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Recovering high-value P-K fertilizer from effluents by integrating adsorption and electrodialysis with bipolar membranes

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Abstract

High-efficient phosphorus (P) recovery from wastewater has recently attracted widespread attention, as worldwide food production is largely dependent on this non-renewable resource. Although some of the existing technologies (e.g., adsorption) can achieve effective phosphate removal and recovery, they require extensive use of chemicals and intensive consumption of energy to achieve substantial recovery of nutrients (Kumar et al. (2019)). Here, we developed a novel P recovery process via integrating bipolar membranes electrodialysis (BMED) with P sorption. Specifically, the integrated system incorporates P adsorption-desorption step, nanofiltration (NF) step, and BMED process in sequence. Surprisingly, a satisfactory accumulated concentration of P (3545.45 mg P/L) in the regeneration solution is obtained under the optimal operating conditions (i.e., column adsorption experiments with single-pass with the flow rate 45 mL/min; acid cleaning using HCl solution with a pH of 2.5; pH of the eluent desorption KOH solution = 13.85 ~ 14.0, concentration = 2.29 M). The desorption solution is then treated by NF to further reduce the energy consumption of the whole process. Low rejection of K^+ (20.1 %) is preferred to increase the concentration and lower the ratio of K/P of the desorption solution. The P-rich eluate after NF is used as a source for subsequent BMED steps. Therefore, the high purity of the KH_2PO_4 solution is obtained when the pH in the salt compartment reaches ~ 4.5. Finally, the bipolar membrane (BPM PCCell) and the cation exchange membrane (CEM FKS-50) are utilized within the BMED stack with two cell pairs (2cp) under the voltage of 8 V to process the salt solution after the NF step, which has the minimum specific electricity consumption (SEC). Moreover, it is estimated that the cost of PCCell-FKS-50-2cp-8V-NF is only 188.595 $/dry ton KH_2PO_4, while the net profit is 1236.405 $/dry ton KH_2PO_4, which offers the critical potential to translate this relatively small-scale lab example to a larger scale. Overall our results demonstrate the techno-economic viability of this new concept for sustainable P recovery from effluents, justifying further development and scaling-up efforts.

Keywords: nutrients recovery, bipolar membranes electrodialysis, nanofiltration, liquid fertilizer

References

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