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Impact of Ultrasonication-Ozonation Pretreatment on Anaerobic Digestion of Sewage Sludge

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ABSTRACT

The increase in the number of wastewater treatment plants and the sewage sludge makes it necessary to improve the efficiency of anaerobic digestion of sludge. Pretreatment of sewage sludge has shown important advantages in the sludge anaerobic digestion. This study investigated the effect of using ultrasonication-ozonation pretreatment on the anaerobic digestion process. It can be seen that this treatment effectively led to the increase of soluble chemical oxygen demand (SCOD). The optimal specific energy input was 6000 kJ/kg TS and the ozonation dosage was 0.10 g O_3/g TS. Under the optimum combined pretreatment condition, the biogas production was nearly 4-8 times than the raw sludge sample. It could be concluded that the combined pretreatment of sludge improved the anaerobic digestion of the sewage sludge.

INTRODUCTION

In China, sewage sludge production is on increase, due to the increase in wastewater treatment plants (Syed et al. 2017, Deng et al. 2017, Deng et al. 2009). At the same time, disposal routes of sewage sludge are subjected to more and more legal and social constraints: land disposal need large land, incineration is quite expensive and agricultural use is highly debated. Due to environmental and economical constraints, the anaerobic digestion of sludge is an efficient and sustainable technology to stabilize sludge (Xu et al. 2017). It can transform organic matter of sewage sludge into biogas, thereby reducing the amount of final sewage sludge solids that need to be disposed off while destroying most of the pathogens in the sludge. However, slow degradation of sewage sludge is a disadvantage of anaerobic digestion leading to a retention time in conventional digesters of about 20 days (Mavi et al. 2007).

Ultrasound is a sound wave with frequency beyond the normal hearing range of humans (>15-20 KHz). Ultrasound assisted sludge degradation has been widely studied for a long time (Braguglia et al. 2012, El-Hadj et al. 2007, Braguglia et al. 2011). It was reported that ultrasonical sludge disruption releases soluble organic cell compounds into the aqueous phase, which produce more biogas in digestion (Antti et al. 2005). However, very few articles handling chemical pretreatment (ozonation) of sludge together with ultrasound before anaerobic digestion are published. The aim of this study was to find out the possibilities to increase the amount of soluble chemical oxygen demand (SCOD) and methane production of sewage sludge using ultrasonication combined with ozonation technologies.

MATERIALS AND METHODS

Sludge sample: The sewage sludge used was collected from the wastewater treatment plant of Hanxi, Wuhan city and stored at 4°C before use. The main characteristics of sludge are listed in Table 1.

Pretreatment conditions: In the pretreatment experiments, the ultrasound treatment was performed using a Branson 2000 series bench-scale ultrasound unit (FS-600, Shanghai Sonxi Co., Ltd., China) for 8 min. The ultrasound unit had a maximum power output of 2.2 kW and operated at a constant frequency of 20 kHz. The components of the ultrasound system included the booster (gain 1:2) and the catenoidal titanium horn (gain 1:8) with a flat 13 mm diameter face. For exposure, the horn was put 2 cm deep into 500 mL samples with the specific energy input set to 1000, 3000, 6000, 10000,15000 kJ/kg TS.

Ozonation was performed with a CF-YG10 ozone generator (SMSM, Inc., China). Pure oxygen was used as feed gas and converted to ozone with a high voltage converter. The applied ozone dosage were 0.02, 0.08 0.10,0.15,0.25 g O_3/g TS (total solid).

Anaerobic digestion experiment: Plastic bottles of 1.5 L size were used as the digesters for anaerobic digestion of the pretreated sludge. 1 L of the pretreated samples were placed in the bottle and mixed with 200 mL activated sludge serving as inoculum. The bottles were capped and closed tightly

Table 1: Main characteristics of the sewage sludge.

Moisture (%)	Total solid (TS)[mg/L]	pH	Organic matter (%)
98.2	20220	7.0	79.8

with tubing protruding from it which is connected to a gas holder. The biogas volume produced was measured by displacement method.

Analytical methods: Sludge samples were directly used for total solids measurement and total solid was determined according to the standard methods (APHA AWWA, WPCF 1998). The digester performance was assessed through the examination of soluble chemical oxygen demand (SCOD) and volatile fatty acids (VFA). SCOD was determined by the potassium dichromate/ferrous ammonium sulphate method by a detector (ET3150B). VFA concentrations were analysed by a High Performance Liquid chromatograph (GP40, Dionex, CA) with an absorbance detector (AD20, Dionex) and a 300 mm - 7.8 mm Metacarb 67H column (Varian, CA) using 0.05 MH_2SO_4 as mobile phase. As mentioned above, the cumulative biogas production was measured by displacement method.

RESULTS AND DISCUSSION

Effect of specific energy input variation on anaerobic digestion process: The effect of the ultrasonication pretreatment on sludge solubilization was first investigated (Fig. 1 and 2). Fig. 1 and 2 present the increase of SCOD and VFA concentration of sludge with different specific energy input when the ozonation dosage was 0.10 g O_3/g TS. It can be shown that, after ultrasonication and ozonation pretreatment, SCOD and VFA concentration were both increased. As seen in Fig. 1, the SCOD of raw sewage sludge was 218 mg/L. With the increase of specific energy input, the SCOD climbed rapidly to 954 mg/L when the specific energy input increased from 1000 to 6000 kJ/kg TS. As seen in Fig. 2, VFA concentration also clearly increased with specific energy input reaching a value of 538 mg/L for sludge pretreated with 15000 kJ/kg TS. This may be explained by the fact that ultrasonic treatment can specifically alter the cell membranes of microorganisms and released intracellular fluids with a high content of proteins, so a large amount of insoluble organics of sludge flocs was transferred into soluble organics and it will promote the biogas production. However, the increase in SCOD was very limited when the specific energy input increased further from 6000 to 15000 kJ/kg TS. It may be inferred that the application of specific energy input higher than 6000 kJ/kg TS does not provide significant solubilisation. Based on the above, the specific energy input 6000 kJ/kg TS was concluded as the optimum for effective floc disruption.

Effect of ozonation dosage variation on anaerobic digestion process: Fig. 3 represents the effect of ozonation dosage on the concentration of SCOD. In the experiment, the pretreatment was performed with the specific energy input set to 6000 kJ/kg TS, while the ozonation dosage varied from 0.02 to 0.25 g O_3/g TS. It has been observed that the SCOD concentration first increased with the increase in ozonation dosage. However, higher ozonation dosage (>0.1 g O_3/g TS) may lead to limited increase of SCOD and further increase in ozonation dosage even caused a reduction in SCOD. This may be due to the process called mineralization which results from the consequent oxidation of the released soluble organics to carbon dioxide (Kameswari et al. 2011). Thus, it can be concluded that the optimum ozonation dosage may be 0.10 g O_3/g TS.

Effect of ultrasonication-ozonation combined pretreatment on biogas production: The biogas production experiments were employed to evaluate the effect of pretreatment on the biogas production. The combined-pretreated samples were performed with the optimum specific energy input and ozonation dosage. Meanwhile, the untreated samples were also investigated for comparison. All results are shown in Fig. 4. As it can be observed, the specific biogas production of combined-pretreated sludge was significantly higher than the one obtained with the same untreated sludge. Especially sample produced for 18 days, the biogas production reached to about 385.2 mL, nearly 8 times of the raw sludge production. For the different stage in sludge anaerobic digestion process, the biogas production of combined-treated sample was 4-8 times of the raw sludge production. This increase in biogas production may be because the ultrasonication-ozonation pretreatment released more organics for anaerobic digestion in comparison to the untreated process and ozone, as a strong oxidant, can not only solubilize organics, but also able to convert nonbiodegradable solids into biodegradable ones. On the other hand, the biogas production of combined-pretreated samples increased insignificantly in the first nine days, followed by a slower biogas production increase from day 9th to 18th, and no significant increase was observed with further digestion.

CONCLUSIONS

This work demonstrated the possibility of using

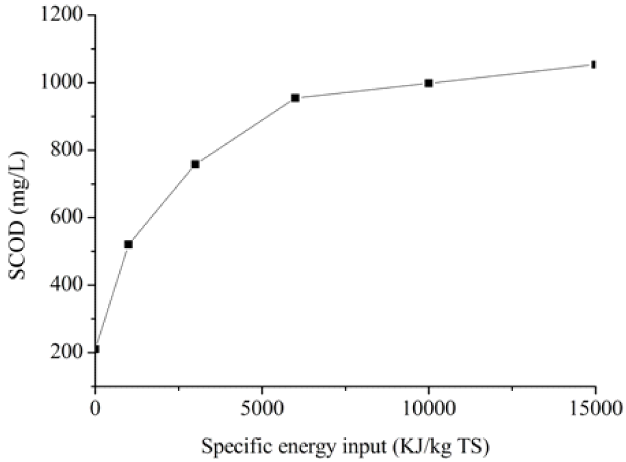

Fig. 1: SCOD of combined pretreated sludge as a function of specific energy input.

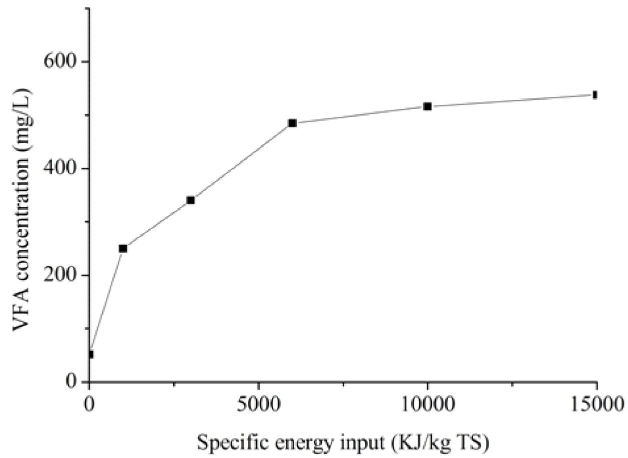

Fig. 2: VFA concentration of treated sludge as a function of specific energy input.

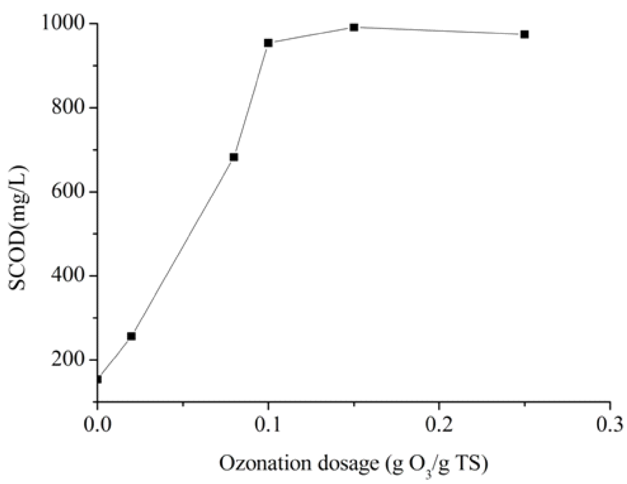

Fig. 3: SCOD of combined pretreated sludge as a function of ozonation dosage.

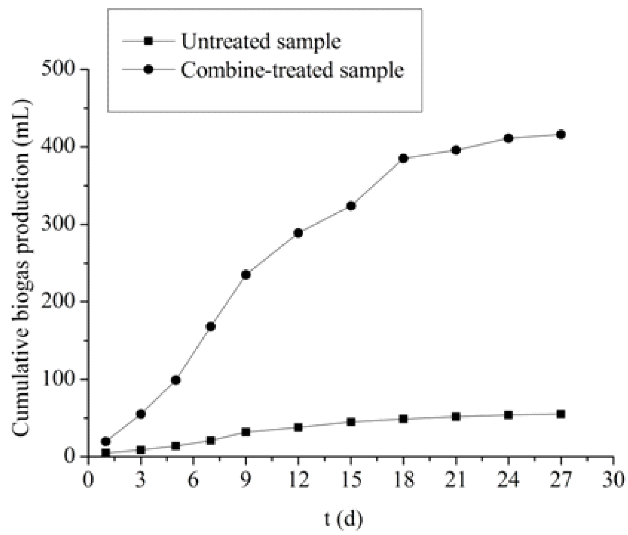

Fig. 4: Cumulative biogas production of combined-treated sludge samples and raw sludge sample as a function of time.

ultrasonication-ozonation pretreatment to sludge anaerobic digestion to enhance the biogas production. Both, ultrasound and ozone lead to solubilisation of sewage sludge solids, but with higher specific energy input and ozonation dosage, the SCOD increased slowly. The optimum combined pretreatment condition was 0.10 g O_3/g TS ozonation dosage and with the specific energy input of 6000 kJ/kg TS. Under the optimum condition, the cumulative biogas production was nearly 4-8 times of raw sludge. The enhanced performance obtained in combined ultrasonication-ozonation pretreatment make this process very promising for future application in wastewater treatment plants.

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