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Evaluation of two-stage biological treatment with attached filter media on treatment of tofu-processing wastewater

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Abstract

Tofu-processing wastewater treatment using combination of two-stage biological treatment with filtration system was assessed in relation to the process stability and efficiency. The biological treatments were operated anaerobic and aerobic, with filter media (river stone) was attached to one of the compartments in both anaerobic and aerobic reactor system. The two-stage biological treatment was configured under different sequence include anaerobic-aerobic and aerobic-anaerobic system operated for 30 days. The results indicated that both systems enhanced the effluent quality in the same degree; however the anaerobic-aerobic system showed a better process stability over the aerobic-anaerobic system. The steady state point in the anaerobic-aerobic system was obtained from day 24 to day 30 with the fluctuation of ~5% between days. While, in the aerobic-anaerobic system no process stability have been observed. The results further suggested that anaerobic treatment prior to aerobic treatment was preferable for treating tofu-processing wastewater.

Keywords: anaerobic treatment; aerobic treatment; mixed culture; soybeans curd waste

INTRODUCTION

Tofu (soybean curd) processing industry is known as one of the popular most industry in Indonesia. During the production process, about 43.5 liters per 1 kg of the soybeans is released. In Indonesia, tofu-processing wastewater contains Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) in the range of 7500-14000 mg l^{-1} and 6000-8000 mg l^{-1} [1]. Without proper handling, abundant amount of tofu processing wastewater can cause severe environmental problems and disruption of ecosystem.

One of the alternative solutions in treating tofu-processing wastewater is two-stage biological treatment under anaerobic or aerobic condition. A study by Rosman, et al [2] focused on anaerobic granular system to treat rubber wastewater showed an increase in effluent quality. In6this study, anaerobic system was operated at 6-24 hours Hydraulic Retention Time (HRT). The results also demonstrated that up to 98.4% COD reduction was achieved when the reactor was operated at low HRT (6 h). There is an opportunity to improve the performance of two-stage biological treatment by changing the order of the treatment. Studies on the effectiveness and stability of anaerobic-aerobic system to aerobic-anaerobic system under optimum operation condition and inoculums addition have also been reported [3-4].

Combination with attached filter media may also be a solution to further enhance the performance of two-stage biological treatment. This is supported by Jullyanti *et al*. [5] who found that treating tofu-processing wastewater using anaerobic reactor with an attached filter media was able to further improve the effluent quality, with BOD concentration decreased by 74.46%. Previous studies have also reported that the use of natural filter media attached to aerobic system in treating of tapioca-processing wastewater further improve the removal efficiency of BOD, COD and TSS, as well as enhance the effluent quality [6-8].

This research was focused on the effectiveness of two-stage biological wastewater treatment with attached filter media, aimed to compare the characteristics of anaerobic-aerobic and aerobic-anaerobic systems configuration in terms of process efficiency, stability, and effluent quality. It is expected this system configuration have greater removal of organic materials in tofu-processing wastewater, thus the effluent can meet the Indonesian regulatory effluent quality guidelines and can be recycled back to tofu plant.

MATERIALS AND METHODS

Materials

Tofu-processing wastewater was collected from tofu wastewater disposal channel in small scale industry in Dau, Malang East Java Indonesia. The sample was then packed into 5-litre container and incubated at anaerobic condition and another container incuvated at aerobic condition with aerated. Mixed culture consisting of wild bacterial were growth wastewater and sludge.

Methods

Inoculums Preparation

Inoculum was prepared for anaerobic and aerobic system from the mixture of sludge and tofu-processing wastewater at ratio of 1:9 incubated for two days at room temperature. Prior mixing, the sludge was filtered using sieve (80 mesh). For anaerobic system, the incubated mixture was added to reaction tube that contained 5 ml of Nutrient Broth (NB), with addition of paraffin (1 ml) to provide anaerobic environment. While for aerobic system, the incubated mixture was mixed with

Natrium Agar (NA). The prepared inoculum was then incubated until colonies were formed. The colonies were stroke to agar slant and incubated again for 2 days at room temperature. Then, the inoculum was harvested and added to 6 ml NB. The inoculums both for anaerobic and aerobic systems were scaled up on a 2-day basis.

Adaptation System

System adaptation was conducted in scale-up reactor with 25-litre working volume. The prepared inoculums (how much??) were added into 25 litres tofu-processing wastewater and incubated at room temperature for 5 days [6]. Tofu-processing wastewater was substituted on day 6 and 7. This treatment was aimed to form biofilm in filter media used in both reactors.

Reactor Configuration

Two types of reactors were used in this study, namely aerobic (Figure 1.a) and anaerobic reactor (Figure 1.b). The total working volume of each reactor was 25 litres. The aerobic reactor was designed to allow aeration of the system through the aerator [6]. On the other hand, anaerobic reactor was tightly closed to avoid any oxygen infiltration. Both reactors were made from stainless steel to prevent any corrosion might occurred. Filter media was attached to one of the compartments in the reactors. Anaerobic reactor used nylon fibre and aerobic reactor used river stone (Ø= 0.5-3.5 cm). The addition of filter media was aimed to enhance the metabolic diversity of aerobic or anaerobic microbial community thus further improving the removal efficiency and the effluent quality, as has been reported by Hidayat *et al.* [6-7] and Suhartini *et al.*[8].

The two-stage biological treatment was operated days processing system and arranged into the following sequence: anaerobic reactor followed by aerobic reactor (anaerobic-aerobic system) and aerobic reactor followed by anaerobic reactor (aerobic-anaerobic system).

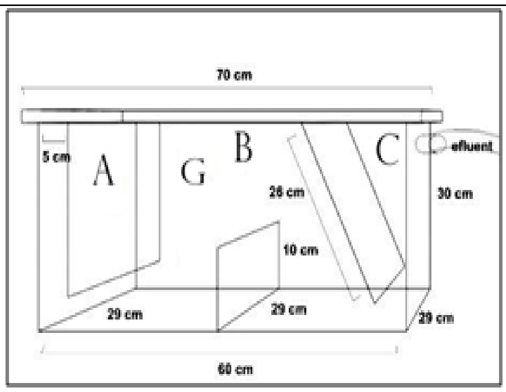	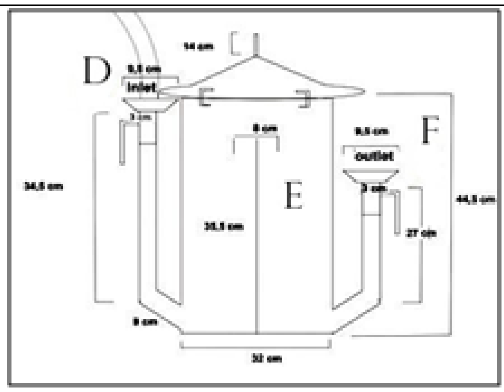
(a)	(b)

Figure 1.Schematic diagram of (a) aerobic reactor (b) anaerobic reactor. (A) Aerobic reactor inlet (B) Aerobic biofilter (C) Aerobic reactor outlet (D) Anaerobic reactor inlet (E) Anaerobic biofilter (F) Anaerobic biofilter outlet (G) Aerator

Operation System

Anaerobic-aerobic system

In this system, prior feeding to anaerobic reactor, 25-litre of tofu-processing wastewater was added with prepared anaerobic inoculum (5% v/v) and mixed thoroughly for homogeneity. The tofu-processing wastewater was incubated in this reactor for hydraulic retention time (HRT) of 12 hours. After 12 hours, fresh tofu-processing wastewater (25 l) was added, and the effluent of anaerobic system was used as influent for aerobic reactor, which was previously added with 15% (v/v) of aerobic inoculums. In the aerobic system, tofu-processing wastewater was aerated with air at flow rate of 0.45 vvm and incubated for HRT of 9 hours. Then, 2 litres of the effluent sample was withdrawn from the system. The whole system was operated for 30 days.

Analysis of Organic Material Removal of Tofu Wastewater

pH was measured using electrometer analysis with the glass electrode calibrated in buffers at pH 4, 7 and 9. Total suspended solids (TSS) were determined according to gravimetric methods. Chemical oxygen demand (COD) was measured using spectrophotometer method. Biochemical oxygen demand (BOD) was determined using BOD_5 methods as explained in Jenny and Rahayu [9].

RESULT AND DISCUSSION

Characterisation of Tofu Wastewater

The characteristics of tofu-processing wastewater used in this study are shown in Table 1. The results indicated a very high concentration of COD, BOD and TSS, with lower pH value compared to that of reported by Purnobasuki, *et al* [10] who found that the majority of tofu-processing wastewater in Indonesia contains COD of 4.450 mg l^{-1}, BOD of 3.526 mg l^{-1}, TSS of 0.640 mg l^{-1}, and pH of 5.3. The difference was possibly caused by many factors such as different type of soy bean used, different processing method applied, and different technology used.

Table 1: Characteristics of tofu-processing wastewater

Parameter	**Value**
BOD (mg l^{-1})	8.85
COD (mg l^{-1})	9.70
TSS (mg l^{-1})	0.936
pH	3.8

COD Removal

Figure 2 shows COD removal for aerobic-anaerobic and anaerobic-aerobic systems, taken as average values over a 30-days period. The COD removal in the aerobic-anaerobic system was more fluctuation from days 1 to 30, with no signs of stability was observed. In contrast, the anaerobic-aerobic system has three stable conditions. In the first stable condition (days 1-10), COD removal was fluctuated from 31.31% to 47.14%. In the second stable condition (days 11-23), the COD removal was in the range of 68.18%-90.64%, and this was more fluctuation compared to that of in the first stable condition. A more stable condition, was achieved in the third condition (days 24-30), where the COD removal was between 58.25% and 67.54%, with the fluctuation between days was lower than 5% (Figure 2).

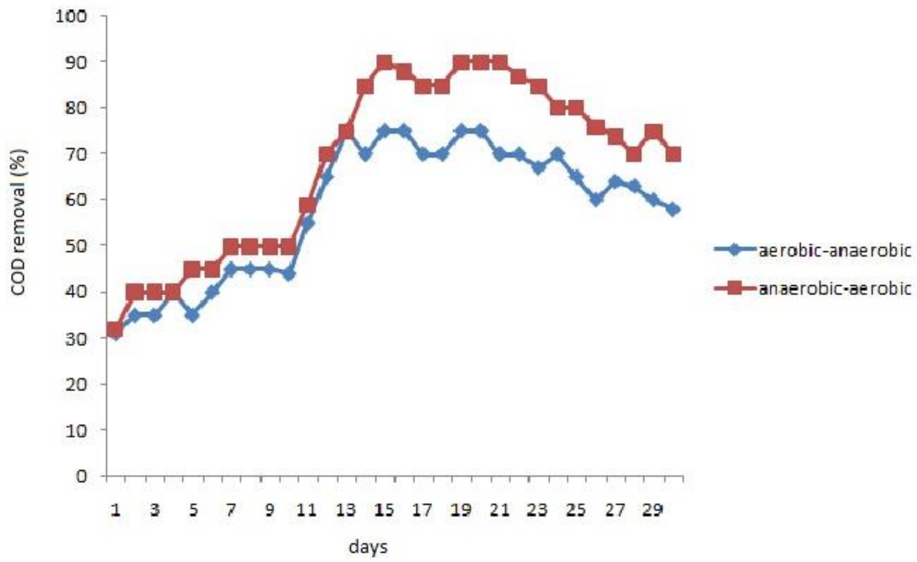

Figure 2: Percentage of COD Removal

The variation and fluctuation in the COD removal, was possibly due to the uneven growth of microbes inside the system, thus differ the ability of microbes to reduce organic material. This finding is consistent with the results reported by Aquino, *et al.* [11]. In facultative anaerob COD removal at 65.68 and 67.89% and biofilm growth at aerobic condition [12]. Therefore, in this study, it is assumed that the COD removal reduction process was not only occurred in the surface of biofilm (aerobic system) but also in anaerobic system too. Furthermore, the result also suggested that COD removal in anaerobic aerobic systems (COD removal at 80-90 %) more effective than the integrated wastewater treatment system (65 %) [12]. In anaerobic system (UASB), COD value sharply decreased [13].

BOD Removal

Similar trend was occurred in the BOD reduction (Figure 3).The BOD removal in aerobic-anaerobic system was fluctuated and varied between 50%-88% throughout the operation period. While in anaerobic-aerobic system, the BOD removal was higher and more stable than in aerobic-anaerobic system with the value in the range of 55-75% (stable 1/days 1-13) and 85-90% (stable 2/days 13-25). In the third stable condition (days 25-30), although the BOD removal was lower (75-60%), the removal value was significantly more stable than that of stable condition one and two. The difference in BOD removal was possibly due to uneven role of microbe to reduce BOD, similar to the cause of phenomena of COD reduction.

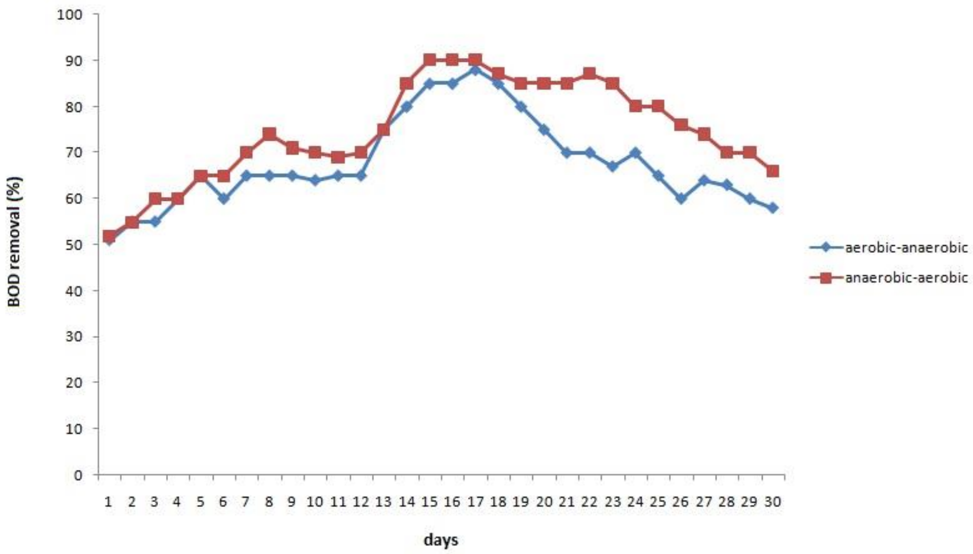

Figure 3: Percentage of BOD Removal

Jasmiati [14] stated that adaptive microbes always have the ability to consume food and grow therefore these microbes are dominant in the system. Astuti [15] also explained that the BOD concentration reduction, which often happens in the beginning of nutrient addition, is caused by microbes that has been previously adapted to nutrient. As microbes adapt to the nutrient, BOD reduction is getting more stable. Therefore, it is important to determine the adaptation period for microbes in order to get more effective result.

TSS Removal

The TSS removal from anaerobic-aerobic and aerobic-anaerobic system is shown in Figure 4. In the anaerobic-aerobic system, the first stable condition was achieved from days 7 to 13, where the the TSS removal was in the range of 46-56%. This result was less effective than when using a coagulation process reported by Lee, *et al.*[16]. In the second stable condition (days 21-24), system showed significant stability where TSS removal was between 48% to 44%. In the aerobic-anaerobic system, the TSS removal was fluctuated from days 1 to 24, within the range of 35-50%. After 17 days the process, both systems similar result.

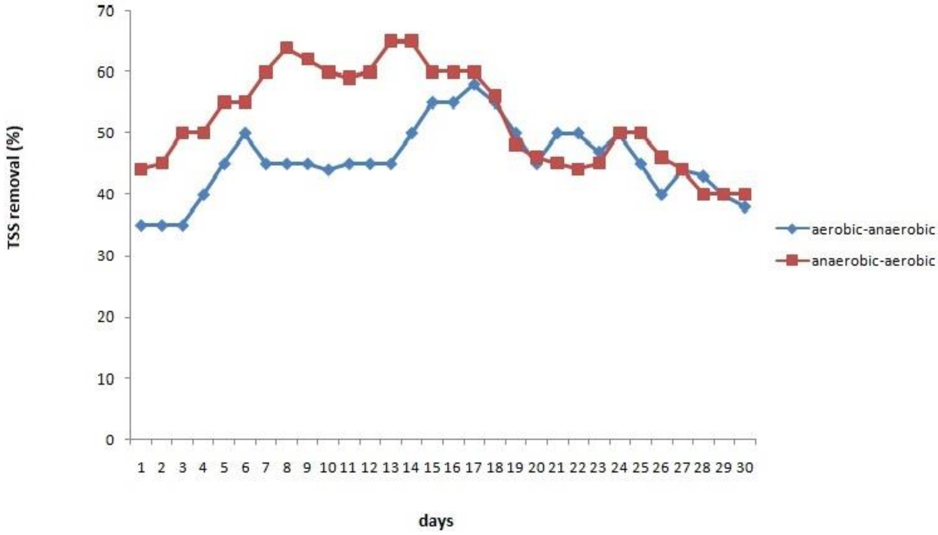

Figure 4: Percentage of TSS Removal

Geraldi [17] explained that increasing value of TSS is caused by bacteria, protozoan and metazoan activity. Putro [18] also stated that an increase in the thickness of and the width of filter layers increased the filter's ability to retain suspended solid using a thick and wide filter media can prevent big particles of suspended solids from washing out.

pH Profile

Figure 5 shows pH profile for aerobic-anaerobic and anaerobic-aerobic systems, taken as average values over a 30-days period. During days 1 to 19, the pH in both systems was fluctuated between 3.9 to 5.3. In days 20-30, pH profile in anaerobic-aeribic system was relatively constant at value of 5.0-5.6, while in aerobic-anaerobic system the pH slightly increased to more than pH 6.5 (days 20-28) then decreased to pH 6 (days 29-30). However, the overall fluctuations for both systems were still lower than 5%. These results indicated that the fluctuation may possibly cause by the amount of lactic acids forming bacteria. These microbes performed symbiosis to degrade organic materials in tofu-processing wastewater [4]. The value of pH is closely related to microbial activity in organic wastewater treatment, where the pH can affect microbial activity or can be interfered by microbial activity. Most of microbes live in neutral pH, but there are microbes that can grow in acid environmental condition, such as acidophillic microbes (pH 2.0-5.0) and mesophillic microbes (pH 5.5-8.0). The increase of th pH can be affected by denitrifying bacteria [17].

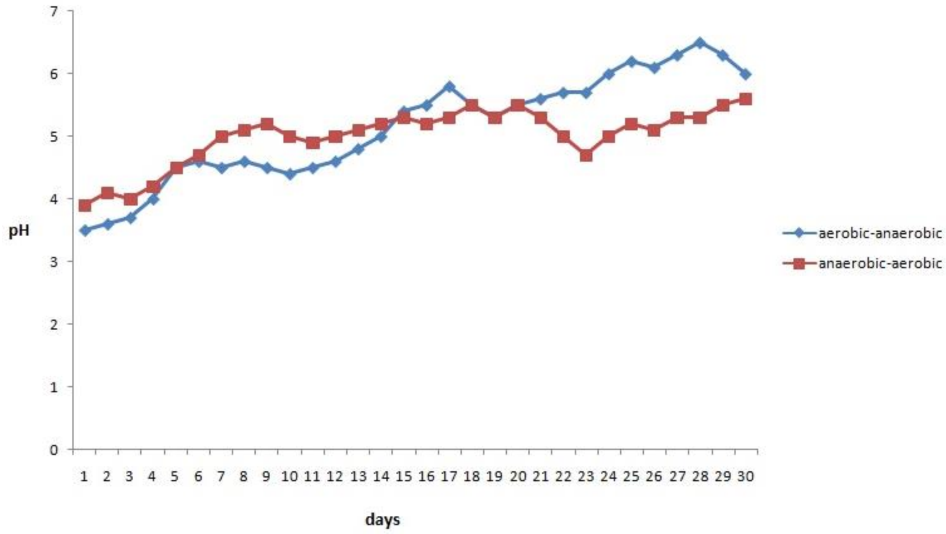

Figure 5: pH Profile

Effectiveness and Stability Evaluation

According to Astuti [15], a system is stable and steady when the parameter fluctuation of each bacth is in the range of 0-5%. This study revealed that, from all parameters examined (COD, BOD and TSS removal), the anaerobic-aerobic system with attached filter more stable than the aerobic-anaerobic system. In the anaerobic-aerobic system, the first day were more fluctuative than last days. Overall, the system was more stable from days 22 to 30. The value of pH is also known to influence microbial growth in the system, which automatically determines the dominant bacteria live in the system.

The results suggested that the stability of the system requires a longer process (up to 22 days), for the system to be more stable and to provide outstanding performance in treating tofu-processing wastewater.

The effectiveness of two-stage biological treatment with attached filter media can be determined from the percentage of BOD, COD and TSS removal. This system was able to reduce BOD and COD concentration by up to 90%. Therefore, this system used in this study was found to be more competitive compared with other method of treatments which showing only have ± 80% reduction of BOD, COD and TSS.

CONCLUSIONS

Two-stage biological treatment with attached filter media has shown to enhance the BOD, COD and TSS reduction. Both configurations of anaerobic-aerobic and aerobic-anaerobic systems produced similar and high quality effluent, indicating that two-stage biological treatment can have a more beneficial impact compared with one-stage treatment. The anaerobic-aerobic system of tofu-processing wastewater treatment, however, showed superior performance over the aerobic-anaerobic system due to a better process stability with lower fluctuation between days. The aerobic-anaerobic systems showed signs of instability where no steady state points have been observed. The results suggest anaerobic-aerobic treatment with attached filter media as the best option in treating tofu-processing wastewater, which could discharge effluent that meets Indonesian regulatory effluent quality guidelines. Yet, further studies on inoculums identification during the operation and adaptation of the system and on filter utilisation in the aerobic system are needed to obtain more effective results.

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