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Hydrogen Looping During Electrolysis of Wastewater Filtrate for Ammonia Recovery

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Atmospheric nitrogen fixation via the Haber-Bosch process ($N_2 + 3H_2 \rightarrow 2NH_3$) accounts for up to five percent of global natural gas consumption and two percent of global energy consumption. The produced ammonia fertilizes crops globally but runoff from industrial agriculture distributes this nitrogen into groundwater and causes concerns for human and environmental health. Much of this nitrogen is processed out of domestic wastewater at wastewater treatment plants (WWTP), making these facilities ideal sites for mitigation of the effects of industrial ammonia production. The ideal target waste stream for nitrogen harvesting must be concentrated and free of particulate matter. At WWTPs, sludge and scum from settling tanks are sent for anaerobic digestion where microorganisms digest biological matter into its component parts. The sludge is then coagulated and pressed, producing filtrate enriched with ammonium produced during the process. Electrolysis of this filtrate using a cation exchange membrane (CEM) offers a possible pathway to nitrogen recovery but the effectiveness of the process must rival the energy consumption of the Haber-Bosch process to be feasible for widespread implementation. Manipulation of the pH of the filtrate converts ammonium (NH_4^+) into ammonia (NH_3) at the cathode. Hydrogen looping is a strategy that utilizes the hydrogen evolution reaction that occurs at the cathode to fuel a hydrogen oxygenation reaction at the anode instead of an oxygen evolution reaction, reducing the power input needed to maintain an effective pH well above 9.2 at the cathode for ammonia recovery. Filtrate from the village of Potsdam, NY WWTP was analyzed and multiple synthetic analogues were created containing different ratios of two pH buffer species commonly found in filtrate (NH_4Cl, $NaHCO_3$). The filtrate and analogues were subjected to currents ranging from 5 to 20 mA/cm2 of electricity via two platinum carbon (Pt/C) electrodes separated by a CEM to examine the voltage consumption of the system. A synthetic filtrate determined to be the most accurate analogue was also examined under hydrogen to investigate the effect of hydrogen on energy consumption. Real filtrate resisted pH change compared to the synthetic analogues, implying the presence of unidentified compounds buffering pH.