Study of tofu wastewater treatment using anaerobic baffled reactor: laboratory scale

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Abstract. One of the foods favorites by Indonesian people is tofu. In the process of making tofu, it produces wastewater. The tofu wastewater must be treated first to reduce environmental pollution. To treat the liquid waste, it is using biological treatment by an anaerobic baffled reactor with bio-ball. The purpose of this study was to determine the optimum time at 75% tofu wastewater concentration. The detention time used in this study was 12 hours, 24 hours, 36 hours and 48 hours. Seeding takes time about 45 days, with the obtained VSS was 5550 mg/L. Furthermore, acclimatization in the reactor takes about 30 days, with an efficiency of removing COD of 86.3%. The results obtained that at 12 hours of detention, there is a COD allowance of 79.8%, 24 hours of detention time there is a COD allowance of 85.4%, 36 hours of detention time 86.3%, and 48 hours of detention time 88.4%. It shows that the optimum detention time in this anaerobic reactor is 48 hours. However, the COD level was 765.3 mg/L is still slightly above the quality standard according to the Minister of Environment Regulation No.5 2014, which is the maximum COD level of 300 mg/L.

1. Introduction
Tofu is one of the processed food products made from soybeans. The tofu industry in the processing process produces waste, both solid and liquid waste. Most of the wastewater treatment in the tofu manufacturing industry has not been appropriately treated. The tofu manufacturing industry only disposes of its liquid waste in the waters. The liquid waste generated from the tofu manufacturing process comes from the washing, boiling, pressing and printing processes. Therefore, the resulting liquid waste contains high organic content. Therefore, because the organic content in tofu wastewater is high and has high BOD and COD levels, if tofu wastewater is directly discharged into water bodies, it will reduce the environment's carrying capacity.

Tofu wastewater is organic waste and does not contain heavy metals. Thus, the processing can be done biologically. The biological treatment process is wastewater treatment by utilizing microorganisms in degrading pollutant content in the wastewater. The currently existing tofu wastewater treatment technology is generally waste treatment with an anaerobic system. It is because the operational costs are cheaper and allow it to be used on a large scale.

KOPTI or Indonesian Tofu-Tempe Production Cooperative in Semanan was established in 1972. This cooperative was founded by tofu-tempe craftsmen, the majority of whom came from Pekalongan, Central Java. The Semanan Industrial Village was finally inaugurated in 1992 after receiving support from the DKI Jakarta Regional Government, the Minister of Industry, the Minister of Cooperatives and
the Minister of Housing. In 1974 Kopti Semanan changed its name to PRIMKOPTI Swakerta, West Jakarta. Primkopti is a tofu and tempeh production cooperative located in Semanan, West Jakarta. This cooperative has a land area of 12 hectares used for members’ homes and as a tofu and tempeh production house. The cooperative located in Semanan Primkopti has a shared kitchen which members use to produce tofu and tempeh. The location of the shared kitchen is right in front of the Semanan IPAL [1].

Organic materials contained in the waste of the Tofu Industry are generally very high. The organic compounds in the wastewater can be in proteins and fats, which are the largest in number [2]. The characteristics of tofu wastewater include total solids, suspended solids, temperature, color and odor. Chemical characteristics include organic materials, inorganic materials and gases. Wastewater temperature ranges from 37-45 °C, turbidity ranges from 535-585 FTU, color 2225-2250 Pt.Co, Ammonia 23.3 – 23.5 mg/l, BOD₅ 6000-8000 mg/l and COD 7500- 14000 mg/l [3].

Anaerobic Baffled Reactor (ABR) is a suspended treatment system that occurs anaerobically in a bioreactor divided into several compartments. A series of bulkheads installed in the ABR makes the liquid waste flow up-flow and down-flow from the inlet to the outlet so that there is contact between the liquid waste and the active biomass [4]. The concentration of organic compounds varies throughout the ABR, resulting in different populations of microorganisms in each compartment. This condition depends on the specific environmental conditions produced by the decomposition product.

In waste treatment with ABR, it is necessary to pay attention to activated sludge. The higher the activated sludge added, the higher the decrease in COD levels produced by bacteria that decompose organic matter in wastewater. In addition, the type of activated sludge used in the ABR can affect the performance of the ABR unit itself. The content of microorganisms and the environment of microorganisms in their natural habitats affect the performance of activated sludge in treating influent waste in ABR [5].

The bacteria contained in the bioreactor float and settle horizontally towards the end of the reactor slowly, thereby increasing the cell retention time. Liquid waste is in contact with active biomass so that the effluent is free from biological solids. The configuration shows a high degree of removal [6].

The main advantages possessed by ABR, among others:
1. ABR can separate the processes of acidogenesis and methanogenesis longitudinally without any control problems and high costs [7].
2. Simple ABR design, relatively low constructive cost, and stability against hydraulic and organic shock loads [8].
3. The hydrodynamic pattern of ABR can maintain biomass without fixed media [4].

In this study, we want to know the optimal hydraulic detention time in the Anaerobic Baffled Reactor to know the efficiency of COD level and VSS levels in tofu wastewater.

2. Methodology

2.1. Location
The tofu industry, which is located in Semanan Village, Kalideres District, West Jakarta, as a place for sampling tofu wastewater and the location of the insulated Anaerobic reactor processing is carried out on a laboratory test scale located at the Environmental Laboratory of the Environmental Engineering Department, FALTL, Trisakti University.

2.2. Anaerobic Baffled Reactor
The reactor used is a continuous reactor that has four anaerobic zones. This study uses a laboratory-scale reactor. The reactor is made of acrylic glass, 5 mm thick with dimensions of 60cm × 20 cm × 35 cm. The media used in this reactor is bio-ball. The wastewater is put into a waste container with a capacity of 90 liters. Then, it enters the insulated anaerobic reactor from the discharge regulator. Wastewater from the discharge control tub entering the reactor is regulated using a pump with a discharge regulator channeled into the insulated anaerobic reactor according to the predetermined discharge. Discharge is obtained from the volume of treated water divided by the hydraulic residence
time of each treatment. In the 12-hour treatment, it is known that the resulting discharge is 37.5 ml/minute; 24-hour treatment of 18.75 ml/minute; 36-hour treatment of 12.5 ml/minute; and 48 hours treatment of 9.4 ml/minute. Pictures of reactor equipment can be seen in Fig 1.

![Reactor Equipment](image)

**Figure 1.** Reactor equipment.

Description:
1. Waste Container with a capacity of 90 liters
2. Discharge control basin
3. Discharge regulating pump
4. Influent hose
5. Insulated Anaerobic Reactor
6. Bioball Media
7. Effluent Hose
8. Effluent basin

2.3. **Quality Standard**
The wastewater used in this research is tofu industrial wastewater that does not comply with the quality standard requirements to discharge into the environment—the quality of tofu industrial wastewater before processing is shown in table 1.

| Unit   | Quality of wastewater (mg/L) | Quality Standards (mg/L) |
|--------|------------------------------|--------------------------|
|        |                              | PerGub DKI No 69 Year 2013 | PerMen LH No 5 Year 2014 |
| BOD₅   | 3648.5                       | 75                       | 150                      |
| COD    | 6912                         | 100                      | 300                      |
| TSS    | 767                          | 100                      | 200                      |
| pH     | 4.6                          | 6-9                      | 6-9                      |
| VSS    | 756                          |                          |                          |
| N total| 43.3                         |                          |                          |
| P Total| 1.9                          |                          |                          |
3. Result and Discussion

3.1. Seeding
The seeding process is a process to breed bacteria to decompose or degrade wastewater which can form a biofilm layer contained in the buffer media, namely bioball. The seeding process is carried out for 45 days. On the 45th day, the VSS value obtained was 5550 mg/l. It shows that the VSS concentration and the amount of biomass are sufficient to proceed to the next stage, namely acclimatization.

3.2. Acclimatization
The acclimatization stage is a stage of adapting bacteria to the wastewater to be treated. In the acclimatization process, the tofu wastewater is given in stages, starting from a low concentration until it is entirely replaced by 100% pure waste. The addition of tofu wastewater continues to be carried out until it is entirely replaced by tofu wastewater by considering COD removal's efficiency until it is in a stable condition. Provision of tofu wastewater is carried out in stages to avoid a significant decrease in COD removal efficiency and prevent shock loading of bacteria.

In the acclimatization stage, a detention time (td) of 24 hours was used. It is because tofu wastewater can have a reasonably good contact time with the bioball media so that bacteria can grow attached by forming a biofilm layer. The acclimatization process was carried out with a recirculation system directly in an anaerobic insulated reactor attached to the bioball buffer media.

Acclimatization was carried out for 30 days. In the first stage, with a concentration of tofu wastewater at 20% for three days, the COD efficiency was 61.2%. Then, from day 4 to day 9, acclimatization was carried out with a concentration of tofu wastewater of 40%, obtaining a COD removal of 71.5%. From the 10th to the 17th day, tofu wastewater was used with a concentration of 60%, and the COD removal efficiency was 75%. From the 18th day to the 23rd day with 80% tofu wastewater concentration, the COD removal result was 77%, and the last stage of acclimatization, namely on the 24th to 30th day, the replacement of pure tofu waste was made to 100%, the COD removal was 86.3%.

3.3. Running
The insulated anaerobic reactor with bioball media is carried out continuously, which can be started after acclimatization ends with a stable condition, namely in a state of high COD removal efficiency. At this stage, COD and VSS research was carried out at the sampling point at the anaerobic inlet and anaerobic outlet. The hydraulic detention time is 12 hours, 24 hours, 36 hours and 48 hours. The start of the running process is from the longest detention time, which is 48 hours. It is due to avoid shock loading.

| Detention time | Inlet   | Outlet  | Efficiency Removal (%) |
|----------------|---------|---------|------------------------|
| 12             | 6268.25 | 1257    | 79.8                   |
| 24             | 6735.25 | 981     | 85.4                   |
| 36             | 6197.5  | 852     | 86.3                   |
| 48             | 6567    | 765.25  | 88.4                   |

Table 2. Result of detention time against COD efficiency
Based on the analysis of COD removal for variation of detention time, it was found that the greatest efficiency was at detention time of 48 hours with an efficiency of 88.4%. While at the detention time of 36 hours, the results were obtained at an efficiency of 86.3%. Meanwhile, at the detention time of 24 hours, the removal efficiency was 85.4%, and at the detention time of 12 hours, the removal efficiency was 79.8%.

The study results prove that the longer or more fantastic the detention time of wastewater in the bioreactor, the better the removal efficiency. Because the longer the wastewater is in the reactor, the longer the contact time of wastewater with microorganisms. So that the time used to degrade the material is getting more and more, which will eventually be a lot in setting aside the levels of COD in the wastewater. The results of COD on detention time also show that there is an increase and decrease in removal efficiency. It is caused by the condition of tofu wastewater also fluctuating. However, the efficiency results can still be stable in terms of increase and decrease because the increase and decrease in efficiency are still within the difference of 5%.

### Table 3. Result of detention time against VSS efficiency.

| Detention Time | VSS Concentration (mg/L) | Efficiency Removal (%) |
|----------------|---------------------------|------------------------|
|                | Inlet | Outlet |                |               |
| 12             | 2612  | 444    | 83,0            |
| 24             | 2627  | 358    | 86,4            |
| 36             | 2587  | 269    | 89,6            |
| 48             | 2450  | 139    | 94,3            |
Figure 3. Detention time against VSS Efficiency.

From the VSS results above, it is known that the VSS level at the reactor inlet is greater than the VSS level at the reactor outlet; this is due to the large number of microorganisms attached to the bioball media and as a biofilter of the reactor, the bioball media can be able to eliminate the VSS concentration in wastewater quite well.

4. Conclusion

Based on the analysis of the results of the tofu wastewater treatment with the anaerobic baffled reactor, we concluded that the longer or the more significant the detention time of wastewater on the bioreactor, the better the removal efficiency. In this study, the optimum detention time was 48 hours to achieve the COD removal efficiency value of 88.9% with a COD value of 723 mg/L. So as with the VSS removal efficiency value of 94.3% with VSS value is 139 mg/L.

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