Tofu Wastewater Treatment by Using Sequencing Batch Reactor (SBR) with Variation of Feeding Rates

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ABSTRAK

Limbah cair tahu dari industri tahu di Kabupaten Bandung Barat memiliki kandungan senyawa organik yang tinggi. Salah satu sistem pengolahan air limbah yang dapat dilakukan secara efektif adalah Sequencing Batch Reactor (SBR). Tujuan dari penelitian ini adalah untuk mengetahui peforma terbaik SBR dalam meningkatkan efisiensi pengolahan limbah cair tahu. Pada penelitian ini dilakukan pembibitan (seeding), aklimatisasi, dan pengoperasian SBR dengan variasi kecepatan pengumpanan. Kecepatan pengumpanan SBR pada saat pembibitan (seeding), aklimatisasi, dan run 1 sebesar 200 ml/hari dan sebesar 400 ml/hari pada saat run 2. Hasil penelitian ini memperoleh penurunan konsentrasi COD terbaik dari 8.000 mg/L menjadi 96 mg/L diperoleh pada run 1 dan penurunan konsentrasi COD dari 8.000 mg/L menjadi 160 mg/L diperoleh pada run 2. Efisiensi tertinggi yang dihasilkan adalah 98,8% pada run 1 dan 98% pada run 2.

Kata kunci : Limbah cair tahu, Sequencing Batch Reactor (SBR), Kecepatan Pengumpanan, Performa Reaktor, Efisiensi

ABSTRACT

Tofu wastewater collected from the tofu industries in West Bandung Regency has a high organic content. One of the wastewater treatment systems that can be applied effectively is the Sequencing Batch Reactor (SBR) system. The purpose of this study was to find out the best performance of SBR in improving the efficiency of tofu wastewater treatment. This study conducted seeding, acclimatization, and SBR operation with variation of feeding rates. The SBR feeding rate at the times of seeding, acclimatization, and the first run amounted to 200 ml/day and amounted to 400 ml/day at the time of the second run. The results of this study were the best reduction in COD concentration from 8,000 mg/L to 96 mg/L obtained in the first run and reduction in COD concentration from 8,000 mg/L to 160 mg/L obtained in the second run. The highest efficiency produced was 98.8% obtained from the first run and 98% obtained from the second run.

***Keywords**: Tofu Wastewater, Sequencing Batch Reactor (SBR), Feeding Rates, Reactor Performance, Efficiency*

1. INTRODUCTION

Tofu wastewater is the waste of the production process in the tofu industry. In Indonesia, there are about 84,000 tofu industries dominated by small-scale industries with a simple technology used [1]. With the amount of wastewater produced and the limitations of technology owned, these industries often throw their waste directly into the sewers without treatment so that it has the potential to reduce water quality in the environment.

The wastewater produced by the tofu industry contains many organic substances such as proteins, carbohydrates, and fats. The organic substances contained in wastewater undergo chemical, physical, and biological changes that will produce toxic substances [2]. The treatment of tofu wastewater using conventional active sludge methods has been carried out by Amanda and Rahmaningsih [3]. Their results showed a decrease in COD value from 3,120 mg/L to 320 mg/L (day 46). The effluent COD value of the study results has not met the standard requirements of wastewater quality in the Regulation of the Minister of Environment of Indonesia No. 5 of 2014. Therefore, it needs the development of tofu wastewater treatment methods so that the efficiency of the processing produced is optimal and the effluent parameters meet the quality standard requirements [4].

Sequencing Batch Reactor (SBR) is a method of development of conventional active sludge systems. With this method, the operating time is more flexible because the volume of waste is adjusted to the volume of the reactor. The entire series of processes in this SBR system such as the process of filling, reaction, settle, decant, and idle are carried out in one reactor at consecutive times. Thus the SBR system is more land-efficient, low energy, time, cost, and less operator power needed. Research on industrial wastewater treatment using SBR has been conducted by Dohare et al. [5]. Based on their study, the resulting COD reduction efficiency of 91.27% proved effective for industrial wastewater treatment. Therefore, this study applied the SBR system aerobically with variations in feeding rates. This was conducted to find out the best feeding rate for SBR in lowering the polluting parameters in tofu wastewater.

2. METHODS

2.1 Reactor Used

Tofu wastewater in this study was processed using an SBR. This reactor has a maximum capacity of 5 liters, equipped with supporting equipment such as feed tank, valves, pumps, hose, agitator, aerator, and aerator stones (Fig. 1). The feed tank used is a beaker to make it easier to read the volume when entering the influent into the reactor. Influent feeding into the SBR is carried out by a peristaltic pump. For aeration, the aerator hose is connected to two aerator stones placed in the reactor.

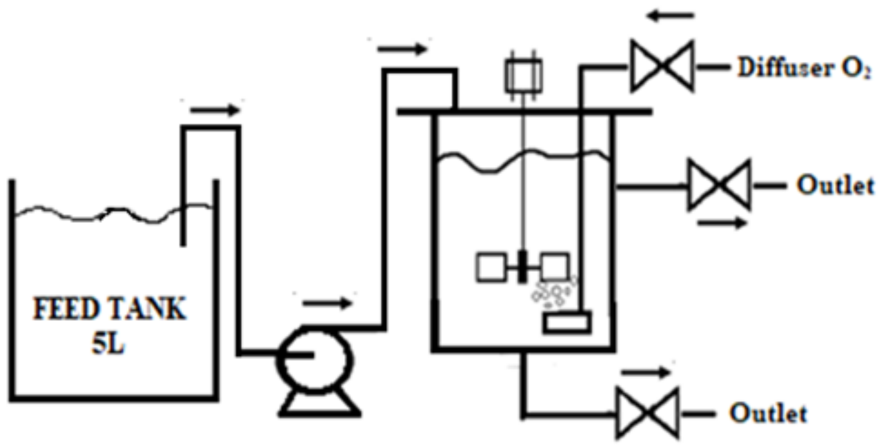

Figure 1. Schematic Diagram of Sequencing Batch Reactor (SBR)

2.2 Raw Materials

The characteristics of tofu wastewater and activated sludge used in this study are as shown in Table 1. Tofu wastewater was obtained from one of the tofu industries in West Bandung Regency with a concentration range of 10,000-16,000 mg COD/L and an acid pH of 3.79, which are normally found in tofu wastewater without treatment. Activated sludge as a source of microorganisms was obtained from one of the food industries in Bogor.

Table 1. Characteristics of raw materials

Characteristics	Tofu Wastewater	Activated Sludge
COD (mg/L)	10,000-16,000	6,400
pH	3.79	6.8
Temperature (°C)	25	25.3

2.3 Preparation Phase

a. The reactor preparation stage carried out is a feasibility test on the reactor, such as a leak test, agitator function test, valve, pump, and aerator function tests.
b. The preparation stage for tofu wastewater was a dilution of tofu wastewater into feed with a concentration of 8,000 mg COD/L. This tofu wastewater feed is a substrate for biological treatment processes during the research. Prior to processing, analysis of COD, pH, and turbidity was carried out in duplo.

2.4 Seeding and Acclimatization Phase

The addition of nutrients at the time of seeding was 200 mL/day with a concentration of 5,000 mg COD/L. These nutrients follow a COD:N:P ratio of 100:5:1 [6] where glucose is the carbon source, KNO_3 is the nitrogen source, and KH_2PO_4 is the phosphorus source. The growth of biomass is indicated by the color of the mud getting darker (blackish brown).

Seedings were carried out in a neutral pH range of 6-8. The pH range at the seeding stage of this study was 7.66-9.42 with an average of 8.53. The addition of H_2SO_4 or NaOH was done if the pH of the reactor was too alkaline or acidic. The concentration of dissolved oxygen (DO) was maintained above 4 mg/L so that the aerobic process can run optimally. The temperature during the seeding stage was in the range of 24.6-26.2°C with an average of 25.03°C. There is no special treatment so that the temperature was maintained at a normal temperature of ±25°C.

The acclimatization stage was carried out for 9 days with feeding as much as 200 mL/day with a ratio of glucose and tofu wastewater of 20:80, 30:70, 40:60, 50:50, 60:40, 70:30, 80:20, 90 :10 and 100:0. During the acclimatization stage, the conditions in the reactor were kept aerobic by supplying oxygen to keep the DO above 4 mg/L. The pH was maintained at neutral pH and the temperature was maintained at room temperature. During acclimatization, COD was maintained at a concentration of 8,000 mg COD/L. COD concentrations in the reactor were also measured to observe adaptation of microorganisms to the addition of tofu wastewater during this acclimatization stage. Acclimatization was considered complete when COD experienced a relatively stable decrease and MLVSS increased [7].

2.5 Operation Stage of Sequencing Batch Reactor (SBR)

The operation of SBR was carried out with variations of feeding 200 mL/day (1st run) and 400 mL/day (2nd run) with a concentration of 8,000 mg COD/L. A total of one cycle of the SBR system in this study was 24 hours with details of the charging and discharging stages for 15 minutes, the reaction stage for 21 hours 30 minutes, precipitation for 1 hour 30 minutes, and rest stage for 30 minutes.

COD concentrations were measured on the influent and effluent samples so that the COD reduction efficiency could be known. In addition, MLVSS, pH, DO, temperature, and turbidity parameters were analyzed to determine the processing conditions that occurred in the reactor.

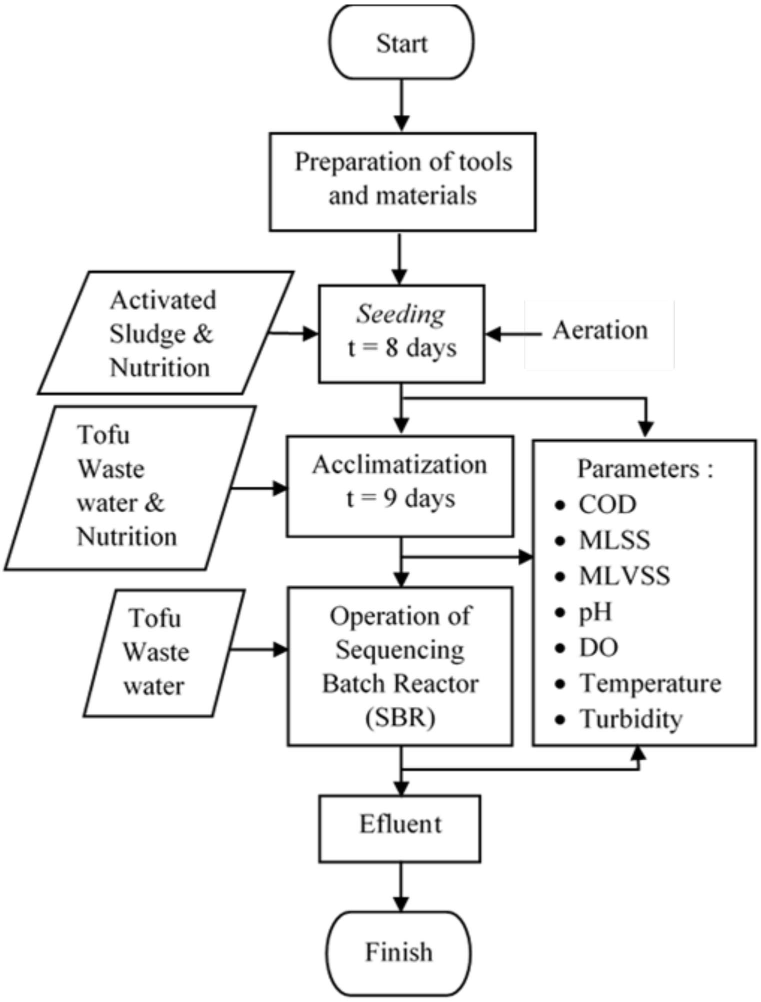

Figure 2. All stages of tofu wastewater treatment using SBR

3. RESULTS AND DISCUSSION

3.1 Seeding Phase

The seeding stage is the initial stage of research that aims to breed microorganism seeds in the reactor. During the seeding stage, the aeration process or oxygen supply through the aerator was carried out to meet the growing needs of aerobic microorganisms, namely by keeping the DO above 4 mg/L.

Correction of the pH value at the seeding stage was carried out once by adding a strong acid in the form of H_2SO_4 6 N. In this study, the average pH value tended to be alkaline, in the range of 7.66 – 9.42. The pH value did not have much impact on the treatment process, as evidenced by the MLVSS and COD values during the seeding process as expected.

a. Dissolved Oxygen (DO) Testing

The value of Dissolved Oxygen (DO) during the seeding stage was in the range of 0.7-8.1 mg/L. Based on Fig. 3, the DO curve during the seeding stage shows a highly fluctuating line. The decrease in DO value indicates an increase in oxygen demand in the reactor, while the increase in DO value is triggered by the increased activity of microorganisms to degrade organic compounds in tofu wastewater [8].

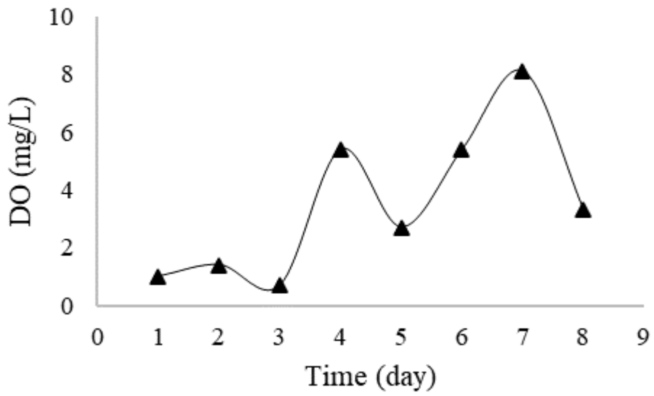

Figure 3. DO Curve during the Seeding Stage

b. MLVSS Testing

The MLSS value represents the total suspended solids, consisting of microorganisms, minerals, and other suspended solids. The MLVSS value represents the concentration of microorganisms that degrade tofu wastewater. In this study, MLVSS data were obtained based on the average MLVSS/MLSS ratio which refers to a similar study conducted by Amanda and Yuningsih, which is 98.02 % [3]. This was carried out because the MLVSS measurement in this study experienced problems in getting representative results due to failure in maintaining constant furnace temperatures.

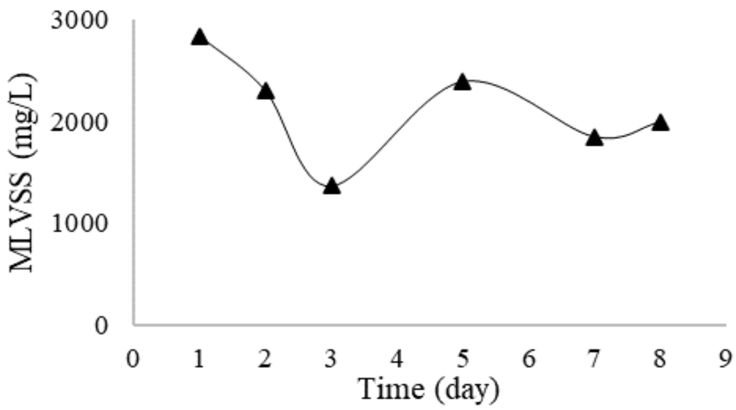

Figure 4. MLVSS Curve during the Seeding Stage

Fig. 4, shows the increase and decrease (fluctuating) of the value of MLVSS during seeding. The highest value was found on the first day of seeding, which was 2,835.1 mg/L, while the lowest value on the third day of seeding was 1,367.3 mg/L. After the third day, an increasing trend of MLVSS occurred which indicated an increase in the concentration of microorganisms. The addition of microorganisms can occur because the nutrients provided are sufficient so that microorganisms can grow properly. Even so, the results of the MLVSS test in the last 3 days showed a concentration of higher than 1,500 mg/L. The seeding process was stopped when the MLVSS value had reached 1,500 – 2,500 mg/L [9].

c. COD Testing

Chemical Oxygen Demand (COD) testing during the seeding process is shown in Fig. 5. Based on the picture, the COD value shows a downward trend except on the fifth day, which might be due to the decrease of DO at the same fifth day (Fig. 3), resulting in an increase of COD. The COD value which was originally 9,600 mg/L decreased to 1,600 mg/L on the eighth day, with a decreasing efficiency of 83.33%. This shows that aerobic microorganisms are very active to decompose the nutrients that are fed. The seeding process was stopped when the COD value was relatively stable with fluctuations less than 10% [10]. With a decrease in the COD value and the appropriate MLVSS values, it can be said that the seeding process had been completed and the process could be proceeded to the acclimatization stage.

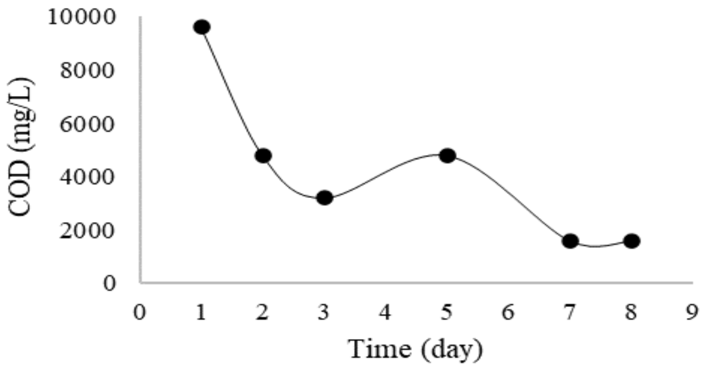

Figure 5. COD Curve during the Seeding Stage

3.2 Acclimatization Stage

The acclimatization stage in this study aims to enable aerobic microorganisms to adapt to the tofu wastewater that is fed. Acclimatization is done by reducing the concentration of nutrients and replacing them with wastewater to be processed. The gradual increase in the concentration of tofu wastewater is intended so that aerobic microorganisms in the reactor do not experience shock loading which results in suboptimal performance of these microorganisms.

During the acclimatization stage, the pH range was 8.07-9.02 and pH correction was carried out three times to maintain optimum conditions in the reactor. The value of Dissolved Oxygen (DO) was in the range of 1.2-9.8 mg/L. The temperature during the acclimatization process was in the range of 24.5-26.2°C. These three parameters can affect the biological treatment process, because microorganisms grow optimally in favorable conditions, namely at neutral pH, normal temperature, and DO higher than 1 mg/L.

a. MLVSS Testing

The results of the MLVSS parameter test show an increase and decrease (fluctuating) trend. This means that as long as the MLVSS value increases, the quantity of microorganisms also increases. Fluctuating values occur because microorganisms are still adapting to tofu wastewater. However, the MLVSS curve during acclimatization tends to increase rather than decrease. This increase indicates that over time, microorganisms are able to adapt well in treating the added tofu wastewater. Based on Fig. 6, the MLVSS value tends to increase, with the highest value on the ninth day of 9,402.1 mg/L, from the MLVSS value on the first day of 2,131.8 mg/L.

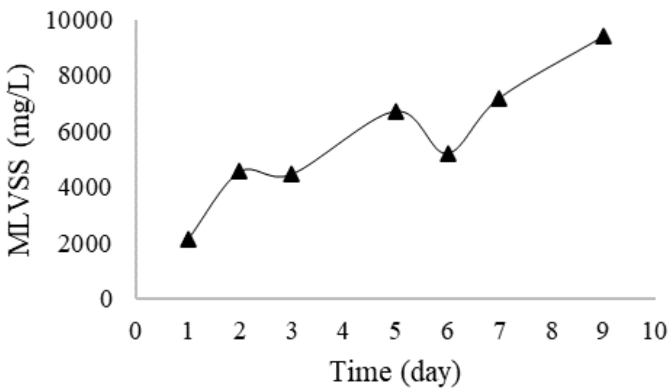

Figure 6. MLVSS Curve during the Acclimatization Stage

b. COD Testing

An increase in the concentration of microorganisms that degrade organic compounds will be followed by a decrease in the COD value. Organic compounds in wastewater are used by microorganisms as substrates for metabolism and growth. Therefore, the higher the concentration of microorganisms, the more organic compounds are decomposed.

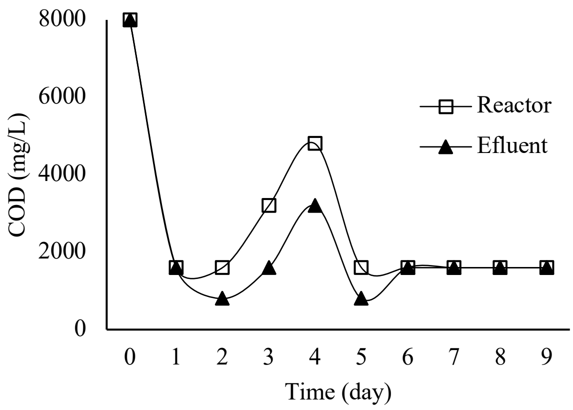

Figure 7. COD Curves during Acclimatization Stage

Based on Fig. 7, the reactor COD and effluent COD values on the second to the fourth day increased. This happens because microorganisms are still adapting to the addition of tofu wastewater. The increase in COD value causes the decomposition of organic compounds by microorganisms to be not optimal, this is reinforced by a decrease in MLVSS on the second day of acclimatization. On the fourth to fifth day, the COD value of the effluent and reactor decreased significantly. This is evident from the COD value of the reactor was originally 4,800 mg/L decreased to 1,600 mg/L. Likewise with the effluent COD which was originally 3,200 mg/L decreased to become 1,600 mg/L. According to Direstiyani [11], the achievement of the acclimatization process is marked by a steady decline in the COD value and an increase in the MLVSS value. On the sixth to ninth day, COD showed stability and the MLVSS value had significantly increased compared to the first day (Fig. 6) so that the acclimatization stage was declared to have been completed.

3.3 Operation Stage

The operation stage of the SBR which was carried out with two variations of the feed was aimed at finding the best COD reduction efficiency in the treatment of tofu wastewater. The following is the MLVSS curve during stages of 1st run (feeding of 200 mL/day) and 2nd run (feeding of 400 mL/day).

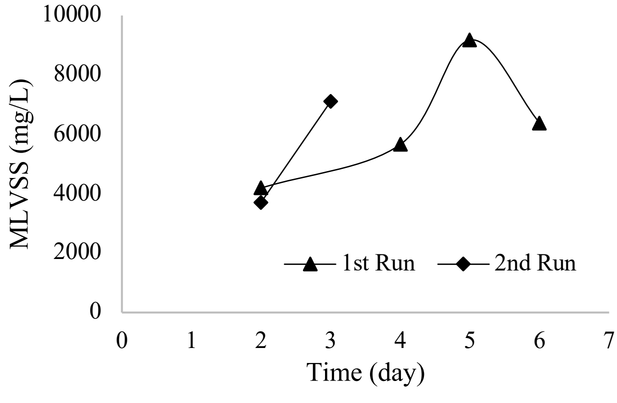

Figure 8. MLVSS Curves during the 1st Run and 2nd Run

MLVSS testing at the operation stage was carried out to ensure the adequacy of the presence of microorganisms during the tofu wastewater treatment process. On the last day of the acclimatization stage, the MLVSS value was 9,402.1 mg/L so that the conditions were very optimal to continue to the SBR operation stage.

Based on Fig. 8, the fifth day of run 1 showed the highest MLVSS value of 9,176.7 mg/L compared to the first day of 4,190.34 mg/L. During the processing of the first variation, the MLVSS value increased on the second to fifth day and decreased on the sixth day. This decrease can occur due to the death of microorganisms in the activated sludge so that it carries out with the effluent. The increase in the MLVSS value can affect the resulting COD value. The more microorganisms, the more organic compounds in the tofu wastewater are degraded.

In the second run, the measured MLVSS value was 3,709.9 mg/L and on the next day it rose to 7,108.5 mg/L. The increase in the MLVSS value indicates the increasing number of microorganisms contained in the SBR. This supports the process of waste degradation by microbes as shown in Fig. 9.

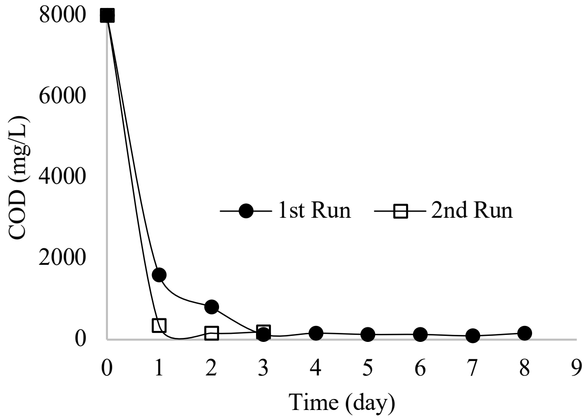

Figure 9. COD Curves during 1st Run and 2nd Run

Based on Fig. 9, the COD value of the first and second variations shows a downward trend from the first day. The results of the COD value indicate the optimum degradation process, thus indicating that microorganisms are very effective in degrading organic compounds in tofu wastewater. The COD value of the first variation of waste was successfully reduced with a value range of 96 mg/L – 160 mg/L. In the second variation, there was an increase in the COD value on the third day, but a downward trend was still visible. The results of the COD value indicate that microorganisms are still effective in degrading organic compounds in tofu wastewater. The COD value of the waste which was previously 8,000 mg/L, could be reduced in the range of 160 mg/L – 192 mg/L.

The highest COD removal was found on the seventh day to become 96 mg/L for the first variation and 160 mg/L for the second variation. Both values have met the quality standards in the Regulation of the Minister of the Environment of Indonesia No. 5 of 2014, in which the maximum allowable COD is 275 mg/L [4]. The success of this COD reduction proves that the treatment of tofu wastewater using SBR with the first and second variations is effective. This statement is supported by the calculation of COD reduction efficiency.

The highest COD reduction efficiency was 98.8% in the first variation, which occurred on the seventh day of processing, while the lowest value was obtained on the first day of 80%. The highest COD reduction efficiency value in the second variation was 98% on the second day of processing, while the lowest efficiency on the first day was 95.6%. Thus, this research has met the quality standards for aerobic wastewater treatment using the SBR system. The experiment in the second run was carried out with a limited time due to the limitations of the experiment in connection with the implementation of restrictions on community activities during the covid-19 pandemic in Indonesia.

Another parameter that supports the success of this wastewater treatment is the turbidity value. The turbidity value was tested to see how much the concentration of suspended solids and colloids decreased in the tofu wastewater after processing. Fig. 10 shows the turbidity curve resulting from the effluent measurement. The turbidity measurement becomes important especially when the reactor applied is the SBR, a reactor type which maintains high concentration of microorganisms inside the reactor [12].

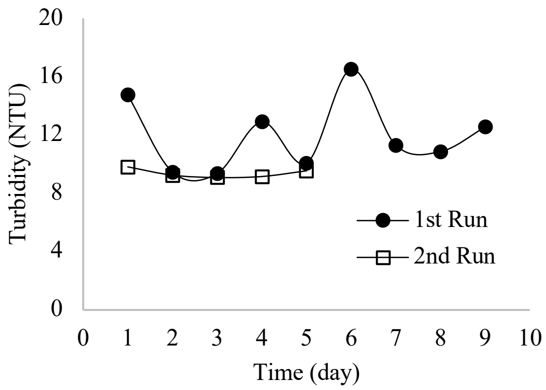

Figure 10. Turbidity Curves during 1st Run and 2nd Run

Based on Fig. 10, the resulting turbidity value fluctuates but is stable in the range of 9-16 NTU for the first variation and less than 10 NTU for the second variation. The lowest turbidity value of the first variation occurred on the third day, namely 9.36 NTU, while the highest turbidity value on the sixth day was 16.5 NTU. The lowest turbidity value of the second variation occurred on the third day of 9.08 NTU and the highest turbidity value on the first day of 9.81 NTU. The tofu wastewater before being fed as an influent had a turbidity value of 196.8 NTU, while the total turbidity value of the effluent from the first day to the last processing day was less than 17 NTU. Thus, in addition to reducing the high concentration of organic compounds in tofu wastewater, this research can reduce the level of turbidity of the effluent.

During experiment, the operating conditions must always be maintained to achieve optimal processing results. Parameters that are maintained are pH, DO, and temperature. These three parameters can affect the COD and MLVSS values. The temperature of the first variation was in the range of 23.7-24.5°C, while the temperature of the second variation was in the range of 24.0-25.3°C. The temperature value is following the ideal criteria for aerobic processing, which is ±25°C.

The pH range in the first variation of this process was 8.13-8.80, while for the second variation the pH range was 8.00-8.34. At this stage, two times of the pH correction were carried out to maintain the optimum conditions in the reactor, so that the microorganisms remain in a suitable environment. In addition, the appropriate pH can affect the COD value of the effluent so that the reduction efficiency is high.

For the value of DO, the first variation was in the range of 4.3-9.8 mg/L, while the second variation was in the range of 5.3-9.2 mg/L. Although the DO curves flactuate, the MLVSS produced is not less than the ideal criteria for SBR operation, namely 1,500 – 2,500 mg/L [9]. This indicates that aerobic microorganisms could still degrade tofu wastewater optimally.

3.4 Pollutant Parameters

Tofu wastewater treatment using SBR in this study could reduce pollutant parameters following the quality standards regulated in the Regulation of the Minister of the Environment of the Republic of Indonesia Number 5 of 2014 (Table 2). Fulfilment of the quality effluent standards supports the results of COD reduction in the first and second run of 98.8% and 98%, respectively, in which it is predicted that the BOD reduction would also result in a high percentage.

Tabel 2. Comparison of Parameters with Regulation*

Parameters	Influent	Effluent		Parameters (*)
		1st Run	2nd Run	
COD (mg/L)	8,000	96	160	< 275
pH	3.79	8.13-8.80	8.00-8.34	6-9
Temperature (ºC)	25	23.7-24.5	24.0-25.3	< 38
Turbidity (NTU)	196.8	9.36	9.08	-

* Regulation of the Minister of the Environment of the Republic of Indonesia Number 5 of 2014 [4]

4. CONCLUSION

Research on the treatment of tofu wastewater using SBR had been successfully carried out with detailed results as follows:

a. Tofu wastewater treatment using SBR resulted in the best COD reduction efficiency at 98.8%, resulting from the highest MLVSS value of 9,176.7 mg/L, and the average pH, DO, temperature, and turbidity of 8.47; 7.05 mg/L; 24.8°C, and 9.36 NTU, respectively.
b. The COD efficiency obtained at 200 mL/day feeding rate was almost the same as the COD reduction efficiency at 400 mL/day feeding rate, which was 98% due to the limited experimental time in the operation of the SBR with the variation of the second feeding rate.
c. For further research, it is recommended that the variation of feeding rate be expanded to below 200 mL/day and above 400 mL/day to support the findings of this study.

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