Study of Aeration TimeEffect on COD and Ammonia removal by Sequencing Batch Reactor

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Abstract

Four operational cyclic modes for a Sequencing Batch Reactor containing activated sludge was investigated in order to treat a part of domestic wastewater from the student's hostels at B campus in Chongqing University in China, comparison was made for these cyclic modes (first, second, third and fourth)in order to remove (COD, Ammonia), each cyclic mode operated in a different conditions as aeration time, cyclic time and concentrations in order to choose best cyclic mode gives a good removal efficiency and in the same time explain effect aeration time on removal COD and Ammonia by using sequencing batch reactor under normal temperature. The results showed that the CODremoval efficiency that has been achieved by SBR system were 90.14%, 87.86%,83.1%and 81.3% under first, second, third and fourthcyclic modes respectively, while Ammonia removal efficiency were 84.56%,74.82 %,52.74% and 32.53% under first, second, third and fourthcyclic modes respectively.

Key words: Sequencing Batch Reactor(SBR)**,** Domestic wastewater, COD, Ammonia,cyclic mode.

المستخلص

تم أختبار أربع دورات زمنية تشغيلية للمفاعل الدفقي المتسلسل SBR والذي يعمل بالاعتماد على مبدأ الحمأة المنشطة وذلك من خلال معالجة مياه الفضلات المنزلية الناتجة من القسم الداخلي للطلبة في الموقع B التابع لجامعة تشونغتشنغ في جمهورية الصين الشعبية ، وقد تم عمل مقارنة بين نتائج فحص معالجة الملوثات (COD والامونيا) وللدورات الزمنية الأولى والثانية والثالثة والرابعة حيث ان كل دورة زمنية تختلف عن الأخرى بوقت التهوية والترسيب والوقت الكلي للدورة وبالتالي يتم اختيار الدورة الزمنية الأفضل وذلك بالاعتماد على نتائج كفاءة الازالة للملوثات (COD والامونيا) باستخدام المفاعل الدفقي المتسلسل SBR وتحت درجة الحرارة الاعتيادية، وكانت النتائج التي تم الحصول عليها توضح بأن كفاءة الأزالة لمتطلب الاوكسجين الكيميائي COD هي: 90,14% ، 87,86% ، 83,1% و 81,3% وللدورات الأولى والثانية والثالثة والرابعة على التوالي، بينما كانت نتائج كفاءة الازالة للأمونيا هي: 84,56% ، 74,82% ، 52,74% و 32,53% وللدورات الأولى والثانية والثالثة والرابعة على التوالي.

الكلمات المفتاحية: المفاعلات الدفقية المتعاقبة، مياه الصرف المنزلية،(COD)، الامونيا، النظام الدوري.

Introduction

The Sequencing Batch Reactor (SBR) is the name that given to a wastewater treatment system based on activated sludge and operated in a fill-and-draw cycle. The most important difference between SBR and the conventional activated sludge systems is that reaction and settle take place in the same reactor. Basically, all SBR have five phases in common (Figure 1), which is carried out in sequence as follows:

1. Fill: Raw wastewater flows into the reactor and mixes with the biomass held in the tank.
2. React: The biomass consumes the substrate under controlled conditions: anaerobic, anoxic or aerobic reaction depending on the kind of treatment applied.
3. Settle: Mixing and aeration are stopped and the biomass is allowed to separate from the liquid, resulting in a clarified supernatant.
4. Draw: Supernatant or treated effluent is removed.
5. Idle: This is the time between cycles. Idle is used in a multitank system to adjust cycle times between SBR reactors. Because Idle is not a necessary phase, it is sometimes omitted. In addition, sludge wasting can occur during this phase.

As mentionedbefore, the operation of a SBR has five basic steps (processes): Fill, React, Settle, Decant, and Idle. Each of these processes is correlated as they occur in sequence optionally. Environmental conditions in each of these steps (processes) have designed to optimize removal efficiencies for the different constituents. The alternating of the cycle time and the sequence of each process affects the quality of the effluent. Therefore it is possible to operate within a single SBR conditions which are anaerobic, anoxic and aerobic for simultaneous nitrogen and phosphorus removal in addition to organic carbon removal (Artan *et.al.*, 1999, Mines *et.al.*, 1997).

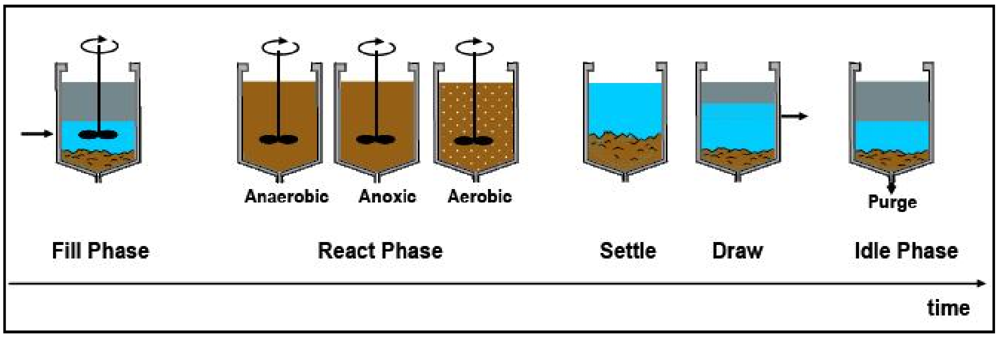

Figure1. Typical sequence operation in an SBR process.

Research on SBR reactors began in the 1970's, (Irvine , Davis 1971)simultaneously with the development of other discontinuous processes (for instance, Goronszy 1979). Even in 1914, the reactors based on active biomass designed by (Arden , Lockett) were operated according to the principles of SBR technology.One of the advantages of these batch systems is that they can easily be adapted for continuous variations of pollutant concentrations (Irvine *et.al.*, 1997).In fact, mass balances of batch systems describe the unstable behavior produced by the natural variations of volumetric flows and pollutant concentrations (Irvine and Ketchum 1998).With the growth in the use of microprocessor-based programmable logic controllers (PLCs) and the increase in the reliability of these systems, SBR treatment technology has become more popular. SBR treatment for wastewater can produce an effluent that is better than that obtained by a secondary treatment and can operate over a wide range of hydraulic and organic flow variations.

Papers by (Norcross 1992) dealing with the design and physical features of sequencing batch reactors are important for an understanding of SBR characteristics. The first considers mechanical, process, and control aspects of the design of SBRs; the second clearly describes the SBR physical system and explains approaches used to develop the bases of design needed to meet different treatment objectives.

In July 2000, the Second International Symposium on Sequencing Batch Reactor Technology was held in Narbonne, France, which indicates the relevance of this technology. Some of the research and developments presented at this symposium are used as sources of data for this review. The diversity of papers in the literature dealing with sequencing batch reactor technology reflects the large number of topics within this area and the capacity of this system to adapt to this large variability. Thus, (Hopkins et al.2001) carried out extensive comparative studies between continuous and batch systems based on biomass, pointing out that flexibility is one of the advantages of discontinuous systems such as SBRs.Because of the SBR has been used to successfully for nutrient removal from a range of municipal and industrial wastewaters.

Table 1. Characteristics of wastewater from student's hostelsin ChonqingUniversity.

Index / Item	COD (mg/l)	NH4 (mg/l)	TN (mg/l)	TP (mg/l)	pH	SS (mg/l)
Range	162 - 365	28.6 - 95	48.3 - 110	2.18 - 9	6.6 – 7.2	61 - 96
Mean	263.5	61.8	79.15	5.59	6.8	82.3

Wastewater from student's hostels Table 1 originates from toilet, bath, shower, washbasin and laundry, also could be divided into blackwater and greywater.

Greywater comes from bathroom, wash basin and laundry while blackwater comes from the toilet.

Basic Principles

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 air diffuser, the reactor was seeded with activated sludge from a municipal wastewater treatment plant in ChongqingCity in China. The concentration of suspended solids was 1600 mg/l after inoculation. Pilot- Scale SBR were operated to study the organic removal as well as nitrification /denitrification in domestic wastewater, as SBR systems provide quiescent settling and less sludge bulking and handle loading variation (Simpkin , Boyle, 1988).

Materials and Methods

SBR reactor consists of SBR tank, Intake (Influent) system, aeration system; decant (discharge) system as shown in Figure 2.SBR tank was made of PVC (1m×1m) base and (1m×1.5m) each side, the effective depth is 1.2 m. In each cycle wastewater is fed to the reactor so that the volumetric exchange ratio in the reactor was 1/2., discharge volume every cycle equal to 0.5 m^3. By using intake pump can carry out influent (wastewater) from primary sedimentation tank (equalization tank) to SBR tank, flow capacity is 35 l/min , wastewater pump start-up and shut down by the tank water level sensor control in the SBR tank by the length of it can be change the quantity (volume) of wastewater in SBR tank. Aeration was achieved by an aquarium-type air pump with sintered-sand diffusers at the bottom of the SBR tank, this sand diffusers firstly fixed at the height 0.3 m from the bottom of the tank but this height is not benefit for the sludge aeration so change it to 0.1 m from the bottom of the SBR tank this height ensure a good aeration for the sludge and wastewater treatment.

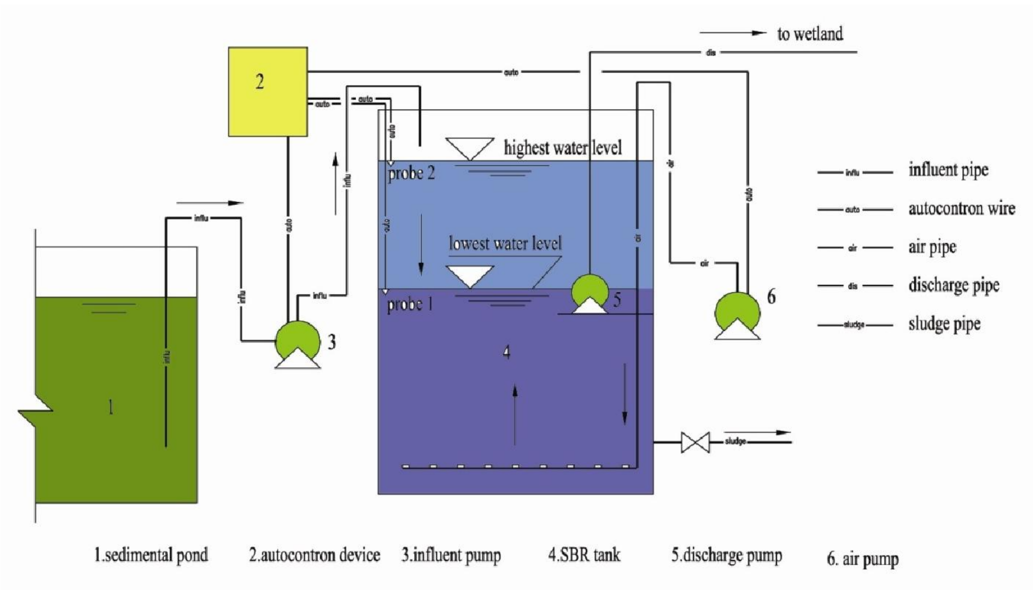

Figure2. SBR schematic diagram (1- sediment tank, 2-autocontrol device, 3-influent pump, 4-Sbr tank, 5-dischrge pump, 6- air pump).

Discharge system consist of (submersible pump and programmable timer) submersible pump carry out a supernatant clear water from the center of the SBR tank, this pump work automatically by the timer control and water level sensor that can be change the length of it to control the depth of supernatant inside the SBR tank and in order to ensure prevent discharge sludge outside the SBR tank, also excess sludge can be control or wasted by manual valve. The reaction durations in the reactor were manipulated with the use of a system with an automatic time set up. Treatment of each batch in the SBR follows a cycle of four sequential phases:

Filling: the SBR is filled with wastewater which is mixed with sludge left from the previous run.

Aeration: compressed air is supplied through the diffusersproviding oxygen for bacteria in the sludge. The bacteria break down carbonaceous organic compounds in the wastes and also simulate nitrification of ammonium to nitrate (which also requires oxygen).

Settling: Aeration is stopped allowing the sludge to settle to the bottom of the SBR.

Discharge: The clear supernatant liquid (partially treated effluent) above the settled sludge is drained off, most of the sludge containing the bacteria, is left on the bottom of the SBR ready for the next batch of wastewater.

About 3%of the sludge volume is removed (and discharged to a nearby slurry tank) to keep the bacteria population at an appropriate level.

Experiments

The SBR system running three cycles per day, the volume of wastewater treating is equal to 1.5m³/day.The experimental period comprised four different operational acyclic modes Figure 3 to choose the best cyclic mode which gives a good results and removal efficiency. These operation cyclic modes were carried out, each with its own set of treatment parameter. For all these cyclic modes (fill, settle and discharge) phases are characterized by one hour but the different here in the extended of aeration time as shown in the first operation cyclic mode was continuously aeratedfor five hour as aerobic condition for enhanced nitrification and then settled for one hour after that clear supernatant water discharge outside, for second cyclic mode aeration time decreased to four hour while third cyclic modeaeration time decreased to three hourand Within second operation cycle mode aeration continuous for long time about eight hour to enhance nitrification after that one hour settle then discharge.

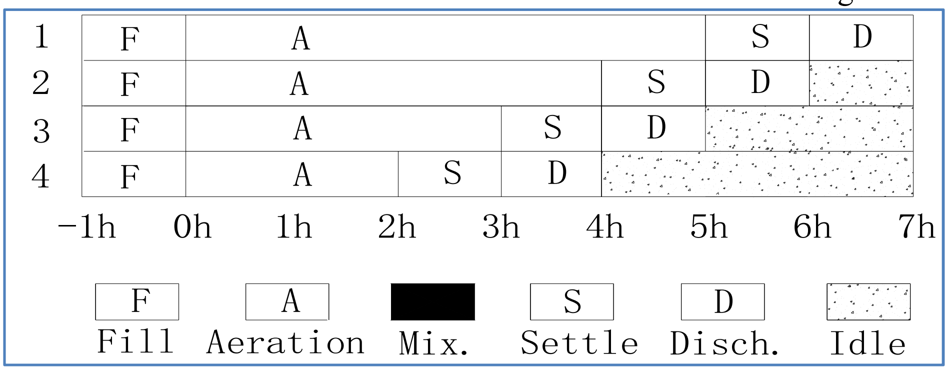

Figure 3. Operation cycle modes in SBR.

Also these operation cycle modes depending on the temperature of the weather for example we do these operation cyclic modes within the temperature is T ≥ 15°C. 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. The optimal temperature for the SBR process should be determined by the consideration of these effects. Solid retention time (SRT) ranged from 12 to 24 days, hydraulic retention time (HRT) is 8 hours, reactor MLSS ranged from 3000 to 4000 mg/l.

Experimental Results

COD removal under different operation cyclic modes

The Chemical Oxygen Demand (COD) is an indication of the amount of energy and carbon there is available to the heterotrophic microbial population within the reactors. A well-designed and well-operated biological reactor should maximize the utilization of the COD. COD describes the oxygen requirement to completely oxidize the organic compounds within a wastewater. The COD concentration was within the range of 100 and 400 mg/L, which is typical for ordinary municipal sewage wastewater. Several COD data points close to 100 mg/L were due to dilution of swage wastewater by rainwater, reflecting the fact that a significant section of the sewage wastewater collection system. The performance of the sequencing batch reactors, in particular the COD removal and nitrification, is dependent on the availability of oxygen within the systems.

At normal temperature (T ≥ 15°C), SBR operation for wastewater treatment represents by selection four operation cyclic modes (first, second, third and fourth) as mentioned before, we do this cyclic modes to optimize the best one give a high COD removal efficiency to reduce COD concentration in the effluent.

Figure 4 and Table 2 shows the COD concentration variation with operation time under different operation cycle mode (first, second, third and fourth). The effect of aeration time on the COD removal was studied at different operation cycle modes under low dissolved oxygen (0.5-1.0 mg/L), as shown in this figure COD degradation has not been significantly affected by low DO.

Table 2. Average values of COD variation along experiment.

Cyclic	**COD variation in the SBR (mg/L)**					
Mode	**influent**	**1h**	**2h**	**3h**	**4h**	**5h**
1st	284	85	63	41	30	28
2nd	280	90	65	43	34	
3rd	272	77	56	46		
4th	267	74	50			

The average influent COD concentration was 275 mg/L during the four operation cycle modes under condition T ≥ 15°C which is characterized by the summer and spring seasons. The results showed the treatment performance was prompted with simple significant difference between various operation cyclic modes (first, second, third and fourth).

The average effluent concentrations of COD reduced from 50mg/L as shown in the fourth cyclic mode to 46mg/L in the third cyclic mode, while the average effluent concentration of COD was 34mg/L in the second cyclic mode and was 28 mg/L in the first cyclic mode, these results attributed to the increase of the aeration period in the operation cyclic modes (first, second, third and fourth). The results of COD removal efficiency under various operation cycle modes are shown in Table 3, all kinds of SBR operation cyclic modes of COD removal at over 80%, the effluent of COD values are reduced to a lower concentration, and the removal of COD mainly occurred in the first hour as depicted in Figure 4, because of the dilution reactor and the biological activated sludge adsorption.Activated sludge floc tablets have a strong ability for adsorption so that soluble and colloidal organic matter was adsorbed by the floc tablets around it until adsorption reached saturation point; on the other hand through the enzyme adsorption the dissolved organic matter carried out, absorbed into the cells, within their conversion into carbon who needsfor thelife activities, making the mixture COD indicators quickly lower. After one hour in aeration, COD value has dropped to a relatively low level, with extended aeration time, the degradation rate not obvious, the degradation rate has declined markedly.

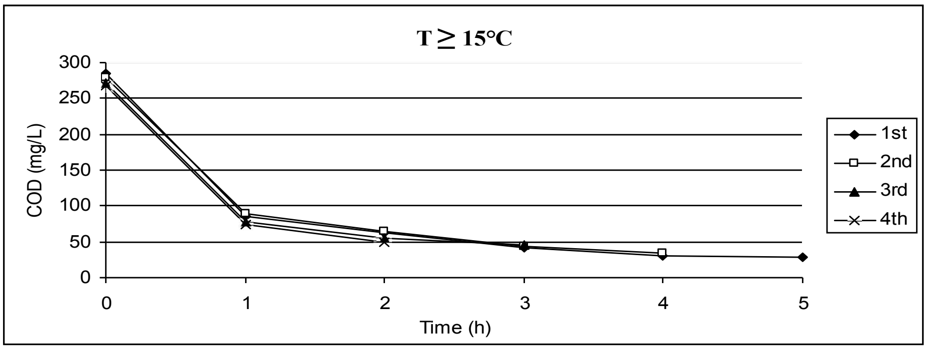

Figure 4.COD Concentration variation under different operation cyclic modes.

The effluent quality was improved obviously when aeration time was extended to four hour, increasing the aeration time to five hour ensure the effluent quality improvement. This implied that longer aeration time spent, higher COD removal efficiency could be achieved.

Table 3. COD removal efficiency by SBR .

Cyclic Mode	Influent (mg/L)	Effluent (mg/L)	Removal Efficiency =(influent-effluent)/ influent *100
1st	284	28	90.14%
2nd	280	34	87.86%
3rd	272	46	83.1%
4th	267	50	81.3%

By consideringFigure 5and Table 3 sequencing batch reactor is effective in COD removal for all these cyclic modes and consider 1st cyclic best cyclic mode and give high removal efficiency (90.14%) as compared as with others cyclic modes (second, third and fourth).

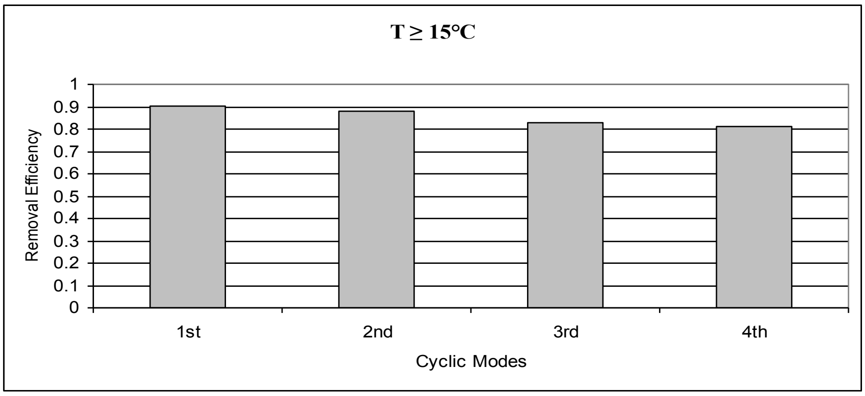

Figure 5. COD removal efficiency by SBR under different operation cyclic modes.

Ammonia removal under different operation cyclic modes

Free ammonia is toxic to fish and many other aquatic organisms; moreover, both ammonium ion and ammonia are oxygen-consuming compounds which deplete the dissolved oxygen in receiving water.In addition, all forms of nitrogen can be made available to aquatic plants and can consequently contribute to eutrophication.

Untreated ammonia can exerta significant oxygen demand through biologicalnitrification and it may cause eutrophication in receivingwaters, and can be toxic to aquatic organisms.The most common and efficient method used toremove ammonia from wastewater is the biological nitrification /denitrification process (Cooper et al., 1996).Ammonia oxidizing bacteria, such as Nitrosomonas, utilize the reduced nitrogen in ammonia as the electron donor, or energy source.

In this section we will discuss removal ammonia under different operation cyclic modes (first, second, third and fourth) in the SBR under the condition of normal temperature (T ≥ 15°C) in order to get high ammonia nitrogen removal rate.

Table 4. Average values of variation ammonia along experiment.

Cyclic Mode	Ammonia variation in the SBR (mg/L)					
	influent	1h	2h	3h	4h	5h
1st	52.71	35.57	34.33	19.12	11.62	8.14
2nd	50.59	37.9	32.48	20.51	12.74	
3rd	47.74	35.71	30.51	22.56		
4th	42.33	34.74	28.56			

SBR reactor operated under restrictive aeration (0.5-1) mg/L, the ammonia oxidation has not been significantly affected;Figure 6 and Table 4 shows ammonia concentration in the SBR dropped from an initial mean value 52.71mg/L to 8.14mg/L in the first cyclic mode, while in the second cyclic mode decreased from 50.59mg/L to 12.74mg/L and from 47.74mg/L to 22.56mg/L in the third cyclic mode as well as from 42.33mg/L to 28.56mg/L in the fourth cyclic mode. Ammonia removal efficiencies for SBR operation cyclic modes (first, second, third and fourth) were (84.56%, 74.82%, 52.74% and 32.53%) respectively as shown inTable 5.

According to these results ammonia removal efficiency was relatively low under the condition of aeration period time two hour in the fourth operation cycle mode. This lead to increasing nitrification rate when the aeration time is longer so that the ammonia removal efficiency increased.

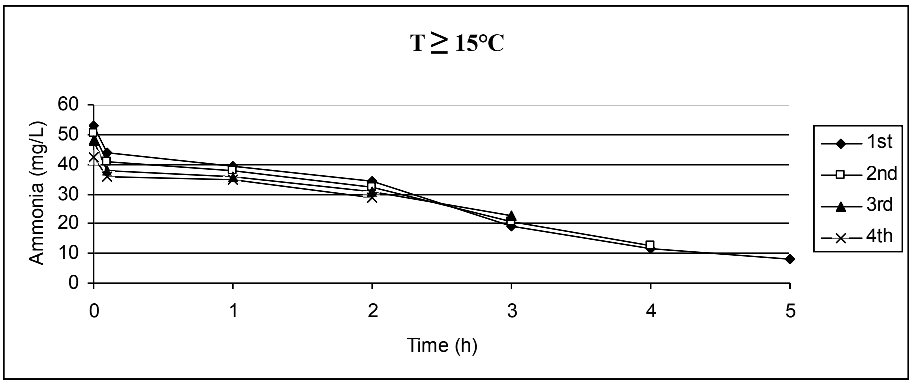

Figure 6.Ammonia Concentration variation under different operation cyclic modes.

The ammonia degradation process effected by COD concentration because the COD removal priority and after that ammonia 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 ammonia concentration be smaller.

Table 5. Ammonia removal efficiency by SBR.

Cyclic Mode	Influent	Effluent	Removal Efficiency
1st	52.71	8.14	84.56 %
2nd	50.59	12.74	74.82 %
3rd	47.74	22.56	52.74 %
4th	42.33	28.56	32.53 %

After one hour aeration COD degradation accomplished and ammonia degradation rate increased.

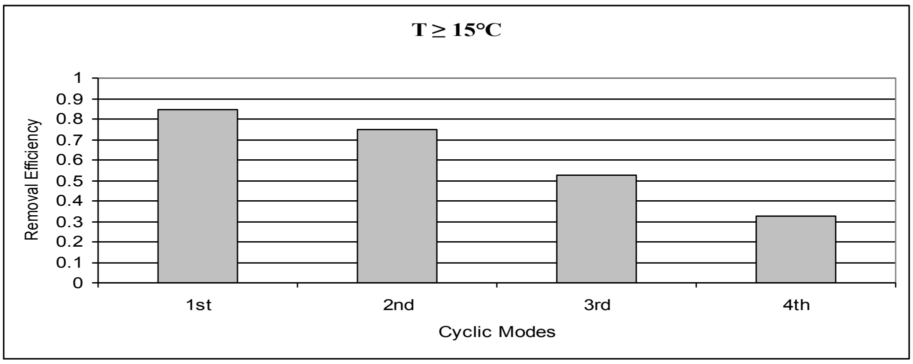

Figure 7. Ammonia removal efficiency under different operation cyclic modes.

Conclusions

The primary objective of this investigation was to compare four operation cyclic modes to elevate the water quality of the treated municipal sewage wastewater and study the effect of aeration time on removal COD and ammonia. Based on the test results, the following conclusions can be drawn:

1- COD and Ammonia test results illustrated that the first cyclic mode is suitable for removal high influent concentrations and give high removal efficiency as compared as with another cyclic modes.
2- The performance of the sequencing batch reactor (SBR) was studied under two different air fluxes ($1m^3/h$ and $2m^3/h$) all the result of this experiment dependent on the aeration flux $2m^3/h$.
3- SBR give a good COD removal efficiency (90.14% in the first cyclic mode) compared with Ammonia removal efficiency (84.56% in the first cyclic mode).
4- The domestic wastewater used in this study varied in characteristics throughout the day. Therefore, it was important to have an equalization (sediment) tank to ensure constant quality and quantity of influent.
5- Denitrification occurs primarily during the settle phase of the SBR operation.
6- The decanting (discharge) system in the SBR discharged good effluent without sludge washout as the loop minimized flow rate in SBR.
7- Because of its low cost, flexibility and high effectiveness, SBR is strongly recommended as a good pretreatment for the wastewater treatment systems.
8- The suspended solids SS concentrations in final effluent were around6.5-8 mg/l.

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