4th EU-ISMET, 2018
Newcastle upon Tyne

Anodic biofilm adaptation to high ammonium concentration: a critical step towards nitrogen recovery from blackwater by means of bioelectrochemical systems

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Source separation of domestic wastewater is one of the pillars of the "new sanitation" paradigm,[1] resulting in highly concentrated black water (BW) streams from the toilet, which can be efficiently treated through anaerobic systems like Upflow Anaerobic Sludge Blanket. Main benefits of such an approach include the possibility to recover energy from wastewater and micropollutants removal. On the other hand, anaerobic treatment does not allow removing nutrients at a significant rate. Bioelectrochemical systems (BES) can be used to recover ammonium (NH_4^+) from BW through the migration ionic flux occurring from anode to cathode chamber.[2] The ammonium flux is driven by the exoelectrogenic degradation of organic matter at the anode, and takes place in both microbial fuel cells (MFC) and microbial electrolysis cells (MEC). A critical step towards the nitrogen recovery of BW by BES consists in adapting the anodic biofilm to high ammonium concentrations.
The Run4Life project[3] aims at implementing new sanitation concepts to achieve complete NPK nutrients recovery from source-separated wastewater. A specific task is dedicated to NH_4^+ recovery from BW streams, previously treated by anaerobic membrane biologic reactor (AnMBR). During a first stage of the study 2 air-cathode MFCs were built and inoculated with the effluent of a long-term operating acetate-fed MFC. These were fed with an acetate-based medium doped at increasing levels of NH_4^+. The MFCs were electrically operated in chronoamperometric mode, while polarization curves and cyclic voltammetry analyses were performed at regular base. Physical-chemical parameters of influent and effluent streams were analyzed, so that process parameters, like treatment efficiency and Coulombic efficiency (CE), could be estimated over time.
One MFC was acclimated at a concentration of 0.5 g N-NH_4^+ L^{-1} (estimated nitrogen content of AnMBR-treated BW), reaching stable performances after 2 months: average current of 0.7 A m^{-2}, 83% COD removal and 12% CE. The second MFC was operated as replicate during first 2 months. Once steady-state was achieved, the influent NH_4^+ concentration was weekly increased by steps of 0.5 g L^{-1}, looking for the critical value causing biofilm inhibition.[4] Currently, we reached a notable value of 7.5 g N-NH_4^+ L^{-1} (equal to 0.5 g L^{-1} of free N-NH_3, according to pH and temperature), without adverse effects towards BES performance. On the contrary, current density increased to 0.9 A m^{-2} due to the increase of electrolyte conductivity, while COD removal remained on values around 80% and CE up to 16%. The next stage of the study will focus on nitrogen recovery optimization from BW in a double-chamber air-cathode BES inoculated with the acclimated biofilm.

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