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Treatment of Residential Complexes' Wastewater using Environmentally Friendly Technology

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Abstract

Residential complexes discharge huge quantities of wastewater, which has a negative impact on nearby water bodies. Moreover, the treatment of this type of wastewater requires a large area, which could be a challenge as construction sites are normally limited in size. Different technologies have been used for the treatment of residential complexes' wastewater (RCWW). Compared to the conventional wastewater treatments methods, sequencing batch reactors (SBRs) are lower cost and have smaller area requirements and sludge bulking rarely occurs. A considerable number of researchers have been optimising SBR operating conditions to gain a better removal efficiency of undesired wastewater pollutants. However, many researchers have reported bad, slow or incomplete particle settling. This study examines the impact of organic loading rate (OLR) on the effluent quality and sludge settling performance in a sequencing batch reactor. Four SBR reactors were used in this study; the working volume of each one is 5l. The reactors were operated under different glucose concentrations (750, 1000, 1250 and 1500 mg/l), constant aeration, 1.0 l/min, ±20 C° temperature and 6 h cycle time. Each cycle of the SBR operation included Fill (30 minutes), React (240 minutes), Settle (30 minutes), Draw (30 minutes) and Idle (30 minutes). Influent and effluent samples were analysed for COD, NH3-N, NO3-N and NO2-N. In addition, the sludge volume index (SVI) and a morphological study were used to study the sludge characteristics. The SVI and morphological study results showed a direct relationship between the glucose concentration and sludge settling behaviour. The results obtained from this study, which operated for 120 days, showed that the sequencing batch reactor could biodegrade up to 93.2%, 95.2%, 94.9% and 96.5% for COD, NH3-N, NO3-N and NO2-N respectively with glucose concentration between 750 and 1250 mg/l, and a steady sludge settling performance occurred during that range.

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Keywords: Organic loading rate; residential complexes' wastewater; sequencing batch reactor; sludge settling performance; sludge volume index

1. Introduction

A residential complex's wastewater is the water that has been used by the residents during their daily activities such as flushing toilets, personal washing, laundry, food preparation and the cleaning of kitchen utensils. It contains large concentrations of organic matter, nitrogen, phosphorus and other trace elements such as carbon, calcium, potassium and iron. These pollutants must be treated before they are discharged into rivers and other waterbodies, otherwise the wastewater will damage the ecosystem, kill fishes and microorganisms in the waterbodies, and negatively affecting other animals that use these waterbodies, and having a detrimental effect on human health if people use the water. There are several types of treatment technologies that deal with this type of wastewater, such as chemical treatment, biological treatment and electrocoagulation. Biological wastewater treatment is considered to be one of the most convenient technologies to treat RCWW due to its economic advantages in terms of operation costs. However, conventional biological treatment takes up a large amount of land and utilises several tanks in its operation; therefore, alternatives such as the sequencing batch reactor are being investigated and used.

The SBR is a wastewater treatment system that works on the same principle as the activated sludge process (ASP). It has been implemented successfully for treating domestic, industrial and other types of wastewater [1]. Additionally, the SBR is a fill and draw system which works in a cyclical time sequence, which means that it can operate in a smaller area than the conventional wastewater treatment methods. The SBR works as an equalisation, neutralisation and biological treatment and secondary clarifier in a single tank through a timed control sequence, which makes it environmentally friendly technology. During one cycle, SBR technology has five operating steps – Fill, React, Settle, Draw and Idle. Due to its one tank design and setup simplicity, SBR has recently become an attractive technology. As shown in Fig. 1, the SBR system outdoes the conventional activated sludge system by including all treatment steps in one tank, whilst in the conventional activated sludge system, the treatment units are in separate basins [2]. A considerable number of researchers have been optimising the SBR operating conditions to gain a better removal efficiency for undesired wastewater pollutants [3]. One of the SBR's operating conditions is organic loading rate (OLR), which is considered to be a significant operating parameter in the SBR's design and operation. The growth rate of microorganisms in biological systems is dependent on the OLR. At a high OLR, microbial growth might rise dramatically, while at a low OLR, microorganism starvation takes place [4].

Due to the limited knowledge on the impact of the organic loading rate on the SBR performance, this study was performed to find the effects of OLR on the effluent quality and sludge settling performance in a sequencing batch reactor.

Nomenclature

ASP	Activated sludge process
COD	Chemical oxygen demand
DO	Dissolved oxygen
HRT	Hydraulic retention time
OLR	Organic loading rate
ORP	Oxidation-reduction potential
pH	potential of hydrogen
RCWW	Residential complexes' wastewater
SBR	Sequencing batch reactor

2. Materials and methods

2.1. Bacteria source and synthetic wastewater

The activated sludge (bacteria) used to biodegrade the organic matter was gained from Liverpool Wastewater Treatment Works, Sandon Docks, Liverpool, UK. The synthetic domestic wastewater was prepared by mixing the following chemicals with deionised water [5]: 500 mg glucose/L; 200 mg NaHCO3/L; 25 mg NH4Cl/L; 25 mg KNO3/L; 5 mg KH2PO4/L; 5 mg MgSO4.7H2O/L; 1.5 mg FeCl3.6H2O/L; 0.15 mg CaCl2.2H2O/L. All reagents used in this study were purchased from Sigma-Aldrich, UK.

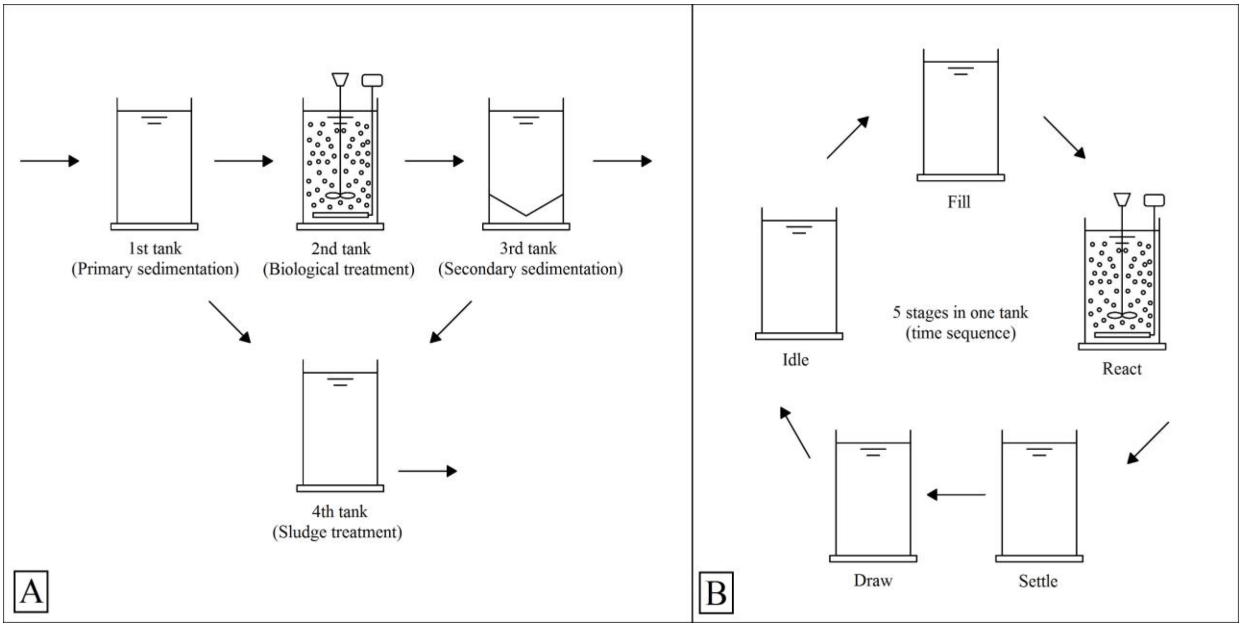

Fig. 1. a) Basic conventional wastewater treatment plant, which can be extended to more than 10 tanks, b) Sequencing batch reactor.

2.2. Lab-scale SBR system, setup and operation

Fig. 2 shows the four reactors used in this study. The capacity of each is 6.5L and the working volume is 5L; 1.5L of bacteria (biomass) plus 3.5L of synthetic wastewater were added to each reactor. The parameters of pH, DO, temperature and ORP were monitored online via sensors installed in each reactor. The four SBR reactors were operated with different glucose concentrations: 750 mg/l, 1000 mg/l, 1250 mg/l and 1500 mg/l respectively. Influent and effluent samples were taken from each reactor to measure the removal efficiency and settling performance and relate it to the OLR.

2.3. Nutrient analyses

In this research, the influent and effluent samples were taken from the SBR reactors before and after the treatment cycle using a peristatic pump, and then the samples were filtered using a vacuum pump containing 0.45 µm filter paper. The parameters of COD, NH3-N, NO3-N, NO2-N and SVI were analysed according to the standard methods [6].

2.4. Morphological study

The morphological characteristics of the sludge were obtained using a light microscope AX10 (Zeiss, Germany) with a colour video camera (PixeLINK, Canada) by capturing images under 100x magnification. Samples were taken twice a week for the whole period of study and the diversity of the sludge characteristics and the diversity of the filamentous growth were recorded for all the reactors to find the effects of OLR on the sludge settleability.

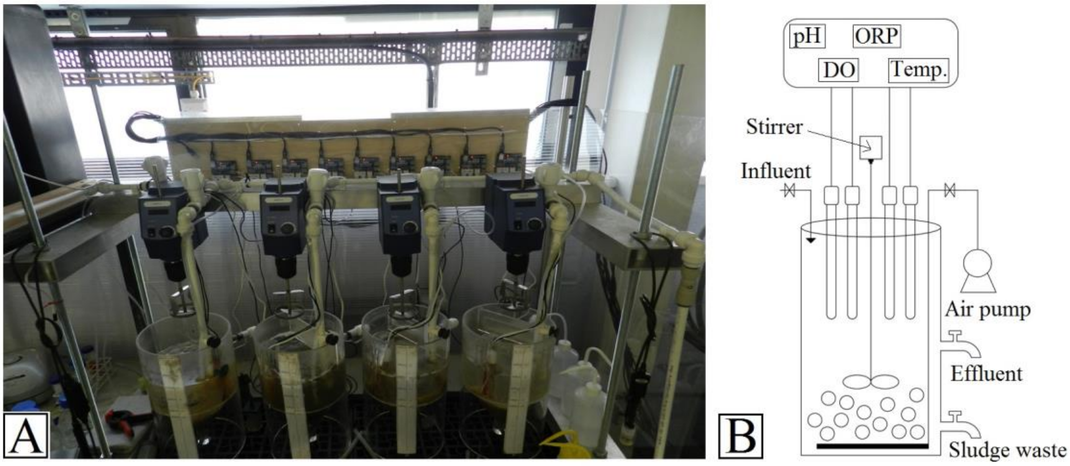

Fig. 2. a) Lab-scale SBR1, SBR2, SBR3 and SBR4, b) Schematic diagram of one SBR.

3. Results and discussion

3.1. The effect of OLR on COD, NH3-N, NO3-N and NO2-N removal

The influent and effluent concentrations and removal efficiency for COD, NH3-N, NO3-N and NO2-N under different OLRs are shown in Fig. 3. There was no big difference in the removal efficiency for COD, NH3-N, NO3-N and NO2-N after increasing the glucose concentration from 750 mg/l to 1000 mg/l and 1250 mg/l; the average removal efficiency for COD, NH3-N, NO3-N and NO2-N under 750 mg/l was 93.2%, 95.2%, 94.9% and 96.5% respectively, and, after raising the glucose concentration to 1000 mg/l, the average removal efficiency for COD, NH3-N, NO3-N and NO2-N became 92.9%, 95.9%, 93.6% and 96.45 respectively. Finally, when the glucose concentration was raised to 1250 mg/l, the average removal efficiency for COD, NH3-N, NO3-N and NO2-N became 93%, 94.6%, 94.1% and 96.1% respectively. However, when increasing the glucose concentration to 1500 mg/l, the removal efficiency dropped dramatically; the average removal efficiency for COD, NH3-N, NO3-N and NO2-N during the 1500 mg/l OLR was 89.8%, 91%, 88.8% and 92% respectively. This result agreed with [7], who stated that at high ORL the removal of COD would be decreased. However, [8] reached high COD removal rates even under high ORL.

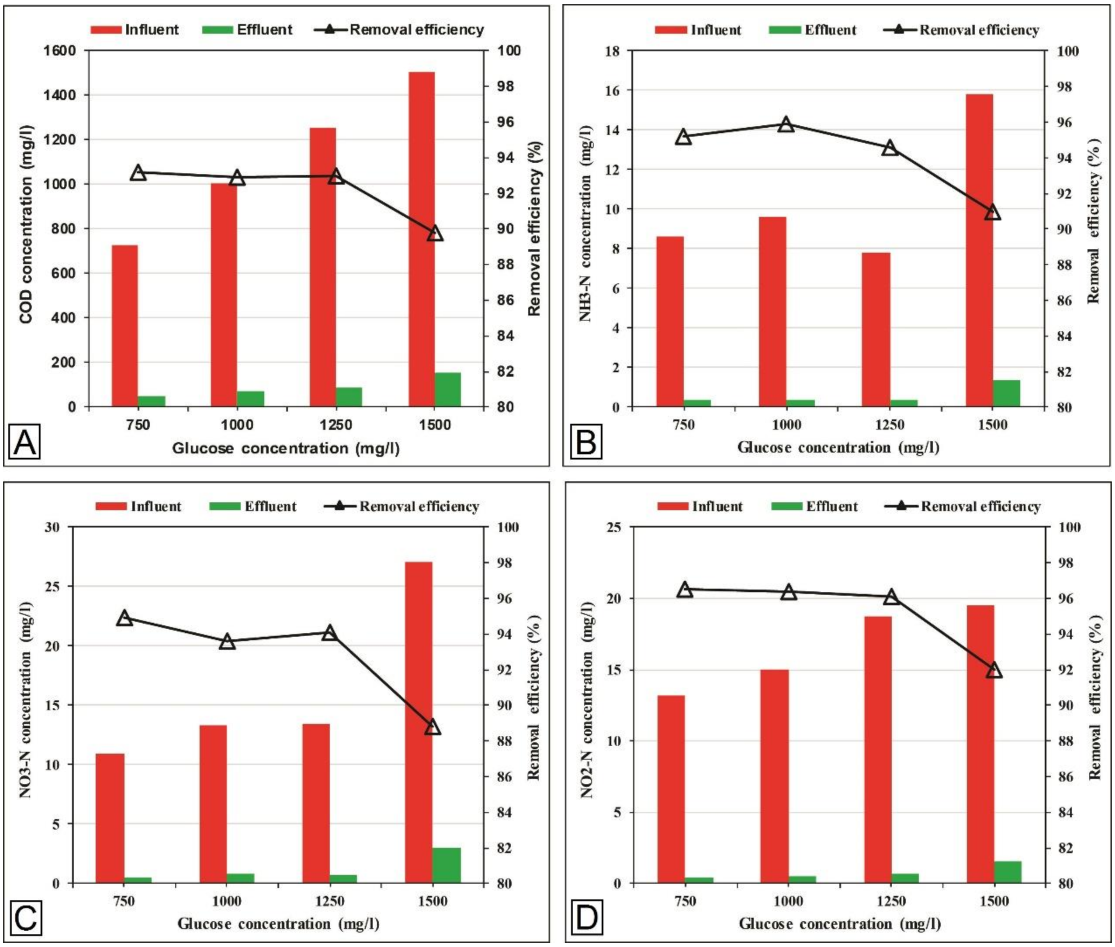

Fig. 3. Influent and effluent concentration and removal efficiency for a) COD, b) NH3-N, c) NO3-N and d) NO2-N under different OLRs.

3.2. The effect of OLR on sludge characteristics

The effect of OLR on sludge settling performance is shown in Fig. 4. The average SVI concentration for the 750 OLR was 31.9 ml/g, and it can be clearly seen that increasing the OLR to 1000 mg/l did not affect the solid settling performance and the SVI was 32 ml/g. However, raising the OLR to 1250 mg/l negatively affected the solid settling performance and the SVI was raised to 39.3 ml/g. Further increasing the OLR to 1500 mg/l made the settling even slower and the SVI was increased to 41.8 ml/g. This was supported by the morphological study, which can be seen in Fig. 5. The sludge characteristics were homogeneous during the 750 mg/l and 1000 mg/l OLR. However, the filamentous growth increased when the OLR was raised to 1250 mg/l. Moreover, the filamentous growth increased dramatically after the OLR was raised to 1500 mg/l. In the same vein, [9] stated that increasing the OLR will lead to a proportional increase in biomass concentration, which will result in high SVI and the settleability of the solids will decrease. This agreed with [10], who reported an increase in the concentration of suspended solids when the initial concentration of COD was increased, which would also lead to an increase in the SVI and a subsequent drop in the solids' settleability.

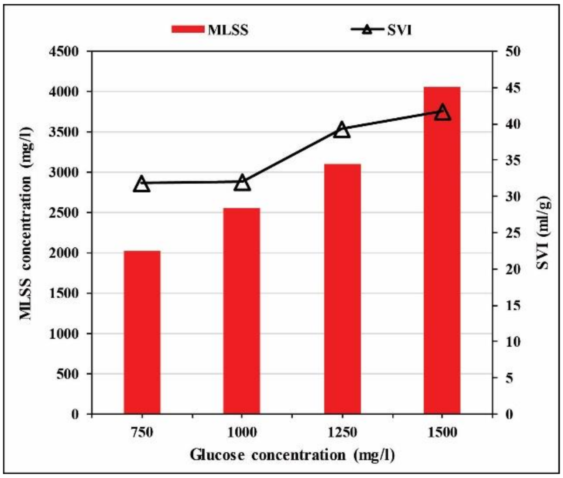

Fig. 4. Sludge volume index and mixed liquor suspended solid under different OLRs.

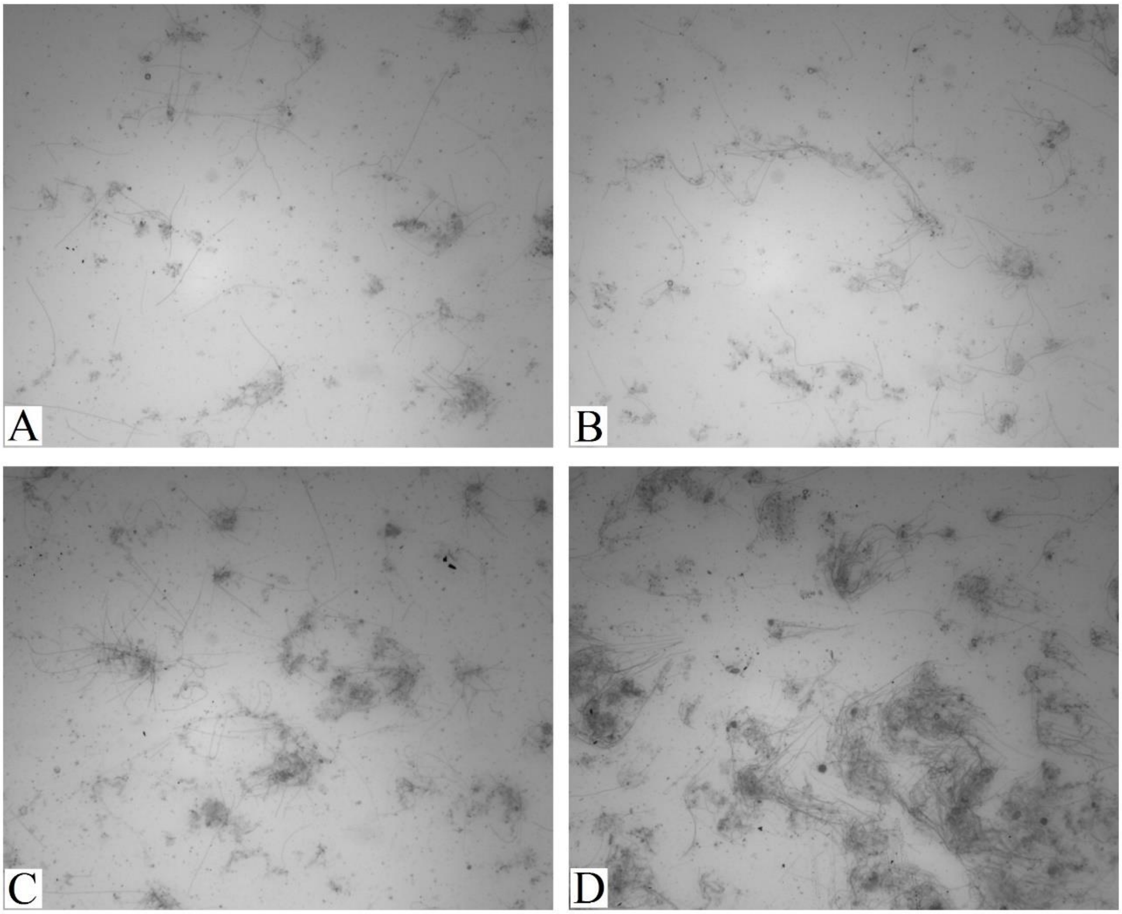

Fig. 5. Microscopic photos (100x magnification) of the sludge under different OLRs: a) 750 mg/l, b) 1000 mg/l, c) 1250 mg/l and d) 1500 mg/l.

3.3. pH, DO, ORP and temperature profiles

The results from monitoring the pH, DO, ORP and temperature for one cycle of treatment are shown in Fig. 6. The pH, DO, ORP and temperature values at the end of the 6 h treatment cycle were between 6.3-8.4, 0.1-5.9 mg/l, -110-205 mV and 7.5-10.5 C respectively. At the beginning of the treatment, the ORP profile started to decrease from 50 mv to -110 mv. From that point, the degradation of COD started, which is indicated by the increase in the ORP profile [11]; the COD degradation was completed when the ORP reached 205 mv and the oxidation of ammonia started [12]. The pH profile was narrow in this study and it flocculated between 6.3 and 8.4. Thus, the ORP profile is more significant in this study than the pH profile. The ORP profile was increased in the same pattern as the DO profile because ORP and DO are related to each other in a linear formula [13].

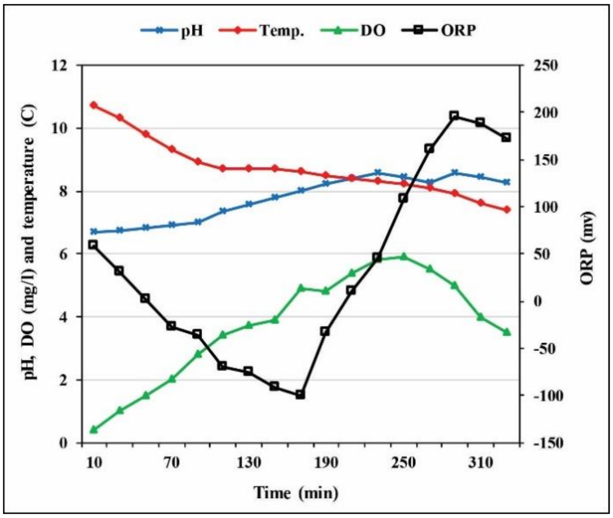

Fig. 6. DO, pH, temperature and ORP for a sample SBR cycle (6 hours).

4. Conclusion

Environmentally friendly technology was used to treat synthetic RCWW. The effects of four different organic loading rates on the performance of four SBRs were examined. COD, NH3-N, NO3-N and NO2-N were tested to determine the SBR treatment efficiency, and the SVI along with a morphological study were used to determine the sludge settling performance. The results showed that SBR technology could work efficiently with glucose concentrations between 750 mg/l and 1250 mg/l and could biodegrade up to 93.2%, 95.2%, 94.9% and 96.5% for COD, NH3-N, NO3-N and NO2-N respectively, and a steady sludge settling performance occurred during that range. However, increasing the glucose concentration to 1500 mg/l decreased the removal efficiency and increased the settling time. Hence, the OLR was found to be a significant parameter that influences the operation of an SBR.

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