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Comparison Between Sequencing Batch Reactors (SBR) and Stirred Tank Reactors (STR) in Handling Hydraulic Shock Loads

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ABSTRACT
The use of Stirred Tank Reactor (STR) in wastewater treatment requires a Clarifier in its operation so that Sequencing Batch Reactor (SBR) is an alternative solution. The clarifier is needed to recover some of the wasted microbes in the effluent stream. With SBR, the Clarifier function is replaced when the settle phase in the SBR operating cycle is executed. The four phases of SBR operation are carried out in stages and sequentially, namely, the fill, react, settle, and draw/decant phases. In this study, the performance of SBR and STR was compared in treating molasses-based wastewater. At an organic loading rate of 516 mg COD L^{-1} day^{-1} and 20 days HRT, these two types of reactors were capable to remove the COD content of wastewater with an efficiency of about 90%. At a hydraulic shock load of 10 days and the same organic loading rate, SBR showed its superiority. The organic compound removal efficiency of around 89% could still be maintained by SBR but the organic compound removal efficiency of only about 57% could be maintained by STR. The parameters of pH could be maintained by SBR in the pH range of 7.2 to 7.4, whereas the pH values in STR were in the pH range of 7.0 to 6.3.

Keywords: *wastewater, hydraulic shock load, Sequencing Batch Reactor.*

1. INTRODUCTION

In wastewater treatment, a Stirred Tank Reactor (STR) is widely used because of the simplicity in design and operation of this reactor type. On the other hand, STR has a disadvantage in which the concentration of wasted biomass in the effluent stream is almost or equal to the concentration of biomass in the reactor. As a result, this type of reactor cannot maintain a sufficient amount of biomass in the reactor without returning some of the wasted biomass in the effluent stream. For this reason, it is required to have additional equipment which is called a Clarifier. It functions to add a certain amount of active biomass into the STR so that a certain amount of active biomass is obtained that can treat wastewater effectively.

The reactor designed based on interrupted flow allows wastewater treatment and wastewater degrading biomass deposition, to occur in the same reactor. With this operating strategy, the Clarifier which functions to return a certain amount of active biomass into the STR is no longer needed. The reactor in question is called the Sequencing Batch Reactor (SBR). The operating principle of the SBR is based on the filling and emptying of the reactor [1]. Treatment with SBR is economical because its operating cycle which includes filling, aeration, precipitation, and effluent discharge occurs in the same reactor [2]. The use of SBR can save more than 60% of the operational costs required for conventional processing and can produce high-quality effluents in a very short aeration time [3].

Pranoto et al. [4] emphasize that activated sludge treatment technology utilizes the role of aerobic bacteria to degrade organic material contained in liquid waste. However, the application of wastewater treatment using a conventional activated sludge has problems in its operation, such as bulking which has a negative impact on treatment performance so that flotation is used in sedimentation to separate the sludge from the effluent that has been treated. This leads to increased costs and more complex installation operations [5]. Therefore, SBR is an alternative solution in wastewater treatment without the need for flotation and sedimentation tanks.

Hydraulic Retention Time (HRT) is an important parameter in observing the performance of a reactor. This parameter states the length of time the presence of a microbial group in the reactor [6]. The level of microbial metabolic activity in the reactor that affects the flow of nutrients, products, and unreacted chemicals can be observed from the HRT value used [7]. Based on this reason, in this study, SBR was chosen to treat molasses-based artificial wastewater. By applying a drastically reduced HRT value, a picture of SBR's performance in treating wastewater can be obtained. To enable to compare more clearly the performance of SBR, a stirred reactor (STR) is also used as a comparison. Both reactors are operated under the same operating conditions except for the operating strategy.

In the previous study, the sequentially operated reactor, SBR was applied to treat wastewater from a fertilizer industry and was able to degrade successfully the wastewater at efficiencies in the range of 70 to 90% both at HRT of 20 days and 15 days [8]. Therefore, this study was conducted to achieve the aim of simultaneously comparing SBR and STR so that objective comparison results can be obtained. The HRT applied was, moreover, decreased drastically by half from 20 days to 10 days.

To objectively compare the two types of reactors, artificial wastewater from molasses was used. This is to avoid the presence of impurities in industrial wastewater that may interfere with the operation of each reactor being compared.

2. RESEARCH METHODS

SBR and STR are made with the same dimensions and are made of gallons of mineral water which are cut off the shoulders and neck so that the tank volume is 15 L. The active volume of 12 L is used as a reference for determining the amount of HRT applied. Schematic drawings of the two reactors are shown in Figure 1. The different operation of each reactor shows the difference of these two reactors. For STR, the stirrer runs continuously while the SBR is operated by stopping the stirrer in the settling phase. The operating temperature was maintained at 30 ± 1 ^{0}C and the stirring speed was 40 rpm. While the oxygen supply was maintained not less than 2 mg/L dissolved oxygen (DO) content in both reactors.

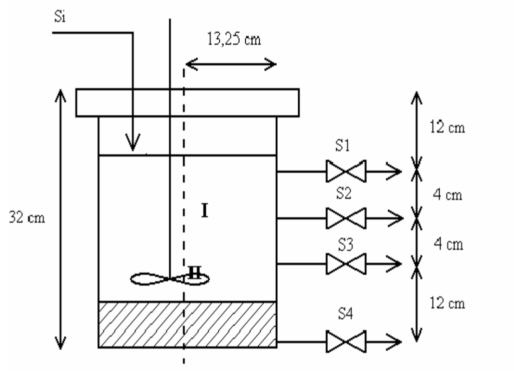

Figure 1 Schematic drawing of SBR and STR. Si = influent/feeding side, I = reactor, II = stirrer, S1 to S4 = effluent valves.

Initially, both reactors were filled with 5 L of activated sludge with relatively the same microbial content (measured from the values of mixed liquor volatile suspended solids/MLVSS in both reactors). Activated sludge was obtained from the textile industry in Rancaekek, West Java, Indonesia. Both reactors were operated as stirred reactors (STR) with the same feed volume and concentration without any effluent removal. This was carried out for 4 weeks until the reactor volume in both reactors became 12 L. After the acclimatization period of 4 weeks was exceeded, each reactor was then functioned according to its designation, namely as SBR and STR.

The concentration of molasses waste fed into the reactor was 5,160 mg COD/L for organic loading of 516 mg COD L^{-1} day^{-1} and 20 days HRT. Determination of the concentration of molasses waste was carried out by determining how many grams of COD were obtained from 1 gram of molasses sample. This determination was done several times to get a representative value. The ratio of grams of COD to grams of molasses samples obtained was then used as a determination of the COD of molasses waste in the feed. Meanwhile, the addition of nitrogen and phosphorus in the feed was determined according to the ratio of COD: N: P of 100: 5: 1. Nitrogen and phosphorus were represented by NH_4Cl and KH_2PO_4, respectively. Meanwhile, $NaHCO_3$ was added as a buffer to maintain the pH in the feed solution [9]. The composition of the feed can be seen in Table 1.

Table 1. Feed composition at the concentration of 5,160 mg COD molasses/L

Component	Composition (mg/L)
Molasses	6,000
NH_4Cl	986
KH_2PO_4	226
$NaHCO_3$	200

The parameters used to observe the performance of SBR and STR include COD efficiency, pH, MLVSS in the reactor, and the effluent. At the beginning of the operation the HRT was set at 20 days and after the above parameters were obtained, the HRT was drastically reduced to 10 days.

3. RESULT AND DISCUSSION

3.1. Determination of Molasses Waste Concentration

The determination of the COD of molasses waste in the feed solution is based on the determination of several times of this COD to obtain a representative value. From these measurements, a value of 0.86 g ± 0.03 g of COD was obtained in each g of molasses sample. Then the ratio of 0.86 g COD/g molasses is used to determine the COD of molasses waste in the feed solution.

3.2. Reactor Performance at 20 days HRT

The performance of the two reactors in removing the organic content of molasses waste at the loading of 516 mg COD L^{-1} day^{-1} and 20 days HRT is shown in Table 2. Both reactors were able to remove organic content in artificial feed wastewater with an efficiency of about 90%. The pH in both reactors remained relatively unchanged for 4 days of operation, which was in the normal pH range. This indicates that the two reactors were capable of receiving organic loading which was fed. Other researchers using SBR also found efficiencies of about 90% for the treatment of industrial wastewater [10], municipal wastewater [11], and slaughterhouse wastewater [12].

Table 2. COD removal and pH variation at 20 days HRT

Time (days)	COD removal (%)		pH	
	SBR	STR	SBR	STR
1	93	94	7,5	7,3
2	95	91	7,7	7,2
3	96	93	7,1	7,0
4	94	89	7,2	7,4

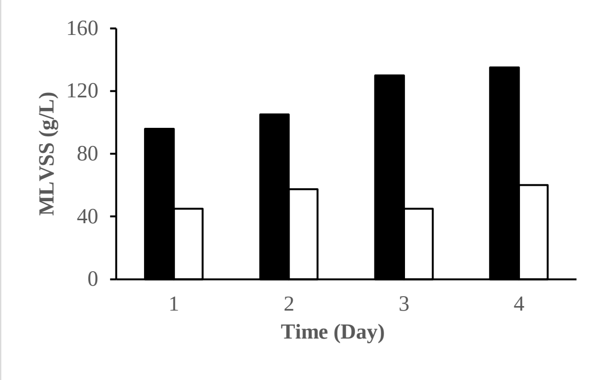

Figure 2 Comparison of MLVSS in the reactor (■) and MLVSS in the effluent (□) in SBR at 20 days HRT

To show the SBR performance specifically, the MLVSS values were checked, both MLVSS in the reactor and MLVSS in the effluent. Figure 2 shows that the MLVSS in the SBR reactor increases with increasing the operation time. The MLVSS that was wasted in the effluent stream was only about 46% of the MLVSS in the reactor. This shows that the number of microorganisms that are wasted in the effluent stream is smaller than the number of microorganisms that can survive in the reactor. This means the SBR system was running correctly. With a phase separation system in the SBR operating cycle, a sufficient number of microorganisms could be maintained in the reactor to degrade the molasses that was fed and could reduce the number of microorganisms that were wasted along with the effluent flow.

3.3. Reactor Performance at 10 days HRT

HRT of the reactors was reduced drastically from 20 days to 10 days. This was conducted to observe the performance of SBR and STR when both types of the reactor were double fed (two times) the feeding rate. Such mentioned in the introduction, by applying a drastically reduced HRT value, a picture of SBR's performance compared to STR's performance in treating wastewater can be obtained. On the other hand, both values of HRT are still in the optimum HRT values for operations of STR, which are in the range of 16 to 30 days [13], [8].

Table 3. COD removal and pH variation at 10 days HRT

Time (days)	COD removal (%)		pH	
	SBR	STR	SBR	STR
1	91	87	7,3	7,0
2	85	75	7,2	6,5
3	84	66	7,7	6,2
4	89	57	7,4	6,3

When HRT was drastically reduced from 20 days to 10 days, SBR was far superior to STR. The stirred reactor was no longer able to operate normally. During this period, there was a drastic decrease in the COD removal efficiency and the pH value in this type of reactor. In this condition, it can be said that wash out occurred in the stirred tank reactor (Table 3). Such as mentioned by Kim et al. [10] STR can operate effectively if operated at HRT of 16 – 30 days.

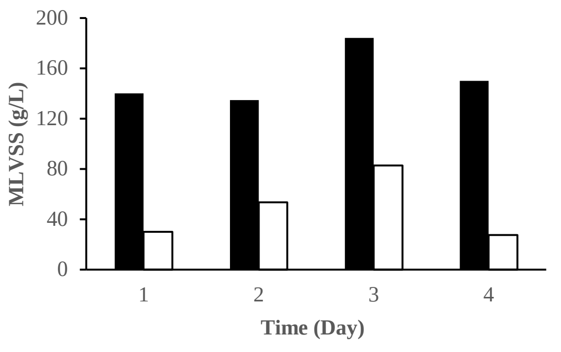

Figure 3 Comparison of MLVSS in the reactor (■) and MLVSS in the effluent (□) in SBR at 10 days HRT

The disruption of SBR performance with a drastic decrease in HRT resulted in the decrease of efficiency of waste removal on the second and third days (Table 3) and fluctuating MLVSS values both in the reactor and in the effluent (Figure 3). However, on the fourth day, the increase in removal efficiency can be recovered. An efficiency of 89% on the fourth day can indicate that the SBR has been able to accept the existing loading conditions. If it is seen that the decrease in MLVSS in the reactor occurred on the fourth day after an increase on the third day, the increase in efficiency on the same day (fourth) could be the result of the degradation of the remaining organic materials on the second and third days as well as the degradation of organic matters on that day. Meanwhile, the MLVSS values in the effluent which reached 47 and 46% compared to the MLVSS in the reactor on the second and third days were more influenced by the low value of HRT.

4. CONCLUSION

At HRT of 20 days, performances of SBR and STR are almost the same. Both reactors could degrade the molasses wastewater at efficiencies around 90% at the normal pH range. However, when the HRT was drastically decreased to 10 days, SBR showed its superiority compared to STR. At the end of the operation, SBR could maintain the removal efficiency of 89% at pH 7.4, whereas STR could only achieve the removal efficiency of 57% at pH 6.3.

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