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Improving methane production during the anaerobic digestion of waste activated sludge: Cao-ultrasonic pretreatment and using different seed sludges

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Abstract

Three individual seed sludges, which domesticated by filter paper (SS1), food waste (SS2) and grease (SS3)，respectively, were used for enhancing the methane production of waste activated sludge (WAS). Also CaO-ultrasonic pretreatment was performed on WAS to evaluate the effectiveness on improving efficient anaerobic digestion (AD). The results showed that WAS being acidated for 24 h after CaO-ultrasonic pretreatment was an effective method for increasing initial methane production rate. The daily concentration of volatile fatty acids (VFAs) during the AD course showed that the propionic was easier to be reduced after adding seed sludge. The optimum seed sludge for improving methane production and biodegradability of WAS was SS3, which led to an increase in the methane production of 68.92% and VS reduction of 69.20% higher than the control. This pretreatment combined with adding optimum seed sludge can greatly improve clean energy generation from WAS.

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Keywords: Waste activated sludge; anaerobic digestion; Cao-ultrasound pretreatment; seed sludge; methane production;

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1. Introduction

Activated sludge process is an effective method for sewage treatment. During AD process, large amounts of excess WAS will be produced in the process. Early in 2007, 4.54×10^6 tons of dry WAS was produced in China[1]. And according to prediction, the production of WAS in China will be more than 6×10^8 tons[2]. WAS not only contains various pathogens and persistent organic pollutants, but also contains large amount of inorganic matters. Traditional handing methods such as landfill and incineration will lead to secondary environment pollution[3].

AD treatment has been widely studied for stabilizing WAS[4]. The advantages of this method were obvious: (1) effective reduction in sludge volume, (2) produce clean energy in the form of biogas, (3) environment friendly reaction products, (4) the lower treatment cost requirement and spaces than the traditional process[5,6,7]. Though AD process brought us environmental and economic benefits, there were still some defects: (1) the limited conversion of organic matter, (2) long retention times (3) non-biodegradable organic structures[8,9,10]. These defects are mainly caused by the retarded hydrolysis of WAS. The microbial cells and membrances in the WAS are not easily to be penetrated by the hydrolytic enzymes[11]. Therefor, various cell disruption methods have been explored to enhance the hydrolysis rate and methane production such as physical, chemical, biological and combined pretreatments[12].

Among these technologies, ultrasonic pretreatment has the advantage of destroying microbial cells to extract intracellular material[13]. Additionally, the short chain acids production can be enhanced and AD process can be shortened due to the release of soluble organic substrates from WAS[14]. In Teihm's study, the VS removal of WAS increased from 21.5% to 33.7% (+36%) after ultrasonic pretreatment at 41 kHz for 150min[15]. Another research showed that 24% increasement of biogas production was reached after ultrasonic pretreatment at 20 kHz for 60s[16].

Similarly, alkaline pretreatment was examined to be an effective method to destroy the cell surface structure and make the the cellular substances more susceptible to enzymatic action. Moreover, alkaline pretreatment needed simple device which was easy to be operated[17]. Combined pretreatment of alkaline and ultrasound pretreatment was demonstrated to be able to reduce the dewaterability of WAS more effectively[18]. NaOH and KOH was used as the alkaline part because of the strong alkalinity. However, a high concentration of Na^+ or K^+ may cause AD process slow down and even inhibit the activity of methanogens[19]. $Ca(OH)_2$, as a kind of alkalis, also can improve the AD efficiency of WAS and have less inhibiting effect than NaOH or KaOH[20]. Lime, as a cheap industrial raw material which mainly contains CaO, can improve carbohydrate digestion and biogas production with smooth cordgrass as fermentation substrate[21]. However, few reports have been published about pretreatment of WAS using CaO as an alternative to NaOH or KaOH.

In order to enhance the effective of WAS degradation, the pretreatment methods have been widely explored, but the effect of seed sludge addition was often ignored. Anaerobic seed sludges may come from the bottom from the pond, deep in the sewer, cattle cesspool or the pig cesspool[22]. Also inoculums can be domesticated by pig manure, cow dung, cornstalk, vinasse or food waste[23,24]. Different inoculum may result in different biogas production rate, total biogas production or methane percentage because of the special species and amounts distribution. Using the appropriate seed sludge can shorten start-up period and improve the methane production[24].

Consequently, in our research, three kinds of seed sludges domesticated with grease, food waste and filter paper, respectively were added into the WAS which pretreated in CaO-ultrasonic way, aim to: (1) evaluate the effect of CaO-ultrasonic pretreatment, (2) enhance the methane production rate, VS reduction and total methane production of WAS, (3) explore a better combined method to deal with WAS, (4) lay a theoretical foundation for further industrial application.

2.Materials and methods

2.1 WAS and seed sludges

The WAS was collected from department of dehydration of Xianyanglu wastewater treatment plant (Tianjin, China). Total solids (TS) of WAS was diluted from 20% to 8% before used in the experiments. The basic characteristics of WAS is shown in Table. 1.

The resource of seed sludges was from the sewage treatment plant in Chengdu, Sichuan, China. The sludge was separated into three parts and domesticated in the same conditions except only one factor, inoculation of carbon source. The first inoculum was grease with daily dosage of 1g·L-1d-1. The second and the last inoculums were food