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THESIS SUMMARY: “A CONTRIBUTION TO THE STUDY OF AEROBIC GRANULATION AND ALE PRODUCTION: EFFECTS OF A HIGH ORGANIC LOAD, AND DIFFERENT COD/N”

For wastewater treatment, because of its layered and dense structure aerobic granular sludge allows multiple reactions and fast-settling among the same tank (Morgenroth et al., 1997) resulting in a significant reduction of energy consumption and of the size of the plant (Pronk et al., 2015). In addition, the potential valorization of ALE (alginate-like exopolymers) contained in these granular sludge seems an appealing route to transform the treatment plant into a resource factory (van Leeuwen et al., 2018). Granular sludge processes are already used for both domestic and industrial wastewaters treatment (Pronk et al., 2015). However, in the case of industrial wastewater, the best operating conditions to achieve stable granulation together with a high ALE production still need to be determined.

This thesis focuses in studying the possibility to produce ALE from particular (industrial), highly loaded wastewaters that may have different COD/N ratios and a high COD/P ratio. The main objectives of this thesis are to get a better understanding on (1) the granulation process under different COD/N ratios in the feeding; (2) the stabilization mechanisms of slow growers on granulation; (3) to determine the dependence between the specific organic loading rate (or food/microorganism ratio (F/M)) and the ALE production rate.

Our approach combined both experimental studies on lab-scale (17 L) aerobic granular sludge reactors and kinetic modelling including the main biological transformations. Reactors were bubble columns operated as sequenced batch reactors (SBR) with an anaerobic/aerobic cycle. Conditions to force granulation were a progressive increase of the organic loading rate (OLR) from 1 to 3 kg COD/m³/d and a reduction of the settling time. The COD substrates were glucose, VFA (acetate and propionate) and peptone.

In the first chapter of this thesis, the granulation processes under high and low COD/N were compared. While stable granulation was successful at high COD/N, granules disappeared at low COD/N when increasing the OLR. Failure of stable granulation installation was attributed to inhibition of some heterotrophic populations by a too high free ammonia concentration which raised consecutively to nitrifiers washed out due to the high selection pressures applied. Nevertheless, this inhibitory effect was not observed when the stable granules developed in the reactor run at high COD/N were submitted to high free ammonia concentrations. Inhibition of heterotrophic microorganisms by free ammonia has been hardly reported in the literature and to our knowledge our results are the first reported for granules. Moreover, they also underlined the importance of microbial dynamics during granulation processes for reaching stable granules and confirm the higher resistance to inhibitors of biomass entrapped in granules compared to biomass in flocs.

In the second chapter, the role of PAO and GAO in granulation under high COD/P and COD/N ratios was studied by comparing granulation dynamics with and without washout of those slow growers. In our experiments, consecutively to the sharp decrease of the anaerobic COD consumption and phosphates release indicating the loss of PAO and GAO populations, high concentration of filamentous bacteria were observed. This shift of microbial populations was replicable confirming that the presence of PAO and GAO which ensured anaerobic consumption of the COD leading to less COD available for fast aerobic growers is key for stable granulation development. The capacity to recover granules after the installation of the filamentous bacteria was also studied. Decreasing the selection pressure allowed to restore a capacity to form granules thanks to another microbial shift. However, as the anaerobic COD consumption never rose again it was concluded that the new granulation ability relied on a completely different mechanism. The results obtained were compared with simulation to link

experimental observations to possible dynamics in microbial populations. Even if difficulties persist concerning the description of selective purges, and therefore of dissociated residence times, this made it possible to discuss the hypotheses concerning the fate of carbon consumption during a cycle.

Finally, the third chapter studied the impact of F/M (0.3 to 0.65 g COD_s/g VSS/d) on the aerobic granular sludge system stability and evaluated the ALE production under these conditions. The quantitative relation between the applied organic loading rate and the F/M (and thus the SRT) was determined. Granule stability was not affected by increasing or decreasing the F/M in the range tested. Though the EPS content of the sludge was constant whatever the F/M (close to 500 mg EPS/g VSS), the ALE proportion in VSS decreased with the increase in the F/M ratio (from 90 to 30 mg EPS/g VSS for F/M ranging from 0.35 to 0.68 g DCO_s/g VSS/L). The mechanism of ALE synthesis appears to be inversely correlated to the global specific growth rate of the microorganisms. Moreover, the ALE content in VSS produced in this study was significantly lower than the reported content from the literature. The nature of the feeding may explain these differences. The capacity of these ALE to form a hydrogel was confirmed and a young modulus of 16 kPa was found. These results suggest that under our conditions, despite proven gelling capacities, ALEs may be not the only gelling compounds responsible for the structure of the granules. The extraction method therefore could be not able to recover all the structural EPS.

As a conclusion, different challenges to be faced for valorization of industrial wastewaters have been studied during this thesis, in order to bring new knowledge to better face them.