Performance Effectiveness of Wastewater Treatment Plant of Meat Processing Industry in East Java Province

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Abstract. The meat processing industry is a sector of the food industry that has great potential to grow. One of that have been built in East Java Province with the product being processed frozen food meat. The production capacity can reach up to ±80 tons per day and affects the volume of wastewater produced. Preliminary studies about waste water treatment with the WWTP system (Wastewater Treatment Plant) in the meat processing industry is still not optimal due to the presence NH_3 in the effluent. This study aims to evaluate the performance effectiveness of WWTP for the meat processing industry in East Java Province. This study is a quantitative study. The data collection technique used grab sampling and then field measurements were carried out covering parameters of temperature, DO, pH, SV_{30} as well as laboratory tests including COD, NO_3^-, TSS, NH_3, FOG which were adjusted for each WWTP unit. Parameter test results analyzed based on suitability of design criteria including residence time and removal efficiency as well as WWTP effectiveness according to the quality standards of East Java Governor Regulation Number 72 of 2013. The results of this study indicate that WWTP is still not effective in eliminating the FOG parameters because it still exceeds the quality standards according to East Java Governor Regulation Number 72 of 2013, which is 5 mg/L and does not meet the latest regulatory standards of Government Regulation Number 22 of 2021, namely that the waste water disposed must at least meet class II water quality.

Keywords: wastewater, WWTP, meat processing industry

1 Introduction

The meat processing industry is engaged in food processing with frozen food processed meat products. The National Meat Processor Association or NAMPA has predicted that the growth of the meat processing industry will increase by 7% per year. This growth was driven by the factor of people who love to consume fast food or frozen food such as meatballs, sausages and nuggets [1–3].

T. Triwiyanto et al. (eds.), *Proceedings of the 6th International Conference of Health Polytechnic Surabaya (ICoHPS 2023)*, Advances in Health Sciences Research 72,
https://doi.org/10.2991/978-94-6463-324-5_32

The meat processing industry in East Java Province produces products in the form of frozen fast food such as sausages, meatballs, nuggets, scallops and processed marinated chicken. The basic ingredients for processed meat come from chicken, beef and fish. The composition of other ingredients used includes flour, oil, protein, sugar, salt, skim milk, food flavors, sodium stabilizers, food preservatives and other ingredients according to the type of preparation. The processed meat production process is capable of producing two different products in one production shift. On one day of production is able to produce ±80 tons of product.

The wastewater of meat processing has COD characteristics of 977.54–1,147.3 mg/L, BOD_5 434.36–632.63 mg/L, fats, oil and grease (FOG) of 547.6 mg/L, dan TSS 162.19–364.96 mg/L, pH 6.5–8.0, and temperature of 25.13–26.77°C [4–9]. Besides organic compounds, there are inorganic compounds like TN (Total Nitrogen) which covers nitrite (NO_2^-), nitrate (NO_3^-), and ammonia (NH_3) as well as TP (Total Phosphorous) which usually in the form of orthophosphate (PO_4^{3-}) produced from the decomposition of meat protein [4, 10, 11]. Nitrite and phosphate concentrations of wastewater were obtained from meat protein, food additives and color stabilizers [12].

The Wastewater Treatment Plant (WWTP) system that is commonly used in the meat processing industry in Indonesia is a biological system [19, 24]. The building structure of the WWTP consists of equalization basins, aeration basins, sedimentation basins and control basins. From a preliminary study in the meat processing industry in East Java Province, it was found that the WWTP effluent quality of NH_3 parameter was still above the quality standards according to East Java Governor Regulation Number 72 of 2013, which is 10 mg/L. This is supported by the results of the study that the application of a wastewater treatment plant is not fully effective in reducing parameters according to quality standards [4]. This is also proven in the meat processing industry at PT. So Good Food Pesawaran Lampung [15]. There is another recent regulation that regulates the quality standards for waste water disposal, namely Government Regulation Number 22 of 2021 with the requirement that the water waste disposed must meet class II water quality at a minimum. Based on this, it is necessary to evaluate the wastewater treatment system in the meat processing industry in East Java Province.

2 Research Methods

This study uses a quantitative research design. Quantitative research use to emphasizes numerical data, starting from data collection, analysis to statistical presentation. Samples were taken from each unit of the Wastewater Treatment Plant (WWTP), namely equalization basins, aeration basins I and II, sedimentation basins I and II, constructed wetlands and control basins. The technique used to take samples is grab sampling and the procedure for taking samples of wastewater refers to SNI 57:2008. The grab sampling method is used for sampling at a certain time. Sampling was carried out at 9.00 - 10.00 a.m. The parameters tested have been determined including temperature, pH, DO, SV_{30}, FOG, COD, NH_3, NO_3^-, and TSS. Parameters of wastewater to be analyzed according to the type of test. The following is a data analysis method based on testing each parameter:

1. FOG : SNI 6989.10:2011 gravimetric analysis
2. COD : SNI 6989.2:2019 with a closed reflux spectrophotometer
3. NH_3 : SNI 06-6989.30-2005 with a phenate spectrophotometer
4. NO_3^- : APHA. 4500-NO_3 B, Ed. 23. 2017, SNI 6989.79-2011 with a UV-Visible spectrophotometer
5. TSS : SNI 6989.3-2019 gravimetric analysis

3 Results and Discussion

3.1 Production Liquid Waste Processing Flow

Processed meat production can produce as much as 200-265 m^3 of liquid waste per day. The source of industrial liquid waste that flows into the WWTP channel comes from the production of processed meat and the washing of production tools/machines. The cleaning of production equipment uses high-pressure water at room temperature which is carried out at 6.00 a.m., 9.30 a.m. and 2.00 p.m. so that the wastewater disposal fluctuates at that time.

Wastewater from the production process (Fig.1) is first collected in a holding basin to equalize the flow from the two different production rooms. In the first stage, the water waste enters the equalization basin to equalize the flow rate. The second stage is in the form of biological treatment, namely an aeration basin consisting of aeration basin I and II as secondary wastewater treatment using activated sludge and an aerator machine as a supply of oxygen. In the third stage, there are sedimentation basin I and II for the deposition of dissolved solids. The effluent from the sedimentation basin will flow to the constructed wetland with water hyacinth (*Eichhornia crassipes*) as a phytoremediator. The constructed wetland unit was built as an additional biological treatment under the guidance of the East Java Province Environmental Service. The effluent from the constructed wetland unit will flow to the control tub as the final stage of processing which is used to control the quality of the wastewater before being disposed into the environment.

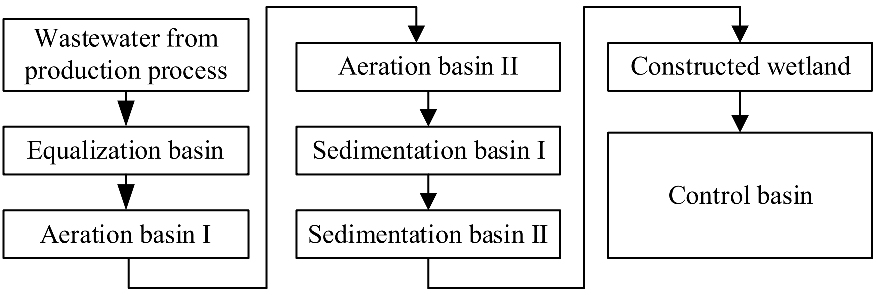

Fig. 1. Wastewater Disposal Flow Process

Wastewater treatment is divided into three stages, namely primary, secondary and tertiary [16]. The existence of pre-treatment such as oil and grease catchment basins can affect the processing performance of the entire WWTP unit [13, 17]. This causes sludge bulking in the equalization basin, aeration basin and sedimentation basin. Efforts that can be made include reprocessing wastewater to be used as raw material for production water and not disposing of it into the environment in accordance with the latest Government Regulation Number 22 of 2021.

3.2 Design of the WWTP Unit

Based on Table 1., the results of the calculation of the residence time of the existing building show that only sedimentation basin I and II meet the criteria. The residence time of sedimentation basin I and II are 5.79 hours with a comparison of design criteria of 2 - 6 hours. Shorter or exceeding residence times compared to design criteria causes a decrease in removal efficiency [19]. The short residence time causes the processing load on the next WWTP unit to become heavier [20]. The factor of daily debit fluctuation factor also affects the efficiency of COD and TSS removal [21]. In the aeration basin unit, it is important to drain the basin a temporarily discharge it in the equalization basin to reduce the risk of shock loading and sludge bulking.

Table 1. Design of the WWTP Unit

WWTP Units	Building Dimension (meter)			Building Construction	Time of Detention (hour)	
	Length	Width	Height		Design Criteria	Existing
Equalization Basin	4	2	3	Constructed by bricks and cements	4 – 8	2.17
Aeration Basin I	4	4	4	Constructed by bricks and cements	8 – 24	5.79
Aeration Basin II	4	4	4	Constructed by bricks and cements	8 – 24	5.79
Sedimentation Basin I	4	4	4	Constructed by bricks and cements	2 – 6	5.79
Sedimentation Basin II	4	4	4	Constructed by bricks and cements	2 – 6	5.79
Constructed Wetland	3	3	1.5	Pond with tarpaulin at the bottom	24 – 168	1.22
Control Basin	1	1	1.5	Constructed by bricks and cements	-	0.13

Note: Design criteria [18]

Table 2. Parameter Test Results of Raw Wastewater

Parameter	Test Results			
	Day 1	**Day 2**	**Day 3**	**Average**
Temperature (°C)	28.68	29	29.68	29.12
pH	7.29	7.78	6.33	7.13
TSS (mg/L)	228	1,431	300	653
COD (mg/L)	549.21	2,173	408.60	1,043.60
FOG (mg/L)	17.01	9.75	13.80	13.52
NH_3(mg/L)	7.15	23.01	7.25	12.47

Note: Samples taken from equalization basin

Fig. 2. Equalization Basin Construction

Based on Table 2., the results of tests and measurements at the inlet of the wastewater treatment plant (WWTP) show that raw wastewater contains the largest components, namely COD, followed by TSS, NH_3, FOG. This shows that the main component of wastewater from the meat processing industry is organic substance [4, 22]. Organic matter in industrial wastewater comes from raw materials for product manufacturing processes such as flour, sugar, oil, protein and meat. In wastewater, meat will be decomposed into ammonia compounds from protein [4, 10, 11]. In addition to organic matter, inorganic materials such as ammonia, nitrate and nitrite also dissolve in wastewater derived from meat protein, food additives or sodium stabilizer [12].

Laboratory test results show that COD and TSS have the highest concentrations and are interrelated [7–9]. FOG can also increase the TSS value because its density which is lighter than water makes it easier to rise to the surface and cover the surface of the wastewater [23].

3.3 Parameter Wastewater Test Results in each WWTP Unit

Aeration Basins. Based on Table 3., the aeration basin I was not efficient in reducing the concentration of parameters in the first test and the aeration basin II was also not efficient in all tests. The COD removal efficiency in the aeration basin I was 53.72% and in the aeration basin II was -3.43%, while the standard removal efficiency for the activated sludge method was 80 - 95% [18]. The presence of sludge bulking that covers the surface of the wastewater prevents oxygen from rising to the surface and disrupts the decomposition process [10]. The low DO measurements in the two aeration basins also affected the performance of decomposing microorganisms. In addition, the settling rate of activated sludge is also low or does not reach 400 - 600 mL/L [24] as indicated by the SV_{30} parameter, causing microorganisms to lack oxygen and even die [25] (Fig. 3 and Fig. 4). To increase efficiency, it is possible to recycle activated sludge or modify the activated sludge treatment method by making the media a breeding ground for bacteria.

Table 3. Parameter Laboratory Test Results in Aeration Basin

Parameter	Test Results							
	Day 1		Day 2		Day 3		Average	
	AB-I	AB-II	AB-I	AB-II	AB-I	AB-II	AB-I	AB-II
COD (mg/L)	141.85	601.59	8,292	2,063	629.60	603.67	2,354.48	1,089.42

Note: AB-I = Aeration Basin I and AB-II = Aeration Basin II

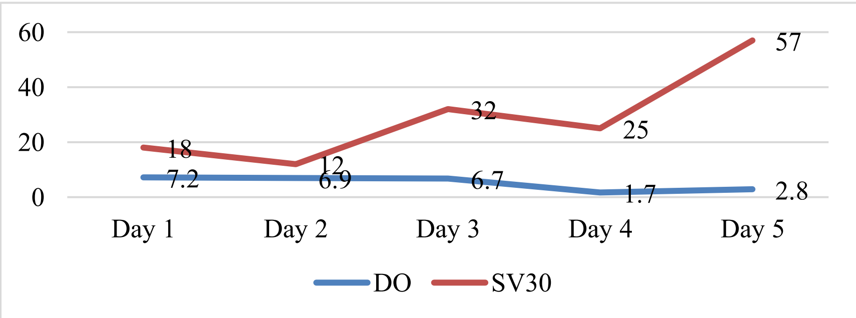

Fig. 3. Measured Parameters DO and SV_{30} Test Results in Aeration Basin I

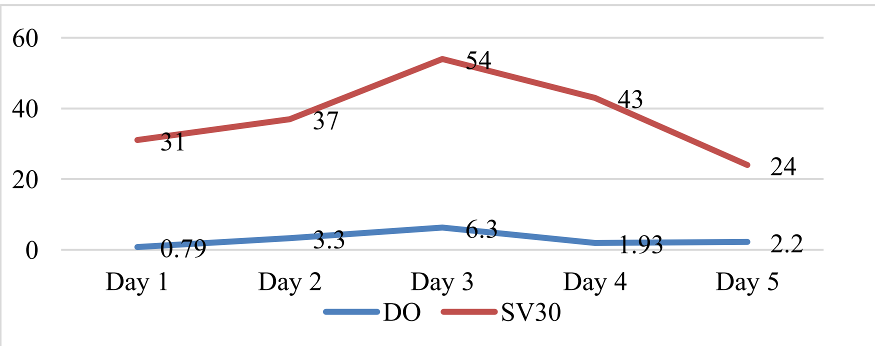

Fig. 4. Measured Parameters DO and SV_{30} Test Results in Aeration Basin II

Fig. 5. Aeration Basin Construction

Sedimentation Basins. Based on Table 4., the concentrations of TSS and COD parameters in the first and second sedimentation basins were higher than the equalization basins and sedimentation basin II in the first and second tests. The average removal efficiency of TSS and COD in the sedimentation basin I was -47.99% and -63.49%, while in the sedimentation basin II were 91.98% and 67.92%. The design criteria for TSS and COD removal efficiency for sedimentation basins were 50 - 65% [18]. This shows that sedimentation basin I is not efficient, while sedimentation basin II is efficient in reducing TSS and COD parameters. Parameter concentrations fluctuate significantly and cause a decrease in parameters to be inefficient when processed in the sedimentation basin I. One way to overcome this problem is to increase the residence time of the previous WWTP units [26].

Table 4. Parameter Laboratory Test Results in Sedimentation Basin

Parameter	Test Results							
	Day 1		Day 2		Day 3		Average	
	SB-I	SB-II	SB-I	SB-II	SB-I	SB-II	SB-I	SB-II
TSS (mg/L)	551	986	329	1,473	1,393	905	757,67	1,121.33
COD (mg/L)	653.11	658.69	2,072	4,248	655.37	620.18	1,126.82	1,842.29
NO_3^- (mg/L)	3.55	4.44	3.69	1.47	6.74	6.94	4.66	4.28

Note: SB-I = Sedimentation Basin I and SB-II = Sedimentation Basin II

Constructed Wetland. Based on Table 5., constructed wetland using water hyacinth (*Eichhornia crassipes*) as a phytoremediator, able to reduce TSS, COD and NH_3 parameters with an average efficiency of 87.14%, 83%, and 91.93% respectively based on the design criteria of 90%, 90%, dan 95% [18]. Even so, the existing removal efficiency is still not efficient because it does not meet the design criteria.

Several contributing factors include initial processing, residence time, vegetation, porous media and operating strategy [27, 28]. The presence of nitrate content in the test results indicates that the nitrification and denitrification processes are not running perfectly. To improve removal efficiency, this can be done by increasing the residence time or by adjusting to design criteria through replanting according to their life time of 24 - 168 hours and expansion of artificial ponds.

Fig. 6. Sedimentation Basin Construction

Table 5. Parameter Laboratory Test Results in Constructed Wetland

Parameter	Test Results			
	Sample 1	**Sample 2**	**Sample 3**	**Average**
TSS (mg/L)	54.5	156	59.20	89.9
COD (mg/L)	314.97	1,050	407.18	590.71
NH_3 (mg/L)	7.02	0.63	5.17	4.27
NO_3^- (mg/L)	32.45	62.4	40.50	45.11

Fig. 7. Constructed Wetland Construction

3.4 Parameter Removal Efficiency

pH. The pH value at the outlet increased by an average of 0.82, indicating a decrease in the level of pollutant liquid waste [29]. The results of wastewater treatment still meet quality standards because the pH value is in the range of 6 - 9, in accordance with the conditions of aquatic life [4, 30] (Table 7). High pH values are related to the level of ionization of the solution and affect the decomposition or adsorption of organic substances in water [31]. pH as a characteristic of wastewater is important to understand as acidic or basic properties which are influenced by production materials such as salt and food additives.

Table 6. Parameter Removal Efficiency

Parameter	Sample	Test Results (mg/L)		Effectiveness (%)
		In	Out	
TSS	Sample 1	228	23.3	89.78
	Sample 2	1.431	8	99.44
	Sample 3	300	3.40	98.86
	Average	653	11.57	98.22
COD	Sample 1	549.21	141.85	74.17
	Sample 2	2,173	34	98.43
	Sample 3	408.60	125.28	69.33
	Average	1,043.63	100.37	90.38
FOG	Sample 1	17.01	15.27	10.22
	Sample 2	9.75	<0.24	97.53
	Sample 3	13.80	12..97	6.01
	Average	13.52	9.49	29.80
NH_3	Sample 1	7.15	4.15	41.95
	Sample 2	23.01	3.21	86.04
	Sample 3	7.25	3.58	50.62
	Average	12.47	3.64	70.80

Note: Inlet samples taken from equalization basin, outlet samples taken from control basin

Table 7. Outlet Parameters Test Results Compared to Quality Standards

Parameter	Quality Standard (East Java Governor Regulation 72 of 2013)	Outlet Test Results		
		Sample 1	Sample 2	Sample 3
pH	6-9	7.28	8.72	7.95
TSS (mg/L)	100	23.3	8	3.40
COD (mg/L)	250	141.85	34	125.28
FOG (mg/L)	5	15.27	<0.24	12.97
NH_3 (mg/L)	10	4.15	3.21	3.58

Note: Samples taken from control basin

TSS. TSS is the parameter with the highest effectiveness because the average value of its reduction reaches 98.22% (Table 6) according to the quality standard of 100 mg/L (Table 7). All tests showed results that were in accordance with the quality standards, although there were fluctuations due to production and processing volume in the previous unit. The concentration of TSS at the outlet is affected by the inefficiency of pre-processing [32]. Another influencing factor is the condition of the WWTP building, such as the entry of rainwater into the tub which increases the volume of wastewater and the processing load [33].

COD. The effectiveness of COD removal reached 90.38% (Table 6) and was included in the effective category because the COD concentration was below the quality standard threshold (Table 7). Analysis of the effectiveness of WWTP on the COD parameter is carried out in each processing process, especially in the aeration basins unit. The relationship between COD concentrations in the effluent and the treatment process and the ratio of treated water waste to production [34]. High levels of COD in wastewater increase BOD and reduce dissolved oxygen, inhibiting the survival of microorganisms and causing pollution [35, 36].

FOG. FOG parameter allowance in the WWTP system for the meat processing industry in East Java Province is considered ineffective because there are test results that exceed the quality standard of 5 mg/L (Table 7). This is due to the absence of processing in the form of separation of oil and fat. The importance of using the fat, oil and grease trap method with a removal efficiency of 45.50% [37]. The use of FOG traps can achieve an average efficiency of 89.83% [38]. COD and TSS parameters can also be reduced with a removal efficiency of 18% and 27.72%. Therefore it is necessary to apply pre-processing of oil and fat separation. Operational maintenance can be done by draining and cleaning regularly.

NH_3. The NH_3 parameter was successfully reduced effectively by the WWTP system in the meat processing industry In East Java Province, according to the quality standards for all tests. The average value of reducing NH_3 reached 70.80% (Table 6) with a quality standard of 10 mg/L (Table 7). However, ammonia is not completely decomposed through the denitrification process, which is indicated by the presence of nitrate (NO_3-) which was still found in the test.

Aeration basins have an important role in ammonia and degradation and have been proven in the studies [39]. The effect of aeration time and low DO levels in the existing WWTP affects the denitrification process by decomposing microorganisms, so it is necessary to increase the oxygen content in the aeration basins to increase the efficiency of ammonia decomposition [15].

4 Conclusion

The effectiveness of the performance of the Wastewater Treatment Plant (WWTP) for the meat processing industry in East Java Province according to the East Java Governor Regulation Number 72 of 2013 is still not effective in reducing the FOG parameter because it does not comply with the quality standard, which is 5 mg/L. For the industry, it can add a preliminary process, which is the separation of oil and fat by building an oil and fat separator tub, increasing the supply of oxygen and re-seeding microorganisms to increase organic removal efficiency in aeration tank, and recycle activated sludge from aeration basin to avoid sludge bulking.

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