Ammonia Removal using Sequencing Batch Reactor: The Effects of Organic Loading Rate

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Abstract

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 potassium nitrate concentrations (50, 100, 150 and 200 mg/l), constant aeration, 1.0 l/min, ±20 Cº 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 NH3-N to determine the removal efficiency. In addition, the sludge volume index (SVI) was used to study the sludge characteristics. The results obtained from this study, which operated for 60 days, showed that the sequencing batch reactor could biodegrade up to 91.5% for NH3-N with potassium nitrate concentration between 50 and 150 mg/l, and a steady sludge settling performance occurred during that range.

***Keywords*:**
Ammonia; organic loading rate; sequencing batch reactor; sludge settling performance; sludge volume index.

1. Introduction

Every year, large concentrations of industrial wastewater contain organic matter, nitrogen, phosphorus and other trace elements such as carbon, calcium, potassium and iron are dumped into the rivers. This type of wastewater must be treated before it is 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 physical treatment, chemical treatment and biological treatment. The latter is considered to be one of the most convenient technologies to treat industrial wastewater due to its economic advantages regarding 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 [1, 2].

The SBR is a wastewater treatment system that works on the same mechanism as the activated sludge process (ASP). It has been applied successfully for treating domestic, industrial and other kinds of wastewater [3]. Additionally, the SBR is a fill and draw system which works in a cyclical time sequence, which means that it can operate in a lesser 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 attractive technology. Throughout one cycle, SBR technology has five operating steps – Fill, React, Settle, Draw and Idle. Due to its distinct one tank design and setup easiness, SBR has recently turn out to be an attractive technology. The SBR system outdoes the conventional activated sludge system by containing all treatment stages in a single tank, while in the conventional activated sludge system, the treatment units are in separate basins [4]. A substantial number of researchers have been optimising the SBR operating conditions to gain a better removal efficiency for undesired wastewater

contaminants [5, 6]. 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 increase intensely, while at a low OLR, microorganism food shortage takes place [7].
Due to the inadequate knowledge on the influence of the organic loading rate on the SBR performance, this study was implemented to find the impact of OLR on the effluent quality and sludge settling performance in a sequencing batch reactor.

2. Materials and methods

2.1 Experimental set-up of the SBR

Fig. 1 shows one of the four reactors used in this research. The capacity of each is 6.5L and the occupied 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 observed through sensors fitted in each reactor. The four SBR reactors were operated with different potassium nitrate concentrations: 50 mg/l, 100 mg/l, 150 mg/l and 200 mg/l respectively. Influent and effluent samples were taken from each reactor to determine the removal efficiency and settling performance and relate it to the OLR.

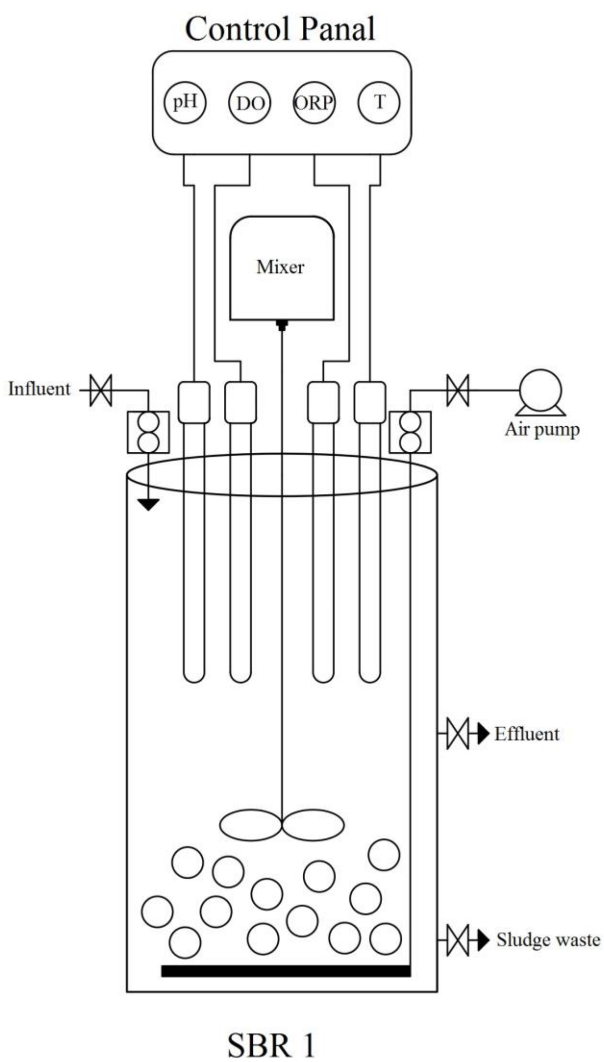

Fig. 1 Schematic diagram of one SBR

2.2 Synthetic wastewater

The activated sludge (bacteria) used to biodegrade the organic matter was taken from United Utilities, Sandon Docks, Liverpool, UK. The industrial wastewater was prepared by mixing the following chemicals with deionised water [8]: 500 mg glucose/L; 200 mg $NaHCO_3$/L; 25 mg NH_4Cl/L; 25 mg KNO_3/L; 5 mg KH_2PO_4/L; 5 mg $MgSO_4.7H_2O$/L; 1.5 mg $FeCl_3.6H_2O$/L; 0.15 mg $CaCl_2.2H_2O$/L.

2.3 Nutrient analysis

In this study, the influent and effluent samples were taken from the SBRs before and after the treatment cycle using a peristatic pump, and at that moment, the samples were filtered via a vacuum pump having filter paper (0.45 µm). The parameters of NH3-N and SVI were analysed according to the standard methods [9].

3. Results and discussion

3.1 The impact of OLR on NH3-N removal

The concentrations and removal efficiency for NH3-N under different OLRs are shown in Fig. 2. There was no big change in the removal efficiency for NH3-N after increasing the potassium nitrate concentration from 50 mg/l to 100 mg/l and 150 mg/l; the average removal efficiency for NH3-N under 50 mg/l was 91.3%, and, after raising the potassium nitrate concentration to 100 mg/l, the average removal efficiency for NH3-N became 91.5%. Finally, when the potassium nitrate concentration was raised to 150 mg/l, the average removal efficiency for NH3-N became 91.1%. However, when increasing the potassium nitrate concentration to 200 mg/l, the removal efficiency dropped dramatically; the average removal efficiency for NH3-N during the 200 mg/l OLR was 86.5%. This result agreed with [10], who stated that at high ORL the removal of COD and nitrogen would be decreased. However, [11] reached high COD and nitrogen removal rates even under high ORL.

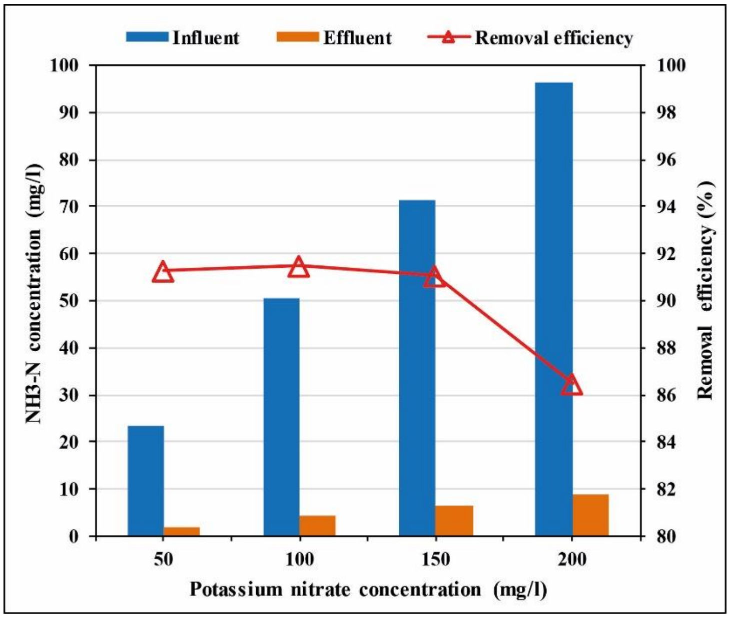

Fig. 2 The effects of OLR on the removal efficiency of ammonia

3.2 The impact of OLR on sludge settling performance

The impact of OLR on solids settling performance is shown in Fig. 3. The average SVI concentration for the 50 mg/l OLR was 32 ml/g, and it can be obviously seen that increasing the OLR to 100 mg/l did not affect the solid settling performance and the SVI was 33 ml/g. However, raising the OLR to 150 mg/l negatively affected the sludge settling performance and the SVI was raised to 37 ml/g. Further increasing the OLR to 200 mg/l made the settling even slower and the SVI was increased to 40 ml/g. In the same vein, [12] stated that increasing the OLR will lead to a relative increase in biomass concentration, which will result in high SVI and the settleability of the solids will decline. This agreed with [13], 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.

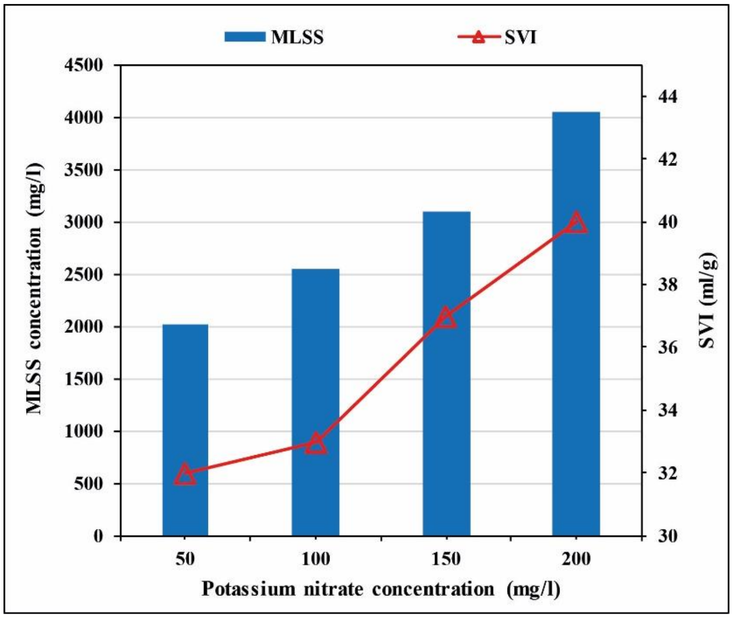

Fig. 3 The effects of OLR on the sludge settleability

4. Conclusion

SBR was investigated to treat synthetic industrial wastewater. The effects of four different organic loading rates on the performance SBR were examined. NH3-N was tested to determine the SBR treatment efficiency, and the SVI was used to determine the sludge settling performance. The results showed that SBR technology could work efficiently with potassium nitrate concentrations between 50 mg/l and 150 mg/l and could biodegrade up to 91.5% for NH3-N, and a steady sludge settling performance occurred during that range. However, increasing the potassium nitrate concentration to 200 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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