Experimental study on the methane production of municipal sewage sludge anaerobic digestion

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Abstract. Conducting different moisture content conditions and different added amount conditions of bacteria municipal sludge anaerobic digestion experiment is to optimize the best moisture content condition and the best bacteria condition. The results show that under the different moisture content conditions of respectively 85%,87%,89%,91%,93%,95%,conducing sludge anaerobic digestion experiment, the cumulative methane production reaches 222.8ml/g-VS when moisture content is 93% and is increasing 13.5% contrasted with the sludge with moisture content 85%, and VS removal rate reaches 47.41%. Under different bacteria added amount condition to conduct sludge anaerobic digestion, namely 0,15 and 30ml/kg-sludge, the cumulative methane production reaches 293.23ml/g-VS when bacteria addition amount is 30ml/kg-sludge and is increasing 43.5% contrasted with the sludge without adding bacteria, and VS removal rate reaches 49.09%. Integrating moisture and bacteria condition, the cumulative methane production reaches the maximum 345.51ml/kg-VS when the sludge moisture content is 89% and the bacteria amount is 30 ml/kg-sludge. At the same time, VS removal rate reaches the maximum 51.46% when the sludge moisture content is 91% and the bacteria amount is 30 ml/kg-sludge.

Keywords: municipal sludge, anaerobic digestion, moisture content, bacteria.

1. Introduction

Sludge production increased dramatically in the cities, and most of the urban sewage treatment plants are not building sludge stabilization facility construction and only sin trans after sludge dewatering. Sludge safe disposal is no more than 20% [1]. Sludge contains pathogens, heavy metals, PCBs and dioxins, accompanied with odor released [2], but also has high moisture content, and high organic matter, leading to disposal difficult. Now account for 44.3% of China's land use of sludge disposal, sanitary landfill or about 31%, about 11% of the other methods, no disposal accounts for about 13.7% [3]. Due to the lack of viable disposal technology and related policies, standards and norms, improper disposal of sludge in recent years has brought a lot of environmental problems. With the increase of emissions from urban sewage, sewage treatment rate continues to improve, but also a sharp increase in the amount of sludge, sludge treatment and disposal problems have become increasingly prominent.

Anaerobic digestion under anaerobic conditions, by facultative and obligate anaerobic bacteria degradation of organic matter in the sludge, the final product is carbon dioxide and methane gas (or gas sludge digestion gas), the sludge stable. Anaerobic digestion and aerobic digestion, compared with low cost, low energy consumption and digestion process is more stable [4] and so on. Anaerobic digestion has a good volatile solids removal, if using methane, the net operating cost is low, and bio-solids are for garden or agricultural, and pathogen activity is low, and it can reduce the total amount of sludge [5].

In order to get the process of anaerobic digestion gas production in the best optimum moisture content and the amount of bacteria added to improve the efficiency of anaerobic digestion, the test carried out in different moisture content and different dedicated amount of bacteria to study the methane-production and the change of organic matter during sludge anaerobic digestion.

2. Materials and methods

2.1 Test material

Municipal dewatered sludge used in the experiment is from a sewage treatment plant in Wuhan. And the moisture content is 85.02%. The main properties of the sludge are shown in table 1. The sewage treatment plant mainly treatments domestic sewage and adopts the traditional A^2/O process.

The bacteria using in this trial is from Wuhan Institute of Virology, CAS. It gets two bacteria bacillus, two bacteria Staphylococcus and one bacteria Pantoea Agglomerans cultivation at pH 7.0-7.2, temperature 30℃ and enlarges cultivation in fermentation tanks.

Table 1 the main properties of sludge

Main items	value
Moisture content/%	7.08
pH	85.02
TS/(g Ł-1)	149.8
VS/(g Ł-1)	85.13
COD/(mg Ł-1)	24080
TN/(mg Ł-1)	1570
NH3-N/(mg Ł-1)	1400

2.2 Test methods

Take enough sludge sample to dilute and measure its moisture content, COD, TS, VS and other parameters. It adjusts the moisture content to 87%, 89%, 91%, 93%, 95% by adding water after retrieving, and then put 4℃ freezer to save for later using. The sludge with six kinds of moisture content will separately take 2kg to the 2000ml suction flasks. And a certain amount bacteria is added in these suction flasks and the other are adding an equal amount tap water. Suction flasks are placed in constant temperature water bath with temperature 35℃ and with spring net to secure it. The temperature difference is ±0.5℃. Gas components and methane are measure every 24h.

2.3 Measurement items and methods

TS (total solids mass fraction), VS (volatile solids mass fraction): gravimetric method [7]; COD (chemical oxygen demand): reactor digestion and colorimetric; TN (total nitrogen mass fraction): TNT persulphate digestion and colorimetric; NH_3-N content: salicylic acid and colorimetry; the amount of methane-production: infrared biogas analyzer and drainage act.

3. Results and discussion

3.1 Influence of different moisture content to methane-producing in sludge anaerobic digestion

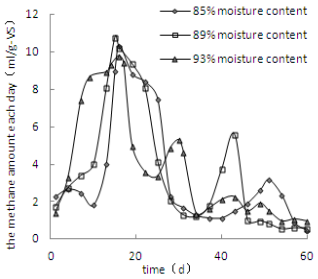

Fig 1 daily volume of different moisture content sludge anaerobic digestion

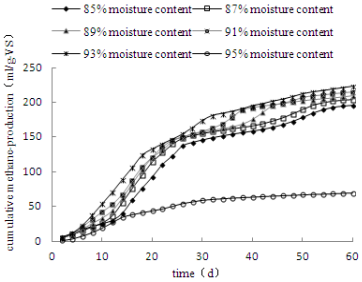

Fig 2 cumulative methane-production volume of different moisture content sludge anaerobic digestion

Methane-production. Sludge moisture content is the percentage of water contained in the sludge and sludge weight ratio of the total weight is an important indicator of sludge detection. Shown in Figure 1, the moisture content in the range of 85% to 93%, the higher the moisture content, the shorter the methanogenic phase into the rapid time required: when the moisture content is 85%, to the rapid time required for methanogenic phase is about 10d; when moisture content is 89%, it is about 9 days; when the moisture content was 93%, the time required to enter the methanogenic phase is only five days. At the same time, the moisture content 93% of the sludge anaerobic digestion reaches peak methane-production in the fourteenth day, and sludge moisture content 89% and 85%, respectively are the fifteenth day and the sixteenth day. As the experiment, after a large number of methane-production, 93% moisture content sludge in the first 30 days and reached another peak, and sludge moisture content 89% and 85% were the 43rd day and the 51st day. When the moisture content ≤93%, with the increase of moisture content that into the fast methanogenic phase is shortened, but the amount of methane-production per unit mass VS gradually increases. The reason may be the increased moisture content, providing more adapted environment to methanogens breeding. There are two peaks in methane-production of sludge anaerobic digestion process. The first peak is that a large number of easily degradable organic matter is disintegrated by microorganisms and produces methane; the second peak occurs after a lot of easily degradable organic matter is decomposed use, and microbial degradation of organic matter will be difficult to gradually decompose and produce methane and reach a peak.

After 60 days of anaerobic digestion, accumulated methane production is shown in Figure 2 with sludge anaerobic digestion of different moisture content. After anaerobic digestion 60 days, the most cumulative amount of methane production is 93% moisture content sludge, and achieves 222.8ml/g-VS, increasing 13.5% compared with 85% moisture content sludge; the least cumulative production of methane is 95% moisture content sludge, be 69.9ml/g-VS, compared with 85% moisture content sludge declining much.

Removal efficiency of VS. The main purpose of sludge anaerobic digestion is a biochemical degradation of organic matter, and makes the sludge matrix to reach a steady state. Typically matrix organic content is expressed using VS or SCOD. Figure 3 shows VS change the different moisture content before and after anaerobic digestion. As the moisture content of the original sludge were 85%, 87%, 89%, 91%, 93% and 95%, VS contents were 85.13g/L, 73.88g/L, 62.51g/L, 51.15g/L , 39.78g/L and 28.42g/L. After 60 days of anaerobic digestion, sludge VS removal rate increases at first and then decreases, with moisture content increasing, and increases again, and finally decreases. Wherein, when the moisture content was 93%, VS removal rate reaches a maximum 47.41%.

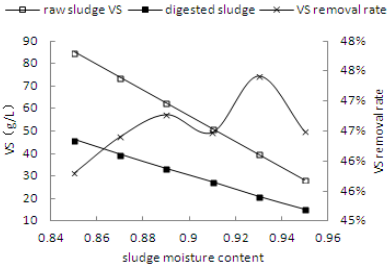

Fig 3 VS changes of sludge in different moisture content

3.2 The influence of different amount of bacteria to methane-producing in sludge anaerobic digestion.

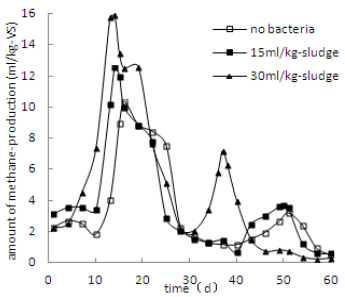

Fig 4 different bacteria amount of 85% moisture content sludge's methane-production

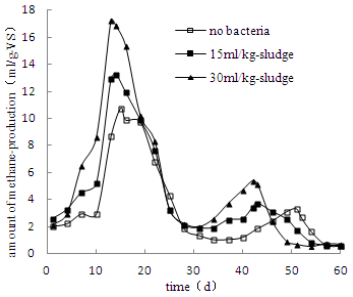

Fig 5 different bacteria amount of 87% moisture content sludge's methane-production

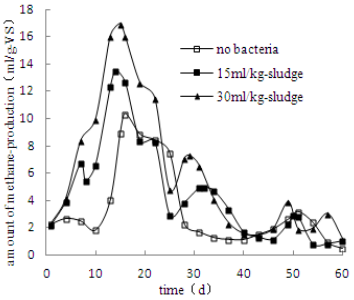

Fig 6 different bacteria amount of 89% moisture content sludge's methane-production

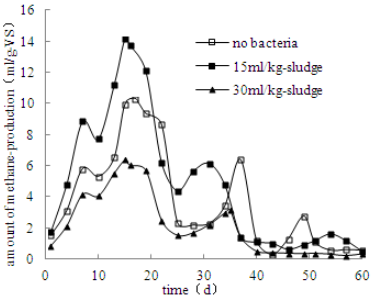

Fig 7 different bacteria amount of 91% moisture content sludge's methane-production

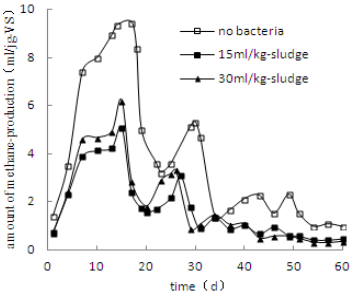

Fig 8 different bacteria amount of 93% moisture content sludge's methane-product

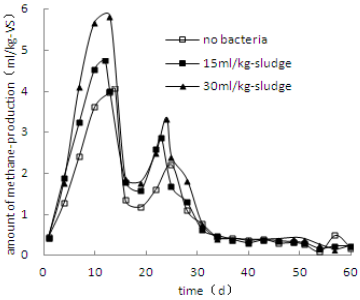

Fig 9 different bacteria amount of 95% moisture content sludge's methane-production

Methane-production. It impacts the amount of methane-production anaerobic digestion that adding bacteria. Fig 4 shows that methane-production of bacteria dosage 15ml/kg-sludge and 30ml/kg-sludge conditions increases compared with no bacteria added, and the highest methane-production per day, respectively be 12.54ml/g-VS and 15.92ml/g-VS, and increases 21.0% and 53.7% compared with that without bacteria added. At the same time, the time to reach peak methane-production is also different: the time that no bacteria added anaerobic digestion reaches the first peak and the second

peak is the 16th day and the 51st day, while the bacteria 15ml/kg-sludge is the 14th day and the 50th day, and bacteria 30ml/kg-sludge is the 14th day and 37th day. Seen from Fig 4 to Fig 6, bacteria is added to promoting the decomposition of organic matter, be accelerated anaerobic digestion. Reasons for such results are: Bacillus in their reproduction, they can also release the high activity of enzymes to divide the hardly decomposable macromolecules into smaller molecules; Under anaerobic environment staphylococcus can get glucose, maltose and sucrose decomposition of organic acids; Pantoea is facultative anaerobic, and may be maltose, sucrose and Xylose sugars to produce acid decomposition. In the initial stages of anaerobic digestion, bacteria multiply and sludge decomposition of organic sugar improve the efficiency of the anaerobic digestion.

When the sludge moisture content of 91%, as shown in Figure 7, the bacteria dosage 15ml / day increased gas production without adding bacteria when compared with sludge kg, but the dosage 30ml/kg-sludge when daily gas production without adding bacteria relatively reduced. Moisture content to 93%, the Figure 8, the experimental group added gas production bacteria not added bacteria in the experimental group compared with varying degrees of reduction. Adding bacteria causes gas production declining and that may be due to the anaerobic digestion process, increases the moisture content of the sludge, and the buffering capacity decreased. Bacteria decomposes organic matter and continues to produce organic acids, leading to acid hydrolysis and fermentation stage phase reaction rate exceeds methanogenic phase, so pH decreases that affects the methanogens's living environment.

For the 87% moisture content sludge, shown in Figure 10, bacteria is added to increase the amount of cumulative methane production: no bacteria added, the cumulative amount of methane-production 204.28ml/g-VS after anaerobic digestion; Add bacteria 15ml/kg of sludge and 30ml / kg of sludge than those without increased 43.5% and 22.3% of bacteria added.

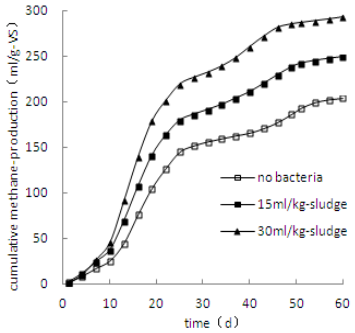

Fig 10 cumulative methane-production volume of different amount bacteria sludge anaerobic digestion

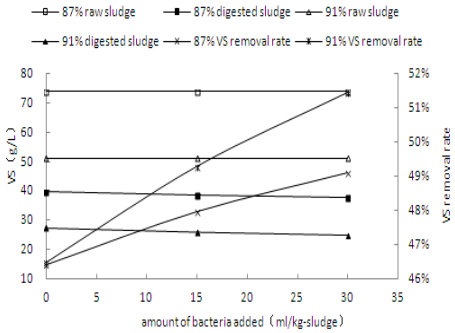

Fig 11 VS change of sludge in different amount bacteria

Removal efficiency of VS. Add bacteria to promote anaerobic digestion of conduct, but also increased the VS removal. 11, species was added in varying degrees of increased removal VS: moisture content of 87% for sludge, bacteria added amount 0, 15 and 30ml/kg sludge, the anaerobic digestion after 60 days , VS removal rates were 46.41%, 47.96% and 49.09%, adding bacteria 15 and 30ml/kg-sludge in the experimental group compared with the experimental group did not add bacteria were increased by 3.33% and 5.77%; for the moisture content of 91% when the sludge, bacteria dosage 0,15 and 30ml/kg of sludge, anaerobic digestion, after 60 days, VS removal rates were 46.48%, 49.30% and 51.46%, adding bacteria 15 and 30ml/kg-sludge the experimental groups are compared no species in the experimental group and increase 6.05% and 10.71%. Visible, adding bacteria to a higher moisture content sludge removal VS better.

3.3 Influence of different moisture content and different amount of bacteria to methane producing in sludge anaerobic digestion.

Considered different moisture conditions and the effects of different conditions on the anaerobic digestion of bacteria produce methane experiments, in this set of experiments integrated moisture and bacteria conditions of different moisture content, different bacteria of sludge repulsive conditions oxygen digestion and methane production. Anaerobic digestion for 60 days, it basically stopped gas production. Cumulative production of methane and VS removal rate are shown in Figure 12. The results show that with the increase of moisture content, the cumulative amount of methane produced was increased slowly at first, after a sharp downward trend, and the moisture content of 89%, lower

amount of bacteria added 30ml/kg sludge conditions, the cumulative maximum amount of methane value 345.51ml/g-VS. Meanwhile, VS removal in 91% moisture content, the amount of bacteria added 30ml/kg when the sludge reached the maximum 51.46%.

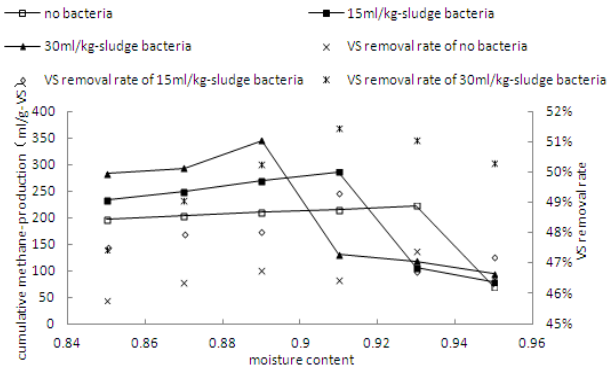

Fig 12 influence of different moisture content and different bacteria amount to methane-producing in sludge anaerobic digestion

4. Conclusions

(1) The higher moisture content is, the shorter time that has a rapid methane-production enters. And the cumulative methane production gradually increases and it reaches 222.8ml/g-VS when moisture content is 93% and is increasing 13.5% contrasted with the sludge with moisture content 85%, and VS removal rate reaches 47.41%.

(2) Bacteria be added promotes the decomposition of organic matter and is accelerated anaerobic digestion. As the amount of bacteria increases, the amount of methane production increases. The main reason is that bacteria will release enzymes during which could divide the macromolecules into small molecules that can be used during fermentation breeding. Bacteria could break down part of carbohydrate to organic acids that promote sludge anaerobic digestion. When the amount of bacteria is 30ml/kg-sludge, 60 days cumulative methane production is increasing 43.5% comparing with that not add bacteria and VS removal rate is increasing 10.71%.

(3) Integrated moisture content and bacteria conditions, the cumulative methane production reaches the maximum 345.51ml/kg-VS when the sludge moisture content is 89% and the bacteria amount is 30 ml/kg-sludge. At the same time, VS removal rate reaches the maximum 51.46% when the sludge moisture content is 91% and the bacteria amount is 30 ml/kg-sludge.

(4) Due to the amount of bacteria is inadequate, so it needs more researches to carry out experiments in the aspects of bacteria.

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