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Bioelectrochemical Systems for Ammonia Recovery from Wastewater

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Motivation

An increasing world population and rising nutrient demand will require higher agricultural output and therefore more fertilizer to sustain humanity. At the same time, nutrients in wastewater need to be removed to protect waterbodies from eutrophication. Therefore nutrient recovery from wastewater streams is important to create a sustainable future. Bioelectrochemical Systems (BES) can convert biodegradable organic compounds in waste streams into electricity (Figure 1). This electrical current can be used to recover total ammonia nitrogen (TAN) as resource (i.e. fertilizer), combining both needs in an elegant and energy efficient solution. [1]

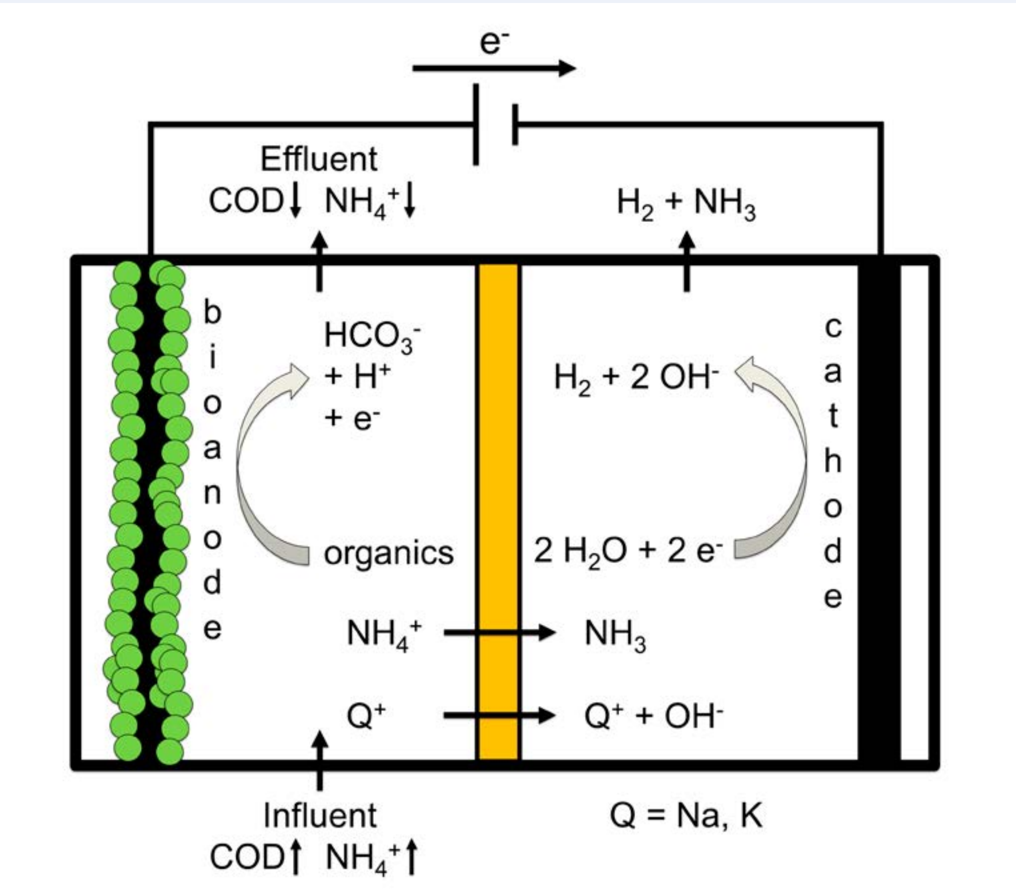

Figure 2: Ammonia separation with a microbial electrolysis cell as BES. Credits: M. Rodríguez Arredondo.

Research goals and challenges

Current research recovers TAN from human urine (Figure 3). Since urine collection is not widely performed, new waste streams need to be identified to broaden the TAN recovery application. A literature search for suitable wastewater streams will be followed by laboratory screening with small-BESs and degradation assays. Suitable wastewaters will be tested in lab-scale BES reactors to identify limiting factors as well as best reactor designs and operating conditions. Resulting insights will be used to design, build and run an up-scaled BES to recover ammonium as resource from the most suitable wastewater stream and clean the effluent from organic compounds at the same time.

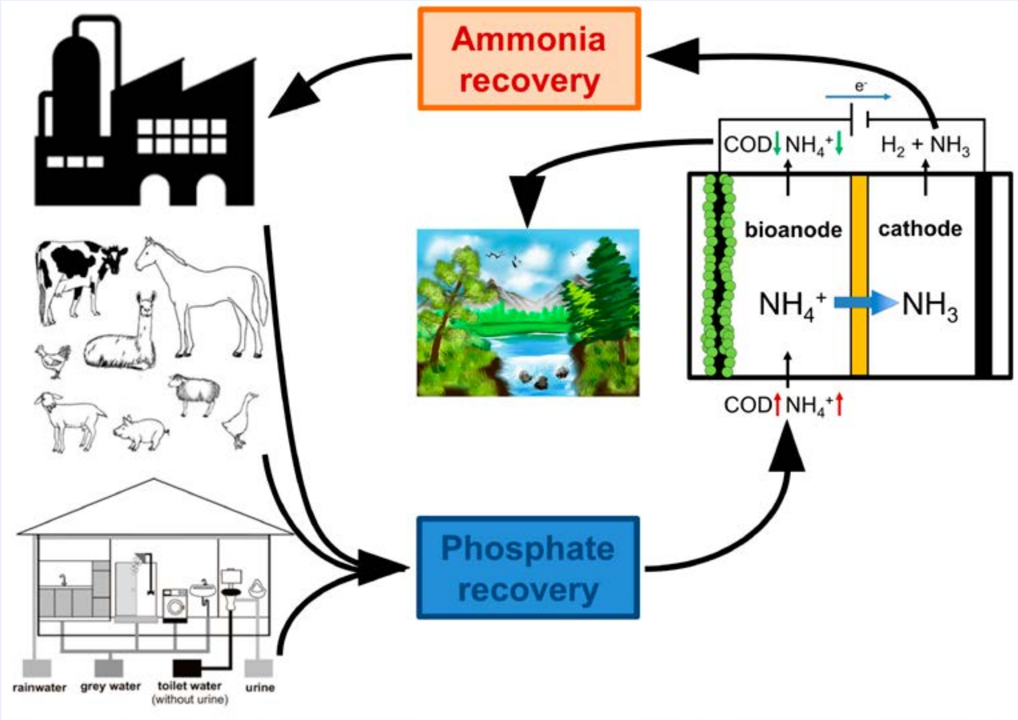

Figure 1: Envisioned phosphorus and nitrogen recovery from industrial, agricultural and source separated household wastewaters. BESs are used as ammonia separation and organics removal technology, which helps to create a resource cycle and a sustainable world.

Technological approach

Organic compounds in wastewater are degraded and ammonium (NH_4^+) recovered by combining a BES with a membrane distillation unit (Trans Membrane ChemiSorption, TMCS). Microbes growing on the anode of the BES convert organic compounds into electricity (Figure 2). The electric current is used to drive NH_4^+ across a membrane to the cathode. There, H_2 and OH^- are produced by water reduction and the ionic NH_4^+ is deprotonated under these alkaline conditions into gaseous ammonia (NH_3). This NH_3 is extracted from the cathode via the TMCS, where it diffuses through a gas permeable membrane into an acid solution. This converts NH_3 back into NH_4^+ and hence a solubilized, ready-to-use resource.

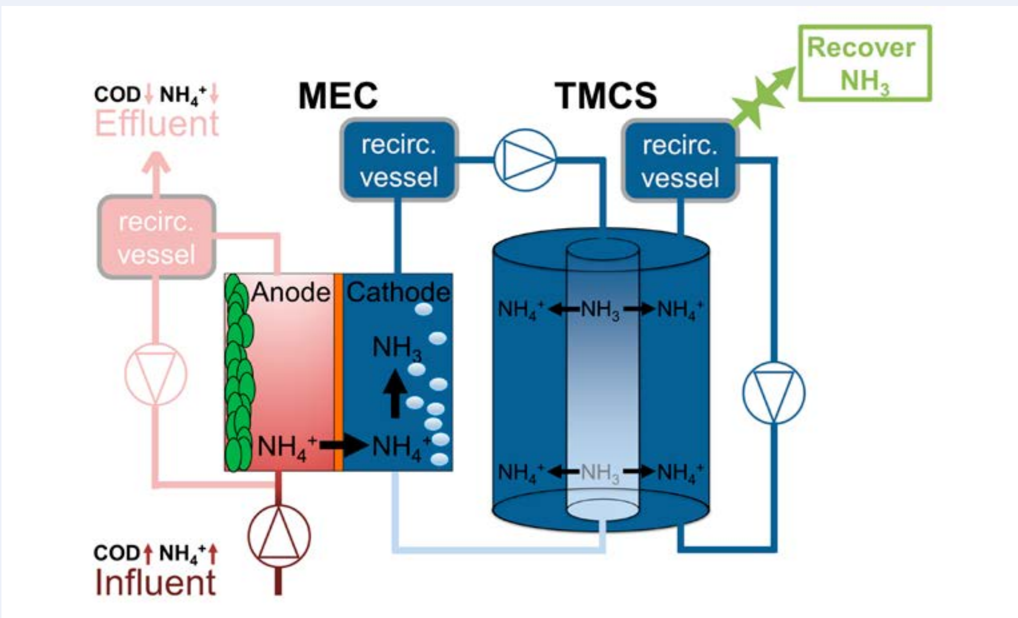

Figure 3: Technical setup depiction of a microbial electrolysis cell (MEC) as BES combined with a TMCS to recover ammonia. Adapted from Rodríguez Arredondo et al. 2017. [2]

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[1] M. Qin, Y. Liu, S. Luo, R. Qiao, Z. He (2017) Integrated experimental and modeling evaluation of energy consumption for ammonia recovery in bioelectrochemical systems; doi: 10.1016/j.cej.2017.06.182
[2] M. Rodríguez Arredondo, P. Kuntke, A. ter Heijne, H.V.M. Hamelers, C.J.N. Buisman (2017) Load ratio determines the ammonia recovery and energy input of an electrochemical system; doi: 10.1016/j.watres.2016.12.051

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