Use of Chitosan-Fe for Phosphorus Recovery and Promoted Methane Production from Anaerobic Digestion of Waste Activated Sludge

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Abstract

The increasing generation amount of waste activated sludge (WAS) from wastewater treatment plants (WWTPs) is becoming a major problem for the sustainable management of WWTPs. Anaerobic digestion (AD) has been successfully applied for WAS treatment in WWTPs, owing to its capability of simultaneous bioenergy production and resources recovery. However, low methane yield and sludge reduction rate to some extent limit the application of AD in WAS treatment. Besides, the post treatment of liquid digestate containing high level of phosphate is also one of the main problems for AD systems, due to the massive phosphorus (P) released during AD process. Therefore, it is highly demanded to develop new methods for simultaneous P recovery and enhanced methane production from AD of WAS.

Previous studies indicate that conductive carbon-based materials or Fe (III) might improve AD of WAS through the direct interspecies electron transfer (DIET). Chitosan-Fe (III) complex (CTS-Fe) as an inexpensive and environmentally friendly carbon-based material possesses excellent P adsorption capacity and has been successfully employed to adsorb phosphate. Therefore, it is speculated that CTS-Fe has great potential for methane production and P recovery from AD of WAS. This study for the first time attempted to simultaneously recover P and enhance methane production from WAS with the supplementation of CTS-Fe.

This study attempted for the first time to simultaneously recover P and enhance methane production from WAS by adding CTS-Fe. The potential mechanisms of P removal/recovery and methane production improvement from WAS by CTS-Fe addition were also revealed. The results showed that:

(1) CTS-Fe had an excellent adsorption capacity in a wide pH range. The maximum phosphate adsorption capacity for CTS-Fe was estimated to be 15.7 mg-P/g. Under acidic conditions, the route of the adsorption process was the reaction between phosphate and functional groups by electrostatic attraction and iron hydrolysates by ligand exchange, respectively. Owing to the increase of challenging OH^- ions, the electrostatic attraction weakened and ligand exchange was the dominant mechanism for phosphate adsorption under alkaline conditions.

(2) CTS-Fe addition could significantly improve the AD of WAS. The cumulative

methane yields at CTS-Fe dosage of 5.0, 10.0 and 20 g/L of were detected to be 209.9, 236.6 and 247.9 mL/g-VS, respectively, about 12% - 32% higher than the control (187.5 mL/g-VS). Moreover, the VS reductions in the CTS-Fe reactors were increased by about 1.04 - 1.22 times compared to the control (27.4%). Microbial community analysis confirmed that iron reducing bacteria (IRB) and acetoclastic methanogens were enriched in the CTS-Fe added reactors, most probably due to that CTS-Fe facilitated dissimilatory iron reduction (DIR) and DIET during AD process.

(3) P fractionation results indicate that 2.4 times higher non-apatite inorganic phosphorus (NAIP) reduction occurred in the solid phase of sludge at 20 g/L of CTS-Fe (6.72 mg/g-SS) when compared to the control (no CTS-Fe addition, 2.77 mg/g-SS). 57.8 mg of P was efficiently recovered from the liquid and solid phases in CTS-Fe (20 g/L) added AD reactor. Notably, under the test conditions, P adsorption capacity of CST-Fe was about 36.15 - 91.43 mg/g at dosage of 5 - 20 g/L, much higher than its use for synthetic phosphate-containing wastewater treatment (15.70 mg/g, as mentioned above). This observation is mainly due to the more complex composition of the liquid digestate involving more pathways to remove P. Characterization analysis demonstrated that partial Fe (III) on the CTS-Fe was reduced and effectively combined with P to form vivianite crystals on the CTS-Fe surface during AD process, with the mechanisms for P recovery dominated by ligand exchange and chemical precipitation.

Results from this work are useful for P removal/recovery from wastewater and WAS with enhanced AD process, which will help to provide a new approach for simultaneous P removal/recovery and enhanced methane production from AD of WAS.

Keywords**:** Chitosan-Fe (III) complex; Waste activated sludge; Anaerobic digestion; Methane production; Phosphorus recovery; Mechanism