Municipal Waste Water Treatment Using Sequencing Batch Reactor (SBR)

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Abstract: The sequencing batch reactor (SBR) method was used throughout this research; the experiments were carried out at the site of the Zafaraniya (MBR) project. This system has also the advantages of low initial and performance costs. Different time periods were used in this study ranging (3-8) hours for 9 months, the tests has been conducted in the environmental laboratory of the Zafaraniya (MBR) project. The removal efficiency of PO$_4$ from waste water depends on the change of anoxic conditions to aerobic. This efficiency is a maximum when the periods of the two types of conditions are equal; the removal of NO$_3$ depends on food supply for micro-organisms which convert nitrates to nitrogen gas under anoxic conditions so it is change able. According to the results gained, this kind of treatment could be used to removal phosphates & nitrates from waste waters, several experiments were conducted for the process and with different times that occur in a reactor (SBR) to reach the appropriate time to remove all pollutants from the waste water. The removal ratio was achieved when the time of the anaerobic process was equal to the time of the aerobic process that followed it. High removing efficiency in the pollutants was obtained. Phosphorous and nitrate from waste water, the percentages of removal were reached at (91.3% & 98%) for PO$_4$ and NH$_3$ relatively.

1. Introduction

The liquid formulations of wastewater vary from time to time and from one season to another, as well as the nature of their characteristics similar to the liquid industrial effluents. Therefore, the effluents of wastewater contain various pollutants, including phosphorus and ammonia compounds, as well as some nitrogen compounds. The active sludge using Sequencing Biologic Reactor (SBR) is the same as conventional sludge treatment using active Sludge. Both systems contain ventilation, sedimentation and purification. The difference between the two processes is that the flow in the conventional treatment process is continuous and the treatment processes are carried out in sequential basins at the same time, where a basin which that using to treat a sewage water using SBR, is being one basin in sequence stages. This in turn eliminates need for the basins of ventilation, sedimentation and precipitation, as well as active sludge shaking. [1]. SBR treatment consists of sequencing of processes series in one basin, the total of these sequencing processes (filling, reaction, ventilation, sedimentation, treated water withdrawal, sludge stop and withdrawal) is called one cycle. The operation of the SBR system is controlled by Programmable Location Control (PLC) that regulates the sequence of the treating processes by controlling the electric valves as well as controlling the adding and withdrawing pumps of the produced water and controlling the air drive through Sequencing automatic timers, thereby controlling sequence of different operations at different periods of time [2]. SBR is a system of activated sludge that operates by filling and draining for
the treatment of sewage and industrial wastewater. In this system, drainage water is added to a single flow reactor to remove undesirable components as well as pollutants and then discharging that. Balance, ventilation, and circulation can all be achieved using a single batch reactor. In order for this system to function optimally, a single flow reactor is used after determining the serialized processes. SBR systems have been successfully used to treat municipal wastewater and industrial waste water and are uniquely suited to wastewater treatment applications characterized by low or intermittent flows. Hence, successive sequential processes in the SBR reactor basin can be observed in Figure (1) [3].

![Figure 1. One Cycle occurring in the SBR](image)

Experiments began used the method of SBR in the 1970s [4]. Dosing fluctuation negatively affects the performance of the treatment plant, so it is possible to benefit from the treatment method with (SBR) in wastewater treatment [5]. One of the reasons for avoiding this method of treatment previously was the need for continuous monitoring. However, this problem was addressed with programmatic logical controls [6]. Made this method an ideal solution to the problems occurring in the traditional method of treatment of wastewater. In addition to the economic benefit achieved by dispensing from the secondary sedimentation basin, the counterbalance basin, and the sludgy return pumps [7]. In another study [8] to treat wastewater using the (SBR) method, the researchers stated that using a single basin in the (SBR) system to treat municipal wastewater which is the best choice because it prevents the growth of algae common in pond systems and achieves excellent removal of BOD and SS.

2. Work method and materials used

The study was carried out in the operations hall in Al-Zaafaraniya residential complex. The wastewater was taken from the residential energy complex, the laboratory tests were carried out with an aerobic and anaerobic treatment using activated sludge system of sequencing dosing along with the adoption of Batch flow. It was called sequencing due to the sequence of the treatment processes in the same basin. The basin or reactor used in the research has the dimensions of (85 cm x 12 cm x 100 cm) as shown in Figure (3). The size of this reactor is(100 liters) which contains two holes, the first is at the top to add sewage, the other hole is to withdraw the water produced, there are also two openings at the bottom of the reactor for adding air to the reactor and the other opening to pull the excess biomass. A single reactor system is designed in which all processes of addition, Anoxic, Aeration, sedimentation and withdrawal excess sludge were conducted, as shown in figure 2 Where the addition of a pump to add sewage to the reactor and the addition of a pump to withdraw water produced from the top of the reactor, an air pump was also placed to supply the system with oxygen to complete the process of aerobic so as to convert the NH4 in the sewage to nitrogen compounds, besides two small pumps were put to complete the process of Anoxic in order to remove Nitrogen compounds. The system was operated according to different times for the processes, the withdrawal of models and to conduct necessary tests to know the best time to remove pollutants from sewage and get the best water produced.
3. Research Methodology

The method of work can be summarized by adding the biomass to the reactor where it was taken from the system of the Zafaraniya (MBR) and then the air pump was operated within two weeks to activate the biomass. The value of the activated sludge within the reactor reached MLSS (2000 - 4000 mg / L). Having the activated sludge reached this value; it becomes ready for the treatment process. After activating the biomass, treatment processes have been started, including the withdrawal, addition, Anoxic process, then the process of ventilation Aeration was followed by the process of sedimentation and withdrawal of excess activated sludge in the same reactor at different time intervals according to the following schemes.
3.1. Anoxic for 30 min (Aerobic for one hour and Anaerobic for two hours).
During this period, the experiment was conducted according to the times mentioned above. The water produced by pump was withdrawn at a time interval of 45 minutes, and then new sewage was added by a pump that was set for this purpose. The average time of the addition process was 3.5 minutes. After completing the adding, the Anoxic phase was operated by running two pumps which were placed inside the reactor where the period of this stage was 30 minutes, then the pumps were turned off and the air pump was started to supply the reactor with the oxygen necessary for the biomass as well as to complete the nitrification process in which NH4 is converted into nitrate. The duration of the Aeration process is one hour. After completing the Aeration period, the air propulsion has been switched off to begin the sedimentation phase which lasted for 25 minutes. Sedimentation process for the biomass with drawing a sample of the produced water and laboratory tests were conducted for this sample inside the Zafaraniya MBR Project Hall. The NO3 test was carried out in the produced water sample and the NH4 test was conducted within the waste water, the system was then left for two hours for the anaerobic process to remove the phosphates. By taking a sample from the produced water, the quantity of phosphate was measured both in this sample and in wastewater. This process is carried out several times and the results of the tests for the produced water were taken from one period to another as illustrated in Tables 2 and 3.

3.2. Anoxic for one hour (Aerobic for one hour and Anaerobic for two hours).
During this cycle, experiments were conducted according to the above periods and according to the specified times beside each stage and in the same manner as paragraph (1). After fixing the times of the discharge, filling as well as sedimentation, a sample was then taken after the sedimentation of activated sludge, then wastewater and treated water were tested to determine the concentrations of NH4, NO3, PO4, and TN.

3.3. Anoxic for one hour (Aerobic for two hours and Anaerobic for two hours)
During this cycle, experiments were conducted according to the above periods and according to the specified times beside each stage and in the same manner as paragraph (1). After fixing the times of the discharge and filling as well as sedimentation, a sample was taken after the sedimentation of activated sludge, then waste water and treated water were tested to determine the concentrations of NH4, NO3, PO4, and TN.

3.4. Anoxic for two hours (Aerobic for two hours and Anaerobic for two hours)
During this cycle, experiments were conducted according to the above periods and according to the specified times beside each stage and in the same manner as paragraph (1). After fixing the times of the discharge and filling as well as sedimentation, a sample was then taken after the sedimentation of activated sludge, and then waste water and treated water were tested to determine the concentrations of NH4, NO3, PO4, and TN. The results were confirmed in Tables 2 and 3.

3.5. Anoxic for two hours (Aerobic for three hours and Anaerobic for one hour)
During this cycle, experiments were conducted according to the above periods and according to the specified times beside each stage and in the same manner as paragraph (1). After fixing the times of the discharge and filling along with sedimentation, a sample was then taken after the sedimentation of activated sludge, then wastewater and treated water were tested to determine the concentrations of NH4, NO3, PO4, and TN. The results were confirmed in tables 4 and 5.

4. Results and discussion
The BOD5 concentrations for sewage water, as well as BOD5 concentrations of water produced after treatment by the SBR system during the period of month from (22/5 to 1/12), that shows in Table 1 a decrease in values of BOD5 concentration after SBR system, than the values of BOD5 concentrations in wastewater, this indicates the success of the biological process in the SBR reactor.
Table 1. BOD$_5$ concentrations of wastewater and treated water

| Date  | 22/5 | 27/5 | 3/6 | 9/6 | 21/6 | 17/7 | 22/7 | 4/11 | 1/12 |
|-------|------|------|-----|-----|------|------|------|------|------|
| BOD$_5$ mg/l Inward water | 310  | 280  | 300 | 270 | 240  | 360  | 220  | 232  | 190  |
| BOD$_5$ mg/l treated water | 60   | 45   | 90  | 45  | 55   | 85   | 45   | 65   | 25   |

Figure 4. BOD$_5$ concentrations in wastewater and treated water

We see from Figure 4 a value of BOD$_5$ curve after treatment is decrease from the value of BOD$_5$ curve of the internal water. According to the first cycle which the system was run (30 minutes Anoxic, 1 hour Aerobic and 2 hours Anaerobic), NH$_4$, PO$_4$ and total nitrogen TN concentrations in wastewater are shown in Table 2.

Table 2. Concentrations of NH$_4$, PO$_4$ and TN during four tests inward of drainage water in various period times

| Test | TN mg/L | PO$_4$ mg/L | NH$_4$ mg/L |
|------|---------|-------------|-------------|
| 5/6  | 79.2    | 12.6        | 48.2        |
| 7/6  | 48.2    | 10.7        | 34.5        |
| 12/6 | 65.6    | 14.4        | 42.9        |
| 15/6 | 68.7    | 12.6        | 45.2        |
Table 3. Concentrations of pollutants in water produced after treatment through four tests

| Test | Phosphorus removal ratio % | Nitrogen removal ratio % | Phosphate PO₄ Mg/l | TN Mg/l | NO₂ Mg/l | NO₃ Mg/l |
|------|----------------------------|--------------------------|-------------------|---------|---------|---------|
| 5/6  | 91.6                       | 85.5                     | 1.3               | 25.2    | 0.076   | 6.9     |
| 7/6  | 89.8                       | 72.5                     | 1.07              | 27.5    | 0.214   | 9.3     |
| 12/6 | 84                         | 88.6                     | 1.81              | 23.4    | 0.056   | 4.6     |
| 15/6 | 91                         | 94                       | 1.16              | 21.8    | 0.057   | 2.7     |

Figure 5. NH₄, NO₃ Concentration in wastewater and in treated water

Figure 6. Removal efficiency of NO₃ and PO₄ from waste water

Another treatment cycle for a wastewater with change in time for each process, the reactor was operated in a time (2hour Anoxic, 2 hour Aerobic, 2 hours Anaerobic), NH₄, PO₄ and total nitrogen TN concentrations in wastewater are shown in Table 4 and the efficiency ratio of nitrogen removal, it reached at 98%, and also the increase in the efficiency of removing phosphorus, where it reached at 85.5%, this is...
due to the fact, when the times of the process that occur inside the reactor is equal, so the efficiency of removing pollutants increases, this note show clearly in Table 5 and Figures 6 and 8.

**Table 4.** Concentrations of NH₄, PO₄ and TN during four tests inward drainage water in various period time

| Test  | TN mg/L | PO₄ mg/L | NH₄ mg/L |
|-------|---------|----------|----------|
| 20/9  | 45      | 12       | 40       |
| 23/9  | 63.4    | 14.5     | 50.4     |
| 27/9  | 67.8    | 13.6     | 54.8     |
| 2/10  | 58.4    | 14.6     | 47.3     |

**Table 5.** Concentrations of pollutants in Water produced after Treatment through four tests

| Tests | Phosphorus removal ratio % | Nitrogen removal ratio % | Phosphate PO₄ Mg / l | TN Mg / l | NO₂ Mg / l | NO₃ Mg / l |
|-------|----------------------------|--------------------------|----------------------|-----------|------------|------------|
| 20/9  | 83.5                       | 93.3                     | 1.98                 | 26.7      | 0.187      | 2.5        |
| 23/9  | 85.5                       | 93.5                     | 2.09                 | 16.1      | 0.144      | 3.1        |
| 27/9  | 82                         | 98                       | 2.45                 | 18.3      | 0.062      | 1.05       |
| 2/10  | 83.6                       | 97.5                     | 2.38                 | 20.6      | 0.154      | 1          |

**Figure 7.** NH₄, NO₃ Concentration in wastewater and in treated water
For the purpose of finding a cycle time that removes $\text{PO}_4$, $\text{NH}_4$, $\text{NO}_3$ pollutants with acceptable efficiency. By observing the results of operation and with different times, it was found that the non-oxygen phase in the beginning of the process is important in removing phosphates and not less than 2 hours and in the reaction period the period of air conditions should be prolonged to remove $\text{NH}_4$ and be about 2 hours. The nitrates were removed quickly during the period of the non-oxygen phase to provide the organic food, as the nitrates are present from the previous cycle, and with the initiation of ventilation and nitrification, the nitrate concentration increases and the In the Anoxic phase, nitrates are removed, depending on the cell stock of carbon. The low concentration of phosphorus occurs in the non-oxygen phase when microorganisms are active and provides conditions for the lack of oxygen to remove phosphorous. In a previous study to remove phosphorous and ammonia from wastewater for a hospital in the city of Mosul using the reactor, we note that the efficiency of phosphorous removal was reached at (67%) and the efficiency of removing nitrates was reached at (99%). And in this research, we show clearly the efficiency of removing the phosphorus is (91.3%) and the efficiency of removing ammonia is (98%). The reason for that They used different times for each stage of treatment, but during our research, several times were used for the treatment stages until we concluded that at the approximate times of the anaerobic phase and the ventilation stage, the best efficiency was obtained to remove phosphorus, ammonia, and nitrate. Show this result clearly in Table 6.

**Table 6.** Comparison between the characteristics of wastewater after SBR treatment and the conventional wastewater treatment plant.

| The property | SBR System | Conventional plant |
|--------------|------------|-------------------|
| Mg/L pH      | 7.61 - 7.13| 7.8 - 6.9         |
| BOD$_5$      | 10 – 90    | 10 - 110          |
| $\text{PO}_4$| 2 - 5.9    | 3.5 – 12          |
| $\text{NH}_3$| 0.5 - Nil  | 0.6 – 2.3         |
| $\text{NO}_3$| 2 - 9      | 24 - 36           |

![Figure 8. Removal efficiency of NO$_3$ and PO$_4$ from waste water](image)
We note in Table 6, the efficiency of pollutants removing from wastewater in a system (SBR) is better than a conventional treatment plant and also that the system (SBR) is considered to be economically feasible better than a conventional treatment plant because it consists of only one basin, while the conventional plant contains several basins for processing.

5. Conclusion
Based on the results obtained from the experience and discussions that have been made about the removal efficiency of NH$_4$ from waste water was affected by the cycle time, and high removal efficiency of the suspended materials is achieved by (90-100%), due to high efficiency sedimentation and biodegradation process. The removal rate for PO$_4$ is achieved by (91.3%), and the removal of phosphate increased by increasing the cycle time to a time limit of approximately 3 hours. The process is reversed; the phosphate will be released again because the excess ventilation leads the phosphates again. So the removal ratio of NO$_3$ is achieved by (98%), where the ammonia in the waste water is converted to Nitrates by the nitrification process when the appropriate ventilation is available. And after that the nitrate is removed by the anoxic process. The best cycle time in this work at 2 hours Anoxic, after that, 2 hours in ventilation, and sedimentation for half an hour, then the system has stopped for two hours, the withdrawal and addition is done again.

References
[1] Ganesh R., Balaji G. and Ramanujam A. 2006 Biodegradation of tannery wastewater using sequencing batch reactor Respirometric assessment. Bioresource Technology, 97, pp. 1815–821
[2] Mohseni B. and Bazari, H. 2004 Biological Health Eng., 1(2), pp. 65-69.
[3] Rezaee A. and Khavanin, M. 2008 Treatment of Work Camp Wastewater Using a Sequencing Batch Reactor Followed by a Sand Filter American Journal of Environmental Sciences 40, pp. 342-346.
[4] Wilderer P., Irvine R. and Goronszy M. 2005 Sequencing Batch Reactor Technology scientific and Technical Report No. 10, IWA Publishing, London, UK.
[5] Abu-Ghunmi N. and Jamrah A. 2006 Biological treatment of textile wastewater using sequencing batch reactor technology. Environmental Modeling and Assessment 11, pp. 333 – 343.
[6] Ndegwa P., Hamilton D., Lalman, J. and Cumba H. 2005 Optimization of anaerobic sequencing batch reactors treating dilute swine slurries. Transaction ASAE 48, pp. 1575–1583.
[7] Boopathy R. 2009 Biological treatment of shrimp production wastewater. J I and Microbiol Biotechnol 36, pp. 989–992.
[8] Artan N., Wilderer P., Ohon D. and Morgenroth E. 2008 mechanism and design of sequencing batch reactor systems for nutrient removal. Water Sci Techno 43, pp. 53–60.