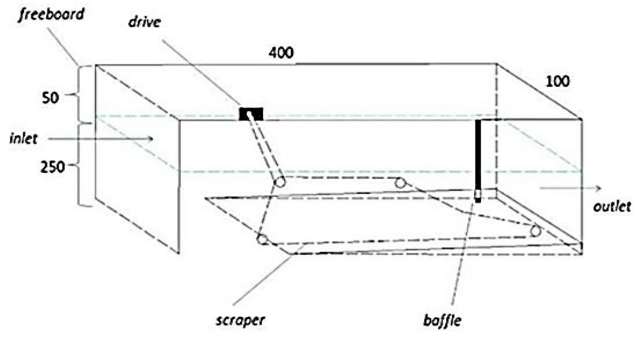

Fig. 5. Design of Deposition Zone Dimensions

The mud zone is designed with a height not exceeding 2/3 of the height of the deposition zone. Based on the calculation results, the amount of TSS that was set aside was 16.93 kg/day which resulted in a mud volume of 2.1 m3. The draining time was carried out 6 times, i.e. every 4 hours. The mud zone sketch can be seen in Figure 6.

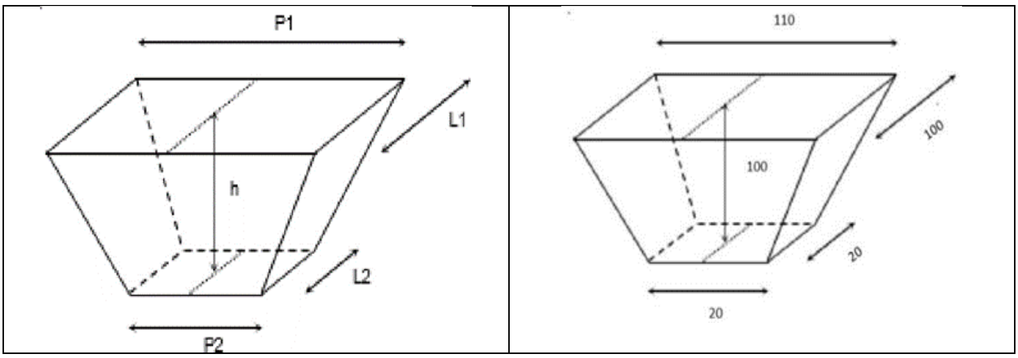

Fig. 6. Sludge Zone Cross-sectional Space Sketch and Its Dimensions

3.3 Outlet Zone

The outlet zone needs to be designed so that the flow that will come out of the pre-sedimentation tank does not cause turbulence in the sedimentation zone. If this happens, the particles to be deposited will be lifted so that they will be carried through the deposition channel. Therefore, it is necessary to design an effluent basin so that the flow that will come out to the next unit does not cause turbulence in the flow which causes a short flow. Weir's sketch of primary sedimentation can be seen in Figure 7.

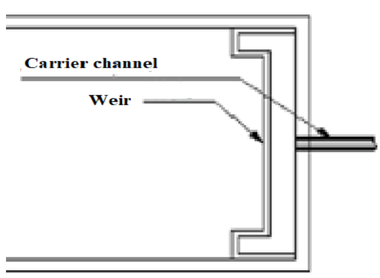

Fig. 7. The Sketch of Primary Sedimentation Weir

Based on the design results, the outlet zone is made in the form of a square. The outer part of the outlet zone is made higher than the inner side so that the flow enters the outlet zone through the inner side. A dimensional drawing of the outlet zone unit can be seen in Figure 8.

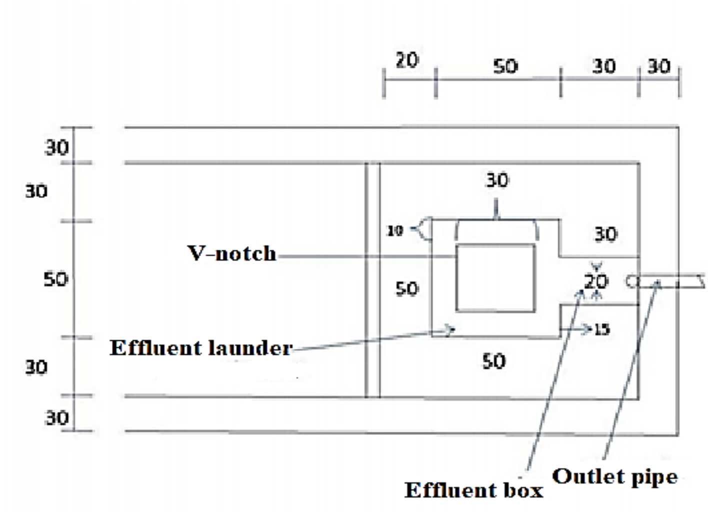

Fig. 8. Dimension of Outlet Unit

4 Conclusion

Based on the results of the primary sedimentation unit design at the wastewater treatment plant at PT X, it was found that the primary sedimentation unit designed was rectangular (rectangular). The quantity of discharge of wastewater entering the primary sedimentation tank is 0.00139 m3/second and the detention time is designed for 4 hours. Sedimentation tank volume is based on the calculation of 10 m3 with a multiplier of 1.1 so that the actual volume of the sedimentation tank is 11 m3. Based on the calculation results, the length of the tub is 4 m, the width of the tank is 1.1 m, 2.5 m deep, and 0.5 m freeboard. The allowance for TSS and BOD levels that occurs is obtained from efficiency (inlet-outlet) calculations based on mud design in the primary sedimentation unit at peak discharge BOD = 34.43% , TSS = 56.28% while at average discharge BOD = 40.82% , TSS = 62.99% .

5 Acknowledgment

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