Aerobic granular sludge process treats real fish canning wastewater

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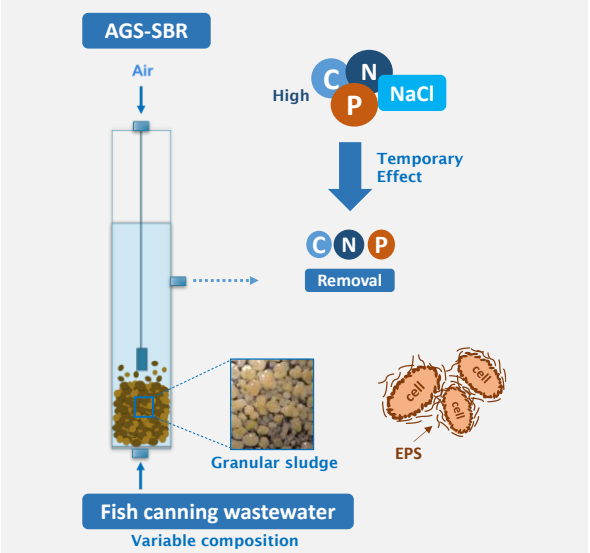

Aerobic Granular Sludge (AGS) is an innovative technology used for carbon and nutrients removal from wastewater, using less space and energy compared to other biotechnological solutions. Aerobic granules present a compact structure, composed of extracellular polymeric substances (EPS), which increase AGS resistance to variable wastewater composition, as those commonly produced by industry. In this study, C, N and P-removal from a fish canning plant wastewater was evaluated using an AGS-SBR (sequential batch reactor). Throughout the first 3 months of operation with variable feed composition, the chemical oxygen demand (COD) at the outlet was below the discharge limit of 125 mg O_2 L^{-1}, phosphorous removal was stable and the nitrification process improved. At the higher organic loading rates (OLR), the AGS performance was temporary affected. This study contributes to understanding the effects of the variability of a real wastewater on an AGS process.

Introduction

Aerobic granular sludge (AGS) is a promising technology for treating wastewater and presents several advantages compared to conventional activated sludge systems. The AGS process allows a higher biomass retention which decreases the need for energy and space. Besides, the aerobic granules are composed of extracellular polymeric substances (EPS) which protect bacteria towards stress conditions. Therefore, aerobic granules are stable structures with a higher tolerance to toxic substrates and higher resistance to variable wastewater composition [1]. The fish canning wastewater is characterized by a variable composition in organic matter, mainly containing nitrogen and phosphorous as nutrients. This type of wastewater often contains salt, which can be very high and affect the biological processes. This variability occurs along the year but also throughout the day, depending on the processing at the plant [2].
The main objective of this work is to use an AGS-SBR for treating wastewater from a fish canning plant. The performance of the AGS process was evaluated in terms of chemical oxygen demand (COD), phosphorous and nitrogen removal.

Methods

A lab-scale AGS-SBR, with a working volume of 2.5 L, a total height of 110 cm and an internal diameter of 6.5 cm, was operated in four successive treatments of 6 h-cycles per day. The reactor was inoculated with granular sludge from a municipal AGS-SBR. Operation followed procedures previously described [3]. The reactor was fed with wastewater from a fish canning plant, collected after screening and coagulation/flotation processes performed at the plant. The wastewater was collected at different time points for sequential treatment.
The performance of the AGS-SBR was assessed during 142 days for COD, ammonia, nitrate, nitrite and phosphorous removal. Chloride in the feed (wastewater) and in the outlet was also assessed. Samples were filtered using syringe nylon membrane filters (0.45 µm pore-size) in order to remove suspended solids. COD was analyzed in accordance with standard methods [4]. Ammonia, nitrate, nitrite, phosphorus and chloride concentrations were determined with photometric test kits (Spectroquant®, Merck Millipore), according to the manufacturer's instructions.

Results and discussion

The AGS-SBR performance was evaluated during 142 days of operation which were divided into five phases (I, II, III, IV and V). The organic loading rate (OLR) of the wastewater fed to the reactor was variable, as described in Table 1.
Throughout phases I, II and III, most of the COD removal was performed during the anaerobic feeding period, reaching less than 125 mg O_2 L^{-1} at the outlet. A constant and higher OLR was applied during phase IV, temporally affecting COD removal. During this phase, part of the COD was still present in the reactor bulk liquid after the anaerobic feeding. On phase V, the OLR decreased and COD values closer to 125 mg O_2 L^{-1} were obtained at the outlet.
Phosphate accumulation and removal were stable during phases I, II and III, reaching values below 10 mg L^{-1} at the outlet. However, a lower phosphate removal was observed during phase IV. In the presence of a higher amount of carbon, PAOs (Polyphosphate Accumulating Organisms) can be outcompeted by other microorganisms, such as GAOs (Glycogen Accumulating Organisms), affecting phosphate removal. During phase V, phosphate concentration was very low in the wastewater and after the anaerobic feeding.
Concerning nitrogen removal, during phases I, II and III most of the ammonium was converted to nitrate, without nitrite accumulation. On phase IV, the ammonium concentration was higher in the feed. The conversion to nitrate decreased, while nitrite accumulated in the reactor. The presence of extra COD after the anaerobic feeding could have led to the overgrowth of heterotrophic microorganisms, which compete with the nitrifiers for oxygen. This possibly affected the activity of nitrite oxidizing bacteria (NOB). During phase V, most of the ammonium was converted to nitrite and nitrate.

Chloride concentration in the feed and outlet of the AGS-SBR was measured along the operation. During phase IV, chloride concentration values in the outlet were between 3.7 and 4.6 g L^{-1}. While, throughout phases I, II, III and V, chloride concentration in the outlet was more variable and between 0.5 and 3.2 g L^{-1}.

Conclusion

The AGS-SBR presented a good performance while treating a variable composition of real fish canning wastewater. During periods when a higher organic loading rate was applied, the excess of COD present in the bulk liquid during the aeration phase possibly affected phosphate removal and the nitrification process. The higher concentration of salt, associated to the higher OLR values, could also have disturbed the different biological processes. Nevertheless, the process performance was resumed, as observed by the COD removal. The AGS-SBR reactor operation is still ongoing to investigate the key parameters that affect the process and to promote the recovery of the initial performance on phosphate and nitrogen removal. Further, EPS from the AGS will be a source for recovery of biopolymers with application in different fields.

Table 1. Fish canning wastewater OLR throughout the operation

Parameters	**Phase I**	**Phase II**	**Phase III**	**Phase IV**	**Phase V**
Period (days)	0 – 35	36 – 57	58 – 89	90 – 115	116 – 142
OLR (g COD L^{-1} day^{-1})	0.8 – 2.3	0.2 – 0.9	0.5 – 0.8	2.1 – 2.4	0.4 – 1.2

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References

[1] C.L. Amorim, I.S. Moreira, A.F. Duque, M.C.M. Van Loosdrecht, P.M.L. Castro, Chapter 9 in Technologies for the Treatment and Recovery of Nutrients from Industrial Wastewater, A. Val del Río, J.L. Campos Gómez, A. Mosquera-Corral, IGI Global, Hershey, 2017, pp 231-263.

[2] R.O. Cristóvão, C.M. Botelho, R.J.E. Martins, J.M. Loureiro, R.A.R. Boaventura, Journal of Cleaner Production, 87 (2015) 603-612.

[3] C.L. Amorim, I.S. Moreira, A.R. Ribeiro, L. Santos, C. Delerue-Matos, M.E. Tiritan, P.M.L. Castro, International Biodeterioration and Biodegradation, 115 (2016), 277-285.

[4] APHA, Standard methods: for the examination of water and wastewater in American Public Health Association/American Water Works Association/Water Environment Federation, 20th ed., 1998, Washington DC, USA.