Preliminary Design of Tofu Factory Wastewater Treatment with Ozonation Method

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Abstract: Tofu is a food that is often consumed in Indonesia. Every 100 g of tofu contains macronutrients such as 7.8 g protein, 4.6 g fat, and 1.6 g carbohydrates. Tofu also contains micronutrients like phosphorus, potassium, calcium, vitamin B, and vitamin E. The process of making tofu produces liquid waste. Based on one of the tofu factories in Indonesia the qualities of COD, BOD, and Total Coliform are 5964.48 mg/L, 734.1 mg/L, and 59.13 MPN/100 mL. The purpose of this study is to obtain the unit dimensions of the tofu wastewater treatment system using the ozonation method so that the water released will meet the available quality standards. The research was carried out by studying the liquid waste treatment using the ozonation method until the wastewater treatment system was obtained and then calculating the effluent of the system design. Based on the calculation results, the dimensions of the tank are cylindrical and the units can be determined. The treatment system able to reduce COD, BOD, and TC with the qualities of system are 178.67 mg/L, 24 mg/L, and 0 MPN/100 mL, which values are meet quality standards so that they can be released into the environment.

1 INTRODUCTION

Tofu is a side dish that is commonly found. Every 100 g of tofu contains macronutrients such as 7.8 g of protein; 4.6 g fat; and 1.6 g carbohydrates. Tofu also contains micronutrients such as phosphorus, potassium, calcium, B vitamins, and E vitamins. In addition to its low price, tofu is rich in protein so that it is a source of nutrition and is widely consumed by Indonesian people (Seftiono, 2016).

Factory production activity usually produces waste. The tofu production results in liquid and solid wastes. Liquid tofu waste will immediately dispose of the water around the factory (Yudhistira et al., 2016). According to Ratnani, there are organic and inorganic pollutants in waste that can contaminate the environment (Ratnani, 2011). COD (Chemical Oxygen Demand), BOD (Biological Oxygen Demand), TSS (Total Suspended Solid), and TC (Total Coliform) are parameters that can be used to assess environmental pollution.

Tofu waste needs to be processed until it meets the disposal requirements. The wastewater treatment must meet the release criteria or the quality standard value of waste according to the regulation of the state minister of the environment number 5 of 2014 which states the levels of COD, BOD, and TSS of wastewater for soybean processing businesses and/or activities in the form of tofu are 300 mg/L, 150 mg/L, and 200 mg/L.

Ozone can be used to treat wastewater, namely ozonation. Ozone has some functions, such as disinfectant (Basuki et al., 2017), COD, BOD, and TSS values reduction in the waste (Isyuniarto et al., 2006; Isyuniarto and Andrianto, 2009; Estikartini et al. 2016; Karamah et al., 2019).

The plant design of wastewater treatment using the ozonation method consist of several processes such as equalization, coagulation, flocculation-sedimentation, and ozonation unit (Basuki et al., 2017; Isyuniarto et al., 2006) which is environment friendly (Usada et al., 2005). This research was conducted to design the dimensions of the equalization, coagulation, flocculation, and ozonation unit in tofu wastewater treatment using the ozonation method so that the water released will meet the quality standards. The waste parameters reviewed include the levels of COD, BOD, TSS, and Total Coliform as the basis calculation design of the wastewater treatment system.

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2 BASIC THEORY

2.1 Equalization

The equalization unit is needed as an initial container for waste output before it is processed in the coagulation tank. In the equalization tank, there is an adjustment of the discharge and pH before entering the next process (Wang et al., 2006) such as coagulation process in coagulation tank.

2.2 Coagulation: Flocculation

The function of the coagulation unit is to mix the coagulants to form the floc core. The floc core later enlarges in the flocculation unit. The large floc formed will be deposited. These deposits are formed and accommodated in the sedimentation section (Priambodo and Indaryanto, 2017). Coagulation, flocculation, and sedimentation units can be designed as a single unit to facilitate maintenance (Rosidi and Razif, 2017).

2.3 Ozonation

The ozonation method can oxidize contaminants in the wastewater, reduce microorganisms, color, taste, smell, and release NOM (Natural Organic Matter) in water (Chen and Wang 2014).

Wastewater having high COD, BOD, TSS values can be reduced using ozone. Ozone is a strong oxidizing agent with an oxidation potential of 2.08 eV. Ozone can be decomposed into hydroxyl radicals (OH•) with an oxidation potential value of 2.80 eV. This shows that ozone can oxidize organic or inorganic compounds in water effectively and efficiently (Sururi et al., 2012).

Ozone that is discharged into the waste also kills the bacteria present in the waste (Basuki et al., 2017). Ozone kills bacterial cells by attacking glycoproteins and glycolipids in the bacterial cell membrane resulting in the breakdown of the bacterial cell (lysis) (Megahed et al., 2018).

3 METHODS

3.1 Literature Review

Review literature about tofu industrial wastewater treatment techniques, choose tofu industrial wastewater treatment system designs, plan the chosen design.

3.2 Data Collection and Data Analysis

Characterization of COD, BOD, and Total Coliform values of tofu industrial wastewater was carried out at PT SARASWANTI INDO GENETECH and for wastewater, discharge measurements were carried out by storing wastewater within a certain period and stored in a bottle container.

3.3 Data Processing

Calculating the results of the characterization of the wastewater with its quality standard value, determining the quality standards for the design basis, and calculating the unit dimensions in each of the tofu wastewater treatment processes (Basuki, 2016).

3.4 Results Assessment

Calculating the dimensions of the wastewater treatment unit using guide from Reynolds and Richards (1996) and Basuki (2016), calculating the final effluent design of the wastewater treatment unit, and comparing the effluent of the waste treatment design with its quality standards (Indonesian Goverment).

4 RESULT AND DISCUSSION

4.1 Design of Tofu Wastewater Treatment System

The wastewater treatment process starts with the equalization tank. After that, the coagulation-flocculation process – an integral part of the primary waste treatment process, is used to reduce the processing load before the waste is treated by using ozone. The ozonation unit was utilized for a disinfection unit (Basuki et al., 2017) which can simultaneously reduce the COD, BOD, and TSS values in treated waste (Karamah et al., 2019).

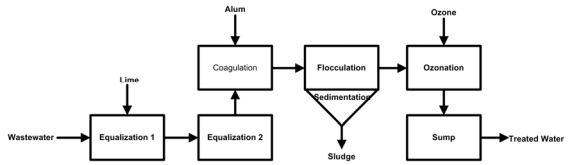

Figure 1: Block diagram of tofu wastewater treatment process (Basuki, 2016).

4.2 Calculation of the Dimensions of Tofu Wastewater Treatment Unit

4.2.1 Equalization Tank

In this equalization tank, the wastewater was collected and then the debit was changed before entered the coagulation tank. The purpose of changing the discharge is to adjust the processing time of the waste. The addition of lime was carried out in the equalization tank and it aims to create optimum process conditions (Isyuniarto et al., 2005). The equalization tank design is as follows:
Lime requirement = 2.0818 g/process

Table 1: Equalization tank design.

Unit	Dimension (m)		t_d (h)
	D	d	
Equalization 1	0,5	0,8	0,517
Equalization 2			1

4.2.2 Coagulation Tank

The function of the coagulation tank is to agglomerate organic substances in tofu liquid waste by mixing it with a coagulant. The coagulation system was stirred relatively quick. Stirring was carried out rapidly to disperse the coagulants well and to create the collisions between particles required to achieve good coagulation conditions. Alum was used as the coagulant. The results of the calculation of the coagulation unit are as follows:
Alum concentration = 1% by weight
Need for alum = 6.5 kg/process
Impeller diameter = 0.437 m
Impeller height = 0.127 m

Table 2: Coagulation tank design.

Unit	Dimension		rpm	P (W)	t_d (s)
	D	d			
Coagulation	0,874	0,874	100	393,183	40

4.2.3 Flocculation Tank

The flocculation unit located after the coagulation unit. The stirring speed in the flocculation bath was relatively slower than the coagulation bath. This makes the coagulation bath called a fast stirring bath, while the flocculation bath is called a slow stirring bath. A slow stirring of the flocculation unit can result in an increase in particle size from the submicroscopic micro-floc to visible soluble particles (Ismail et al., 2019). The results of the calculation of the flocculation unit are as follows:

Impeller diameter = 0.381 m
Impeller height = 0.129 m

Table 3: Flocculation tank design.

Unit	Dimension (m)		rpm	P (W)	t_d (m)
	D	d			
Flocculation	0,762	0,762	20	1,575	20

The sedimentation zone is designed at the bottom of the flocculation unit. The sedimentation zone functions to accommodate sediment resulting from the coagulation-flocculation process.

Table 4: Sedimentation zone design.

Unit	Dimension (m)		Drain period (/day)	t_d (h)
	D	d		
Sedimentation zone	0,762	0,164	1	1

4.2.4 Ozonation Tank

The ozonation unit is the main unit of the installation, which provide ozone to reduce the number of bacteria (Total Coliform) and also reduce the value of COD and BOD as well as TSS. In that case, ozonation replaced two units, namely the COD, BOD, and TSS removal unit, and the disinfection unit. The determination of ozone dosage uses the approach from previous studies (Isyuniarto et al., 2005).

Table 5: Ozonation tank design.

Unit	Dimension (m)		Ozone Dosage (mg/s)	P (W)	t_d (m)
	D	d			
Ozonation	0,6	1,007	60	3900	20

4.2.5 Sump Tank

The final container aims to collect water generated from the waste treatment process with the intention that the water can be controled to release or reused.

Table 6: Sump tank design.

Unit	Dimension (m)		t_d (h)
	D	d	
Sump	1,44	1,74	14

4.3 Calculation Effluent of Tofu Wastewater System

Calculations were carried out on the values of COD, BOD, TSS, and Total Coliform with the management

of each unit based on previous studies (Isyuniarto et al., 2006; Isyuniarto and Purwadi, 2007). The calculation of the influent and effluent of each process is as follows (Basuki, 2016):

4.3.1 COD

Table 7: COD processing results.

Unit	COD influent		EP	COD effluent	
	Q	C		Q	C
Equalization 1	0,8947	5964,48	0	0,8947	5964,48
Ekualization 2	0,8947	5964,48	0	0,8947	5964,48
Coagulation	0,8947	5964,48	0	0,8947	5964,48
Flocculation	0,8947	5964,48	66,16	0,3028	5964,48
Ozonation	0,3028	2018,4	91,15	0,0268	5964,48
Sump	0,0268	178,67	0	0,0268	5964,48

Notes:
Q in kg/hour
C in mg/L

4.3.2 BOD

Table 8: BOD processing results.

Unit	BOD influent		EP	BOD effluent	
	Q	C		Q	C
Equalization 1	0,1101	734,1	0	0,1101	734,1
Equalization 2	0,1101	734,1	0	0,1101	734,1
Coagulation	0,1101	734,1	0	0,1101	734,1
Flocculation	0,1101	734,1	66,12	0,0373	248,67
Ozonation	0,0373	248,67	90,35	0,0036	24
Sump	0,0036	24	0	0,0036	24

Notes:
Q in kg/jam
C in mg/L

4.3.3 TSS

Table 9: TSS processing results.

Unit	TSS influent		EP	TSS effluent	
	Q	C		Q	C
Equalization 1	0,18	1200	0	0,18	1200
Equalization 2	0,18	1200	0	0,18	1200
Coagulation	0,18	1200	0	0,18	1200
Flocculation	0,18	1200	70	0,054	360
Ozonation	0,054	360	53,75	0,025	166,67
Sump	0,025	166,67	0	0,025	166,67

Notes:
Q in kg/hour
C in mg/L

4.3.4 TC

Table 10: TC processing results.

Unit	TC influent		EP	TC effluent	
	Q	C		Q	C
Equalization 1	88695	59,13	0	88695	59,13
Equalization 2	88695	59,13	0	88695	59,13
Coagulation	88695	59,13	0	88695	59,13
Flocculation	88695	59,13	0	88695	59,13
Ozonation	88695	59,13	100	0	0
Sump	0	0	0	0	0

Notes:
Q in MPN/hour
C in MPN/100 mL

4.3.5 Comparison of Effluent Water Quality

The quality of water effluent from the waste treatment system was compared to the regulations governing wastewater standards.

Table 11: Effluent water quality.

Parameter	Before	After	Quality standards	Information
COD	5964,48	178,67	300*	Fulfill
BOD	734,1	24	150*	Fulfill
TSS	1200	166,67	200*	Fulfill
TC	59,13	0	50**	Fulfill

Notes:
*PERMENLH number 5 years 2014
**PERMENKES number 32 years 2017

Based on the regulations referred to the quality standard, the value of water output from the system is appropriate to be released into the environment.

5 CONCLUSIONS

The results of the preliminary design calculation of tofu factory wastewater treatment systems using the ozonation method with a semi-batch system with a capacity of 0.15 m^3 of waste/hour of processing obtained several conclusions, i.e:

1. The dimensions of each unit in the tofu liquid waste treatment system by the ozonation method are shown in the following table:

Table 12: The results of design calculations.

Unit	Dimension (m)	
	Diameter	Depth
Equalization 1 & 2	0,5	0,8
Coagulation	0,874	0,874
Flocculation	0,762	0,762
Sedimentation zone	0,762	0,164
Ozonation	0,6	1,007
Sump	1,44	1,74

2. The wastewater treatment system uses the ozonation method for tofu wastewater produced effluent water suitable for environmental quality standards, so it safe to be released. The outputs of COD, BOD, TSS and Total Coliform at these installations were 178.67 mg/L respectively; 24 mg/L; 166.67 mg/L and 0 MPN/100 mL.

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