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The influence of sludge concentration on its thermophilic anaerobic digestion performance based on low temperature thermal hydrolysis pretreatment

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Abstract: The dewatered sludge with TS of 14.62% was diluted to 4 different concentrations of sludge (TS: 6%, 8% , 9% , 12%) and were pretreated at 90℃ for thermal hydrolysis. The performance of thermophilic anaerobic digestion was evaluated with the removal efficiencies of SS, VSS and biochemical methane potential (BMP) experiments were also carried out at (55±1)℃ to investigate cumulative gas production and biogas production rate. The results indicated that VSS removal efficiency increased with the increase of sludge concentration up to the peak of 26.5% when the sludge concentration was 9%. The VSS removal efficiencies of the sludge with TS of 8%, 9% and 12% were over 20%. The viscosity of the sludge with 9% sludge concentration was 18400 mPa•s , which was much higher than 2900 mPa•s when the sludge concentration was 8% . The result showed that the thermal hydrolysis of sludge with TS of 8% had the best performance. The cumulative gas production of the thermophilic anaerobic digestion with only thermal hydrolysis pretreatment of sludge with TS of 8% was 210.24 mL/g-VS, gas production rate was 0.0074 h^{-1} and the removal efficiency of VSS was 22.8%.

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Keywords: sludge concentration; thermophilic anaerobic digestion; low temperature thermal hydrolysis;

1. Introduction

With the increase of the municipal waste water requirement, the sewage sludge production increases rapidly. By

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the end of 2010, the number of the urban sewage treatment plant reached 2496. The quantity of the urban sewage sludge generated was more than 20 million ton in 2012[1], in which 60% were generated from typical biological waste water treatment process.[2]According to the 12th Five-year Plan of China, the quantity of urban sewage sludge will increase 5.18 million tons per year, reemphasizing the importance and urgency of urban sewage treatment. Due to the large amount of biomass energy in urban sewage sludge, it is beneficial for China to develop biomass energy recycling technique beside energy conservation and waste emission reduction. Anaerobic digestion can effectively reduce the sludge volume and produce biomass gas at the same time via three stages: hydrolysis, acidification, and methanogenesis.[3 4 5 6] Hydrolysis stage is the rate control step for anaerobic digestion.[7] Under anaerobic condition, anaerobic bacteria break down organic matters into simpler organic matters, before turning them into CH_4 and other inorganic matters, such as CO_2, H_2O, H_2S. Sludge hydrolysis rate and efficiency is low due to the difficulty to degradate cell wall, which limits the anaerobic digestion efficiency. Sludge pretreatment can effectively improve the destruction of cell wall and dissolve out intracellular organic compounds, so as to improve the sludge anaerobic digestion performance and maximize the biomass energy recycling efficiency. The current sludge digestion pretreatment technology mainly includes mechanical crushing, thermal hydrolysis, alkali treatment, ultrasonic treatment, ozone oxidation and chlorine oxidation.[8 9 10 11 12 13]

Thermal hydrolysis pretreatment can effectively improve the sludge digestion performance and microbial degradation rate.[14] High temperature (130 ~ 210 ℃) and short-term (15 ~ 60 mins) pretreatment is a commonly used as pretreatment method, which can do degrade sludge organic matters effectively. However, it has many defects such as large energy consumption, high equipment requirements and operation risk.[15] Low-temperature (50 ~ 100 ℃) thermal hydrolysis is an effective way to improve biogas production and organic matter degradation [16]. The high temperature thermal hydrolysis treatment can increase sludge digestion efficiency than low temperature thermal hydrolysis treatment long time (3 ~ 10 h) thermal hydrolysis treatment has been reported to promote cell wall breaking as well.[17] However, long time thermal hydrolysis pretreatment also has defects such as the increase of sludge treatment plant volume as well as and increase the energy consumption. Therefore, the low-temperature and short-term thermal hydrolysis pretreatment will be more suitable for sludge digestion.[18]

2. Methods

2.1. Material

The sludge samples were taken from the full scale waste water treatment plant of Yixing City, Jiangsu Province. The organic matter content of the sludge was 62.04% and sludge moisture content was 85.38%. Sludge samples were diluted with distilled water to TS 6%, 8%, 9%, 12%.

2.2. Thermal hydrolysis pretreatment experiment

According to Mr. Appels's research results[17], after 30 mins treatment of sludge at 90 ℃, its cell rupture proportion, SCOD/TCOD and gas production rate significantly increased. Therefore, low-temperature short-term thermal hydrolysis pretreatment conditions(90℃, 30 mins) was set to be the experiment condition.

Thermal hydrolysis treatment was performed in a 2-L reactor (Figure 1). Sludge samples with TS of 6%, 8%, 9%, and 12% were added into the reactor at room temperature, respectively for 30 mins heating at 90℃. The sludge was stored at 4℃ in the laboratory before the experiments. The removal efficiencies of SS and VSS at different sludge concentration conditions were analyzed.