Adsorption of ammonium from AnMBR effluent using activated hydrochar as potential fertilizer

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1. Introduction

Fertilizers are added to soil to improve crop growth [1]; however, the high cost and environmental impacts of commercial fertilizers are becoming a major challenge. Moreover, commercial fertilizers release nutrients quickly, and the nutrients are either leached to the groundwater or adsorbed on the soil particles, thus becoming unavailable for plant growth [1]. One sustainable source of nutrients is wastewater effluent that contains ammonium, phosphate. Therefore, nutrient recovery from the effluent is gaining much attention as a sustainable alternative to commercial fertilizer. An emerging approach to recover ammonium from the effluent is using sustainable adsorbents produced from wastes, such as hydrochar and biochar. As hydrochar is a known soil amendment and the adsorbed nutrient release rate from hydrochar is typically slow, applying ammonium adsorbed hydrochar in agricultural applications is expected to be highly beneficial. However, very few studies investigated the adsorption of ammonium from real effluent, and even less studied the application of ammonium enriched hydrochar for agriculture application. Therefore, the objective of the research is to recover ammonium from an anaerobic membrane bioreactor (AnMBR) effluent using sludge-derived activated hydrochar and investigate the potential of using ammonium enriched hydrochar as a nitrogen fertilizer.

2. Methods

2.1 Hydrochar production and Adsorption Experiment

Hydrochar was prepared from wastewater sludge via a hydrothermal carbonization process[2]. The hydrochar was activated by the Fenton reaction (5 g of hydrochar powder in 100 mL of 50 mM H_2O_2 solution with 10: 1 mol ratio $H_2O_2/Fe2^+$ for 30 min) based on our previous study [2]. Ammonium adsorption experiments were done using AnMBR effluent from an AnMBR treating domestic wastewater with about 60 mg/L ammonium in the effluent. The adsorption study was conducted with hydrochar and activated hydrochar and synthetic and real effluent. The hydrochar was added to 100 mL effluent (~pH7) in a sealed flask, and the flask was shaken in an incubator at 160 rpm for 12 hours. The hydrochar was separated for the effluent by centrifugation, and the residual ammonium concentration in the solution was measured using the distillation method.

3. Results and Discussions

Fig.1a-b shows the effect of the activated hydrochar dosage on the ammonium removal efficiency and adsorption capacity from real effluent and synthetic effluent (with 60 ppm NH_4^+-N), respectively. An increase in hydrochar dose from 0.3 g to 1 g enhanced the ammonium removal efficiency from 30 to 43 % in the case of real effluent (Fig.1a), whereas the ammonium removal efficiency was from 39 to 56 % when using synthetic water (Fig.1b). The adsorption capacity (Q_e) of the activated hydrochar to ammonium from the real effluent was lower than from the synthetic effluent, probably due to competitive adsorption of other cations found in the real effluent, such as Na^+, Ca^{2+}, Mg^{2+}, and adsorption of dissolved organic matter [3] [2]. The decrease in adsorption capacity with adsorbent dose may be attributed to the decrease in available active sites on the adsorbent due to the aggregation of particles [4].

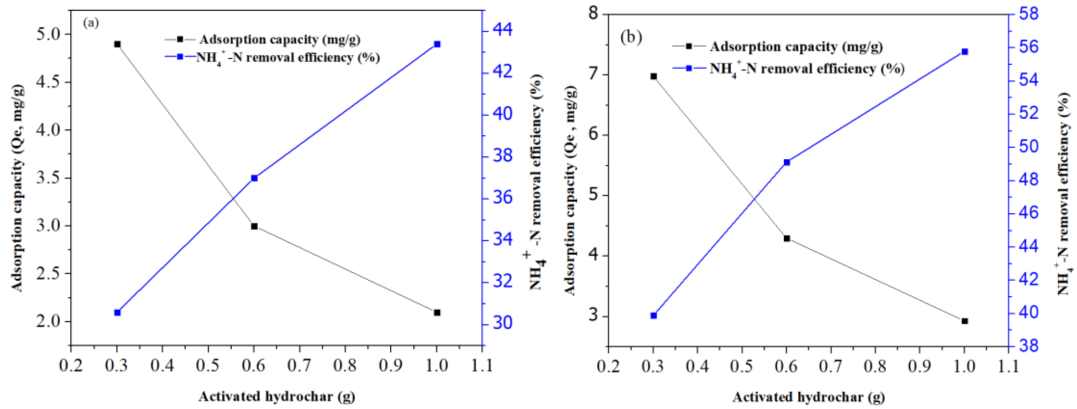

Fig.1. Effect of adsorbent dosage on NH_4^+ -N removal efficiency and adsorption capacity (Q_e) (a) from real effluent and (b) from synthetic effluent with 60 mg/L NH_4^+-N concentration

The effect of the activation using the Fenton reaction on the ammonium adsorption was evaluated by comparing the residual ammonium concentration in the effluent following adsorption with hydrochar and activated hydrochar. 32 and 23 mg/L ammonium remained in the effluent following the adsorption step using raw and activated hydrochar, respectively (Fig. 2a.). This indicates that the activation increases the hydrochar adsorption capacity due to increased concentration of the functional groups on the hydrochar (such as C=O, O-C=O) and thus the adsorption sites [2]. Nevertheless, the residual ammonium concentration in the effluent was higher than the standard concentration for unrestricted irrigation (NH_4^+-N < 20 mg/L)[5]. Thus, a second adsorption step was conducted. The ammonium concentration in the effluent following the second step adsorption was reduced to 7 and 4 mg/L using raw and activated hydrochar, respectively (Fig. 2a), rendering the effluent suitable for irrigation.

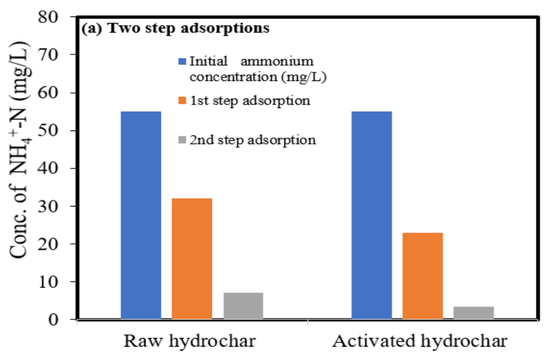

Fig. 2. Two-step adsorption test from real effluent using 1 g of activated and raw hydrochar

Conclusion and future works

Hydrochar generated from hydrothermal carbonization of wastewater sludge was activated by Fenton reaction to modify its surface compositions to enhance ammonium adsorption capacity from AnMBR effluent. The activation enhanced the adsorption capacity (Q_e =4 mg/g) compared to hydrochar. The activated hydrochar can remove the ammonium concentration below the standard for resuing the effluent for unrestricted irrigation. The ammonium enriched hydrochar has the potential to be used as sustainable fertilization, and this is currently under investigation,

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