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Phosphorous removal from anaerobically digested municipal sludge centrate by an electrocoagulation reactor using metal (Al, Fe and Al-Fe) scrap anodes

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ABSTRACT

Phosphates are a major cause of eutrophication and growth of algal blooms in surface waters. The current study investigated phosphorus removal from sludge centrate effluent (SCE) of a municipal wastewater plant by packed-bed electrocoagulation (EC) reactor. Distinctively, iron (Fe), aluminum (Al) and Al-Fe hybrid scrap anodes were used. The influence of initial pH_i, applied current and packed anode bed density were evaluated. Phosphorous removal efficiency of 99.99 % was obtained at applied current of 0.20A with anode bed densities of 0.18 kg Al/m^3 (pH_i 5.0) and 0.48 kg Fe/m^3(pH_i 7.0). Optimum operating costs entailing sludge disposal, chemical, energy and electrode consumption were calculated as 0.379 US \$/m^3 (6.04 \$/kg PO_4-P) for Fe scrap, 0.494 US \$/m^3 (9.46 \$/kg PO_4-P) for Al scrap and 0.501 US \$/m^3 (9.59 \$/kg PO_4-P) for Al-Fe hybrid scraps. Phosphorus removal per electrochemically generated metal was 191.22 mg P/g Al, 104.88 mg P/g Fe, and 61.08 mg P/g (Al + Fe). The molar metal to phosphorus ratio at optimum conditions were calculated as 5.41, 3.97 and 7.65 mol/mole for Al, Fe and Al-Fe, respectively. The key mechanisms for phosphorus removal were metal-phosphorus precipitation and adsorption. Herein, metal scrap anodes have been proved effective for phosphorous removal from SCE.

1. Introduction

Phosphorus is an essential nutrient for development of plants, animals, and humans. However, excessive presences of phosphates in surface water sources has been recognized a major cause of eutrophication and growth of algal blooms in surface waters and marine ecosystems (Tu et al., 2019). The major point sources of phosphorus in natural water bodies includes industrial and domestic wastewater treatment facilities (Withers et al., 2014). Approximately 30–50% of the phosphorus present in domestic wastewater originates from human excreta while the remaining 50–70% is from laundry detergents. On the other hand, industrial sources of phosphorus include large scale manufacture and application of phosphate fertilisers and commercial laundry (Ogbuewu et al., 2012; Schoumans et al., 2015)

Total phosphorous concentration in municipal wastewaters generally ranges from 5 to 20 mg/L, yet, only 1−2 mg/L of phosphorus is removed by secondary treatment (Mezenner and Bensmaili, 2009). The activated sludge treatment process removes a limited amount of phosphorous through biosorption and biomass growth. Greater percentage of phosphorous (60–70 %) is removed in primary or secondary clarifiers as particulate phosphorous (Carrillo et al., 2020). Municipal sludge is normally subjected to anaerobic digestion to destroy pathogens, reduce BOD and lower the sludge volume. Consequently, stabilized biomass and biogas are produced as final products (Metcalf and Eddy, 2007). The digested biomass is further subjected to centrifugal dewatering to produce biosolids and liquid fractions (supernatant or centrate) (Ren et al., 2015), which is characterized by high phosphorous levels (60−300 mg P/L)(Ansari et al., 2016; Desmidt et al., 2015). Conventionally, the centrate is recirculated and mixed with the treatment plant influent. Phosphorus and nitrogen influent loads of up to 8% and 20 %,

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