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Decision Making for Biological Tofu Wastewater Treatment to Improve Quality Wastewater Treatment Plant (WWTP) Using Analytical Hierarcy Process (AHP)

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ABSTRACT

This research aims to build a support system for tofu wastewater treatment using the Analytical Hierarchy Process (AHP) method. This research was conducted in one of the household tofu industries in Jakarta. AHP method was used to choose/decide the most effective combination of technologies to treat tofu wastewater. Based on the literature study and inlet characterization, Three alternatives were proposed. Alternative 1 consists of a Collecting tank, Neutralization Tank, Preliminary Sedimentation, Anaerobic Digester, Aeration Tank, and Final Settlement Body. While alternative 2 consists of a Collecting tank, Neutralization Tank, Preliminary Sedimentation, Anaerobic Biofilter, Aeration Tank, and Final Settlement Tank. Alternative 3 consists of a Collecting tank, Neutralization Tank, ABR, Aeration Tank, and Final Sedimentation Tank. The decision criteria used for AHP were effluent quality, land requirement, construction cost, and maintenance convenience. The primary data used were wastewater flow and outlet concentration. While data on area use, maintenance cost, and construction cost were extracted from literature study. The result shows that alternative 3 was the most effective sequence of technology. Eigen Vector Analysis Recapitulation showed that alternative 1 has an overall value of 0.31, alternative 2 has a value of 0.2 and alternative 3 has a value of 0.5. Using alternative 3, BOD5 can be removed up to 95%, COD can be removed by a maximum of 95% by ABR, and TSS can be removed by 80% which met the quality standard.

1. INTRODUCTION

The production of tofu consists of washing soybeans, soaking, washing soaked soybeans, grinding, boiling, filtering, compacting, molding, and cutting tofu (Guo, Hu, Wang, & Liu, 2018; Yanti, Setyaningsih, Triwitono, Yuniansyah, & Admi, 2021). The process starts with washing soybeans with running water to remove impurities from soybeans (Yanti et al., 2021). Next, the soybeans are soaked for 6 – 12 hours. The remaining water from the soaking process that is not absorbed by the soybeans will be discarded. Soybeans that have been soaked are then rewashed. After that, the soybeans are put into the grinder. Finally, soybeans are ground into porridge. Soybean porridge will be boiled until boiling ± 15 - 40 minutes. Then, the soybean pulp is filtered using a cloth to obtain soybean juice (Ahmad et al., 2017).

Tofu wastewater quality parameters were indicated by concentrations of BOD5, COD, TSS, and pH (Aras, 2020; Hajar, Fadarina, Zamhari, & Yuliati, 2021). Acidic water contains high protein levels, so the content of organic matter in tofu wastewater is also high (Vidyawati & Fitrihidajati, 2019). This is because the use of vinegar is quite a lot in the process. If this wastewater is disposed of

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without prior treatment, it can pollute the environment. BOD and COD parameters are indicators of the amount of organic waste that pollutes river water in industrial areas, the amount of these organic compounds can be associated with ongoing community activities.

Biological wastewater treatment reduces dissolved components, especially organic compounds, to a safe limit for the environment by utilizing microbes or plants. To get rid of dissolved organic matter, existing microorganisms will use organic matter as nutrients for their growth into new cells and carbon dioxide. The biotransformation process occurs in various ways according to the microorganisms that play a role in it, such as autotrophs or heterotrophs. Conventionally, wastewater treatment has successfully reduced BOD and COD, although the removal of nutrient compounds (nitrogen and phosphorus) is still being sought for efficient models and methods. In general, biofilter media can significantly increase the efficiency of the tofu and tempeh waste treatment process compared to processing without using a biofilter (Herlambang, 2001). For example, the efficiency of reducing the BOD5 value in the reactor using biofilter media ranged from 53.33 to 91.36%, and the COD value ranged from 61.15 to 85.83% with a residence time of 1-7 days (Herlambang, 2001). For application on a large scale, the decision to use which technology can rely not only on one but also on several important criteria. The cheapest and most accurate way to decide which technology can treat tofu wastewater effectively is using decision support system tools.

One of the relevant decision support systems that have a consistent value calculation in determining the priority level of criteria and alternatives is the Analytical Hierarchy Process (AHP) method (Sari et al., 2022). The concept of AHP is to convert qualitative values into quantitative values. This method also combines the strengths of the feelings and logic involved in various problems. It then synthesizes different considerations into results that match intuitive estimates as presented in the concerns that have been made. This study aims to build a support system for tofu wastewater treatment using the AHP method. The results of the decisions given can provide recommendations for tofu wastewater treatment with various criteria considered by the stakeholders of the tofu industry.

2. METHODS

The data were collected in two ways, primary and secondary. Primary data were collected directly in the field. The primary data included measurement of flow and wastewater concentration such as BOD, COD, and TSS. While secondary data used to analyze the decision criteria of land requirement, maintenance convenience, and low construction cost were extracted from literature studies. Volumetric measurements obtained wastewater discharge data in the field. In the WWTP design (Sakinah, 2018), the wastewater discharge is measured by collecting the wastewater generated in a Tank or bucket. The volume of wastewater accommodated in a Tank or bucket is then recorded, and data on the volume of wastewater produced per day will be obtained. Based on the design that has been done, the measurement of wastewater flowrate discharge in this design will be carried out in the same way but using two 60 L buckets with a measuring line every 5 L. It is enough to collect this data in 1 day because based on interviews with the owners of the tofu-making industry, the activities and the amount of tofu production in this industry are the same every day. Therefore, the resulting discharge is relatively the same.

The method used for sampling refers to SNI 6989.59:2008 concerning Wastewater Collection Methods. The container used to store the sample is adjusted to the parameters to be measured, namely BOD5, COD, TSS, and pH. According to SNI 6989.59:2008, the containers used for these parameters are plastic (polyethylene and the like) or glass. The laboratory testing results in the form of data on the concentration of tofu wastewater quality parameters were compared with the Regulation of the Governor of the Special Capital Region of Jakarta Number 69 of 2013.

If the concentration of each tofu wastewater quality parameter meets the quality standard, the design stage is complete. Suppose it does not meet the quality standards. In that case, planning is carried out for the design of the Waste Water Treatment Plant (WWTP), starting with determining alternative solutions for designing the WWTP to treat the tofu wastewater. A comparison is made for each alternative tofu wastewater treatment technology. Comparisons were made by calculating mass balance and preliminary sizing for each alternative. Next, the best and most suitable WWTP design solution will be chosen to be applied to the tofu-making industry in South Sukabumi Village using the analytical hierarchy process (AHP) method. This method is already used in the environmental engineering field for technology development (Hilmi et al., 2022; Sari et al., 2022). The framework steps in research using AHP can be seen in Figure 1.

Table 1. Characteristics of RS and SM

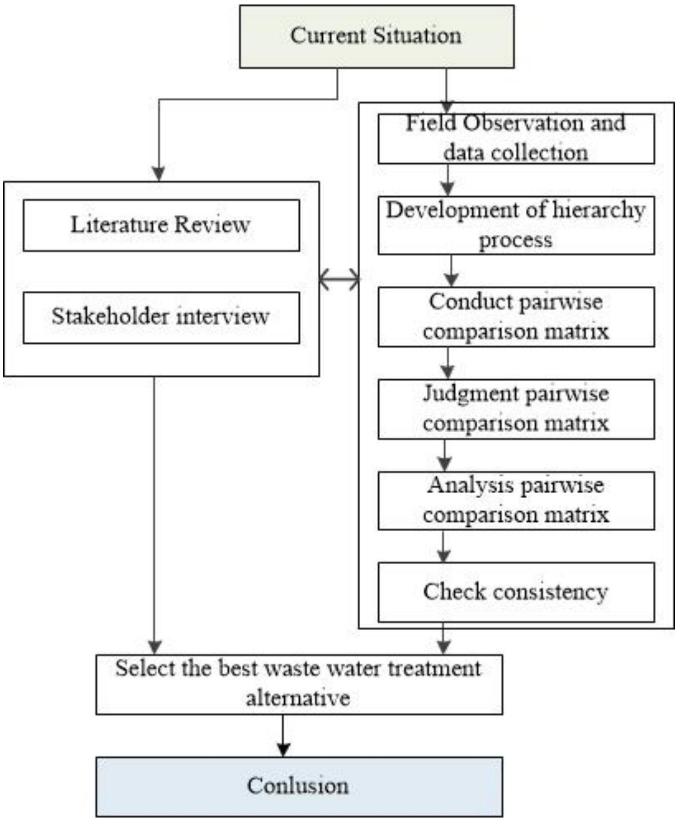

Figure 1. AHP Framework for WWTP Unit Decision Analysis

The tofu wastewater quality test results were compared with the quality standards of tofu wastewater quality parameters based on the Governor of the Special Capital Region of Jakarta Province Regulation Number 69 of 2013. The comparison results will show the parameters that have met or did not meet the quality standards. This comparison purpose is to determine which processing units can process parameters that exceed the quality standard. The unit designed must meet the design criteria to treat wastewater optimally. These processing units will form three alternative series of WWTPs.

Units in the WWTP series will treat tofu wastewater. Therefore, it is necessary to get the data from literature studies to find out alternative series of WWTPs capable of treating wastewater. One of these alternatives must then be chosen as the most effective WWTP design solution. Determination of the selected alternative is based on the fulfillment of the desired criteria effluent meets the quality standard, does not require large land, has easy operation and maintenance, and has low construction cost.

3. RESULT AND DISCUSSION

3.1. Identify problems and determine alternative solutions

Tofu wastewater is produced from soaking, washing, and compaction. The problem related to the tofu industry is untreated wastewater. Untreated wastewater occurs because the industry does not have a WWTP. An effective WWTP requires proper technology that suits the waste characteristic, sufficient land to build, and low cost of construction and maintenance. The land for the tofu-making industry in South Sukabumi Village has a length of 12 m and a width of 13 m with 156 m2. On this land, the land used for tofu production activities is 114.28 m2.

Tofu wastewater quality data was obtained from laboratory test results. Previously, a wastewater sample from the tofu production process had to be taken. Sampling is done by collecting tofu wastewater in a bucket first. The tofu wastewater is homogenized and then taken as much as 2 L from the bucket with 2 plastic jerry can measuring 1 L. In the table below, it can be seen the results of the two samples testing for each parameter. After being compared to the quality standard, none of the tofu wastewater quality parameters met the quality standard. The data shows that as the day progresses, the quality of tofu wastewater gets worse. This is because the containers used for the tofu production process are not rinsed every time. Therefore, tofu solids from the previous wastewater are still left behind and increase the TSS concentration.

The concentration of wastewater quality parameters is needed as a design reference in designing the WWTP. The mean and standard deviation were then calculated from the two samples of tofu wastewater quality in Table 1 to see the variation in the data. A high standard deviation indicates the data is too varied because individual information is far from the average (Hidayat, Sabri, & Awaluddin, 2019). Therefore, tofu wastewater quality data for designing WWTPs cannot be represented by the tofu wastewater quality data standard. However, the design can be done using the highest parameter concentration data so that the WWTP can work optimally in the worst conditions.

Based on the results of laboratory tests, it can be seen that the concentrations of BOD, COD, TSS, and pH in tofu wastewater in South Sukabumi Village do not meet the applicable quality standards. Therefore, these parameters are used to determine alternative wastewater treatment units that can treat them. The units needed to treat tofu wastewater, in general, are equalization tanks, pre-settling tanks, anaerobic biological units 1, aerobic biological units 2, and purification tanks or settling tanks (Simanjuntak, Zahra, & Suryawan, 2021). In this design, the equalization tank is replaced with a collecting tank as both have the same function and also added a neutralization tank to enhance the pH. The collecting tank accommodates the tofu wastewater produced until the production process is completed at 17.00. During the collection of wastewater, it is assumed that no treatment will occur at this well. After that, the tofu wastewater can be pumped to the first treatment unit, namely the neutralization tank.

The wastewater of the tofu manufacturing industry in Sukabumi Selatan Village has a pH of 4. This indicates that the wastewater is acidic and does not meet quality standards. Therefore, a neutralization process is needed to raise the pH to become neutral, namely pH = 7. The suitable biological unit to overcome the problem of tofu wastewater is a combination of anaerobic and aerobic treatment (Astuti & Ayu, 2019). Therefore, neutralization is essential because the wastewater will be treated in biological unit 1 anaerobically. Anaerobic processes can occur at pH 6-8, and bacteria can live and reproduce optimally at pH 6.5-7.5 (Metcalf & Eddy, 1991).

Table 1. Results of Tofu Wastewater Quality Testing

Parameters	**Mean**	**Stdev**	**Standard**
BOD_5 (mg/L)	2.843,5	317,1	75
COD (mg/L)	7.743,5	493,9	100
TSS (mg/L)	827	359,2	100
pH	4	0	6 – 9

The initial settling tank is needed to settle suspended solids in wastewater, especially tofu solids that are wasted from the tofu production process. Then, the biological unit removes dissolved organic substances that can be decomposed (biodegradable). Wastewater containing biodegradable organic substances can be seen from the BOD5/COD ratio. Tofu-making industrial wastewater in South Sukabumi Village has a BOD5/COD value of 0.39. Wastewater that has a BOD5/COD value of 0.3 can be treated biologically (Suryawan et al., 2021). This means that the tofu-making industrial wastewater in the South Sukabumi Village can still be treated biologically.

Biological unit 1 uses anaerobic treatment because this treatment can treat wastewater that has a high organic content (Said, 2000)v. Anaerobic biological treatment is suitable for treating wastewater with a BOD5 concentration of 3,000 – 80,000 mg/L (Said & Rahardiyan, 2015). In previous studies, anaerobic biological units that can be used to treat tofu wastewater include an anaerobic digester (S. S. Hidayati, 2017), an anaerobic biofilter with honeycomb media (Marhadi, 2016), and an anaerobic baffled reactor or ABR (Sani, 2006). The high organic content in tofu wastewater is treated in the biological unit (Budiastuti, Amanah, Pratiwi, Muhari, & Isna, 2021).

Figure 2 shows the treatment units used in the WWTP circuit. Before being treated, the tofu wastewater is collected in the collecting tank. Then, the wastewater is pumped into a neutralization tank to be stirred with a CaCO3 solution. The wastewater in a neutral state then flows into the initial settling basin. After that, enter biological unit 1. In alternative 1, the biological unit 1 used is the anaerobic digester. In the anaerobic digester, microorganisms will degrade wastewater without oxygen. A methanogenesis phase occurs in the processing process, which converts volatile organic acids into methane gas and carbon dioxide (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2017). Methane gas mixed with carbon dioxide gas will form biogas (S. S. Hidayati, 2017). Biogas will be collected in an anaerobic digester dome and can be used as fuel (Rathod et al., 2018). After that, the water will flow into the aeration tank to be treated using activated sludge. The final processing takes place in the final settling basin. The activated sludge that settles in the final settling basin will be recirculated to the aeration tank for reuse.

Figure 3 shows the treatment units used in the WWTP circuit. Before being treated, the tofu wastewater is collected in a collecting tank. Then, the wastewater is pumped into a neutralization tank to be stirred with a CaCO3 solution. The wastewater in a neutral state then flows into the initial settling basin and enter biological unit 1. In alternative 2, the biological unit 1 used is an anaerobic biofilter. In an anaerobic biofilter, microorganisms will be cultured on a honeycomb-type buffer media to form a biofilm. Microorganisms in biofilm decompose organic compounds such as BOD5 and COD (Said & Rahardiyan, 2015). After that, the water flows into the aeration tank to be treated using activated sludge. The final processing takes place in the final settling basin and activated sludge that 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.

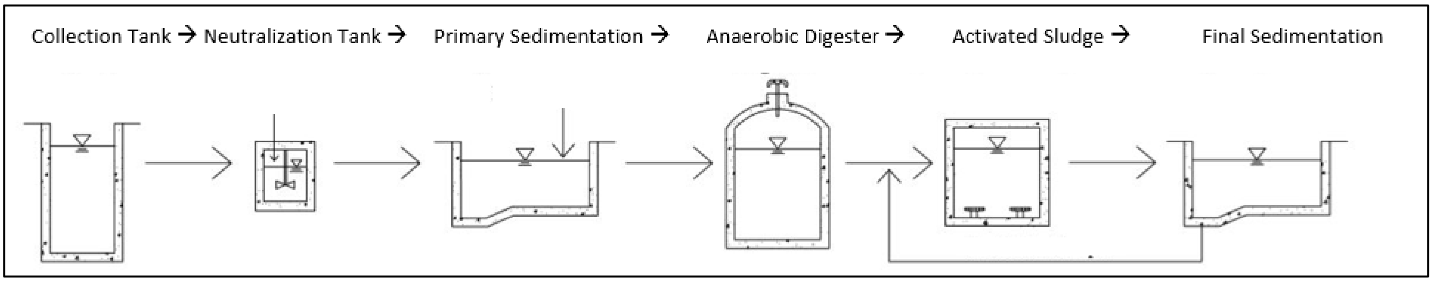

Figure 2. Units WWTP for Tofu Wastewater in Alternative 1

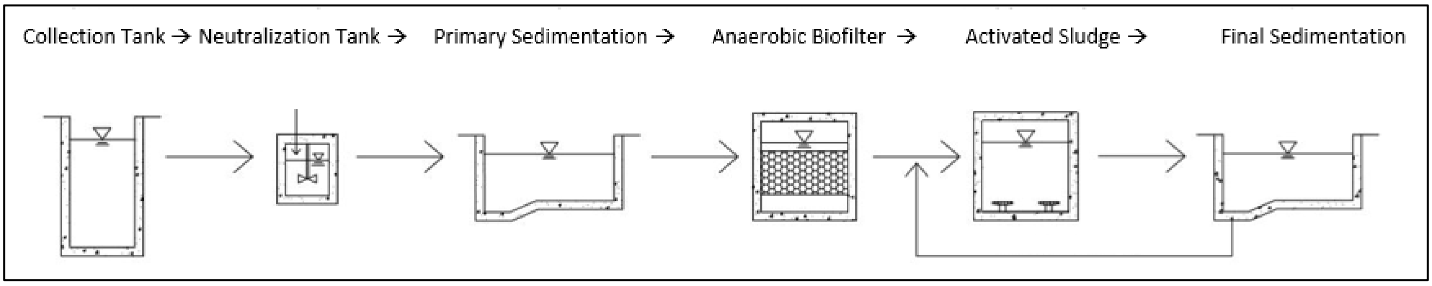

Figure 3. Units WWTP for Tofu Wastewater in Alternative 2

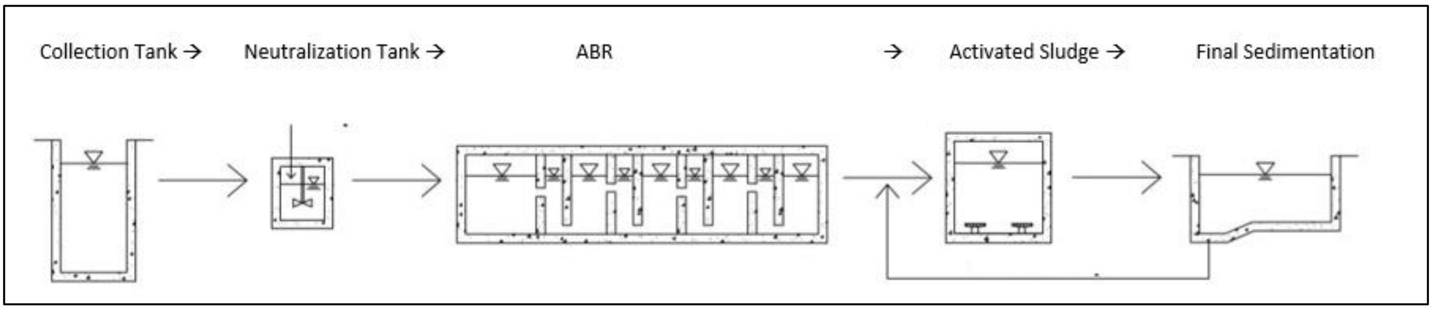

Figure 4. Units WWTP for Tofu Wastewater in Alternative 3

Table 2. Effluent Prediction Calculation Results for Tofu WWTP for Each Alternative

Alternative 1

Parameter	Influent (mg/L)	Collection Tank		Neutralization Tank		Preliminary Sedimentation		Anaerobic Digester		Aeration Tank and Final Sedimentation		**Standard (mg/L)**
		Efficiency	Efluent (mg/L)	Efficiency	Efluent (mg/L)	Efficiency	Efluent (mg/L)	Efficiency	Efluent (mg/L)	Efficiency	Efluent (mg/L)	
BOD_5 (mg/L)	3.292	0%[1]	3.292	0%	3.292	25%[2]	2.469	75%[3]	617.25	85%[6]	92.59	75
COD (mg/L)	8.442	0%[1]	8.442	0%	8.442	25%2	6.331.5	72%[3]	1.772.82	85%[6]	265.92	100
TSS (mg/L)	1.335	0%	1.335	0%	1.335	40%2	801	66%[4]	352.4	90%[6]	35.5	100

Alternative 2

Parameter	Influent (mg/L)	Collection Tank		Neutralization Tank		Preliminary Sedimentation		Anaerobic Biofilter		Aeration Tank and Final Sedimentation		**Standard (mg/L)**
		Efficiency	Efluent (mg/L)	Efficiency	Efluent (mg/L)	Efficiency	Efluent (mg/L)	Efficiency	Efluent (mg/L)	Efficiency	Efluent (mg/L)	
BOD_5 (mg/L)	3.292	0%[1]	3.292	0%	3.292	25%[2]	2.469	84%[5]	395.04	85%[6]	59.26	75
COD (mg/L)	8.442	0%[1]	8.442	0%	8.442	25%[2]	6.331.5	81%[5]	1.202.985	85%[6]	180.45	100
TSS (mg/L)	1.335	0%[1]	1.335	0%	1.335	40%[2]	801	90%[5]	80.1	90%[6]	8.01	100

Alternative 3

Parameter	Influent (mg/L)	Collection Tank		Neutralization Tank		ABR		Aeration Tank and Final Sedimentation		**Standard (mg/L)**
		Efficiency	Efluent (mg/L)	Efficiency	Efluent (mg/L)	Efficiency	Efluent (mg/L)	Efficiency	Efluent (mg/L)	
BOD_5 (mg/L)	3.292	0%[1]	3.292	0%	3.292	95%[2]	164.6	85%[6]	24.69	75
COD (mg/L)	8.442	0%[1]	8.442	0%	8.442	95%[2]	422.1	85%[6]	63.32	100
TSS (mg/L)	1.335	0%[1]	1.335	0%	1.335	80%[2]	267	90%[6]	26.7	100

1: (Hasnaningrum, Ridhosari, & Suryawan, 2021; Khansa, Sofiyah, & Suryawan, 2021); 2(Metcalf & Eddy, 1991); 3(Fdz-Polanco, Pérez-Elvira, & Fdz-Polanco, 2009); 4(Salsabil, Laurent, Casellas, & Dagot, 2010); 5(Said & Firly, 2018); 6(Qasim & Zhu, 2018)

Figure 4 shows the units that will be used in the WWTP circuit. Before being treated, the tofu wastewater is collected in a collecting tank. Then, the wastewater is pumped into a neutralization tank to be stirred with a CaCO3 solution. The wastewater in a neutral state then flows into the initial settling basin. Then, the wastewater flows directly to biological unit 1, namely ABR. Alternative 3 does not have a separate initial settling tank like alternatives 1 and 2 because the ABR unit already has a settling basin. In ABR, a bulkhead causes water to flow upflow and downflow. Both types of flow will increase the contact between wastewater and microorganisms so that organic material can be decomposed efficiently (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2017). After that, the water will flow into the aeration tank to be treated using activated sludge. The final processing takes place in the final settling basin. The activated sludge that 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.

Mass balance calculations were carried out on three alternative series of WWTPs with 1 different biological unit: anaerobic digester, anaerobic biofilter, and ABR. The purpose of calculating the mass balance is to determine the effluent concentration after the wastewater is treated in the WWTP series. The effluent concentration is then compared with the quality standard of tofu wastewater according to the Regulation of the Governor of the Special Capital Region of Jakarta Number 69 of 2013 to determine whether the theoretical effluent concentration has met the quality standard or not. This will show a series of WWTPs capable of treating wastewater to meet quality standards. Following are the results of the calculation of the elimination capacity of the three alternative series of WWTPs.

The series of WWTPs starts from the wastewater reservoir in the collecting tank. No processing occurs in this unit so that the removal efficiency is 0% and the concentration of all parameters remains. Likewise, in the neutralization tank. A neutralization tank serves to neutralize pH but does not exclude BOD5, COD, and TSS parameters so that the removal efficiency for all parameters is 0%. In alternative 1, the treatment unit is the initial settling basin after the neutralization tank. The wastewater is then treated in an aeration tank. The aeration tank and the final settling tank are combined in one system because the sludge in the final settling tank will be recirculated to the aeration tank by as much as 30%. Therefore, the processing in both units will set aside 85% BOD5, 85% COD, and 90% TSS. Then, the final effluent concentration coming out of the aeration tank and the final settling tank is compared with the quality standard. In Table 2, it can be seen that the concentration of TSS in the effluent has met the quality standard. However, the concentrations of BOD5 and COD did not meet the quality standards.

In alternative 2. after the neutralization tank. The treatment unit is the initial settling basin. This unit can remove 25% BOD5, 25% COD, and 40% TSS so that the parameter concentration decreases. The water flows into the anaerobic biofilter. The wastewater is then treated in an aeration tank that combined with final settling tank in one system because the sludge in the final settling tank will be recirculated to the aeration tank by as much as 30%. Therefore. the processing in both units will set aside 85% BOD5, 85% COD, and 90% TSS. Then, the final effluent concentration coming out of the aeration tank and the final settling tank is compared with the quality standard. In Table 2. it can be seen that the concentrations of BOD5 and TSS in the effluent have met the quality standard. However, the COD concentration did not meet the quality standard.

In alternative 3, the treatment unit after the neutralization tank is ABR. The settling tank is inside the ABR. The wastewater is then treated in an aeration tank. The aeration tank and the final settling tank are combined in one system because the sludge in the final settling tank will be recirculated to the aeration tank as much as 30%. Therefore, the processing in both units will set aside 85% BOD5, 85% COD, and 90% TSS. Then. the final effluent concentration coming out of the aeration tank and the final settling tank is compared with the quality standard. It can be seen in Table 2. that the concentrations of BOD5, COD, and TSS in the effluent have met the quality standard.

3.2. Arrange a hierarchical structure

In preliminary sizing used calculations are carried out to determine the size of the WWTP unit. This is related to the limited land available. considering that the tofu-making industry in South Sukabumi Village is a small-scale industry. The land available for the construction of the WWTP is 41.72 m2. The initial calculations for each alternative series of WWTPs are shown in Table 4. The planned series of WWTPs has three alternatives with different biological unit which consists of an anaerobic digester, an anaerobic biofilter, and an ABR. Therefore, it is necessary to select alternatives to choose the best biologic unit 1 to be used in the WWTP series. The selection stage begins by determining the criteria made in the hierarchical structure as follows in Figure 5.

It can be seen that there are four desired criteria. The first criterion is that the effluent meets the quality standard, second criterion is that it does not require a large land area, third criterion is easy to operate and maintain, and the fourth criterion is low construction costs. In criterion one, biological unit 1 can assist the treatment process in the WWTP series so that the tofu wastewater that is disposed of can meet the quality standards. Criterion three avoiding the use of biologic unit 1 is challenging to operate and maintain because the tofu makers are accustomed to working in a conventional simple, and easy process in South Sukabumi. Finally, criterion four bio unit logical 1 is built at the lowest possible cost because in general, The purpose of designing is to find the best and cheapest solution. Comparison matrix for the four criteria which are presented in the following Table 4.

The criteria assessment is carried out by comparing the importance of each criterion with one another. For example, the effluent criterion that meets the quality standard is slightly more critical than the criterion of not requiring a large area of land. so it is given a value of 3. This is because a series of tofu WWTPs meet the quality standard and cannot be built on insufficient land, regarding the tofu-making industry in South Sukabumi Village has limited land. Therefore, the size of biological unit 1 is also essential to consider. Based on the assessment of criteria one against two, the comparison of measures two against criteria one has the opposite value, namely 1/3.

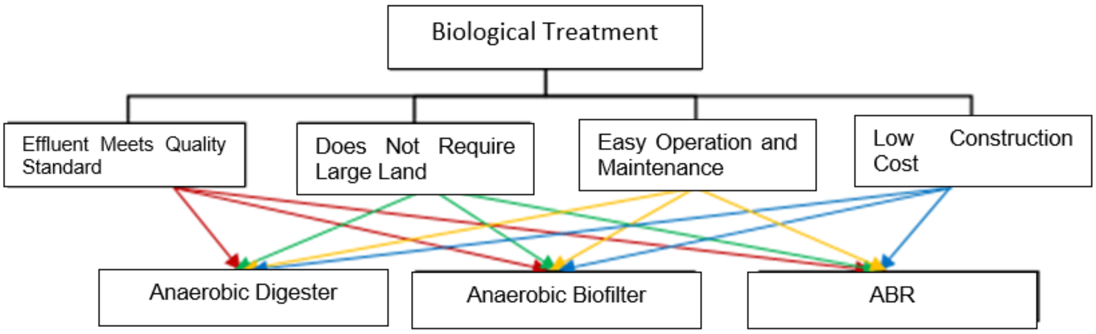

Figure 5. Hierarchical Structure of Determination of Biological Units 1

Table 3. Preliminary Sizing Results

Unit Alternative 1	Results	Unit Alternative 2	Results	Unit Alternative 3	Results
Collecting tank		Collecting tank		Collecting tank	
Long	1.35 m	Long	1.35 m	Long	1.35 m
Wide	1.35 m	Wide	1.35 m	Wide	1.35 m
Area	1.82 m^2	Area	1.82 m^2	Area	1.82 m^2
Neutralization tank		Neutralization tank		Neutralization tank	
Diameter	0.25 m	Diameter	0.25 m	Diameter	0.3 m
Wide	0.05 m^2	Wide	0.05 m2	Area	0.05 m^2
Initial Precipitation Tank		Initial Precipitation Tank			
Long	1.35 m	Long	1.35 m		
Wide	0.7 m	Wide	0.7 m		
Wide	0.95 m^2	Wide	0.95 m^2		
Anaerobic digester		Anaerobic Biofilter		ABR	
Diameter	1 m	Long	1.7 m	Long	6.45
Area	0.8 m^2	Wide	1.7 m	Wide	0.7 m
		Area	2.89 m^2	Area	4.52 m
Aeration tank		Aeration tank		Aeration tank	
Long	1.1 m	Long	1.1 m	Long	1.1 m
Wide	1.1 m	Wide	1.1 m	Wide	1.1 m
Area	1.21 m^2	Area	1.21 m^2	Area	1.21 m^2
Final settling tank		Final settling tank		Final settling tank	
Long	1.1 m	Long	1.1 m	Long	1.1 m
Wide	0.6m	Wide	0.6m	Wide	0.6m
Area	0.66 m^2	Area	0.66 m^2	Area	0.66 m^2
Total land requirement	**5.49 m^2**	**Total land requirement**	**7.58 m^2**	**Total land requirement**	**8.26 m^2**

Table 4. Criteria Assessment

Criteria	Effluent Meets Quality Standard	Does Not Require Large Land	Easy Operation and Maintenance	Low Construction Cost
Effluent Meets Quality Standard	1	3	5	7
Does not require large land	1/3	1	5	5
Easy Operation and Maintenance	1/5	1/5	1	3
Low Construction Cost	1/7	1/5	1/4	1

The criteria of "meet quality standards" are more important than the criteria of " easy of operational and maintenance" measures and easy maintenance. Suppose the operation and maintenance that can treat wastewater to meet quality standards are complex, how to operate and maintain the treatment unit can still be learned, or you can also hire an operator to control the WWTP during operation. Based on the assessment of criterion one against three, the comparison value of criterion three against criterion one is 1/5. Likewise, Operational and maintenance problems can still be overcome compared to the criteria of not requiring a large land area. Therefore, the comparison of criterion two to criterion three is given a value of 5. Based on this assessment. The comparison of standard three to criterion two has a value of 1/5.

The effluent criterion that meets the quality standard is more essential than the low construction cost criterion. so it is given a value of 7. The owner of the tofu industry in the South Sukabumi Village stated that "the order of tofu is constant every day so that the income of this industry is quite stable". Therefore, the large construction costs of the processing unit can still be tolerated. The priority is for this industry to have a unit that can treat tofu wastewater until the effluent meets the quality standard. Based on the assessment of criterion one against criterion four, the comparison value of criterion four against criterion one is 1/7.

The criterion of not requiring a large land area is more important than criterion four. The area is affected by the length and width of the unit. To get the minimum area, the length and width are designed to get the minimum size by adjusting the height or depth of the unit. The larger the unit depth measurement, then the higher the soil's cost. Therefore, the value of criterion two against criterion four is 5. Based on this assessment, the comparison of criterion four to criterion two becomes 1/5.

Operational and easy maintenance criteria are slightly more important than criterion four. This is because the tofu-making industry in South Sukabumi Village is more concerned with the ease of operation and maintenance of the unit. Even if the construction cost of the unit becomes a little more expensive. Therefore, the value of criterion three against criterion four is 3. Based on this assessment. The comparison value of criteria four to three is 1/3. After evaluating each criterion. The next thing to do is to calculate the eigenvectors. The results of which can be seen in the following Table 5.

Table 5. Eigen Vector Value of Each criterion

Criteria	Eigen Vector
Effluent Meets Quality Standard	0.54
Does not require large land	0.29
Easy Operation and Maintenance	0.11
Low Construction Cost	0.06

The eigenvector values indicate the priority level. The higher the eigenvector value, the higher the priority level. Based on the calculations and explanations above. It is found that the priority criterion is criterion one: "The effluent meets the quality standard ". The second priority is criterion two: "it does not require a large land area". The third priority is the third criteria: Easy operation and maintenance. The fourth priority is criterion four: "low construction costs". Then, three alternatives of biological unit 1 were assessed, namely anaerobic digester, anaerobic biofilter, and ABR against each criterion.

The first assessment was to compare the anaerobic digester, anaerobic biofilter, and ABR against the first criterion, namely the effluent meets the quality standard. The effluent concentration of each parameter treated in a series of WWTPs with different biological unit 1 can be seen in Table 2.

In alternative 1 a series of WWTPs that use anaerobic digester as biological unit 1, the concentration of TSS in the effluent has met the quality standard. However, the concentrations of BOD5 and COD did not meet the quality standards. In alternative 2 series of WWTPs using anaerobic biofilters, the concentrations of TSS and BOD5 have met the quality standards. Meanwhile, the COD concentration did not meet the quality standard. Finally, in alternative 3 series of WWTPs using ABR. The TSS, BOD5, and COD concentrations have met the quality standards. After calculating the mass balance, The three alternatives can be assessed compared to criterion one. Here are the results of the assessment:

Table 6. Alternative Assessment against Criterion Effluent Meets Quality Standard

Effluent Meets Quality Standard	Anaerobic Digester	Anaerobic Biofilter	ABR
Anaerobic Digester	1	1/3	1/7
Anaerobic Biofilter	3	1	1/5
ABR	7	5	1

In the flowing criteria that meet the quality standards, the ABR compared to the anaerobic digester is given a value of 7 whereas, the anaerobic biofilter is given a value of 5. This figure is given based on the results of the mass balance calculation. The WWTP series with 1 ABR biological unit can treat tofu wastewater to meet quality standards. The WWTP series with biological unit 1 anaerobic biofilter can treat tofu wastewater whose effluent meets two quality standards. Meanwhile, the effluent from the WWTP series with biological unit 1 anaerobic digester can only meet one quality standard. Therefore, the ABR meets the criteria of one more than the anaerobic digester. Compared with anaerobic biofilters, ABR is more able to meet criteria one.

Meanwhile, the anaerobic digester is slightly more able to meet criteria one than the anaerobic digester, so the value is 3. Based on the above assessment, the ratio of the anaerobic digester to the ABR is 1/7, and the anaerobic digester is 1/5. Meanwhile, The ratio of anaerobic biofilter to ABR is 1/5.

The next step is to calculate the eigenvector of alternative assessments against criterion one. The eigenvector value of the anaerobic digester is 0.08, the anaerobic biofilter is 0.19, and the ABR is 0.72. This figure shows that the alternative that best fulfills criteria one is ABR, then the second is the anaerobic biofilter, and the third is the anaerobic digester.

The second assessment compares the anaerobic digester, anaerobic biofilter, and ABR against the second criterion, which does not require a large land area. Finally, a comparison of alternatives to these two criteria is assessed based on preliminary sizing calculations. In Table 3, the land area required by a series of WWTPs from three alternatives has been calculated. The following is the area of land needed for the three alternative series of WWTPs:

The calculation results in the table above show that the alternative one with a biological unit 1 anaerobic digester requires the smallest land area. At the same time, the largest land area is needed by alternative 2 with 1 ABR biological unit. Finally, alternative 3 with biological unit 1 anaerobic biofilter has a large land area between the anaerobic digester and the ABR. Subsequently, three alternatives were assessed against the second criteria, as Table 7.

The anaerobic digester compared to the anaerobic biofilter was given a value of 5 because the WWTP series with the anaerobic digester was more able to meet the two criteria than the anaerobic biofilter. Based on this assessment, the value of the anaerobic biofilter against the anaerobic digester is 1/5. Meanwhile, The anaerobic digester, compared to the ABR was given a value of 7 because the anaerobic digester was able to meet the criteria compared to the ABR, which required the largest land. Based on this assessment, the ABR value for the anaerobic digester is 1/7. Then, the anaerobic biofilter compared to the ABR was given a value of 3 because the land area was slightly more able to meet the two criteria. Based on this assessment, the ABR value of the anaerobic biofilter is 1/3.

Table 7. Alternative Assessment against Criterion Does Not Require Large Land

Does Not Require Large Land	Anaerobic Digester	Anaerobic Biofilter	ABR
Anaerobic Digester	1	5	7
Anaerobic Biofilter	1/5	1	3
ABR	1/7	1/3	1

The next step is to calculate the eigenvector of alternative assessments against criterion two. The eigenvector values of the anaerobic digester are 0.72, anaerobic biofilter 0.19, and ABR 0.08. This figure shows that the best alternative that meets criteria one is a series of WWTPs with 1 biological unit anaerobic digester, then the second is the anaerobic biofilter, and the third is ABR.

The third assessment compares the anaerobic digester, anaerobic biofilter, and ABR against easy operation and maintenance criteria. The unit's ease of operation and maintenance can be seen in the risks when the unit operates. In alternative 1, the anaerobic digester that produces biogas is at risk of exploding. This can happen because one of the constituents of biogas is methane gas which is explosive if the concentration is 5-15% in the air, especially at high temperatures (BPSDM Ministry of PUPR. 2018). In alternative 2, the anaerobic biofilter treats the wastewater with the formed biofilm. Biofilm on the surface of the media is easily detached so that the process often becomes unstable and can cause blockages to occur (Ministry of Health. 2011). In alternative 3, it can be washed out, which causes the microbes in the mud to come out with the treated water from the ABR so that the decomposition process is less efficient. Then, an assessment of the alternatives is carried out compared to the three criteria. The results of the evaluation are as follows Table 8.

Table 8. Alternative Assessment of Criterion Easy Operation and Maintenance

Easy Operation and Maintenance	Anaerobic Digester	Anaerobic Biofilter	ABR
Anaerobic Digester	1	1/6	1/7
Anaerobic Biofilter	6	1	1/3
ABR	7	3	1

The assessment is given based on explaining the risks that may occur when the unit operates. The anaerobic digester has the highest risk. Therefore, the ABR compared to the anaerobic digester was given a value of 7 because it could very well meet the three criteria, anaerobic biofilter for the anaerobic digester was given a value of 6 because it could meet the three criteria. At the same time, the ABR for anaerobic biofilters is assigned a value of 3. ABR is slightly easier to operate and maintain because it does not use a buffer medium for the growth of microorganisms so that it is not easily clogged (Willistania, Poetranto, Kaavessina, & Margono, 2016). Based on the above assessment, the ratio of the anaerobic digester to the ABR is 1/7 and the anaerobic digester is 1/6. Meanwhile, the percentage of anaerobic biofilter to ABR is 1/3.

The next step is to calculate the eigenvector of alternative assessments against criterion two. The eigenvector value of the anaerobic digester is 0.07, the anaerobic biofilter is 0.30, and the ABR is 0.63. This figure shows that the alternative that best fulfills criteria one is ABR, then the second is the anaerobic biofilter, and the third is the anaerobic digester.

The fourth assessment compares the anaerobic digester, anaerobic biofilter, and ABR against the low construction costs. A comparison of alternatives to these four criteria is assessed based on the estimated initial construction cost of the biological unit 1. Initial construction costs include excavating soil, removing excavated soil, installing foundations, concrete, brick walls, plastering, concrete plastering, installing floor tiles, and waterproofing work. Table 9 shows the results of the initial construction cost calculation for each alternative.

Table 9. Biological Unit Initial Construction Cost

No.	Unit	Cost
1	Anaerobic Digester	Rp 8.651.696.466 (S. Hidayati, Utomo, Suroso, & Maktub, 2019)
2	Anaerobic Biofilter	Rp 24.286.193 (Santoso, 2015)
3	ABR	Rp 9.647.000 (Simanjuntak et al., 2021)

Based on the results of the calculation of construction costs in the table above, it can be seen that the anaerobic digester construction cost is the lowest. On the other hand, the construction cost of ABR is higher than that of an anaerobic digester. Meanwhile, the anaerobic biofilter has the most increased construction cost. Then, an alternative assessment is carried out, which is compared to the four criteria as follows:

Table 10. Alternative Comparison Value against Construction Cost

Construction Cost	Anaerobic Digester	Anaerobic Biofilter	ABR
Anaerobic Digester	1	7	5
Anaerobic Biofilter	1/7	1	1/3
ABR	1/5	3	1

Compared to an anaerobic biofilter, an Anaerobic digester is given a value of 7 because the cost of the biofilter has the highest construction cost and the anaerobic digester has the lowest construction cost. Based on this assessment, the ratio of the value of the anaerobic biofilter to the anaerobic digester is 1/7. Meanwhile, when compared to ABR, the construction costs of the anaerobic digester can meet the four criteria. Therefore, the anaerobic digester to the ABR is given a value of 5. Therefore, the ABR ratio to the anaerobic digester is 1/5. The ABR compared to the anaerobic biofilter was assigned a score of 3 because the construction cost of the ABR was slightly lower than that of the anaerobic biofilter. Based on this assessment, the ratio of the anaerobic biofilter value to the ABR is 1/3.

The next step is to calculate the eigenvector of alternative assessments against criterion two. The eigenvector values of the anaerobic digester are 0.72, anaerobic biofilter 0.08, and ABR 0.19. After each alternative is assessed against all the criteria, a calculation is carried out to get one main priority. All eigenvectors resulting from the comparison of alternatives and criteria are multiplied by the eigenvectors of the criteria. The following are the results obtained from the calculations performed:

The multiplication results in the table above are then compared between each alternative. The higher the product, the higher the priority level. It can be seen from the table above that ABR has the highest product yield. Therefore, the alternative chosen as the solution is ABR. The ABR unit will be used as biological unit 1 in a series of WWTPs designed for the tofu manufacturing industry. ABR is an anaerobic reactor consisting of several compartments separated by baffles (Adi, Razif, & Moesriati, 2016; Afifah, Apritama, Adicita, Septiariva, & Suryawan, 2021). Bulkheads or baffles are installed alternately to flow up and down in the compartment

Tabel 11. Eigen Vector Recapitulation of All Alternatives and Criteria

	Effluent Meets Quality Standard	Does Not Require Large Land	Easy Operation and Maintenance	Low Construction Cost	Criteria	Result
Anaerobic Digester	0.08	0.72	0.07	0.72	0.54	0.31
Anaerobic Biofilter	0.19	0.19	0.30	0.08	0.29	0.20
ABR	0.72	0.08	0.63	0.19	0.11 0.06	0.50

4. CONCLUSION

Tofu wastewater in the tofu-making industry in South Sukabumi Village has poor quality. The results of testing the quality of tofu wastewater against BOD5, COD, TSS, and pH indicate that all parameters do not meet the quality standards of tofu wastewater quality according to the Regulation of the Governor of the Special Capital Region of Jakarta Number 69 of 2013. Therefore, WWTP is designed to treat wastewater to set these parameters aside. The WWTP circuit consists of five units.

The series of WWTPs that have been designed shows there is no removal of BOD5, COD, and TSS in the collecting tank and neutralization tank. However, the pH of the wastewater rose to 7 after being treated in a neutralization tank. BOD5 can be removed by 95% by ABR and 85% by aeration tanks (activated sludge) and pre-settling tanks. COD can be removed by 95% by ABR and 85% by an aeration tank (activated sludge) and initial settling basin. TSS can be removed by 80% by ABR and 90% by aeration tanks (activated sludge) and pre-settling tanks. Based on the mass balance calculation, The wastewater effluent has a BOD5 concentration of 24.69 mg/L, COD 63.32 mg/L, TSS 26.7 mg/L, and a neutral pH. Therefore, the wastewater quality data has met the applicable quality standards. This shows that theoretically, the series of designed WWTPs can treat tofu wastewater and reduce pollution to water bodies.

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