FISH CANNING WASTEWATER TREATMENT IN SEQUENCING BATCH REACTOR WITH ACTIVATED SLUDGE

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ABSTRACT

The biological performance of flocculent sludge in sequencing batch reactor for the treatment of fish canning wastewater was evaluated in terms of organic matter and nutrient removal by gradual increase of salt concentration in the nitritation-denitritation process. Salinity negatively affected the biological system performance in a way that reduced organic and nutrient removal. The removal efficiency of organic matter and nitrogen showed good performance below 20 g NaCl/L, while phosphate accumulating organisms activity was deteriorated and declined during whole experiment. Nitrogen removal occurred as ammonium oxidation with nitrite accumulation. Nitrite reduction was not affected by salt concentration.

Keywords: *fish canning wastewater, nutrient removal, organic carbon removal*

INTRODUCTION

Fish processing industries generate wastewater, the amount and composition of which depend on the type of fish processed, the additives and the water source used, and the type of the operation process applied. Fish processing wastewaters are characterized by high salt (mainly sodium chloride) concentration, high levels of organic matter (up to 90000 mg/L), high suspended solids (up to 5000 mg/L), nitrogen (N) (total N up to 3000 mg/L) and phosphorus (P) (total P up to 44.2 mg/L) and pH 3.8 - 10 [1]. Salinity could affect biological system performance

negatively, it may decline organic and nitrogen removal efficiency, and inhibit bacterial metabolism [2, 3]. Also, during rapid changes in salt concentration, the cell plasmolysis and the increase of soluble chemical oxygen demand (COD) was observed by Uygur and Kargi [4]. Biological treatment of saline wastewater requires a long acclimation process of the non-halophilic biomass to the saline environment [5]. The negative effect of salt is often associated with nitrogen removal. Some studies pointed out that the nitrite oxidizing bacteria (NOB) are more sensitive to the salt concentration than the ammonium-oxidizing bacteria (AOB) [6 - 8]. Zhao et al. [9]

highlighted that activated sludge had good performance below 2.0 wt.% in the treatment of synthetic saline wastewater. Chen et al. [3] reported that at salinity ranging from 0 to 20 g/L, removal rate of ammonium (NH_4^+-N), total phosphorus (TP) and COD gradually dropped from 95.34 %, 93.58 % and 94.88 % (0 g/L) to 62.98 %, 55.64 % and 55.78 % (20 g/L), respectively, in synthetic wastewater. The effect of salt in synthetic wastewater containing 0 and 15 g NaCl/L on the aerobic granular sludge process in terms of granulation and nutrient removal was examined by Wang et al. [10]. 15 g/L NaCl at dissolved oxygen (DO) of 2.5 mg/L significantly affected ammonium and phosphorous removal due to inhibition of AOB and phosphorus accumulating organisms (PAOs). Increasing the DO to 8 mg/L or adapting mature granules by gradually increasing the salt concentration minimized the adverse effect of salt on nitrification. These strategies were not helpful for phosphorus removal. The effect of salt on phosphorus removal was less studied. Bassin et al. [2] showed that at high salt concentrations (22 and 33 g NaCl/L) PAOs gradually disappeared from the sludge, and that AOB could tolerate salt concentration of up to 33 g NaCl/L. Pronk et al. [7] reported that in the absence of nitrite, bio-P removal was not much affected at salt concentrations up to 22 g/L NaCl, but was significantly inhibited at salt concentrations of 33 g/L NaCl. Also, Pronk et al. [7] stated that NOB showed complete inhibition at 20 g NaCl/L. Wan et al. [11] highlighted that full partial nitrification can be achieved under NaCl concentration up to 50 g NaCl/L, resulted with nitrite accumulation of nearly 100 %.

There are several studies investigating the effect of salt on the removal efficiency of nitrogen from real fish-processing wastewaters. Figueroa et al. [12] treated fish canning effluent with salt contents of up to 30 g NaCl/L with granular sludge and achieved complete depletion of organic carbon but less than 40 % nitrogen removal efficiencies. Similar results were obtained by Val del Río et al. [13]. Simultaneous nitritation-denitritation at salinities up to 50 g NaCl/L in the treatment of fish canning wastewater by aerobic granular sludge resulted in total nitrogen below 10 mg/L in effluent [6]. Capodici et al. [14] cultivated autochthonous halophilic biomass for the treatment of real fish canning wastewater (30 g NaCl/L) by a shortcut nitrification-denitrification process and achieved more than 95 % of nitrogen removal. Corsino et al. [15] evaluated the impact of increasing salinity on halophilic biomass in form of flocculent and granular sludge for the treatment of hypersaline fish canning wastewater (from 30 to 50 g/L). They reported that the ammonium uptake rate was slightly affected with salinity above 46 g NaCl/L, while nitrite uptake rate did not show a significant connection with the increasing salinity.

The objective of this research was to study the treatment of fish canning wastewater with a gradual increase of salt concentration in order to evaluate the removal efficiency of organic matter and nitrogen in the sequencing batch reactor (SBR) with flocculent sludge. The results of this study could provide a better understanding of activated sludge performance in terms of organic and N removal from fish-processing wastewaters.

EXPERIMENTAL

Wastewater characterization and analytics

Fish canning wastewater after collecting was left to settle for 2 h. COD, NH_4-N, nitrate (NO_3-N), nitrite (NO_2-N) and PO_4-P were quantified with Merck cuvette kits (Merck, Deutschland), which are analogous to the standard methods [16]. The samples were filtered through the fiberglass filter before analysis. Temperature, pH, and DO were monitored by WTW Multi 3420 SET KS1, Germany. Fish canning wastewater was characterized with average value of $COD_{soluble}$ 1380 mg/L, NH_4-N 72 mg/L, PO_4-P 32 mg/L, pH 7.1 ± 0.1, and salt concentration 30 g/L.

Experimental set-up

Adaptation of the activated sludge to salinity was carried out in a SBR reactor, fed with synthetic wastewater (prepared according to de Kreuk et al. [17]) and trace elements solution according to Vishniac and Santer [18] with a gradual increase in salinity from 0 g NaCL/L up to 30 g NaCl/L. In experiment with no salt added the removal efficiency for COD, NH_4-N and PO_4-P was 96 %, 99 %, and 97 %, respectively. Also, in experiments with synthetic wastewater the activated sludge showed high metabolic activity for organic matter and nitrogen removal at salt concentration below 25 g NaCl/L, while PO_4-P removal significantly decreased at salinity 20 g NaCl/L.

Activated sludge adapted to salinity was used in the treatment of fish canning wastewater (15 g NaCl/L; diluted wastewater with tap water) and with gradually increasing of salinity (2.5 g NaCl/L) by addition of NaCl up to 30 g/L, in terms of organic and nutrient removal efficiency. The pH was not controlled, just recorded. DO concentration was maintained at 7 mg/L and the temperature was 20 ± 2 °C. A bubble diffuser provided the air supply (HIBLOW HP 40; Hagen Model40 A-10011).

RESULTS AND DISCUSSION

The wastewater from the fish canning industry is characterized by huge variations in composition due to the type of fish processed and the type of process. Fish canning produces a large amount of wastewater which contains organic pollutants, high nutrient concentrations, and high salinity (chloride) [1].

The effect of salinity to COD, NH_4-N and PO_4-P removal efficiency from fish canning wastewater, and from synthetic wastewater without salt added is shown in Figure 1.
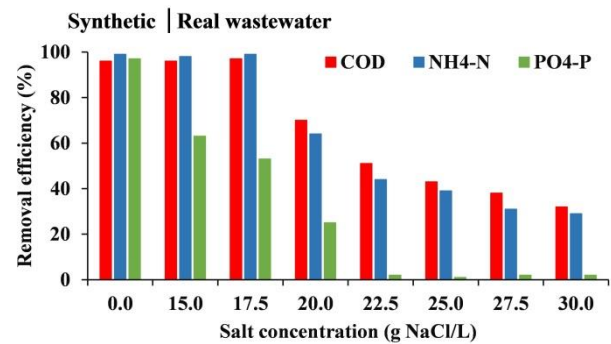

Figure 1. COD, NH_4-N and PO_4-P removal efficiency from fish canning wastewater at different salt concentration, and from synthetic wastewater without salt added

The activated sludge maintained stable operation and high removal efficiency of ≥ 96 % COD and 98 % NH_4-N at a salt concentration below 20 g NaCL/L, in the treatment of real fish canning wastewater. The salt concentration 20 g NaCL/L affected the activated sludge with 70 % and 64 % removal efficiency for COD and NH_4-N, respectively, and further decrease of COD and NH_4-N removal efficiency was observed with the increase of salinity (Figure 1). The negative effect of salinity on the removal of organic C and N was pointed out by other authors [3, 9] in the treatment of synthetic wastewater.

The effect of increasing salinity in the treatment of fish canning wastewater resulted in a decrease in the removal efficiency of organic carbon and nutrients (Figure 1).

Variation in COD, NH_4-N, NO_2-N and PO_4-P during the treatment of fish canning wastewater at 15 g NaCl/L in SBR with activated sludge is shown in Figure 2.
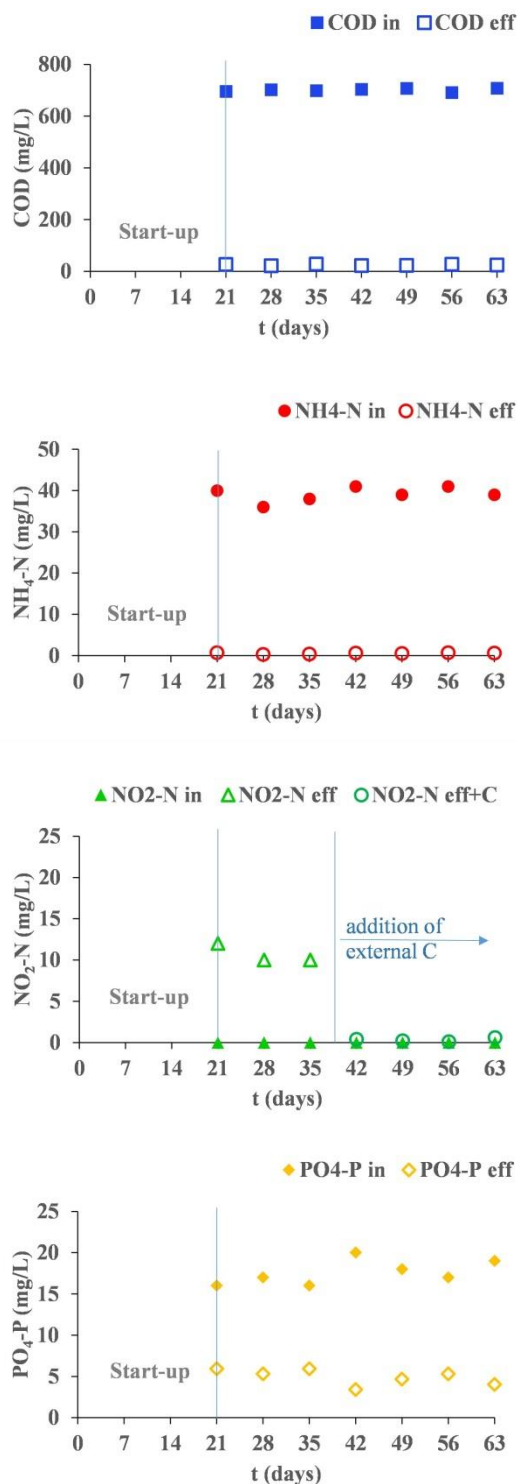
Figure 2. Influent and effluent of COD, NH$_4$-N, NO$_2$-N and PO$_4$-P during biodegradation of fish canning wastewater at salinity 15 g NaCl/L in SBR with activated sludge

At salinity of 15 g NaCl/L (Figure 2), the aerobic react stage of 11 hours resulted in constant effluent quality in terms of COD with effluent values below 30 mg/L, and also with total NH$_4$-N oxidation with NO$_2$-N as the only product in the effluent (only nitritation occurred). No NO$_3$-N recorded in effluent suggested the inhibition of NOB activity. At the steady state, the COD removal efficiency was equal to 96 % and NH$_4$-N to 98 %. During the anoxic phase (before the end of cycle) the NO$_2$-N reduction (denitritation) was observed but not complete due to lack of organic carbon since the COD was removed at the aerobic stage, and with the use only endogenous carbon source. Complete denitritation occurred only after addition of a known amount of sodium acetate as carbon source at the beginning of anoxic phase which contributed to overall N removal. Salinity had no effect on nitrite removal. Partial nitrification is energy cost effective so this could be a good solution. Similar to our findings, the numerous studies highlighted the lack of NOB activity as more sensitive to salinity than AOB [2, 6 - 8, 11, 15]. Salinity deteriorated the C, N and P removal (Figure 1).

Figueroa et al. [12] highlighted that in the treatment of fish canning wastewater by using granular sludge achieved complete depletion of organic carbon but less than 40 % nitrogen removal efficiency with increasing salinity up to 30 g NaCl/L. Also, by using autochthonous halophilic biomass in the treatment of hypersaline fish canning wastewater, Corsino et al. [15] pointed out that ammonium uptake rate was slightly affected with salinity above 46 g NaCl/L, while nitrite uptake rate did not show a significant connection with the increasing salinity. Capodici et al. [14] achieved more than 95 % of nitrogen removal in the treatment of real fish canning wastewater (30 g NaCl/L) by shortcut nitrification-denitrification with autochthonous halophilic biomass.

In this study, the salt significantly affected phosphorus removal efficiency from 63 % at 15 g NaCl/L to 25 % at 20 g NaCl/L, while at 22.5 up to 30 g NaCl/L removal efficiency was negligible with severely deteriorated PAOs activity (Figure 1).

A similar effect of salt on PAOs was observed by Bassin et al. [2], Pronk et al. [7] and Wang et al. [10] who studied the effect of salinity on the treatment of synthetic wastewaters.

In this work, the experiments were conducted at DO 7 mg/L with a gradual increase in salinity (Figure 1), which are reported in the literature as favourable factors to bridge the negative effect of salinity on microbial activity [2, 6, 7, 10 - 12, 15].

Prior to the experiments with real fish canning wastewater, the adaptation of activated sludge was performed with synthetic wastewater with gradual increase of salinity from 0 - 30 g NaCl/L. The importance of sludge adaptation to salinity was highlighted by Lefebvre and Moletta [5].

The results of COD, NH_4-N and PO_4-P removal efficiency were 96 %, 99 %, and 97 % in the treatment of synthetic wastewater with no salt added (Figure 1). High metabolic activity for organic matter and nitrogen removal in synthetic wastewater at a salt concentration below 25 g NaCl/L was recorded, while PO_4-P removal significantly decreased at salinity 20 g NaCl/L (data not shown).

Some authors reported that there was not a significant effect of adaptation of the activated sludge to salt under short- and long-term salt stress [19], while others reported that the rapid shifts in salt concentrations had more adverse effects than the gradual shifts resulting in an increase of soluble COD [5]. In this research, a decreasing trend of C, N and P removal with salinity increasing by using activated sludge was evident.

CONCLUSION

The effect of gradual increase of salinity on the removal efficiency of organic C and N from fish canning wastewater resulted in decline of activated sludge activity in terms of organic carbon and nutrients removal. The process was conducted as nitritation-denitritation. Nitrite reduction was not affected by salt concentration. PAOs activity was deteriorated and declined during the whole experiments.

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