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Sequencing Batch Reactor-Continuous Flow Effectiveness For Treating Restaurant Wastewater

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ABSTRACT

Wastewater produced by untreated restaurants can increase the COD, BOD, TSS, and grease in water content. Household wastewater treatment only uses a grease trap, so it does not meet the quality standards requirement. For this reason, a unit performance evaluation is required. One technology that can improve wastewater quality from grease trap treated wastewater uses a biological process called Sequencing Batch Reactor (SBR). This research is about processing the output of grease trap waste from Padang restaurants using the Sequencing Batch Reactor Continuous Flow unit. C ontinuous influent flow reactor is used in this research. The processed sequentially but discarded intermittently. This study aims to determine the performance of SBR-CF in reducing the content of COD, TSS, Total N, and PO4. SBR-CF was operated with hydraulic retention time (HRT), and the aeration rate varied, which were 12, 24, 36, and 48 hours and aeration rates of 7 L/min and 14 L/min. The results showed thatthe optimum HRT and aeration rates were 24 hours and 14 L / minute. With the efficiency of removal of COD, TSS, Total N, and PO4 produced respectively 96.9%; 98.63%; 86.72%; and 55,6%

Keywords: Sequencing Batch Reactor Continuous Flow, Hydraulic Retention Time (HRT), aeration rate, restaurant wastewater

Introduction

Wastewater produced by untreated restaurants induces increased COD, BOD, TSS, oil, and grease levels in water bodies. Seeing these conditions, the treatment that can improvewastewater quality in restaurants is a grease trap. However, wastewater treatment that onlyuses a grease trap still does not meet the required quality standards (Zaharah et al., 2018). Researchconducted by Zaharah et al. (2018) and grease traps as a solution to reduce the concentration of oil and fat from wastewater has indeed been proven. Still, it is not enough to reduce the concentration of organic matter, TSS, oils, and grease up to quality standard values. For this reason, it is necessary to evaluate the performance of the unit. One technology to improve wastewater quality is the biological treatment process called Sequencing Batch Reactor (SBR) (Yadaturrahmah, 2020).

Sequencing Batch Reactor (SBR) is a variation of the activated sludge process that combines all processing processes in one tank or tank. There are two conditions, aerobic and anaerobic (Said, 2017). The research shows that SBR can remove organic materials from domestic waste in COD, reaching 73.49% and Total N by 75% (Hendrasarie et al., 2021). Then in the study using the Sequencing Batch Reactor-Continuous Flowsystem with an aeration intensity of 9.74 hours and a retention time of 9 hours, it can remove organic materials from domestic waste in the form of the Total-N parameter reaching 75%; and COD of 95% (Li et al., 2019). Based on this background, this research is about the processing of waste grease trap outputat Padang restaurants using the

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Sequencing Batch Reactor Continuous Flow unit. This reactor will use the influent flow continuously processed sequentially but discharged intermittently It will be seen the effect of retention time and variations in the rate of oxygen used.

Materials and Methods

SBR's Process

In this study, there are two types of test reactors used. The first is a combination of an anaerobic reactor and an SBR reactor so that the wastewater can be treated sequentially and discharged intermittently. While the second is the SBR reactor, where the wastewater will be processed in a batch system.

The design of the combined anaerobic reactor and SBR reactor consists of 1 container madeof plastic with a maximum capacity of 120 liters, one discharge control tank with a maximum capacity of 70 liters, four anaerobic reactor tanks with a maximum capacity of 10 liters, and 8 SBR tanks maximum capacity of 5 liters filled with bubble aerator. Discharge control tank made using a sized 70 liters with a valve to draw off the wastewater to the reactor anaerobes. The anaerobic reactor tank also has a valve to drain the treated water to the SBR reactor for reprocessing. Inside the discharge control tank, an overflow hole serves to stabilize the volume to maintain it. The overflow water from the overflowwill return to the reservoir. The processing volume in the SBR reactor that will be used is 5 liters. Inside the reactor, activated sludge is as much as 1/3 of the reactor capacity through the seeding and acclimatization process. Inside the SBR reactor, there is also a bubble aerator with different aeration rates, namely 7 Liter/minute and 14 Liter/minute, which functions like an aerobic reactionprocess. There are also inlet and outlet valves. The reactor sketch can be seen in Figure 1.

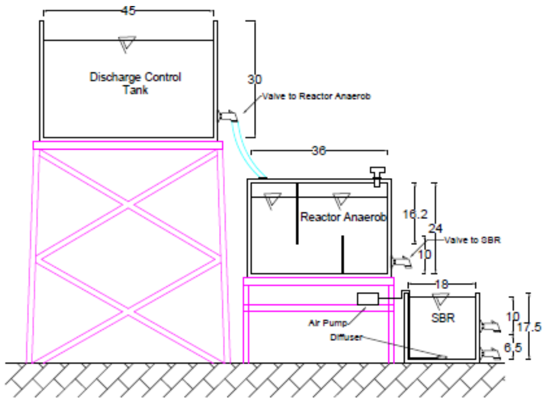


Figure 1. SBR-CF Reactor Schematic and Arrangement

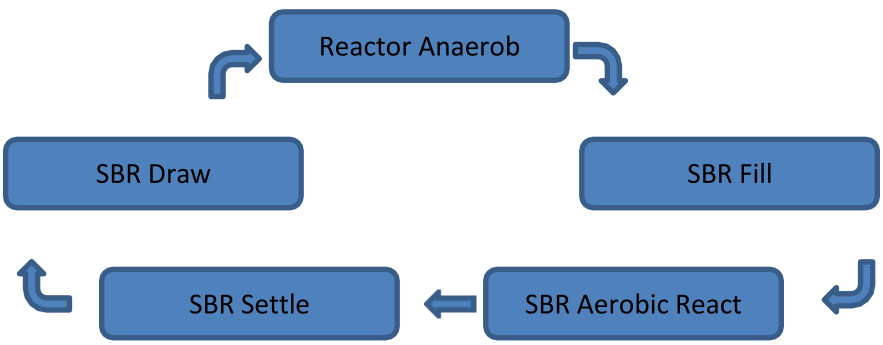


Figure 2. Working Mechanism of SBR-CF

The second design of the tool is the SBR reactor processing, consisting of 8 SBR tanks filled with bubble air aerators with a maximum capacity of 5 L. Inside the reactor. Inside the SBR reactor, a bubble aerator with different aeration rates, 7 Liter/minute and 14 Liter/minute, which functions like an aerobic reaction process. There is activated sludge as much as 1/3 of the reactor capacity through seeding and acclimatization. There are also inlet and outlet valves. The detail of the reactor can be seen in Figure 3.

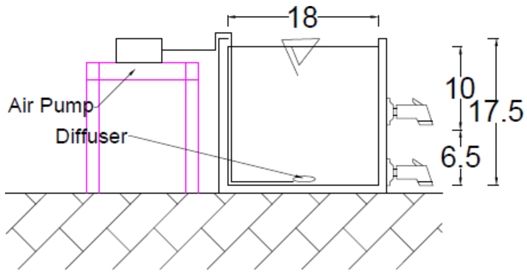


Figure 3. Batch system SBR Reactor Schematics and Arrangements

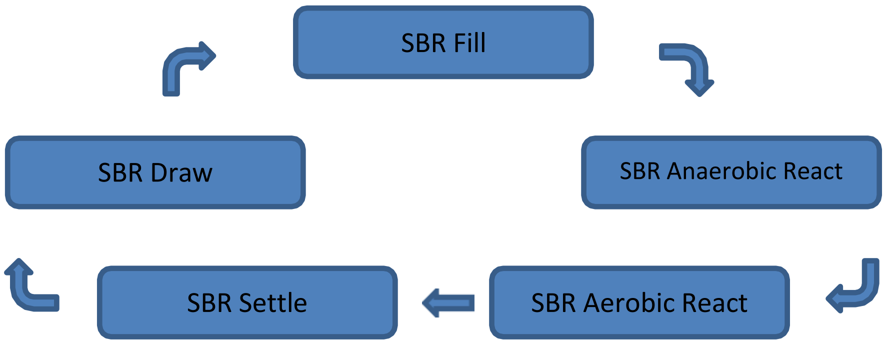


Figure 4. Working mechanism of SBR batch system

Seeding and Acclimatization

The seeding process is part of the preliminary research before entering into the main study. The seeding process is carried out to grow and reproduce microorganisms originating from restaurant wastewater. Microorganisms need nutrients in the form of C: N: P ratio so that microorganisms can grow and reproduce optimally. The ratio of the C: N:P ratio given for microorganisms is 100:5:1 for aerobic. The seeding process is carried out until the biofilm grows. It is indicated by the presence of a black mucus layer that covers the surfaceof the tank wall. On the 10th day, MLSS analysis was performed with the result of 2053.8 mg/L. MLSS (Mixed Liquor Suspended Solids) was conditioned at 2000 – 5000 mg/L in the mud (Metcalf & Eddy, 2003). After going through the seeding process where the microorganisms that grow and reproduce are sufficient, the acclimatization process can be continued. The acclimatization process is the adaptation of microorganisms to wastewater. Acclimatization is carried out in stages by increasing the concentration of wastewater by 50%, 70%, and 90%. The phasing of wastewater concentration aims to make microorganisms adapt to the new wastewater slowly so that microorganisms do not experience shock loading. Acclimatization is carried out until microorganisms can degrade organic matter at the highest concentration of waste. In this process, a decrease in COD value was observed.

Research variables

After the seeding and acclimatization processes were completed, further research was carried out by varying the flow rate of the process and comparing the media used. The discharge for the combined anaerobic reactor and SBR is the flow rate of 15 ml/minute for HRT 12-hour, 30 ml/minute for HRT 24-hour, 45 ml/minute for HRT 36 hour, and 75 ml/minute for HRT 48-hour. Variations in aeration rates compared are 7 liters/minute and 14 liters/minute. Theend of each process phase in SBR requires an analysis of waste parameters, before entering the anaerobic reactor, after SBR in the fill phase, after SBR in the Aerobic step, and after SBR in theSettle phase. This applies to all reactors. Parameters tested were pH, COD, TSS, Total N, and PO 4. The results of the analysis refer to the quality standard of domestic wastewater.

Table 1. Variation of HRT and aeration rate

HRT 12 hours Aeration rate 7 L/min	HRT 24 hours Aeration Rate 7 L/min	HRT 36 hours Aeration Rate 7 L/min	HRT 48 hours Aeration Rate 7 L/min
HRT 12 hours Aeration Rate 14 L/min	HRT 24 hours Aeration Rate 14 L/min	HRT 36 hours Aeration Rate 14 L/min	HRT 48 hours Aeration Rate 14 L/min

Results and Discussion

The ability of Batch Sequencing Reactor-Continuous Flow Compared to Batch SequencingReactor-Batch System in removing parameters COD, TSS, Total N, PO_4 removal.

Chemical oxygen demand

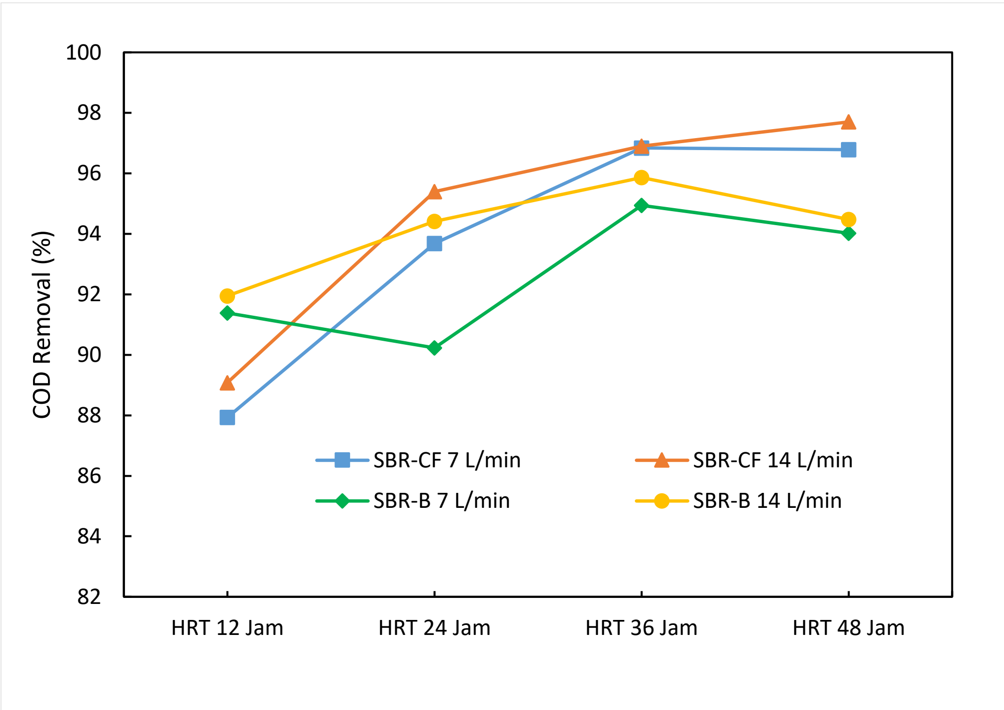


Figure 5. Relationship of Hydraulic Retention Time to COD Reduction

COD removal efficiency in SBR-CF with 48 hours HRT resulted in the highest removal efficiency compared to 12 hours, 24 hours, and 36 hours of HRT, both at aeration rates of 7 L/min and 14 L/min, with values of 96.78% and 97, respectively. ,7%. Meanwhile, the SBR of the Batch system is only capable of charging COD efficiency of 94.48% at 48 hours with an aeration rate of

14 L/minute. This proves that SBR-CF is better at removing COD parameters compared to SBR in batch systems. Figure 6, that the best COD removal efficiency occurred in SBR-CF with HRT48 hours and an aeration rate of 14 L/min, but a significant increase in the efficiency of COD reduction was produced in SBR-CF HRT 24 hours at a rate of aeration 14 L/min. In line with the research of Sekarani & Hendrasarie, 2020, that residence time (HRT) and aeration rate affect the efficiency of COD removal. The longer the residence time, the longer the waste is in contact with the microorganisms present in the activated sludge. And the greater the aeration rate used during the aerobic reaction, the higher the removal efficiency.

Total suspended solid

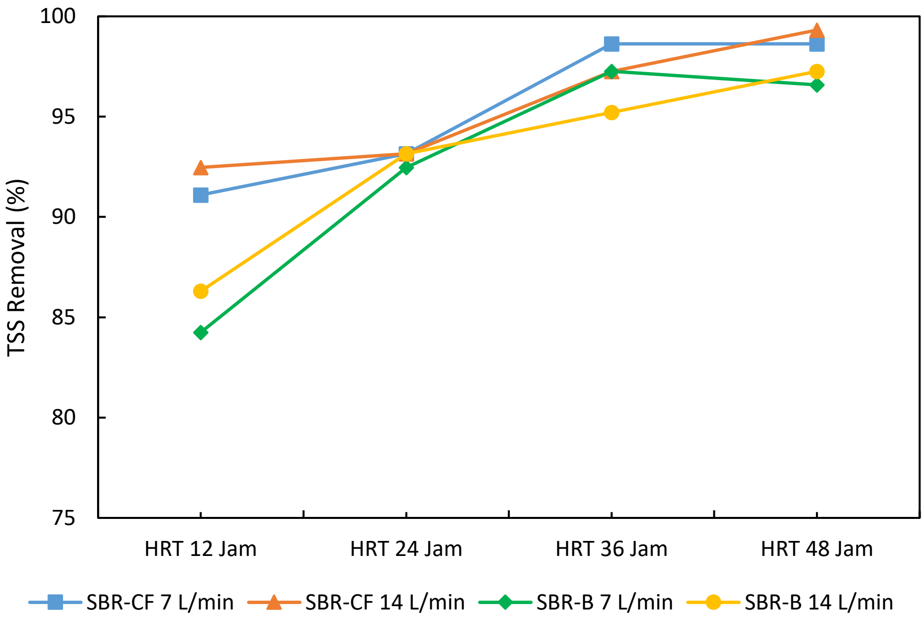


Figure 6. Relationship of hydraulic retention time to TSS reduction

TSS removal efficiency at 36 hours HRT has been able to reduce TSS concentrationaccording to the quality standard. And HRT 48-hour resulted in the highest TSS removal efficiencycompared to 12-hour, 24-hour, and 36-hour, both at aeration rates of 7 L/minute and 14 L/minute, respectively 99.32% and 98.63%. While the SBR Batch system can produce an efficiency of TSS removal of 97.26% at HRT 48 hours with an aeration rate of 14 L/minute. This proves that SBR-CF is better at removing TSS parameters compared to SBR in batch systems. This significant decrease in concentration in the SBR-CF reactor was helped by an anaerobic reactor shaped like a simple septic tank with a bulkhead inside and a small flow rate so that the creation of laminar flow and suspended solids can be trapped in the bulkhead. The factors that affect the decrease in the efficiency of TSS removal are due to the large number of suspended solids that are carried away during the effluent discharge stage when opening the tap for treated water . The decrease can also be affected by theresidence time (HRT) during the operation of SBR CF and SBR batch systems. Where the longerthe residence time used, the longer the time-division at the deposition stage in the SBR, resulting in a better deposition process.

Total N removal

Total N efficiency still does not meet the required quality standards, but the total N concentration can be set aside properly. It is proven by the value of Total N removal efficiency in SBR-CF with HRT of 36 hours and aeration rate of 7 L/minute and 14 L/minute, respectively 81.12% and 82.52% as the highest total N removal efficiency. While the SBR Batch system can produce a total N removal efficiency of 75.52% at HRT 48 hours with an aeration rate of 14 L/minute. Thus, it proves that SBR-CF is better in eliminating Total N parameters than SBR in a batch system.

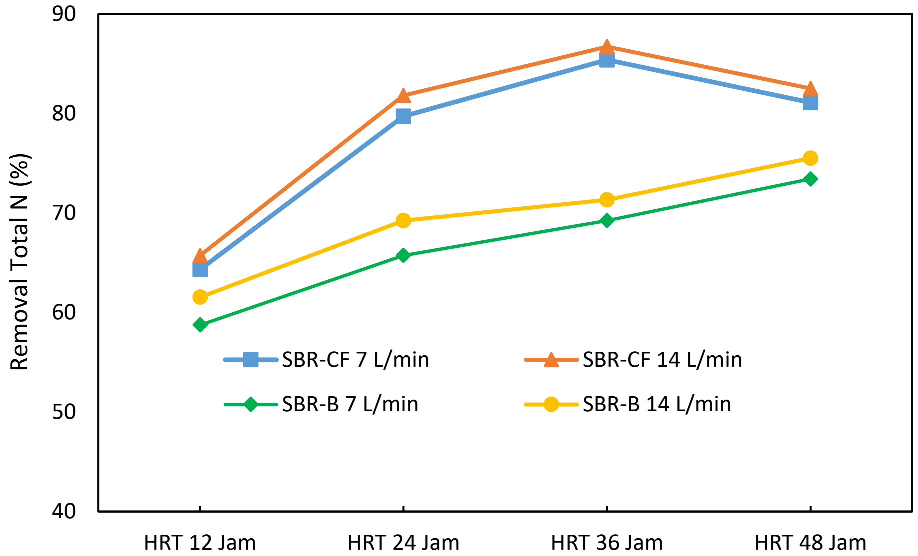


Figure 7 . Relationship of Hydraulic Retention Time to % Total N Decrease in SBR-CF and SBR Batch with Aeration Rates of 7 and 14 L/min

According to Sekarani and Hendrasarie, (2020), stated that the anaerobic reaction process and aerobic reaction could reduce the Total N concentration in wastewater well. This has an effect because in aerobic anaerobic reactions, nitrification and denitrification processes occur, which reduce Total N. The nitrification process can convert ammonia nitrogen into nitrate, and denitrification can reduce nitrate to nitrogen gas. The decrease in Total N concentration in SBR-CF was also helped by a separate anaerobic reactor and had a longer residence time than the aerobic phase in the SBR-CF reactor, which allowed a better nitrification and denitrification process.

PO_4 removal

The resulting efficiency in the SBR-CF processing with HRT 48 hours aeration rate of 14 L/minute is only capable of 55.6% but has met the required quality standards. Thisreduction is better than the batch system SBR. In processing using an SBR batch system at 48 hours and an aeration rate of 14 L/minute, the resulting effluent concentration could only approach the standard quality value of 10.89 mg/L with a decreased efficiency value 47.23%.

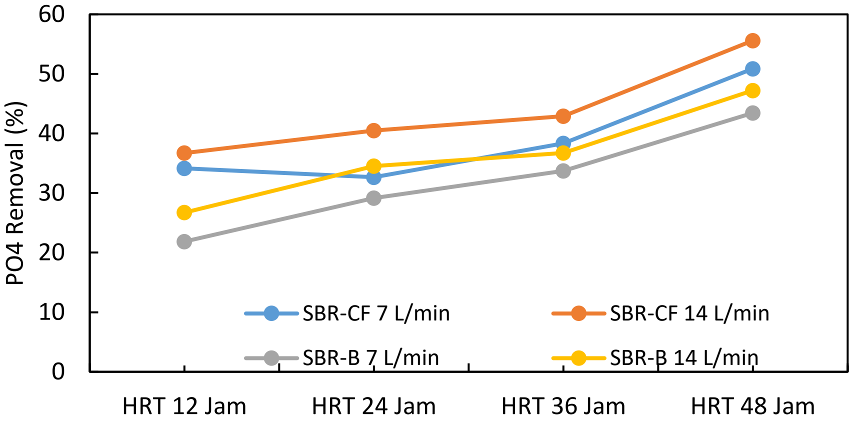
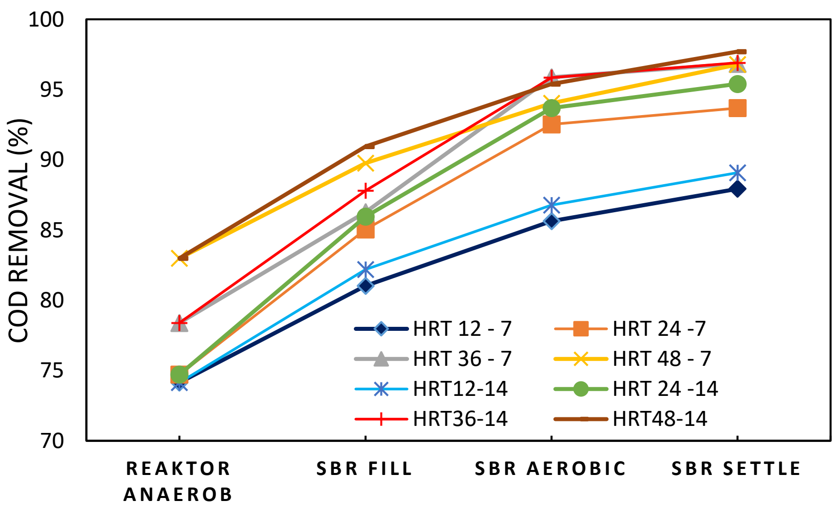


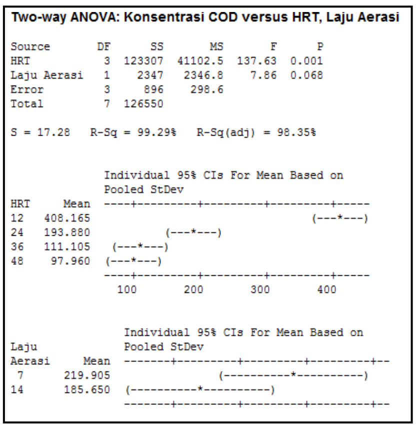
Figure 8. The Relationship of Hydraulic Retention Time to % Decrease in PO4 in SBR-CF andSBR Batch with Aeration Rates of 7 and 14 L/min

The removal of phosphate compounds occurs in the presence of anaerobic-aerobic conditions. Under anaerobic conditions, phosphate will be released, and phosphate compounds will reabsorption (Hendrasarie & Maria, 2021). The decrease in phosphate compounds is also influenced by oxygen concentration and residence time during the process. Lower oxygen concentration causes a lower phosphate absorption rate. Conversely, higher oxygen causes a higher phosphate absorption rate. Then the efficiency of removing phosphate compounds increases with increasing residence time (HRT), because the release of phosphorus usually occurs after denitrification so that the release of phosphate compounds can occur simultaneously (Li et al., 2019).

Effect of Hydraulic Retention Time (HRT) and aeration rate

The effect of HRT and different aeration rates on pollutant reduction efficiency was carried out using a TWO WAY ANOVA statistical test with Minitab16 software.



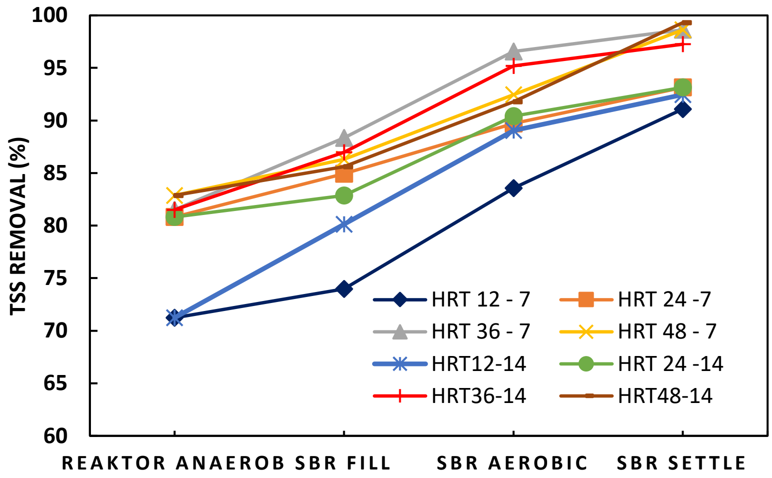


Two-way ANOVA: Konsentrasi COD versus HRT, Laju Aerasi

```
Source       DF      SS       MS       F      P
HRT           3  123307  41102.5  137.63  0.001
Laju Aerasi   1    2347   2346.8    7.86  0.068
Error         3     896    298.6
Total         7  126550

S = 17.28   R-Sq = 99.29%   R-Sq(adj) = 98.35%


              Individual 95% CIs For Mean Based on
              Pooled StDev
HRT    Mean   ----+---------+---------+---------+-----
12   408.165                               (---*---)
24   193.880           (---*---)
36   111.105   (---*---)
48    97.960  (---*---)
              ----+---------+---------+---------+-----
                100       200       300       400


                 Individual 95% CIs For Mean Based on
Laju             Pooled StDev
Aerasi     Mean  -------+---------+---------+---------+--
 7      219.905                (----------*----------)
 14     185.650  (----------*----------)
                 -------+---------+---------+---------+--
```

Figure 9. (a) Relation of SBR-CF Phase to COD Removal Percent with Variation of HRT andAeration Rate
(b) Results of TWO WAY ANOVA Statistics

Based on the results of the Analysis of Variance test, it was concluded that variations in HRT in the operation of SBR-CF can affect the efficiency of reducing the resulting CODconcentration, and can be seen in Figure 10 (a) the difference in the efficiency of decreasing CODconcentration differences based on HRT 12, 24, 36, and 48 hours can already be seen in the anaerobic reactor stage. However, in contrast to the results of the Analysis of Variance test, the difference in aeration rate to the decrease in COD concentration in SBR-CF operation cannot affect the efficiency of reducing COD concentration, which can also be seen in Figure 10 (a) the difference in aeration rate in each HRT the results are not much different between aeration rates 7L/min and 14 L/min. The optimal HRT for COD reduction efficiency in SBR operation was obtained at 24 Hours HRT because the longer HRT of 36 hours and 48 hours, there was no significant difference from the graph above. Then the optimum aeration rate is used at 7 L/minbecause the Analysis of Variance test does not affect the COD reduction efficiency.

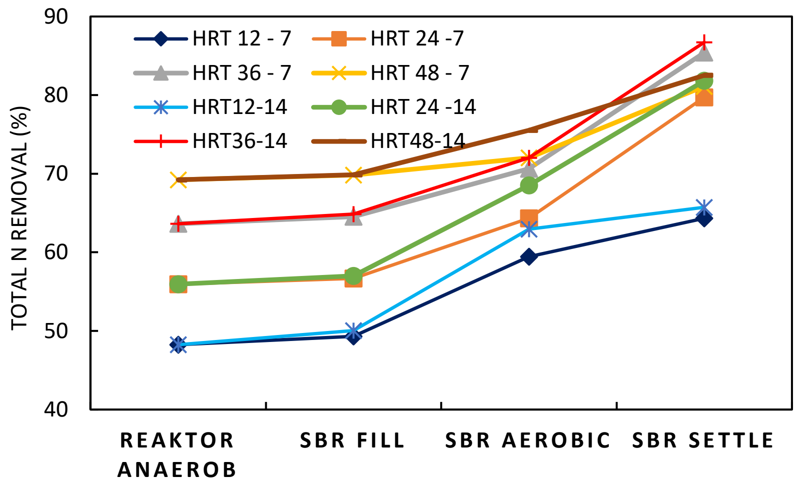


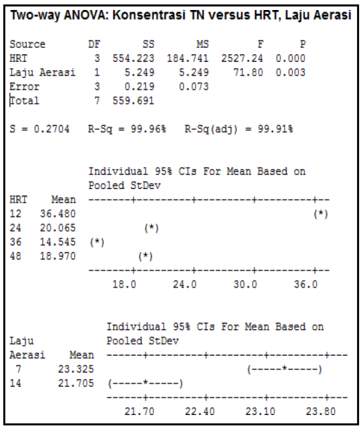
Two-way ANOVA: Konsentrasi TSS versus HRT, Laju Aerasi

```
Source        DF       SS       MS      F      P
HRT            3  15937.5  5312.50  36.43  0.007
Laju Aerasi    1     12.5    12.50   0.09  0.789
Error          3    437.5   145.83
Total          7  16387.5

S = 12.08   R-Sq = 97.33%   R-Sq(adj) = 93.77%

                Individual 95% CIs For Mean Based on
                Pooled StDev
HRT  Mean  ---+---------+---------+---------+------
12    120                         (------*------)
24    100                    (------*------)
36     30       (------*-----)
48     15   (------*------)
           ---+---------+---------+---------+------
              0        40        80       120

                   Individual 95% CIs For Mean Based on
Laju               Pooled StDev
Aerasi  Mean  --+---------+---------+---------+-------
 7      67.5    (---------------*---------------)
14      65.0  (---------------*---------------)
              --+---------+---------+---------+-------
               48        60        72        84
```

Figure 10. (a) Relationship of SBR-CF Phase to Percent Removal of TSS with Variation of HRTand Aeration Rate (b) Results of TWO WAY ANOVA Concentration of TSS effluent on HRT and Aeration Rate

Based on the results of the Analysis of Variance test, it was concluded that variations in HRT in the operation of SBR-CF can affect the efficiency of reducing the resulting TSS concentration, and can be seen in Figure 10 (a) the difference in the efficiency of reducing the concentration of TSS based on HRT 12, 24, 36, and 48 hours can be seen in the anaerobic reactorstage. Still, there is no significant increase in the efficiency of reducing TSS after 36 hours of HRT.However, in contrast to the results of the Analysis of Variance test, the difference in aeration rateto the decrease in TSS concentration in SBR-CF operation cannot affect the efficiency ofdecreasing TSS concentration, although Figure 10 (a) shows a difference in efficiency with variations in the aeration rate at each HRT. It occurs due to several possible factors where solidsare carried along in the effluent and the wobble in the reactor that is accidentally bumped at the time of sampling. The optimal HRT for TSS reduction efficiency in SBR operation was obtained at 36 Hours HRT because the longer HRT of 48 hours had no significant difference, while the 24 hours HRT results were not much different from the 12 hours HRT from the graph above. Then the optimum aeration rate is used at 7 L/min because, in the Analysis of Variance test, variations in the aeration rate do not affect the efficiency of TSS reduction.



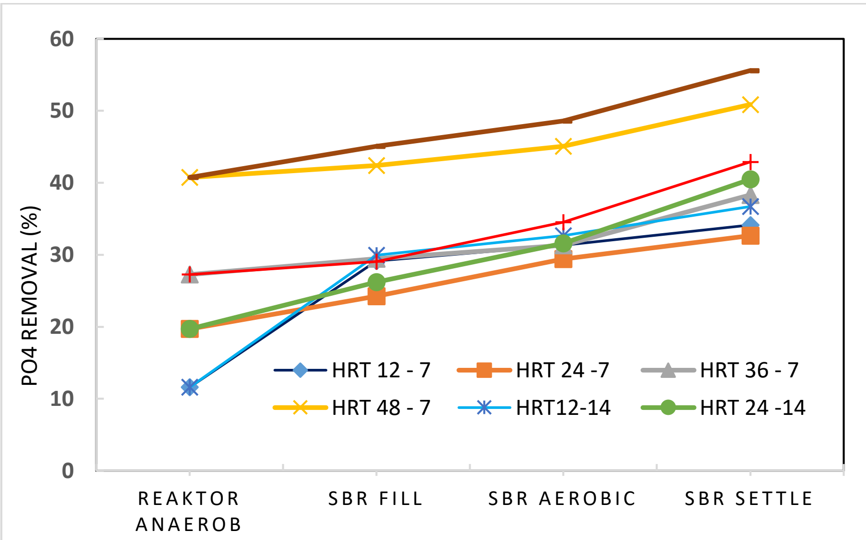


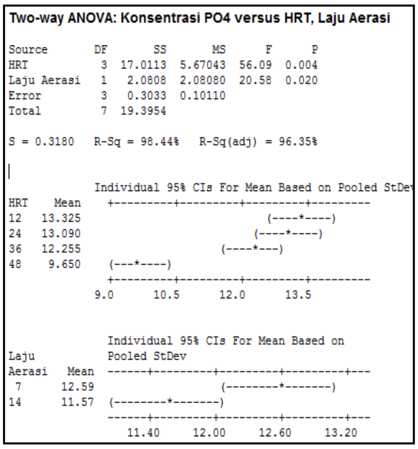
Two-way ANOVA: Konsentrasi TN versus HRT, Laju Aerasi

```
Source       DF       SS       MS        F      P
HRT           3  554.223  184.741  2527.24  0.000
Laju Aerasi   1    5.249    5.249    71.80  0.003
Error         3    0.219    0.073
Total         7  559.691

S = 0.2704   R-Sq = 99.96%   R-Sq(adj) = 99.91%


             Individual 95% CIs For Mean Based on
             Pooled StDev
HRT    Mean  -------+---------+---------+---------+--
12   36.480                                      (*)
24   20.065          (*)
36   14.545  (*)
48   18.970         (*)
             -------+---------+---------+---------+--
                  18.0      24.0      30.0      36.0


                Individual 95% CIs For Mean Based on
Laju            Pooled StDev
Aerasi    Mean  ------+---------+---------+---------+---
 7      23.325                        (-----*-----)
14      21.705  (-----*-----)
                ------+---------+---------+---------+---
                    21.70     22.40     23.10     23.80
```

Figure 11. (a) Relationship of SBR-CF Phase to Percent Removal of Total N with Variation of HRT and Aeration Rate (b) Results of TWO WAY ANOVA Statistics

In the Analysis of Variance HRT test on total N concentration removal, the P-Value was 0.000, which means less than 0.05, so H0 was rejected. This shows that HRT affects the removal of Total N concentration. Furthermore, in the Analysis of Variance Aeration Rate test on the removal of Total N concentration, the P-Value is 0.003, which is more than 0.05, then H0 is rejected. This shows that the aeration rate also affects the total N concentration removal. Based on the test results, the optimal HRT for total N reduction efficiency in SBR operation was obtainedat 24 Hours HRT because the longer HRT of 36 hours and 48 hours, there was no significant difference from the graph above. Then the optimum aeration rate is used at 14 L/min because in the Analysis of Variance test, the use of variations in the aeration rate affects the efficiency of totalN reduction. This affects because, in aerobic, anaerobic reactions, nitrification and denitrification processes occur, which play a role in decreasing Total N.





Two-way ANOVA: Konsentrasi PO4 versus HRT, Laju Aerasi

```
Source       DF       SS       MS      F      P
HRT           3  17.0113  5.67043  56.09  0.004
Laju Aerasi   1   2.0808  2.08080  20.58  0.020
Error         3   0.3033  0.10110
Total         7  19.3954

S = 0.3180   R-Sq = 98.44%   R-Sq(adj) = 96.35%


             Individual 95% CIs For Mean Based on Pooled StDev
HRT    Mean   +---------+---------+---------+---------
12   13.325                           (----*----)
24   13.090                         (----*----)
36   12.255                    (----*---)
48    9.650   (---*----)
              +---------+---------+---------+---------
             9.0      10.5      12.0      13.5


                Individual 95% CIs For Mean Based on
Laju            Pooled StDev
Aerasi    Mean  ------+---------+---------+---------+---
 7       12.59                 (--------*-------)
14       11.57  (--------*-------)
                ------+---------+---------+---------+---
                   11.40     12.00     12.60     13.20
```

Figure 12. (a) Relation of SBR-CF Phase to Percent Removal of PO4 with Variation of HRT andAeration Rate (b) Results of TWO WAY ANOVA Statistics

It indicates that HRT affects the removal of PO4 concentration. In the Analysis of Variance HRT test on the reduction of PO4 concentration, the P-Value is 0.004, which means less than 0.05, then H0 is rejected. Furthermore, in testing the Analysis of Variance Aeration Rate on the removal of PO_4 concentration, the P-Value is 0.020, which is more than 0.05, then H0 is rejected. It shows that the aeration rate also affects the total N concentration removal.

Based on the Analysis of Variance test results, it was concluded that variations in HRT in the operation of SBR-CF could affect the efficiency of reducing the resulting PO_4 concentration. It can be seen in Figure 12(a) the difference in the efficiency of PO_4 concentration reduction based on HRT 12, 24, 36, and 48 hours can be seen at the anaerobic reactor stage. Still, there is a significant increase in the efficiency of reducing PO_4 at 48 hours HRT. The same thing happened with the results of the Analysis of Variance test. The difference in aeration rate to the decrease in PO_4 concentration in SBR-CF operation could affect the efficiency of PO_4 concentration reduction.

Based on the test results, the optimal HRT for PO_4 reduction efficiency in SBR operation was obtained at 48 Hours HRT because there was a significant increase from the graph above. Then the optimum aeration rate is used at 14 L/min because, in the Analysis of Variance test, the use of variations in the aeration rate affects the efficiency of reducing Total N. In line with research conducted by Li et al. (2019) lower oxygen concentrations cause the absorption rate of phosphate compounds lower levels, on the other hand, higher oxygen levels cause higher levels of phosphate absorption. Then the efficiency of removing phosphate compounds increases with increasing residence time (HRT) because the release of phosphate usually occurs after denitrification so that the release of phosphate compounds can occur simultaneously.

Conclusion

The Sequencing Batch Reactor-Continuous Flow can degrade organic content quite well. The removal efficiency of the COD parameter produced at the optimum condition of HRT 24-hourwith an aeration rate of 14L/minute is 95.40%. Meanwhile, for the total N parameter, the removal efficiency is 81.82%. Then for the PO4 parameter, the removal efficiency is 40.48%. Then for the removal efficiency of the TSS parameter of 93.18% at HRT 24 hours with an aeration rate of 14L/minute. Based on the efficiency results, Sequencing Batch Reactor-Continuous Flow can be said to be able to process wastewater better than normal Sequencing Batch Reactor. Hydraulic retention time (HRT) affects decreasing the concentration of pollutant parameters, where 24-hour HRT is the optimal HRT for reducing organic matter content in the wastewater. The aeration rate affects the decrease in the concentration of pollutant parameters, where the aeration rate of 14 L/min is the optimal aeration rate to reduce the organic matter content in the wastewater.

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