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Integration of liquid-liquid membrane contactors and electrodialysis for ammonia recovery from urban wastewaters

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Highlights: *LLMC is an innovative and eco-friendly technology for ammonium salts production; ED can concentrate efficiently ammonium salts; Concentrated ammonium salts can be obtained by means of integration processes (LLMC and ED); Ammonium salts produced can be used as liquid fertilizers.*

Keywords: ammonium valorization; ammonium salts; wastewater treatment; liquid fertilizers; liquid-liquid contactors; electrodialysis concentration.

1. Introduction

Nowadays, reactive nitrogen compounds are excesive released into the environement due to industrial and urban wastewaters. A huge environmental challenge exists due to these compounds, such as nitrogen oxides (NO and NO_2), nitrous oxide (N_2O), ammonia (NH_3), ammonium (NH_4^+) and nitrate (NO_3) pollute the environement and endanger human health (Sareer et al. 2016). In addition, the circular economy policy proposes actions that will contribute to "closing the loop" of product lifecycles through greater recycling and re-use, and bring benefits for both the environment and the economy. From this point of view, two innovative membrane technologies are proposed to valorizate the ammonia present in urban wastewaters by separating and concentrating it as ammonium salts: liquid-liquid membrane contactors (LLMC) (Licon Bernal et al., 2016) and electrodialysis (ED) (Reig et al., 2014).

Using LLMC is possible to separate and recover the ammonia from urban wastewater as ammonium phosphate ($NH_4H_2PO_4$), using an acid stripping solution (e.g., phosphoric acid). Besides, ED allows to increase the $NH_4H_2PO_4$ concentration in order to reach the required nitrogen and phosphorous concentration to be used as liquid fertilizer.

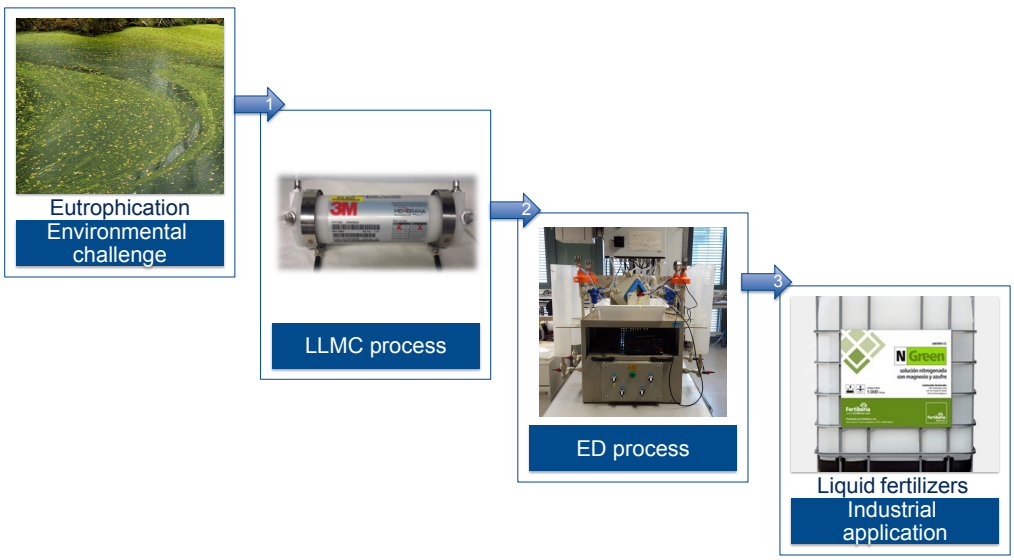

Figure 1. Integration of LLMC and ED membrane technologies for ammonia revalorization as liquid fertilizers.

2. Material and Methods

A liquid-liquid membrane contactor was supplied from 3M Company (USA) to conduct the experiments at lab-scale (2.5x8 Liqui-Cel X-50 PP fiber). Urban wastewaters from regenerated zeolites were used as feed solution, containing 1.6 g NH_3/L at pH 12 in a 60 L tank (lumen side), whereas 0.5 L of 0.4 mol/L phosphoric acid were used as stripping solution (shell side). Both streams circulated through the LLLMC pumped at 450 mL/min and recirculated back into its respective tanks at room temperature during 12 h.

Afterwards, the ammonium phosphate solution obtained from LLMC was fed into an ED system supplied by PCCell GmbH (Germany), named PCCell ED 64-004. The ED system worked with 5 cell pairs of membranes (64 cm^2 active area each one) from two different companies: Fujifilm and PCCell. 1L of $NH_4H_2PO_4$ solution was used to feed the electrode rinse, diluate and concentrate compartments. The first one was pumped at 90-100 L/h, while the others were pumped at 15-20 L/h through the ED stack. Experiments were carried out at constant voltage of 7.5 V, taking into account the voltage drop of the system (2.5 V across the electrodes and 1 V for each chell pair (5 V)), using a power cell HCS-3202 supplied by Manson Engineering Industrial (Hong Kong).

The liquid fertilizer composition, after these processes, was expressed for ammonia as %N and for phosphate as $\%P_2O_5$.

3. Results and Discussion

Ammonia removal from urban wastewaters using LLMC was 86±3% (at the lumen side), whereas its concentration factor was 34±2% after 12 h (in the shell side). Moreover, it was possible to recover it as ammonium phosphate at the shell side, containing 5.0±0.1% of N and 14.9±2.2% of P_2O_5.

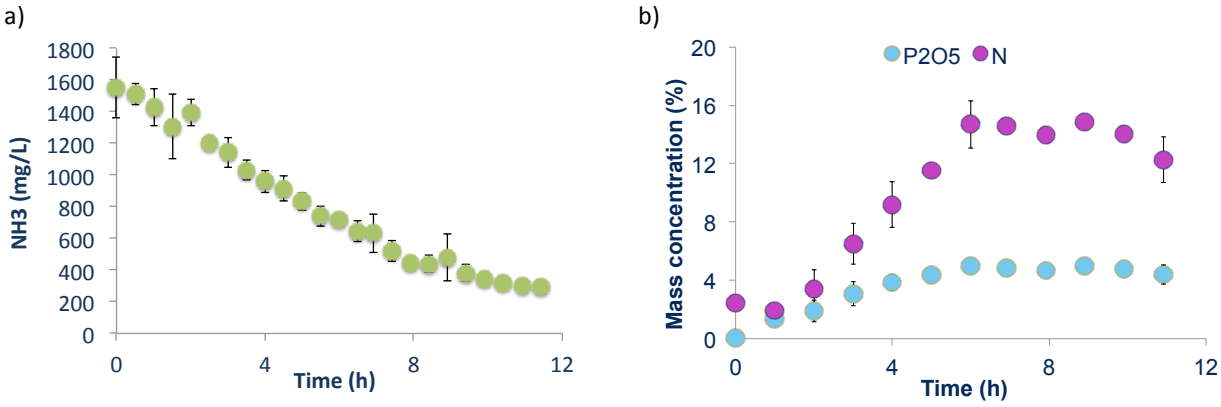

Figure 2. a) Ammonia evolution in the feed side and b) N and P_2O_5 evolution in the stripping side over time.

The ammonia phosphate produced in the LLMC was subsequently concentrated by ED. It was possible to concentrated the ammonium salt by 51±1 % and 54±2 % using PCCell and Fujifilm membranes, respectively, after almost 4 h of operation process.

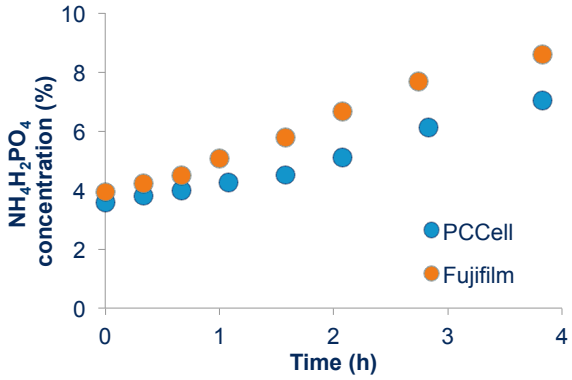

Figure 3. $NH_4H_2PO_4$ evolution in concentrated stream by ED process.

4. Conclusion

To summarize, by the integration of LLMC and ED as innovative membrane technologies was possible to separate, concentrate and valorize ammonia present in urban wastewaters as ammonium phosphate. This salt solution could be used as liquid fertilizer in the agriculture sector, promoting in this way a circular economy scheme.

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