



PERFORMANCE OF SEQUENCING BATCH REACTOR (SBR) FOR DOMESTIC WASTEWATER TREATMENT UNDER LOW TEMPERATURE IN BASRAH CITY (SOUTH OF IRAQ)

Ali H. Al-Aboodi

Assistant Professor, Civil Engineering Department
College of Engineering, University of Basrah, Basrah, Iraq

Husham T.Ibrahim

Lecturer, Civil Engineering Department
College of Engineering, University of Basrah, Basrah, Iraq

Sarmad A.Abbas

Lecturer, Civil Engineering Department
College of Engineering, University of Basrah, Basrah, Iraq

ABSTRACT

In this study, a lab scale aerobic Sequencing Batch Reactor (SBR) containing activated sludge was constructed from PVC material with volume equal to 20 L. The experiment tests was started in early of November 2016 to the end of February 2017 by operating the reactor in two operation cycles modes within the temperature $T \leq 15^{\circ}\text{C}$ to investigate the best one gives a good removal efficiencies for COD, $\text{NH}_4\text{-N}$, and TN, from domestic wastewater in Basrah City (South of Iraq). During the first cycle mode the mixed liquor (ML) was continuously aerated for 2 hours and then 1 hour mixing as anoxic period and then 1 hour aeration, settled for 1 hour, after that water discharge with drainage ratio of 100% for 1 hour, while during the second cycle mode the mixed liquor (ML) was continuously aerated for 8 hours after that 1 hour settle and 1 hour discharge. The results show that the average removal efficiencies of COD, $\text{NH}_4\text{-N}$, and TN that has been achieved by SBR system under first cycle mode were 83.33%, 69.23%, 63.33% respectively, while the average removal efficiencies of COD, $\text{NH}_4\text{-N}$, and TN removal efficiencies that has been achieved under second cycle mode were 89.71%, 75.56%, and 67.07% respectively. According to the results the aeration time period has no effect on the average effluent COD and TN concentration, $\text{NH}_4\text{-N}$ removal efficiency is relatively low under the condition of short aeration time period, but the difference between the first and second mode

average efficiencies was low and not greater than 6.33%. Finally the first operating cycle mode is a better and more economically mode for domestic wastewater in Basrah city (South of Iraq) during winter season due to its high average hourly removal efficiencies for COD, NH₄-N, and TN during aeration period (27.78%, 23.08%, and 21.11% respectively) compare with second mode (11.21%, 9.45%, and 8.38% respectively).

Key words: Sequencing Batch Reactor, Nitrification, Denitrification, Temperature, Domestic Wastewater, COD, NH₄-N, TN, Basrah, Iraq.

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1. INTRODUCTION

The Sequencing Batch Reactor (SBR) is an activated sludge process designed to operate under non-steady state conditions. An SBR operates in a true batch mode with aeration and sludge settlement both occurring in the same tank. The major differences between SBR and conventional continuous flow, activated sludge system is that the SBR tank carries out the functions of equalization aeration and sedimentation in a time sequence rather than in the conventional space sequence of continuous-flow systems. In addition, the SBR system can be designed with the ability to treat a wide range of influent volumes whereas the continuous system is based upon a fixed influent flow rate. Thus, there is a degree of flexibility associated with working in a time rather than in a space sequence (Norcross, 1992, Mace and Mata-Alvarez, 2002, Wisaam S. Al-Rekabi et al., 2008).

Wastewater temperature is the one of the important cyclic stimuli, but inlet flow rates and concentrations, and several features of the annual biochemical cycle, also can contribute to the observed patterns of nutrient and pollutant removal. The temperature is very important in biological wastewater treatment systems because the effects it has on the microbial growth. While most microorganisms are able to exist over a broad temperature range, there is usually an optimum temperature at which each species grow better.

Temperature is not only affects the metabolic activities of the microbial population but also influences the gas-transfer rates and the settling characteristics of activated sludge. In general the rate of biochemical reactions and of substrate transfer processes increases with higher temperature. However, the solubility of oxygen decreases in the mixed liquor as temperature increased, resulting in poor biodegradation conditions for aerobic microbes. Thus, an increase in temperature generates two reciprocal effects on biochemical reactions. Furthermore, sludge is difficult to settle as higher temperature maintained during the settling phase of SBR (Wisaam S. Al-Rekabi, 2008).

In recent years, the use of sequencing batch reactors (SBRs) in the biological treatment of wastewater has been widely extended from lab-scale studies to real WWTPs (wastewater treatment plants) (Mace and Mata-Alvarez, 2002, Steinmetz et al., 2002). While lab-scale SBRs have been used for research on carbon and nutrient removal and the development of urban/industrial wastewater biodegradability assays, real plant applications are still mainly focused on carbon removal. Nevertheless, when operating real plant SBRs the efficiency of nitrogen removal sometimes turns out to be better than the legally required effluent standards (Teichgraber et al., 2001).

Ros and Vrtovsek (2004) also found that the removal of N was not dependent on initial P concentration, but P removal was related to P concentration in the original wastewater by using SBR laboratory pilot plant used in the study consisted of a 70 L rectangular reactor and operation of the pilot plant is monitored by five on-line measurements, i.e. PH, Redox potential (ORP), Dissolved oxygen (DO) concentration, Temperature (T), and water level. All experiments were carried out with synthetic wastewater.

Two bench scale SBR's were used by Keller et al. (1997) to investigate the effect of pretreatment abattoirs and process variations on the BNR (Biological Nutrient Removal) capacity. The reactors were operated at room temperature ($20 \pm 2^\circ\text{C}$) the maximum operating volume of the reactors was approximately 5 liters. The overall removal efficiency of the incoming carbon was very good, particularly in terms of the effluent BOD which reached very low values during the whole reactor operation. The remaining COD has to be regarded as non-biodegradable. This fraction in fact quite small, representing around 2% of the COD initially present in the wastewater.

De Sousa and Foresti (1996) investigated treating domestic sewage in tropical regions by using a combined anaerobic-aerobic system composed of an USAB reactor followed by two sequencing batch reactors (SBR). In such a system, the USAB reactor removes considerable fraction of the influent organic matter, while the SBRs oxidize part of the remaining organic matter and ammonium nitrogen. A proper system operation would also permit the removal of nutrients (N and P). This system was efficient in removing COD (95%), TSS (96%) and TKN (85%).

Kargi and Uygur (2003) operated laboratory SBR to Nutrient removal from synthetic wastewater by sequencing batch operation was studied at different specific nutrient loading rates (SNLR). Nutrient removal in a sequencing batch reactor (SBR) was a five-step process consisting of anaerobic (An), anoxic (Ax), oxic (Ox), anoxic (An) and oxic (Ox) phases with hydraulic residence times (HRT) of 2/1/4.5/1.5/1.5 h, respectively. The settling step used at the end of the operation was 45 min for all experiments. The initial COD concentration was varied between 600 and 4800 mg/l at eight different levels with constant COD/N/P ratio of 100/3.33/0.7. Effects of SNLRs on COD, $\text{NH}_4\text{-N}$ and $\text{PO}_4\text{-P}$ removal were investigated. Percent nutrient removals decreased and effluent nutrient levels increased with increasing nutrient loading rates. The highest COD (99%), $\text{NH}_4\text{-N}$ (99%) and $\text{PO}_4\text{-P}$ (97%) removal efficiencies were obtained with the initial COD concentration of 600 mg/l at COD loading rate of nearly 40 mg COD / (g biomass) / h. However, the sludge volume index (SVI) decreased with increasing COD loading rate resulting minimum SVI of 46 mg/l at COD loading rate of nearly 86 mg COD / (g biomass) / h. Biomass concentration increased with increasing SNLR resulting in biomass concentration of 3.84 mg/l at COD loading rate of 86 mg COD / (g biomass) / h.

The aim of this research is to investigate the performance of Sequencing Batch Reactor (SBR) for domestic wastewater treatment under low temperature in Basrah city (South of Iraq).

2. MATERIALS AND METHODS

2.1 Experimental setup

Figure. 1 show the experiment installation. The sequence batch reactor had a working volume of 20 Liter, with a square base (20 cm x 20 cm) and a height of 60 cm. Four air sparkers were placed at the bottom of the reactor symmetrically and the aeration was controlled by flow meter. Temperature also controlled by thermometer.

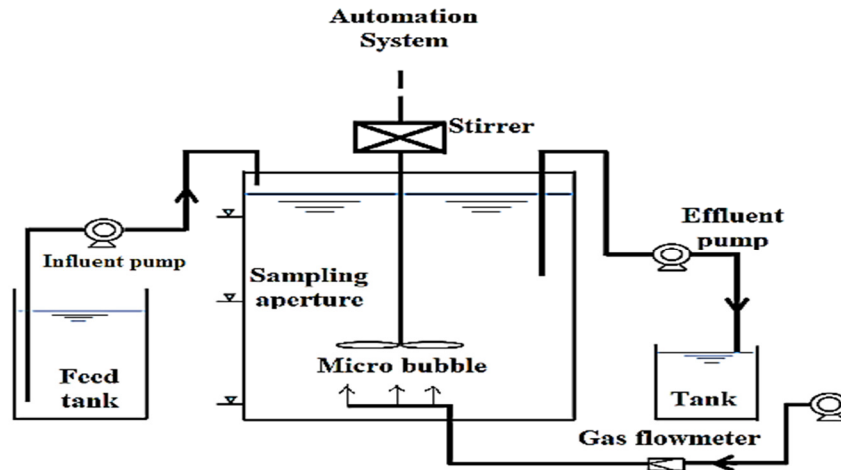


Figure 1 Schematic diagram of the experiment installation.

The SBR was operated in early of November 2016 to the end of February 2017. The experimental period comprised two different operational cyclic modes as shown in Fig.2 in order to investigate the best cyclic mode which gives a good removal efficiency. These operation cyclic modes were carried out, each with its own set of treatment parameter. In the first operation cyclic mode an overhead mixer is installed for anoxic operation, mixed liquor (ML) of raw domestic sewage together with activated sludge, was continuously aerated for two hours as aerobic condition for enhanced nitrification and then one hour mixing as anoxic period for enhanced denitrification, and then one hour aeration, settled for one hour, after that clear supernatant water discharge for one hour. Within second operation cycle mode aeration continuous for eight hours to enhance nitrification after that one hour settle and one hour discharge. Solid retention time (SRT) ranged from 12 to 24 days, hydraulic retention time (HRT) varied from 6 to 10 hours, reactor MLSS ranged from 2350 to 2800 mg/l.

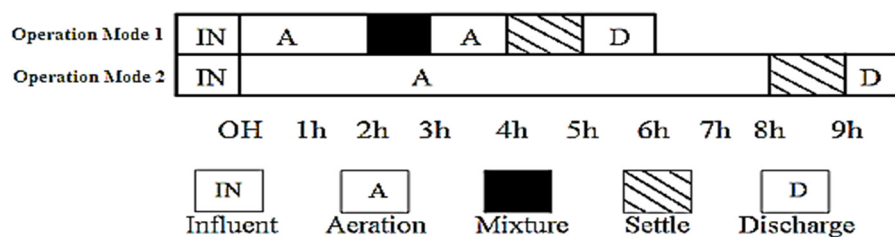


Figure 2 Operation cycle modes.

2.2 Operation procedure

The procedure adopted in the Sequencing Batch Reactor (SBR) is an adoption of that commonly used in sewage treatment works. Biological treatment of wastes is carried out by activated sludge techniques. Aerobic conditions are maintained by continuous and/or intermittent aeration with compressed air supplied through 4 air diffusers, the reactor was seeded with activated sludge from Hamdan wastewater treatment plant in Basrah City (South of Iraq). The concentration of suspended solids (SS) was 1600 mg/l after inoculation, while this concentrations in final effluent were around 7-10 mg/l. All contaminants were measured according to standard methods, as set out by the American Public Health Association (APHA 2005).

3. CHARACTERISTICS OF INFLUENT WASTEWATER

The quality of wastewater resulting from the various daily uses in HAY AL-ASATETHA district at Basrah city in south of Iraq during winter season was show in Table 1.

Table 1 Characteristics of wastewater in Hay Al-Asatetha District at Basrah city in south of Iraq during winter season.

Contaminants	COD		NH ₄ -N		TN	
	First cycle mode	Second cycle mode	First cycle mode	Second cycle mode	First cycle mode	Second cycle mode
Concentration (mg/l)	189.4-366.1	265.3-581.5	23.8-67.4	68.2-97.3	38.4-80.6	74.9-103.1
Average Concentration (mg/l)	300	408	52	90	60	82
Standard Deviation (mg/l)	56.7	120.2	16.2	11.1	14.9	10.6

4. RESULTS AND DISCUSSION

4.1 Examination of COD Removal

The Chemical Oxygen Demand (COD) is an indication of the amount of energy and carbon there is available to the microbial population within the reactors. A well designed and well-operated biological reactor should maximize the utilization of the COD. Figure 3 show the average COD concentration variation with operation time under two operations cycle modes. The average influent COD concentration was 300 mg/l during the first operation cycle mode, while the average influent concentration of COD was 408 mg/l in the second operation cycle mode. The results of average COD removal efficiency under two operation cycle modes is depicted in Figure 4. The results showed that the treatment performance was prompted with no significant difference between the first and the second operation cycle modes. The average concentrations of COD reduced from 300 mg/l to 50 mg/l in the first cycle mode, while decreasing from 408 mg/l to 42 mg/l in the second cycle mode. According to the results, the average COD removal efficiency (83.33%) was relatively low under the condition of the first cycle mode compare with average removal efficiency (89.71%) in the condition of the second cycle mode, the average effluent concentration of COD in the first cycle mode (50mg/l) was very near to the average effluent concentration of COD in the second cycle mode (42mg/l), therefore the aeration time period has no effect on the average effluent COD concentration. By compare the COD average hourly removal efficiency during aeration period between first and second cycle mode (27.78% for first cycle mode, and 11.21% for the second cycle mode) we can present the first mode as a better and more economical mode for COD removal.

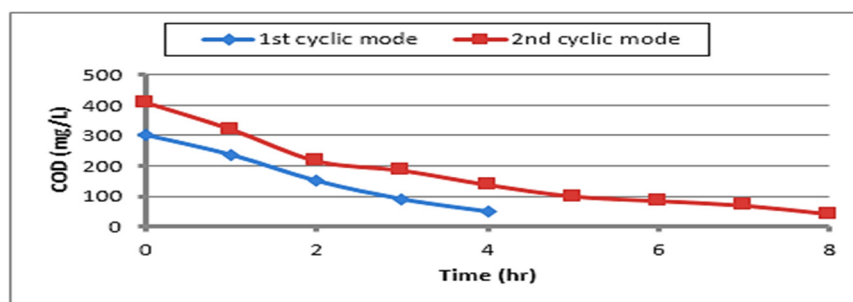


Figure 3 Average COD concentration variation under different operation cycle modes.

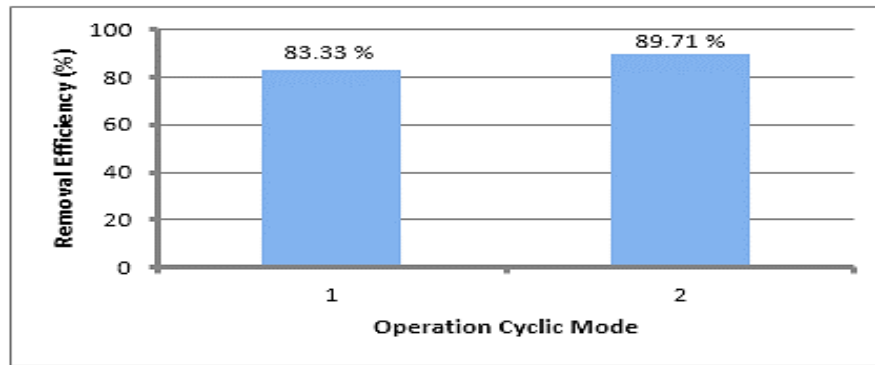
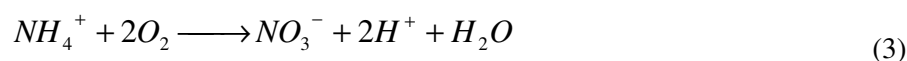
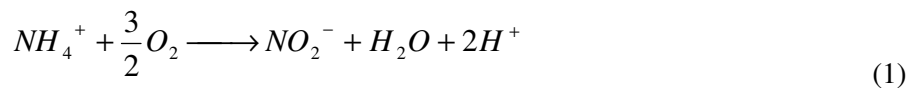


Figure 4 Average COD removal efficiency under two operation cycle modes.

4.2 Examination of Ammonium ($\text{NH}_4^+\text{-N}$) Removal

The ammonium nitrogen in the wastewater originates from the breakdown of urea by the enzyme urease, which is present in fecal matter, and the breakdown of proteins in organic matter, which contain amine groups. The combination of the urine and feces releases a large amount of ammonia. Genera of microorganisms that scientists believe play roles in nitrification are *Nitrosomonas*, *Nitrobacter*, *Nitrospira*, *Nitrosolobus*, *Nitrosovibrio*, and *Nitrosococcus* (Madigan et al., 2000). These genera of organisms are autotrophic, so their carbon source is carbon dioxide (CO_2).

The most common and efficient method used to remove ammonium from wastewater is the biological nitrification /denitrification process (Cooper et al., 1994). According to Metcalf and Eddy (2003) nitrification can be definition as the process that oxidation ammonia to nitrite and then oxidation nitrite to nitrate under aerobic conditions by using oxygen as the electron acceptor. The stoichiometry of the two steps and the total reaction are given below in Equations 1, 2 and 3, respectively:



Denitrification is performed by heterotrophic bacteria that use nitrate and nitrite as electron acceptor when organic matter is oxidized. This processes occurs under anoxic or/and anaerobic condition (dissolved oxygen concentration <0.5 mg/L). Biological denitrification is coupled to the respiratory electron transport chain, and nitrate and nitrite are used as electron acceptor for the oxidation of a variety of organic electron donors (Metcalf and Eddy, 2003).

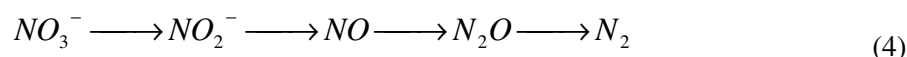


Figure 5 shows ammonium average concentration in the SBR dropped from an initial average value 52 mg/L to 16 mg/L in the first cycle mode, while in the second cycle mode decreased from 90 mg/L to 22 mg/L.

Ammonium average removal efficiencies for first and second operation cycle modes were 69.23% and 75.56% respectively as shown in Figure. 6 According to the results ammonium removal efficiencies was decreased gradually with decreased aeration time of SBR, so

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ammonium removal efficiency is relatively low under the condition of short aeration period time, but the different between the first and second mode average efficiencies was low and not greater than 6.33%.

The ammonium degradation process affected by COD concentration because the COD removal priority and after that ammonium removal begin. One hour before the aeration COD concentration is high and the high rate of heterotrophic bacteria quickly added so that COD degradation is fast making self-support type of nitrifying bacteria inhibited so denitrification rate is slow, the speed of reduce ammonium concentration be smaller.

Economically the first cycle mode is more suitable for ammonium removal from domestic wastewater in Basrah city (South of Iraq) during winter season because its average hourly efficiency during aeration period (23.08%) is more than the average hourly efficiency for the second cycle mode (9.45%).

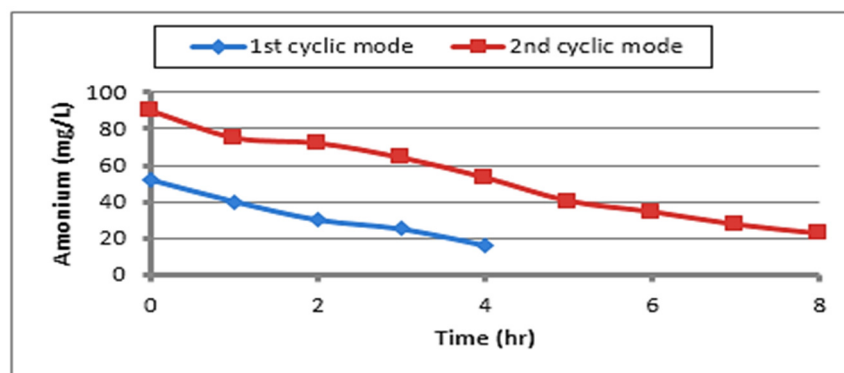


Figure 5 Average Ammonium concentration variation under different operation cycle modes.

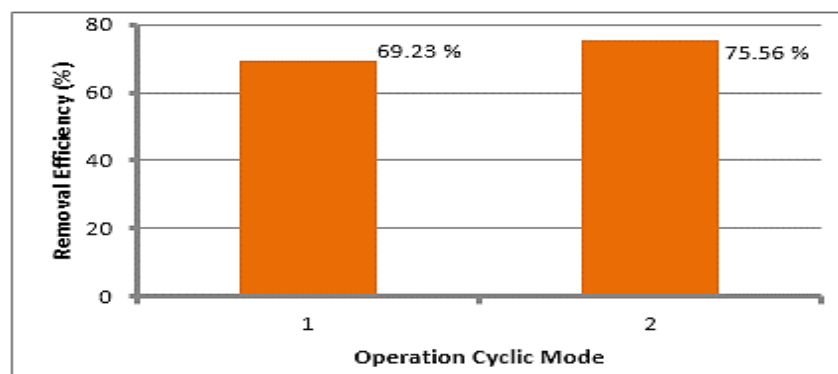


Figure 6 Average Ammonium removal efficiency under two operation cyclic modes.

3.4 Examination of Total Nitrogen (TN) removal

Municipal wastewater treatment plants (WWTP) often employ nitrification/ denitrification for biological nitrogen removal. Because nitrifying bacteria grow slowly and are sensitive to environmental conditions, care must be taken to prevent nitrification failure. The growth and activity of nitrifiers are also greatly influenced by temperature, although “quantification of this effect has been difficult” (Tchobanoglous and Burton, 1991). Bitton (1999) suggests an optimum temperature of 30°C for nitrification with growth in the range of 8–35°C.

Denitrification is most efficient at a neutral pH (Metcalf and Eddy, 2003). Both nitrification and denitrification rates decrease with decreasing temperature over a normal

range of operating temperatures (5–30°C), and, therefore, optimum rates are achieved at higher temperatures (USEPA, 1993).

SBR systems, applied to nitrification and denitrification, offer various advantages including: minimal space requirements, ease of management and possibility of modifications during trial phases through on-line control of the treatment strategy. Increasing interest towards on-line control of biological processes allowed the development of techniques and operation strategies able to optimize treatment plants, both in terms of removal efficiencies and in terms of costs (Andreottola et al., 2001).

In the first cycle mode, the average influent concentration of TN was 60 mg/l, while in the second cycle mode the average influent concentration of TN was about 82 mg/l. Fig.7 illustrated that the TN average value dropped from 60 mg/l to 22 mg/l in the first cyclic mode and from 82mg/l to 27mg/l in the second cyclic mode. Total Nitrogen (TN) average removal efficiencies for first and second operation cycle modes were 63.33% and 67.07% respectively as shown in Figure 8

According to the results the TN removal efficiencies were relatively low even under the condition of long aeration time period in the second operation cycle modes, this indicates that the nitrification occurred and predominant, beside that the denitrification be very low because need more time for anoxic, so the first cycle mode can present as the better and most economic mode for TN removal in Basrah city (South of Iraq) due to its high average hourly removal efficiency during aeration period (21.11%) compare with average hourly removal efficiency for second cycle mode (8.38%).

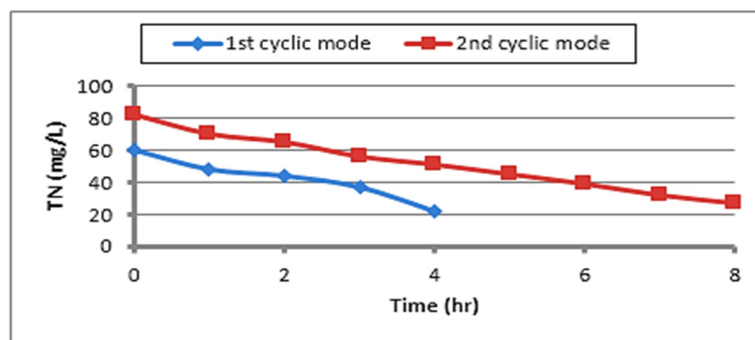


Figure 7 Average TN concentration variation under different operation cycle modes.

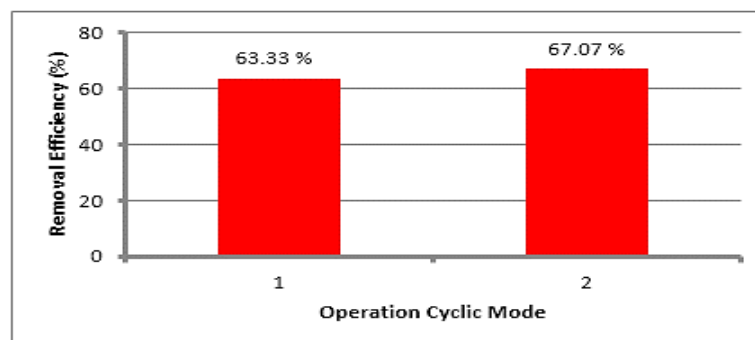


Figure 8 Average TN removal efficiency under two operation cycle modes.

5. CONCLUSION

The primary objective of this research was to investigate the performance of Sequencing Batch Reactor (SBR) for domestic wastewater treatment under low temperature in Basrah city (South of Iraq) by operated the reactor under tow operation cycle mode at different conditions

(Aeration time, and Cycle time). Based on the test results, the following conclusions can be drawn:

- 1) COD removal efficiencies (83.33% in the first cyclic mode and 89.71% in the second cyclic mode) were better than $\text{NH}_4\text{-N}$ and TN removal efficiencies.
- 2) The suspended solids SS concentrations in final effluent were around 7-10 mg/l.
- 3) The aeration time period has no effect on the average effluent COD and TN concentration.
- 4) $\text{NH}_4\text{-N}$ removal efficiencies were decreased gradually with decreased aeration time of SBR, so ammonium removal efficiency is relatively low under the condition of short aeration period time, but the different between the first and second mode average efficiencies was low and not greater than 6.33%.
- 5) The first operating cycle mode is a better and more economically mode for domestic wastewater in Basrah city (South of Iraq) during winter season due to its high average hourly removal efficiencies for COD, $\text{NH}_4\text{-N}$, and TN during aeration period (27.78%, 23.08%, and 21.11% respectively) compare with second mode (11.21%, 9.45%, and 8.38% respectively).

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