Nitrogen recovery from blackwater using bioelectrochemical systems

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Abstract:
In the present work, the latest achievements of Run4Life project are presented, aiming at the bioelectrochemical recovery of ammonium (NH_4^+) from blackwater (BW) for the production of fertilizers. The anodic biofilm of adopted bioelectrochemical systems (BES) was first acclimated to high NH_4^+ concentration, as a requirement for the effective treatment of BW in the anode chamber. Afterwards, the design and construction of adopted BES system is described. Preliminary results in terms of BW treatment, NH_4^+ recovery and energy consumption are finally exposed.

Keywords: air-diffusion cathode; cation exchange membranes; ammonium acclimation;

Introduction

Bioelectrochemical systems (BES) were previously reported as a promising technology for ammonium (NH_4^+) recovery from blackwater (BW) (Ledezma et al., 2015). The exoelectrogenic oxidation of the organic matter contained in BW and the resultant polarization of BES electrodes becomes the driving force for NH_4^+ migration from the anolyte to the catholyte through a cation exchange membrane (CEM). Application of external voltage to BES system can help increasing the process kinetics and NH_4^+ migration flux. A downstream separation system is then required to recover NH_4^+ in form of fertilizer. In this study, has been adopted a stripping system based on air bubbling over an air-diffusion cathode. The basification of the catholyte, due to oxygen reduction, causes NH_4^+ to convert to NH_3 and its stripping and recovery outside BES reactor.

Material and Methods

The experimental set-up adopted for NH_4^+ acclimation tests consists of 2 air-cathode microbial fuel cells (MFCs), previously inoculated with an electroactive biofilm from a laboratory-operating MFC. The two MFCs were fed with an acetate-based synthetic medium mimicking the composition of a source-separated BW. MFC1 was operated in steady-state mode at a concentration of 0.5 g-N/L. MFC2 was fed at subsequent increases of NH_4^+ concentration, looking for its inhibition threshold over anodic biofilm. The two MFCs were operated in chronoamperometric mode and monitored through electrochemical techniques (polarization curves and cyclic

voltammetries). Also, physical-chemical parameters of influent and effluent wastewater were analysed according to Standard Methods: [NH_4^+], Total Nitrogen (TN), pH, conductivity and chemical oxygen demand (COD).

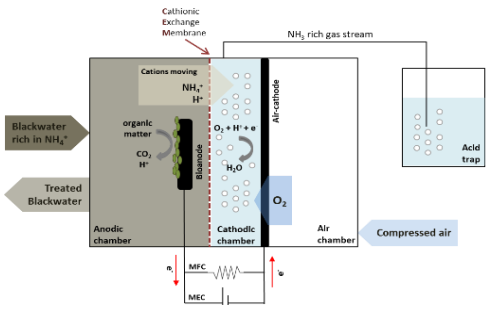

Figure 1 Diagram of N-recovery BES reactor.

For the nitrogen recovery trials a tailor made BES reactor equipped with an air-diffusion cathode was designed and constructed (see Figure 1). In detail, the system was composed by a bicameral reactor with a cation exchange membrane (CEM) between anodic and cathodic chambers, allowing the migration of cations (as NH_4^+) from anolyte to catholyte. There, assisted by the air bubbling system and due to the basification of the catholyte, the NH_4^+ turned to NH_3 and migrates to the acid traps. The system was operated in batch cycles of 5 days, with synthetic medium (the same one adopted for N acclimation tests) doped with 1 g/L of N-NH_4^+ as anolyte, and a 10.7g/L NaCl solution as catholyte. Two acid traps were installed downstream the BES reactor, each one containing a solution of 0.1 M H_2SO_4. The BES reactor was electrically operated in a 2-electrodes configuration, applying a voltage of 200 mV between anode and cathode. Process performances were assessed by means of physical-chemical parameters determination such as ammonium removal, nitrogen recovery and organic matter removal (expressed as COD) and electrochemical calculations (as anodic Coulombic efficiency).

Results & conclusions

MFC1 was successfully acclimated at a constant concentration of 0.5 g N-NH_4^+/L (estimated nitrogen content in the Run4Life end-user BW), reaching stable performances over a period of more than 6 months: average current density of 0.7 A m^{-2}, 83% COD removal and 12% Coulombic efficiency. MFC2 was employed to determine the inhibitory [N-NH_4^+] threshold. Severe affectation in biofilm performance occurred when reaching 9 g N-NH_4^+/L, but a decrease in biofilm performance could be observed already at 3,5 g N-NH_4^+/L. The COD and Coulombic efficiency remained constant during all the concentration gradient, around 80% and 16% respectively.

Regarding nitrogen recovery trials, 79±3% of the ammonium was removed from the anolyte during the batch treatment cycle. A 61±13% of removed N-NH_4^+ was finally recovered in the acid traps. Moreover the COD removal rate was around 0.827±0.07 Kg/m^3·d with an anodic coulombic efficiency of 10.9±1.7%.

Performed experiments demonstrate that nitrogen recovery from BW is possible using bioelectrochemical systems. Economic sustainability of proposed process is yet to be verified. For this reason, following experiments will focus on process optimization, acting on parameters like air flow-rate, catholyte composition, voltage application, etc.

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References

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