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Tofu Wastewater Treatment Planning with Anaerobic Baffled Reactor (ABR) and Activated Sludge Application

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Abstract

Wastewater from tofu industry produces water with high organic content. Organic pollutant pollution from tofu industry has an impact potential on receiving water bodies. The purpose of the study is to understand the characteristics of the wastewater and conducting the study design of the wastewater treatment plant (WWTP) in the tofu industry. Characterization of tofu industrial wastewater was carried out based on BOD5, COD, TSS, and pH parameters. Sampling was carried out in the tofu-making industrial area of South Sukabumi Village. The organic content in the form of BOD5 and COD respectively is 2843.5 m/L and 7743.5 mg/L. Thus, the aerobic process could not be applied directly as requiring very high oxygen supply. BOD5, COD, TSS, and pH parameters in the industry do not meet Minister of Environment Regulation Number 05 Year 2014 Concerning Wastewater Materials Quality. The units needed in the planning are a collection well, neutralization tank, abr, activated sludge, and final settling tank. Land area needed in the planning of the units is 8.89 m^2. The effluent of wastewater which expected to have a neutral pH and the concentration for each BOD5, COD, TSS parameter reaches 24.69 mg/L; 63.32 mg/L; 26.7 mg/L. The total cost of the required WWTP design is Rp 187,977,000.00.

Keywords:WWTP, Tofu wastewater, BOD5, COD, quality standard

INTRODUCTION

Most of the wastewater produced from tofu making is acidic water which comes from a thick liquid separated from the tofu clumps during the compaction process (Angraeni, 2014). Tofu industrial wastewater contains large amounts of carbohydrates, fats, and proteins. Organic molecules contained in the tofu industrial wastewater generally experience remodelled especially in carbohydrates, fats, and proteins contained, carried out by decomposer microorganisms. Complex organic materials in the form of carbohydrates, fats, and proteins are first converted into simpler forms of glucose, glycerol, fatty acids, and amino acids (Nugroho, 2014). Amino acids which are the result of protein breakdown will be oxidized to nitrous ammonia (NH_3) and carboxyl compounds. The (NH_3) compound is re-oxidised into nitrite (NO_2).

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If this wastewater is discharged without prior treatment, it can pollute the environment. Tofu wastewater quality parameters are indicated by the concentration of BOD_5, COD, TSS, and pH. Tofu wastewater quality parameters are indicated by the concentration of BOD5, COD, TSS, and pH. Generally, tofu wastewater, which directly discharged to water bodies could cause water pollution. Impacted on aesthetics, such as odours and colours, and disturbs the ecological balance to the death of aquatic biota. The high COD and BOD_5 indicate the amount of organic material that must be broken down by microorganisms. The too high concentration of organic materials will create anaerobic conditions that could produce ammonia, carbon dioxide, methane, acetic acid, and so on. The environmental impact due to tofu making industry water discharge directly into water body must be minimized (Afifah dan Suryawan, 2020).

In the selecting process of alternative treatment, both the terms of the ability to eliminate pollutants, as well as the financial ability should be considered. One of the treatment alternatives that are widely used is the anaerobic degradation process. The anaerobic process had a cost overrun operation and cheap cost maintenance, little mud formed, and have high efficiency of the organic substances processing. On the other hand, nutrients removal from anaerobic processes is small, so that other processes are needed to process nutrients (Elmitwalli *et al*., 2001). Tofu waste treatment technology existed today is generally in the form of an anaerobic waste treatment system. The biological process of anaerobic processing had processing efficiency by approximately 70% -80% (Herlambang, 2002).

The anaerobic process has the advantages of cheap costs operating and maintenance, sludge which formed is little, as well as having the high efficiency of the substances organic processing. On the other hand, the anaerobic process has a small deficiency in nutrient removal so that another process is needed to process nutrients (Lettinga, 1995). The current anaerobic baffled reactor (ABR) technology has the potential to overcome this problem. ABR with modification with the anammox process can increase the efficiency of nitrogen nutrient removal (Wijaya *et al.,* 2019).

Wastewater treatment units planning with ABR in the tofu industry is expected to be able to provide information about the model in WWTP development for the tofu industry. The purpose of this research is to design tofu industrial wastewater treatment which consists of the characteristics' analysis of the quality and quantity of wastewater, mass balance, and budget plan.

MATERIALS AND METHODS

Tofu Wastewater Quality Parameters

The testing results of the tofu wastewater quality compared with the standard quality parameters of the tofu wastewater quality by Minister of Environment Regulation Number 05 Year 2014 Concerning Wastewater Materials Quality. The comparison results will show the parameters that already meet or do not meet the quality standard. The parameters tested were BOD_5, COD, TSS, and pH. BOD_5 was measured by SNI 6989.72:2009 concerning water and wastewater – Part 72: How to Test Oxygen Biochemistry Needs (Biochemical Oxygen Demand/BOD). COD was measured by Search Results SNI 06-6989.15.2004 concerning Water and Wastewater – Part 2: How to Test Chemical Oxygen Demand (COD). TSS was measured by SNI 06-6989.3.2004 and the pH measured with SNI 06-6989.11.2004. Organic was measured by the permanganate number (KMNO4) based on SNI06-6989.22.2004. The measurement parameters were carried out in a laboratory that has been accredited.

Process and Mass Balance Charts

The mass balance was conducted to calculate the flow and parameters concentration of the tofu wastewater quality ranging from influent to effluent after processed in the WWTP. The calculations are essential to ensure the effluent from the tofu wastewater treatment meets the quality

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standard of Minister of Environment Regulation Number 05 Year 2014 Concerning Wastewater Materials Quality, theoretically.

Detail Engineering Desain dan Profil Hidrolis

The dimensions of the selected units were calculated based on literature studies and waste characteristics and mass balance. Then, conducted a detailed depiction of each unit needed. The detailed image is a visualization of building unit dimensions calculation. From the detailed image, information about the size, volume of work, and land requirements of the two planning alternatives could be obtained. Profile hydraulic itself is a level comparison picture of water surface with the elevation of the land. In making the hydraulic profile, it determined by the amount of decrease in the water surface level due to some like major headloss, minor headloss, speed headloss, pumps, and others.

Budget Cost Plan

From the detailed image made, then carried out the calculation of bill of quantity and plan budget costs that were further analysed. Analysis related to the amount of each work volume of two alternatives as well as the cost that is required for the construction of the WWTP in each unit.

RESULTS AND DISCUSSION

Initial Characteristics

Tofu wastewater quality data was obtained from testing samples in the laboratory. In a study conducted by Pamungkas (2017), tofu wastewater samples were taken using the grab method. Therefore, wastewater sampling from the tofu production process in the tofu making industry in South Sukabumi Village will also be carried out using the grab method. According to SNI 6989: 59: 2008, the grab method is carried out by taking a momentary sample at a certain time and location. The operational time of the tofu making industry in South Sukabumi Village lasts 12 hours from 05.00 - 17.00 interspersed with rest periods from 12.00 – 13.00. Samples will be taken at two different times, one sample in the morning before the break and one sample at noon after the break. Table 1 shows the results of the two-sample tests for each parameter. After comparing against the quality standard, none of all parameters of the tofu wastewater quality meets the quality standard. In designing WWTP, a concentration data of wastewater quality parameters are needed as a design reference.

Table 1. The characteristics of wastewater from tofu industrial activities in South Sukabumi Village

Parameter	Mean	Deviation Standard	Quality standards	Information
BOD_5 (mg/L)	2,843.5	317.1	75	Not fulfil the requirement
COD (mg/L)	7,743.5	493.9	100	Not fulfil the requirement
TSS (mg/L)	827	359.2	100	Not fulfil the requirement
pH	4	0	6 – 9	Not fulfil the requirement

Process and Mass Balance Diagram

Figure 1 shows the units that will be used in the WWTP. Before being processed, the tofu wastewater was collected in collecting well. Then, the wastewater was pumped into a neutralization tank to be stirred with a $CaCO_3$ solution. Wastewater in a neutral state then flows into the initial

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settling tank. In the ABR, there is a bulkhead that causes water to flow upflow and downflow. These two types of flow would increase the contact between wastewater and microorganisms so that organic material could be broken down efficiently (Ministry of Public Works and Public Housing, 2017). After that, the water would flow into the aeration bath to be treated using activated sludge. The final processing takes place in the final settling tank. The activated sludge which settles in the final settling tank will be recirculated to the aeration tank for reuse so that the aeration tank and the final settling tank are one system. The area of the land that will be used as the WWTP construction site is 41.72 m^2. The land area that is needed for unity collector wells, neutralization tank, ABR, active sludge, and final settling tank is 1.82 m^2, 0.05 m^2, 5.15 m^2, 1.21 m^2, and 0.66 m^2. The total land needed for the WWTP of tofu industry is 8.89 m^2.

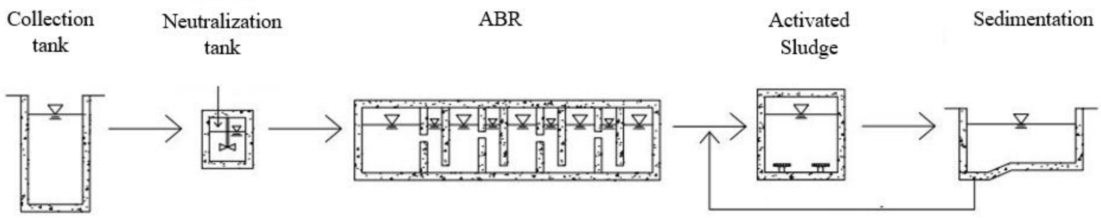

Figure 1. Flow chart of WWTP design structure in South Sukabumi Village

The settling tank placed inside the ABR. This unit was able to remove 95% BOD_5. 95% COD, and 80% TSS thus there was a decrease in the parameter concentration. The wastewater then treated in an aeration tank. The aeration tank and final settling tank were combined in one system because the sludge in the final settling tank would be recirculated to the aeration tank as much as 30%. The processing in these two units will remove 85% BOD_5, 85% COD, and 90% TSS. Then, the final effluent concentration comes out from the aeration tank and final settling tank was compared with the quality standard. ABR is a reactor anaerobic which consists of several compartments that are separated by a baffle (Adi, Razif, & Moesriati, 2016). Bulkhead or baffles mounted in alternating so that water will flow to the top and to the bottom on the compartment. It would increase the contact between wastewater and microorganisms. This technology could remove TSS by 80%, BOD_5 by 70 - 95% (Sasse, 1998), and COD from 80 to 95% (Tchobanoglous, Burton, and Stensel, 2003). It can be seen in table 1 that the concentrations of BOD_5, COD, and TSS in the effluent have met the quality standard.

Table 1. Estimated concentration of effluent wastewater from each unit in the tofu industrial WWTP

Parameter	Influent (mg/L)	Collection Well		Neutralization Tank		ABR		Aeration Tank and Final Settling Tank		Quality standards
		Efficiency of Allowance	Effluent (mg/L)	Efficiency of Allowance	Effluent (mg/L)	Efficiency of Allowance	Effluent (mg/L)	Efficiency of Allowance	Effluent (mg/L)	
BOD_5 (mg/L)	3,292	0%	3,292	0%	3,292	95%	164.6	85%	24.69	75
COD (mg/L)	8,442	0%	8,442	0%	8,442	95%	422.1	85%	63.32	100
TSS (mg/L)	1,335	0%	1,335	0%	1,335	80%	267	90%	26.7	100

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The wastewater effluent from treatment has a discharge of 6.85 m3/day with a BOD5 concentration of 0.17 kg/day or 24.69 mg/L, COD 0.44 kg/day or 63.32 mg/L, and TSS 0,19 kg/day or 26.70 mg/L. The initial pH value of tofu wastewater is 4. After going through the treatment in the neutralization tank, the wastewater will become neutral, which has a pH of 7. If it is compared with the quality standard in Table 1, all parameters have met the applicable quality standards. In this WWTP, nutrients cannot yet be processed optimally. Based on research by Hastuti, Nuraeni, & Darwati (2017), ABR is not effective for removing nutrients. Meanwhile, activated sludge can remove nutrients in the form of ammonia and phosphate 49 – 54.9% and 57.1 – 70.2%, respectively (Suryawan & Sofiyah, 2020). The preanoxic process is one way of increasing the efficiency of nutrient removal (Fadhilah et al., 2020).

Detailed Engineering of Hydraulic Design and Profiles

The calculations in this section are a continuation of the results of preliminary sizing. Each unit was designed from dimensions, freeboard or free space, sludge chamber, inlet and outlet pipes, headloss, and additional auxiliary devices such as pumps and stirrers. The design carried out must meet the design criteria of each unit. Detailed dimensions for each unit of wastewater can be seen in Table 2.

Table 2. Dimensions for each unit in the WWTP of tofu industrial wastewater

Unit	Total Unit	Length (m)	Width (m)	Depth (m)	Free Space Height (m)	Additional Specifications
Collecting Well	1	1.35	1.35	2.2	0.8	• 1 *submersible* pump Capacity = 480 m^3/day *Head* = 12.6 m • 1 *submersible mixer* Diameter = 0.51 m
Neutralization Tank	1	Diameter = 0.25 m		0.5	0.2	• 1 *Mixer agitator* Diameter = 0.2 m • 1 *dosing tank* • $CaCO_3$ required = 1.48 kg/day
ABR	1	7.35	0.7	1	0.5	• Mud chamber p x l x h = 6.45 x 0.7 x 0.3 m
Aeration Tank	1	1.1	1.1	2.5	0.5	• 1 *roots blower* Capacity = 0.24 m^3/day • 2 *air diffuser* Oxygen transfer = 0.15 m^3/minute
Final Settling Tank	1	1.1	0.6	1	0.3	• Mud chamber: 1.1 x 0.6 x 0.55 m • 1 *heavy duty slurry pumps*

The entire unit is only 1 unit each. Based on previous WWTP designs carried out in the tofu making industry, the number of units is not added by redundancy because the industry is small (Hidayati, Harisuseno, and Sayekti, 2017). This also relates to the limited available land thus there is no redundancy. The same applies to the tofu-making industry in South Sukabumi Village. The hydraulic profile is a description of the difference in water level elevation of each unit in the WWTP from inlet to outlet (Nanga, 2017). The hydraulic profile calculation considers soil elevation, unit

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height, and pressure loss or headloss which includes major and minor headloss. The calculation of headloss will show the drop level amount of water due to friction, flow velocity, falls, and turns during water flowing in the WWTP.

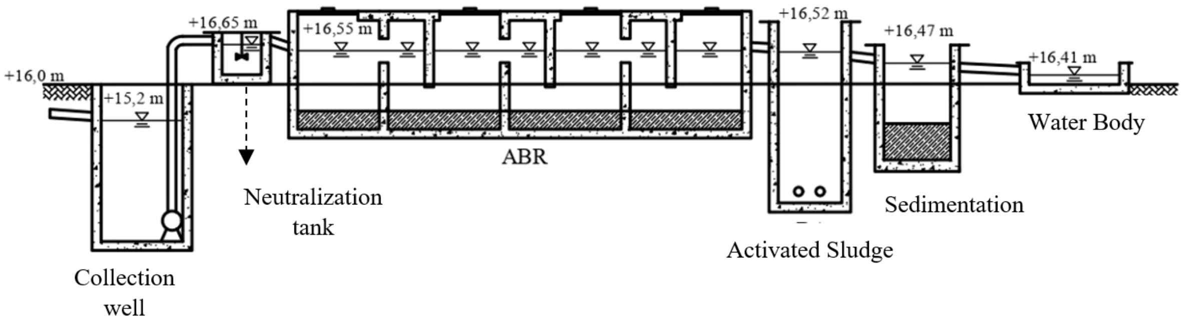

Figure 2. Hydraulic profile of WWTP design structure in South Sukabumi Village

Budget Cost Plan

The calculation of the WWTP design construction required cost starts from calculating the number of materials and accessories needed which is called BOQ. The quantity, then, is multiplied by the unit price of work to form the RAB (Yandanika, Nyoto, and Irwansyah, 2014). The unit price used refers to the SNI Work Unit Price Analysis for 2017 – 2018. These are the BOQ and RAB from the WWTP construction for the tofu making industry in South Sukabumi Village. Total investments required for the processing unit and an ABR unit is Rp 187,976,602.66 when compared with the unit Biodigester-Settler-Anaerobic Filter which tends to be more expensive i.e. Rp 200,571,373. Total investasi yang dibutuhkan untuk unit pengolahan dengan unit ABR adalah Rp 187.976.602,66, jika dibandingkan dengan unit Biodigester-Settler-Anaerobik Filter yang cenderung lebih mahal yaitu Rp 200.571.373.

Table 3. Budget Cost Plan for planning units of WWTP design in South Sukabumi Village

No.	Unit	Cost
1.	Collection well	Rp 64,696,258.37
2.	Neutralization tank	Rp 10,994,501.52
3.	ABR	Rp 14,113,222.41
4.	Aeration tank	Rp 62,681,460.74
5.	Final settling tank	Rp 35,491,159.62
	Total Cost	**Rp 187,976,602.66**
	Rounding	**Rp 187,977,000.00**

CONCLUSION

Based on the analysis of tofu wastewater, the BOD5, COD, TSS, and pH parameters does not meet the quality standard. The units needed in the tofu industrial wastewater were collection well, neutralization tank, abr, activated sludge, and final precipitator tank. The expected wastewater quality discharged into water bodies, with the application of the units, were 24.69 mg/L; 63.32 mg/L; 26.7 mg/L for each BOD5, COD, TSS parameter. The total cost needed from the units that were Rp 187,977,000.00 Rounding.

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