Reduction of Organic Parameters in Apartment Wastewater using Sequencing Batch Reactor by adding Activated Carbon Powder

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Abstract. A Sequencing Batch Reactor (SBR) was used to reduce the concentration of organic parameters, that consisted of Chemical Oxygen Demand (COD), Total Nitrogen (N Total) and Total Suspended Solid (TSS) in an apartment wastewater, because the SBR system had a high space efficiency and was low in cost. The apartment wastewater was especially from the effluents of water closets and kitchen. In this study, we applied the SBR method and added activated carbon powder to treat apartment wastewater which had previously gone through the first settling process. This SBR was operated with various hydraulic retention times (HRT) which were 12, 24 and 36 hours respectively, and aeration rates of 3.5 and 7 L/min. Dissolved Oxygen (DO) testing was carried out at each stage of SBR, which aimed to measure and maintain stability at each stage of SBR. The results of the study were the optimum HRT and aeration rate, which were 36 hours and 7 L/min respectively. FTIR test was carried out to determine the efficiency of activated carbon addition in this SBR process. It was found that Activated Carbon increased SBR performance as evidenced by the COD removal rate reaching 89.5% and Total N 94.54%.

1. Introduction
Domestic wastewater usually contains organic ingredients derived from kitchen and bathroom washing water and there would be microorganisms from black water and nutrients in the form of nitrogen (N) and phosphorus (P) compounds [6] [11]. The application of waste treatment would be better at a low cost and effective way, with space efficiency and using an easy-to-operate technology, especially for the wastewater treatment industry. To make this happen, in this study we tried adding activated carbon powder in Sequencing Batch Reactor (SBR) method treating domestic waste water that had previously been through a preliminary treatment process.

It has been known through research journals that SBR could remove organic materials and could be operated and applied on a small scale. SBR is one of the many types of activated sludge processes, though SBR is different from conventional activated sludge treatment in that all steps in an SBR treatment process occurs in one tank [2] [4] [11]. With this, it could be concluded that this type of waste treatment is effective, cost-effective and space efficient.

This research used SBR process that had been carried out and developed a lot. Research was conducted in South Africa [2] on SBR to process waste from a brewery. The removal efficiency of Chemical Oxygen Demand (COD) was 90% and Biological Oxygen Demand (BOD) almost 80%.
2. Research Methods

This study used domestic wastewater which was taken from an apartment along with the activated sludge. First, testing was done on MLSS of the activated sludge. MLSS was measured at 5450 mg/L in Reactor 1 (R1) and 5190 in Reactor 2 (R2). Recommended MLSS on SBR systems is within the range of 2000-5000 mg/L [10]. After that, acclimatization was done because MLSS had been fulfilled.

Acclimatization was done for 12 days until it reached a steady state. The variations used in the acclimatization were 30% wastewater 70% distilled water, 50% wastewater 50% distilled water and 70% wastewater 30% distilled water. During acclimatization, Chemical Oxygen Demand (COD) was checked at each variation, if it reached 50% removal percentage and was constant, then it could proceed to the next stage.

After reaching a steady state, the main research could be started. The study used two reactors, R1 with an aeration rate of 3.5 L/minute and R2 with an aeration rate of 7 L/minute. Each reactor was operated with a HRT of 12 hours, 24 hours and 36 hours and 3 cycles for each HRT. SBR was operated with intermittent batch flow, for ± 10 days. During the SBR operation process, Powdered Activated Carbon (PAC) was added to the reactor as much as 3 g/L at the beginning of entering aerobic reaction stage. Things that were controlled during the study were the volume of activated sludge, the volume of incoming and outgoing wastewater, Dissolved Oxygen (DO) at each stage of SBR, temperature and pH.

Following are the stages of the SBR that were operated in this study: Filling: filling was the stage where the wastewater that would be treated was added into the SBR reactor; Reaction: the reaction was operated anaerobically and aerobically, which aimed to produce a good percentage of total N removal; Settling: at this stage the treated wastewater would be separated from the activated sludge by sedimentation/settling; Draw: after passing through the settling stage, the treated effluent or wastewater was ready to be taken and tested; Idle: this stabilization stage aimed to make the reactor effluent ready to enter the next cycle. If the volume of activated sludge was excessive, it must first be removed so it would not disturb the next cycle.

Each HRT was operated in 3 cycles, with the stage times of each cycle were as follows:

| Stage        | 12 hours | 24 hours | 36 hours |
|--------------|----------|----------|----------|
|              | Time (minutes) | Time (minutes) | Time (minutes) |
| Filling      | 15       | 15       | 15       |
| Anaerobic Reaction | 180      | 360      | 540      |
| Aerobic Reaction | 450      | 900      | 1350     |
| Settling     | 40       | 80       | 120      |
| Draw         | 15       | 15       | 15       |
| Idle         | 20       | 70       | 120      |
Figure 1. Visualization of the Experimental Setup

It could be seen in the SBR reactor sketch that during operation, the volume of activated sludge was maintained at 4L and the volume of incoming wastewater was equal to the volume of wastewater that came out, which was 4L. The purpose was that so the cycles in operation could continue to run optimally.

3. Results and Discussion

3.1 SBR Ability of removing COD, TSS and Total N

The ability to eliminate organic parameters from apartment wastewater using SBR with added activated carbon is shown in the discussion below.

1. The Ability of removing COD

COD removal efficiency increased from HRT to another HRT. The 36 hours HRT produced the highest COD removal efficiency compared to 12 hours and 24 hours HRT, both at R1 and R2, each worth 87.96% and 89.5%. From the graph of the efficiency of COD removal, it could be interpreted that the best COD removal efficiency occurred at R2 with HRT of 36 hours and aeration rate of 7 L/minute.

COD removal efficiency gained from the acclimatization process to the operation of the SBR was increased. It means that during the acclimatization and operation of SBR, the microorganisms found in activated sludge could live well in the SBR reactor. Microorganisms played a role in decomposing and removing organic materials contained in wastewater, so that COD could be decomposed. The method...
with activated sludge was a wastewater treatment process that utilized the microorganism process [10] [17].

2. The Ability of Removing Total Suspended Solid
A decrease of TSS removal efficiency occurred in 24 hours HRT at R1. This was most likely due to the large amount of suspended solids which was carried out during the effluent release stage. Several factors might have caused a lot of suspended solids being carried away, one of them being the lateness in shutting down the aerator. Because it would affect the duration of settling, the settling time would be reduced if the turning off of the aerator was done late. If settling time was reduced, solids would not be able to settle optimally.

Figure 3. The Efficiency of Total Suspended Solid (TSS) Removal

Based on the stages occurring in the SBR reactor, the settling stage would support TSS removal, as with sedimentation processing units could remove TSS by the deposition process. But in the SBR reactor, the time of the settling stage was shorter; surely this had some effect on the efficiency of TSS removal. Besides, the addition of PAC when operating the SBR would certainly produce more suspended solids, hence the settling stage should take a longer time so the solids could settle perfectly. Based on this, it could be said that TSS parameters could not be processed properly with SBR processing units even though there was a settling process at the SBR stage.

3. The Ability of Removing Total Nitrogen (Total N)
Total N rate could be removed properly. It was proven by the average value of total N removal efficiency that reached 94.54% in R2 with 36 hours HRT and 7 L/minute aeration rate as the highest total N removal efficiency. Based on that, it was proven to be true that the intermittent aeration process or the anaerobic reaction and aerobic reactions could reduce the total N level in wastewater properly.

Figure 4. The Efficiency of Total Nitrogen (Total N) Removal
But there was a decrease in the removal efficiency at 24 hours HRT. That was because when the SBR operation process with 24 hours HRT was in the first cycle, there was a lack of oxygen supply because the aerator could not be function. This surely would affect the efficiency of Total N Removal, because at the anaerobic and aerobic reaction stages there were processes of denitrification and nitrification which played a major role in the Total N Removal. The process of nitrification converts ammonia nitrogen to nitrate, while denitrification reduces nitrate to nitrogen gas. When there was not much oxygen available, in cycle 1 of the 24-hour HRT process, the concentration of Total N influent was quite high, which should require sufficient oxygen supply to remove total N. At that time more oxygen was used for the removal of organic materials. So, the remaining oxygen from the removal of organic materials was not enough to oxidize ammonium to nitrate. In order to oxidize ammonium, 4.3 mg of O₂ is needed [3] [19] [13].

3.2 Effluent Quality Regarded from Quality Standard

The effluent COD met the Indonesia quality standards according to East Java’s Governor’s Regulation No. 72 of 2013, where the threshold limit for domestic wastewater is 50 mg/L. The effluent of SBR process all met the established standards in the concentration range of 12.28–21.02 mg/L. From the results of the percentage of COD removal that had been produced, it could reach 89.5%, where the best quality of effluent was produced at 36 hours HRT with an aeration rate of 7 L/minute.

On the other hand, the remaining TSS level of the effluent did not meet the quality standards yet. The Indonesian TSS threshold limit from East Java’s Governor’s Regulation No. 72 of 2013 is 50 mg/L. Generally, to reduce TSS levels in wastewater, physical processes are used, namely the process of sedimentation, while biological processes are generally used to reduce organic materials contained in wastewater. No previous studies have ever tried to reduce TSS levels with the SBR system and it has been known that SBR is one of the biological wastewater treatment units, so that if it was used to reduce TSS it would give a less efficient removal level even though there is a settling stage in the process [16] [18]. Also, because the settling time in this study was not long, TSS removal was less optimum. It was proven by the results of TSS removal efficiency which only reached 61.41% as the highest TSS removal efficiency average value. Based on the results of the efficiency of the allowance obtained, the reduction of TSS would be better if sedimentation process was used, because it had been proven to reduce TSS parameters optimally.

The result of effluent Total N did not meet the quality standards even though the removal efficiency was very high. The threshold limit set by the East Java’s Governor Regulation No. 72 of 2013 is indeed very low at 0.1 mg/L. The total N removal efficiency reached 94.54% so that it could be said that sequencing of batch reactors had been able to remove Total N in domestic wastewater.
Figure 5. The Efficiency of: (a) COD; (b) TSS; (c) Total N Removal

Figure 5 presents the effluent quality from the results of SBR operations in a graphical form for each of the COD, TSS and Total N parameters in apartment wastewater treatment using SBR treatment units. Then, the quality of effluent was matched to the Indonesian quality standard according to East Java Governor’s Regulation No. 72 of 2013.

3.3. The Effect of Hydraulic Retention Time (HRT) and Aeration Rate

Based on the removal efficiency it could be said that the hydraulic retention time (HRT) and the aeration rate affected the value of effluent quality and the efficiency of removal. The longer the HRT was, the higher the efficiency of the removal, meaning that the resulting effluent was getting better and closer to the quality standard.

Likewise, with the aeration rate, the higher the aeration rate i.e. oxygen supply, the higher the efficiency of the resulting removal. This was because oxygen was very important in biological wastewater treatment in order to support the life of microorganisms that would reduce or eliminate the content of organic materials in wastewater. It was found that the best hydraulic retention time (HRT) in decreasing total COD and N parameters was 36 hours with the best aeration rate of 7 L/minute.
Figure 6. The Graph of DO on HRT and Optimum Aeration Rate

Although 36 hours was the best HRT, the DO concentration at the anaerobic reaction stage was only 1 mg/L, so that it could be interpreted that 1 mg/L was included in facultative conditions. This facultative condition was very influential in decreasing the parameter Total N, where denitrification ran less optimally with DO of 1 mg/L. In general, the DO value for denitrification was <0.5 mg/L or, to be exact, 0.2 mg/L [7] [8] so that it could be said that anaerobic and denitrification conditions ran optimally.

3.4. The Test Result of Fourier Transform Infrared (FTIR)

FTIR was one of the instruments used to determine the molecular vibrational spectrum and predict the structure of chemical compounds through the identification of functional groups of compound compiler [12] [14]. FTIR test results of activated carbon at R1 and R2 based on % Transmission (% T) and wavelength, indicated the presence of organic carbon compounds and organic nitrogen (Figure 7 and Table 2.)

Figure 6. Spectrum Analysis of Active Carbon FTIR: (a) Starting Active Carbon (b) Final Active Carbon R1 (c) Final Active Carbon R2

| %T  | Wave Length | Bond      | Function Group     | %T  | Wave Length | Bond     | Function Group     |
|-----|-------------|-----------|--------------------|-----|-------------|----------|--------------------|
| 23.24 | 538.23      | C-H or OH | Alkane or Alcohol  | 23.24 | 538.23      | C-H or OH | Alkane or Alcohol  |
| 58.02 | 1384.58     | C-H      | Alkane             | 58.02 | 1384.58     | C-H      | Alkane             |
| 21.15 | 1634.21     | C=C      | Alkene             | 21.15 | 1634.21     | C=C      | Alkene             |
| 59.63 | 2065.59     | 3-Fold   | Nitrile            | 59.63 | 2065.59     | 3-Fold   | Nitrile            |
COD parameters contain organic materials such as protein, carbohydrates and oil, which contain the elements C, H, O, N and S. So, looking at the group that existed in the final activated carbon, these elements were presented in all groups, namely alkanes, alkenes, nitriles and amines. Parameters Total N contain ammonia, nitrite, nitrate and organic nitrogen such as proteins and urea [5] [15]. The removal of these nitrogen compounds could be proven by the presence of nitrile and amine groups which are the derivatives of ammonia. Contrarywise, TSS parameters did not have supporting groups of evidence, because TSS itself is a non-dissolved solid such as mud, clay and microorganisms. And the presence of TSS could inhibit the production of organic substances in water, due to the occurrence of heterogeneous chemical reactions.

In the theory of spectrophotometry, % Transmission is the result of measuring scattered light. If the % transmission’s wave peaks are low, then more light is absorbed. Absorbed light was measured as absorbance. There was a wave peak with low % transmission on the R1 and R2 final activated carbon. This was because the amount of absorbance was said to be that absorbed by organic matter. Based on this, it was evidenced that the PAC used during the operation of the SBR worked well and could absorb organic materials.

4. Conclusion
Based on the results of the research and data processing that was done, several things could be concluded as follows, that Sequencing Batch Reactor (SBR) could process COD parameters very well so that the resulting effluent met the quality standards of East Java Governor Regulation No. 72 of 2013. With the efficiency of the resulting removal on 12 hours, 24 hours and 36 hours HRT each at 62.34%, 75.5% and 87.96% in R1 while in R2 each at 73.39%, 81.07% and 89.5%. While the parameter Total N could be processed with SBR, the effluent produced did not meet the quality standard even though the resulting efficiency was high, which was equal to 94.54%. For TSS parameters, the SBR reactor could not process it because the effluent produced was fluctuating. The hydraulic retention time (HRT) had an effect on reducing the concentration of the parameter, where 36 hours was the optimal HRT to reduce the organic matters contained in wastewater. The aeration rate had an effect on the decrease in the concentration of the parameter, where 7 L/minute was the optimal aeration rate to reduce the organic matters contained in wastewater.

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