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Phosphorus and Ammonia Removal and Recovery through Ion Exchange (IEX) Process at Demonstration Scale

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Abstract: The operational performance of a demonstration scale ion exchange process, treating 10 m^3 /day of secondary treated wastewater, was investigated. For the removal of ammonia and phosphorus, a synthetic zeolite and hybrid anion exchanger (HAIX) were used, respectively. To ensure the economic feasibility of the process, the resins regenerant solutions were re-used and recycled back to the process after the nutrients were recovered. After 1.8 years of operation, the synthetic zeolite removed up to 98% of the initial NH_4-N and regenerant reached 689 mg NH_4-N/L, after being reused 5 consecutive cycles. The recovery of the NH_4^+ as ammonium sulphate through stripping process was investigated (recovery >90%). The HAIX underwent 56 cycles of adsorption and regeneration without any significant loss in capacity. The sodium hydroxide used as regenerant reached 490-572 mg PO_4-P/L after 9 consecutive cycles and the phosphorus was recovered by precipitation as hydroxyapatite.

Keywords: ion exchange; nutrients; recovery

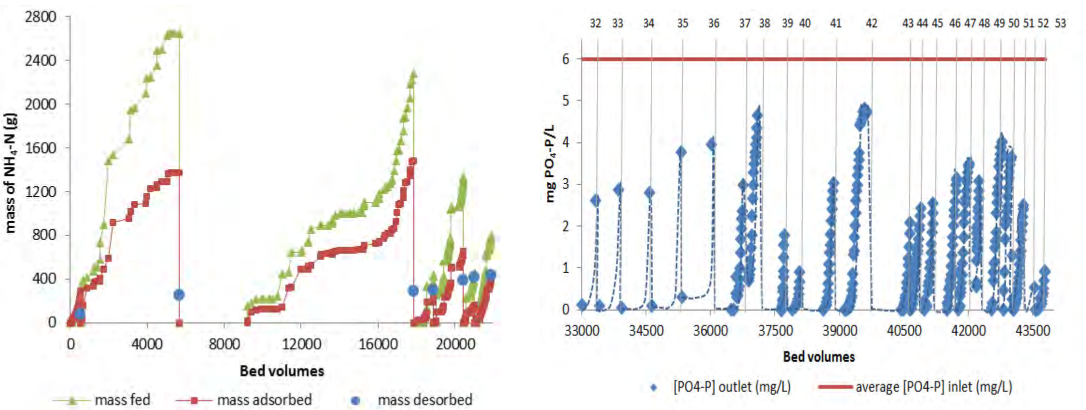
INTRODUCTION Traditional biological and chemical technologies used for nutrient removal from wastewater have important drawbacks such as high energy and chemical consumption. On the other hand, the use of ion exchangers for nutrient removal as tertiary treatment processes allows for full control of the effluent quality and for the recovery of the nutrients as valuable product from the concentrated regenerant solutions (Sancho et al., 2017). However, previous studies have just focused on the use of ion exchanger at laboratory scale or pilot-scale for a short operational period of time (Mackinnon et al., 2003; Martin et al., 2009). This study investigated the resilience and long-term management of synthetic zeolite and HAIX to remove nutrients from secondary effluent wastewater at demonstration scale treating 10m3/day under a fixed operational envelope. The recovery of phosphorus and ammonia as marketable products was presented as a solution to maintain the regeneration capacity of the brine solutions and ensuring the economic feasibility of the process.

MATERIALS AND METHODS The demonstration-plant consisted of a drum filter, an ammonia removal column filled with 69 L of synthetic zeolite (BYK Additives LTD, UK) and a phosphorus removal column filled with 35 L of HAIX, LayneRT (Layne, USA). The regenerant solutions were made of 10% KCl and 2% NaOH to regenerate the synthetic zeolite and the HAIX, respectively. The columns were fed with secondary treated wastewater (after carbonaceous organic matter removal in a trickling filter) (Table 1.1) taken from a municipal wastewater treatment plant with 2,840 population equivalent (Cranfield, UK) at a flow of 10m^3/day. The synthetic zeolite and the HAIX performances were tested at an empty bed contact time of 10 and 5 minutes, respectively.

Table 1.1 Characterization of the secondary treated wastewater fed to the demonstration plant

Parameter	Concentration
Total suspended solids, TSS	54.91±20.90 mg/L
Chemical oxygen demand, COD	37.00±12.30 mg/L
PO_4-P	6.04±0.25 mg PO_4-P/L
NH_4-N	4.89±2.74 mg NH_4-N/L (from 17:00 to 04:00) 15.65±4.12 mg NH_4-N/L (from 05:00 to 16:00)

RESULTS AND CONCLUSIONS The ion exchange demonstration plant was operated under stable operational condition for a period of 17 months. Repeating adsorption and regeneration cycles were performed with both the synthetic zeolite and the HAIX. The performance of the synthetic zeolite was influenced by the daily variability of the inlet ammonia concentration (Table 1.1.). Due to the high variability, a representation of the cumulative mass fed, adsorbed and desorbed was preferred to represent the media performance over 7 cycles of adsorption and regeneration (Fig. 2.1a). In the last two cycles, the influent ammonia concentration was more stable at 17.5±2.0 mg/L and the number of BV in between regenerations was 300. The average inlet phosphorous concentration was 6.04±0.25 mg PO_4-P/L, the effluent wastewater reached 0.1-0.9 mg PO_4-P/L, indicating that 95% of the PO_4-P was removed. These results, obtained over 56 cycles of adsorption and regeneration, showed that HAIX can be used with to treat wastewater over a long time while retaining its high capacity of adsorption (Fig. 2.1b).



a b

Figure 2.1 (a) Cumulative mass (g NH_4-N) fed, adsorbed and desorbed in the ammonia removal column; (b) Performance of adsorption of synthetic zeolite over 6 cycles; (c) breakthrough curve of phosphorus adsorption by HAIX and regeneration cycles number 32-53.

After reusing the KCl 5 cycles, a concentration of 689 mg NH_4-N/L was obtained, indicating 90% NH_4-N recovery. The NH_4-N was converted to a concentrated NH_3 solution in the stripping process and recovered as ammonium sulphate precipitate after adding sulphuric acid (Fig. 2.2a and 2.2c). Following dehydration, a recovery of 79 kg per year can be estimated. In case of the 2% NaOH regenerant, after 9 cycles it reached 572 mg PO_4-P/L. After addition of hydrated lime, following filtration, a recovery of 25-30 kg of hydroxyapatite per year can be expected (Fig. 2.2c and d).

a b c d

Figure 2.2 Recovered products: ammonium sulphate (a) and calcium phosphate (b); SEM images of recovered crystalline products: ammonium sulphate (c) and calcium phospate (d)

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