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The Effect of Salt Concentration on Anoxic/aerobic Sequencing Batch Reactor Performance

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Abstract

In this study, the effect of salt concentration on anoxic/aerobic sequencing batch reactor performance was studied. With this purpose, four different salt concentrations (0, 5, 10 ve 15 g NaCl/L) were tested. Chemical oxygen demand (COD), ammonium nitrogen (NH_4^+-N), total nitrogen (TN) and total phosphorus (TP) removal efficiencies decreased with gradual increase in salt concentration. Similarly, mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS) concentration and MLVSS/MLSS ratio decreased with increasing salt concentration. But, the increased salt concentration relatively decreased sludge volume index (SVI) value.

Keywords: *Anoxic/aerobic sequencing batch reactor, salt effect, chemical oxygen demand, nitrification, sludge volume index.*

1. Introduction

High saline wastewater is mainly discharged from chemical, pharmaceutical, petroleum industries, fish caning, seafood processing, meatpacking, tannery and cheese factories [1]. Seawater has been used as an alternative water source for toilet flushing, resulting in a high salt content in the wastewater that reaches the treatment plant [2]. Saline wastewater could represent as much as 5% of worldwide effluent [3].

High salinity concentration can cause the plasmolysis as water is lost from microbial cells through osmosis. This is results in low chemical oxygen demand (COD) removal efficiency [4]. The results related on the influence of salt on nitrification are difficult to compare and show contradictory results. The system configuration, instability in the experimental conditions with respect to temperature, pH, presence of inhibitory compound are among factors that directly influence the extent of salt effect on the nitrification process [5,6]. There are also conflicting reports of the influence of salt on denitrification [7]. Besides that, salt is to affect the structure and settling properties of activated sludge [6,8].

A variety of processes are applied to treat saline wastewater, such as a conventional aerobic wastewater treatment process [9], a sequencing batch reactor [10], a sequencing batch biofilm reactor [11], an anaerobic/anoxic/aerobic process [12], an upflow anaerobic sludge blanket (UASB) [13] and anaerobic compact system [14]. From the practical point of view, it is significant to evaluate the performance of biological treatment by processing real saline sewage [15]. Anoxic/aerobic activated sludge process is one of the most widely used biological nutrient processes. In recent years, sequencing batch reactor (SBR) system has attracted a great deal of interest because SBR can carry out biological nitrogen removal in a single reactor by maintaining anoxic and aerobic stages sequentially. Compared with the conventional anoxic/aerobic activated sludge process, the anoxic/aerobic SBR eliminated the recirculation of sludge and mixed liquor, thus reducing the operation cost [16]. The most of the studies in literature describe the effect of salt on the performance of biological treatment using synthetic wastewater, but real wastewater is really scarce [17].

The aim of this work was to evaluate the performance and sludge settling property of a laboratory scale anoxic/aerobic SBR operating with real saline wastewater.

2. Material and Method

2.1 Reactor setup

A laboratory-scale anoxic/aerobic SBR with a working volume of 5 L was used in this study. SBR was operated in cycles of 8 h, with three cycles performed per day. Each cycle consisted of 15 min feeding, 135 min anoxic reaction, 270 min aerobic reaction, 30 min settling, 15 min decant and 15 min idle time. A peristaltic pump was used to feed the influent into reactor. A stirrer was used to provide liquid mixing during anoxic phase. The air was introduced at the aerobic phase by an air pump through a porous stone diffuser located at the bottom of the reactor. The dissolved oxygen (DO) concentration at the anoxic phase was below 0.5 mg/l, and the dissolved oxygen concentration at the aerobic phase was maintained at 2-2.5 mg/L. The solid retention time was maintained at about 20 d through direct removal of mixed liquor at the end of the aerobic phase. The operational pH ranged between 7.2-8.0 without control. The reactor was operated at room temperature of 25^{o}C.

2.2 Reactor operation strategy

The real wastewater was supplemented with different salt concentration. The salt concentration was gradually increased from 0 to 15 g/L. Initially, the reactor was run for 17 days without salt and corresponding results were used as the control. After, the reactor was run at salt concentration of 5 g NaCl/L for over 19 days. Following, salt concentration of 10 g NaCl/L was added to reactor for over 20 days. The reactor was subsequently run at salt concentration of 15 g NaCl/L for over 22 days.

2.3 Wastewater and sludge

The raw wastewater was obtained from the local municipal wastewater treatment plant. The raw wastewater contained chemical oxygen demand (COD) of 420 mg/L, total nitrogen (TN) of 44.5 mg/L, ammonium nitrogen (NH_4^+-N) of 32 mg/L, and total phosphorus (TP) of 14 mg/L. The seed sludge was obtained from a full-scale municipal wastewater treatment plant which employed a biological nutrient removal process.

2.4 Analytical methods

Chemical oxygen demand (COD), mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) were analyzed in according to standard methods [18]. Total nitrogen (TN), ammonium nitrogen, and total phosphorus were measured by standard kits (Merck Specquorant, Nova 60). Dissolved oxygen concentration (DO) was measured with a DO-electrode (WTW OXI 330, Germany).

3. Results and discussion

The results of the effect of gradual increase of salt concentration on COD removal efficiency are shown in Figure 1. The COD removal efficiencies in salt concentration of 0, 5, 10 and 15 g NaCl/L were 92%, 89%, 85% and 79%, respectively. The decrease in COD removal efficiency might be due to the adverse effect of salt on microbial activity. It is generally known that high salinity cause plasmolysis and loss of cell activity [19,20].

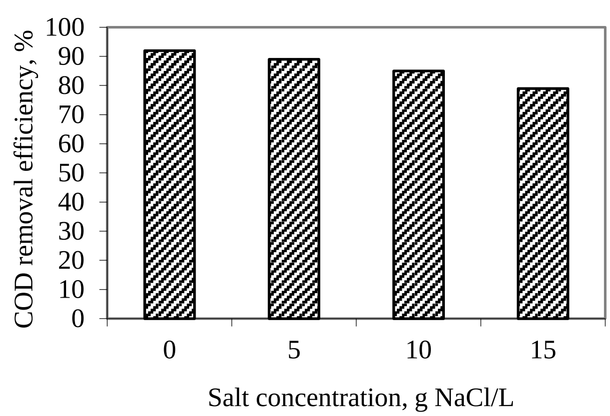

Fig. 1 COD removal efficiency at different salt concentration.

Figure 2 shows the NH_4^+-N removal efficiencies at different salt concentrations. When no salt was added, the NH_4^+-N removal efficiency was

92%. When salt concentration was 5 g NaCl/L, the NH_4^+-N removal efficiency was affected little. When salt concentration was 10 and 15 g NaCl/L, the decrease in NH_4^+-N removal efficiency increased. These results demonstrate the effect of high salt concentration on nitrification. Yogalakshmi and Joseph [21] have found that the removal ammonia was 84 to 64 % with a NaCl loading of 5-30 g/L. Chen et al [22] reported that nitrification was good up to Cl^- concentration of 2.5 g/L and beyond that nitrification rate started to decrease. The decrease in nitrification efficiency can be connect to repression of the synthesis of enzymes that utilize nitrate and nitrite as electron acceptor [23], to more sensitive to short and long-term salt stress of nitrite oxiders and ammonia oxidizers [5,19] and to large changes in osmotic pressure [24]. Moreover, elevated salt concentrations are reported to reduce specific activity and increase the decay rate of nitrifiers [5].

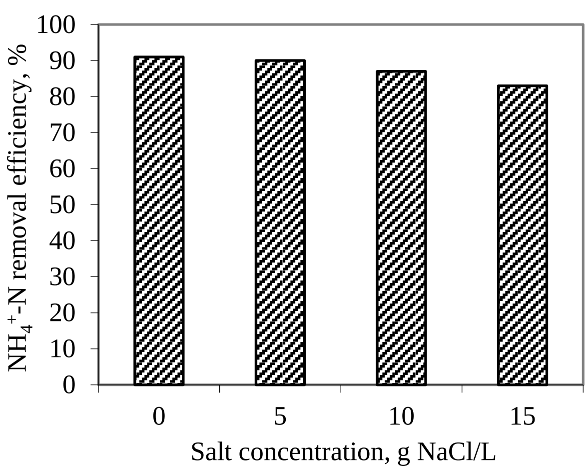

Fig. 2 NH_4^+-N removal efficiency at different salt concentration.

The TN removal efficiency decreased with gradual increase of salt concentration (Figure 3). The TN removal efficiencies in salt concentration of 0, 5, 10 and 15 g NaCl/L were 64.1%, 60.8%, 56.0% and 48.8%, respectively. The decrease in TN removal efficiency with increasing salt concentration was due to wash out of dead biomass and lysed cell constituents [25] and inhibition of nitrification [19,20,25], denitrification process[8].

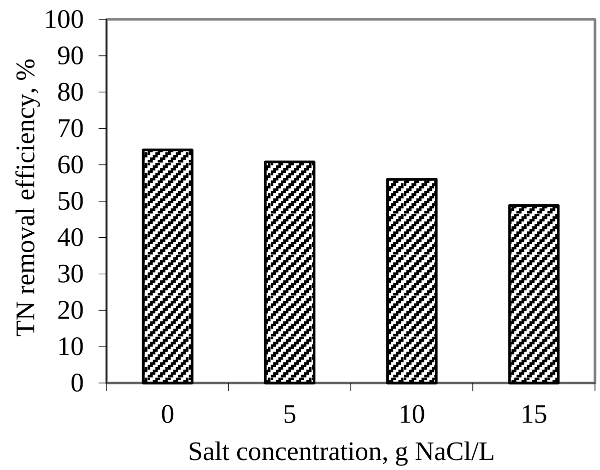

Fig. 3 TN removal efficiency at different salt concentration.

The TP removal efficiencies at different salt concentration are shown in Figure 4. The TP removal efficiencies in salt concentration of 0, 5, 10 and 15 g NaCl/L were 46.2%, 44.6%, 42.5% and 39.3%, respectively. It is clearly seen that the high salt concentration has adverse impact on TP removal.

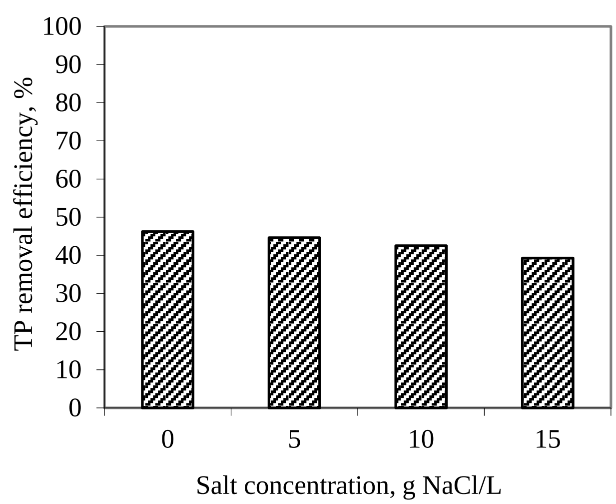

Fig. 4 TP removal efficiency at different salt concentration.

The MLSS and MLVSS concentrations are compared at different salt concentrations (Figure 5). The MLSS concentrations in salt concentration of 0, 5, 10 and 15 g NaCl/L were 3.0, 2.8, 2.5 and 2.1 g/L, respectively. Similarly, the MLVSS concentrations in salt concentration of 0, 5, 10 and 15 g NaCl/L were 2.46, 2.25, 1.9 and 1.5 g/L, respectively. The MLSS and MLVSS concentrations decreased with gradual increase of salt concentration. The decrease in MLSS and MLVSS concentration indicates that death and washout of biomass. The MLVSS/MLSS ratios also decreased at high salt concentrations. The MLVSS/MLSS ratios in salt concentration of 0, 5, 10 and 15 g NaCl/L were 0.82, 0.80, 0.76 and 0.71, respectively. The drop in MLVSS/MLSS ratio indicates the accumulation of more inorganic constituents.

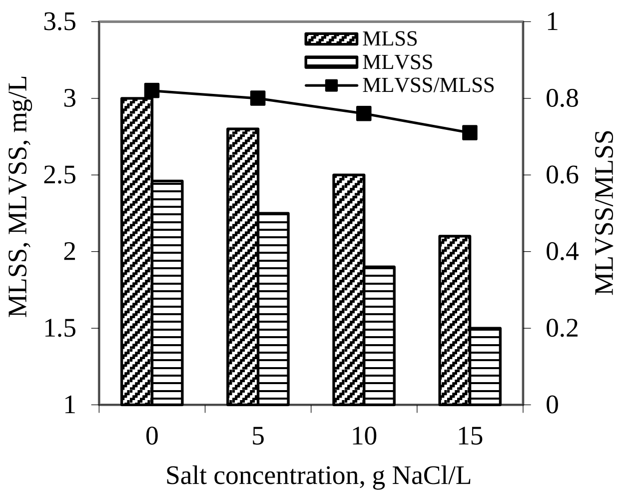

Fig. 5 MLSS, MLVSS concentrations and MLVSS/MLSS ratios at different salt concentration.

The sedimentation issues of saline wastewater are high density of saline water and separation problem due to bouncy forces, reduction of filamentous bacterial population and lack of mechanical connections in floc structure, absence of protozoa in saline environment and cellular plasmolysis due to salinity [26]. The sludge volume index (SVI), which indirectly indicate the settling characteristics of biomass were found to decrease with increasing salt concentrations (Figure 6). The SVI values in salt concentration of 0, 5, 10 and 15 g NaCl/L were 105, 102, 98 and 92 ml/g, respectively. Elevated salt concentrations are leading to an increase in water density which could have a negative impact on the settling characteristics [5]. However, this study showed improved settling at higher salt concentrations, which were also shown by the other studies [1,6,27].

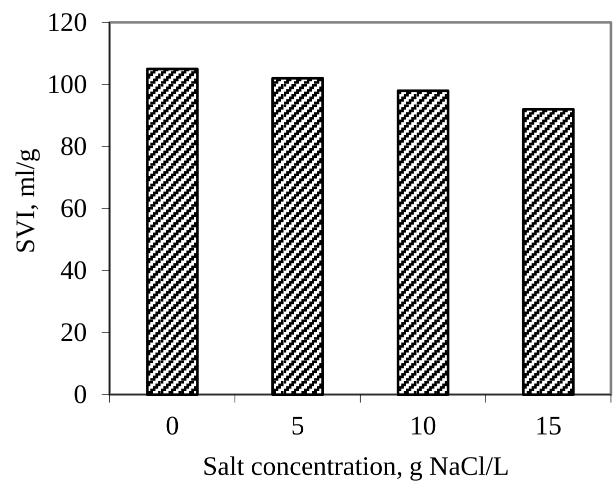

Fig. 6 SVI values at different salt concentration.

4. Conclusion

The performance of an anoxic/aerobic sequencing batch reactor was evaluated at different salt concentrations. The removal efficiencies of COD, NH_4^+-N, TN and TP were good up to salt concentration of 5 g/L and beyond that started to decrease. The MLSS, MLVSS concentrations and MLVSS/MLSS ratio decreased with the increase in salinity. But, the gradual increase of salt concentration relatively improved the sludge settling characteristics.

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