The Quality Improvement of Biogas by Air Mixing

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Abstract

The primary objective of this study is to design and optimize air insertion Components for biogas system widely implemented in swine farms. This experiment is performed with a small-scale 2.5 m^3 operating on Controlled swine waste. The result shows that an optimum ratio of injected air per volume of biogas production is approximately 4.5 %. In this condition, measurement of H_2S trace can be reduced from an average level of 644 ppm to undetectable amount within 48 hours. Another Significant Finding is the methane content of biogas produced from digester with air supplement is decreased by maximum of 3.5 % to the lowest level of 77 % which is still acceptable by all utilization equipment. Finally economic analysis suggests that an investment in air mixing equipment and operating costs results in an average payback period of 1.32 years benefiting from utilization equipment maintenance cost reductions. And long Life cycle Period.

Keywords: Biogas, Air Mixing

Introduction

Biogas is mostly used to act as fuel to produce thermal power such as for cooking in kitchens or as fuel for machines. From the elements of biogas that includes methane (CH_4) with a percent of 60-70, carbon dioxide (CO_2) with a percent of 28–38, etc., about 2% of the amount has hydrogen sulfide (H_2S) and steam [1]. By which hydrogen sulfide gas is the leading cause of the decaying of machines as well as other equipment with gas usage. Despite that the amount of hydrogen sulfide gas is very little within biogas, it is still yet dangerous to the health and triggers a disturbing smell resulting in pollution to the environment. Because of these reasons most entrepreneurs don't have the motivation to use biogas as renewable energy. Also, most elimination systems for hydrogen sulfide gas that are being used in the present day usually must be imported from foreign countries which would result in high expense. Therefore, there are limited entrepreneurs that can install it while the regulations of the series production of electricity of biogas limit the intensity of hydrogen sulfide gas to only 200–500 ppm. Because of the given problems it can be seen why it is necessary to manage a system to improve the quality of biogas in order to then use it for the elimination of hydrogen sulfide gas. This would be done by letting it is according to its application for it to be qualified before being applied for any beneficial use, until its efficiency has been improved.

Theory and Operation Process

Biogas

Biogas is formed from the decomposition of organic matter with a complicated structure which includes carbohydrates, proteins and fat [2]. These are used to act as nutrients in the holding fund of bacteria in the groups without air insertion, by which the bacteria in the waste water treatment system without air insertion can be divided by its reactions in three ways which are [3-4]:

-Acid Former Bacteria

These groups of bacteria will biodegrade organic substances in the waste water to become different types of organic acids.

-Methane Former Bacteria

Its function is to biodegrade organic acids to become methane gas and carbon dioxide.

-Sulfate Reducing Bacteria, SBR

The amount of this bacteria depends on the intensity of sulfate (SO_4) within the waste water, by which it's function is to suck oxygen from sulfate compounds which changes the sulfate— that is in the form of sulfate— to become hydrogen sulfide (H_2S)

The Formation of Hydrogen Sulfide (H_2S)

Hydrogen sulfide is a gas that can be generally found in nature. Because of its similar smell to rotten egg, it's become a gas that is widely recognizable. This gas is formed from the decaying and biodegradation of organic substances. From the chemical reaction that is called sulfate reduction, an air-free bacterium has the function to biodegrade organic substances. This is done by using sulfate as an electron receiving substance and transforms into sulfide. The reaction between sulfide (s^{2-}) and water triggers the formation of hydrogen sulfide (H_2S). Hydrogen sulfide (H_2S) can be often found in sewage manholes or in sewage drains. Waste water that has a high amount of sulfide is waste water that comes from different types of industrial factories such as an oil refinery. The formation of hydrogen sulfide in an air–free waste water treatment system with a high sulfate rate can result in many problems such as the smell of rotten egg, the problem of low endurance of the erodibility of metal, the poison of methane former bacteria and how it makes the amount of methane gas decrease. It can also affect the aeration system which recently, because of sulfide, is a reducing agent that can react to oxygen. Then, when taking biogas that has hydrogen sulfide for beneficial use, there will be an eroding problem with different tools. This makes it necessary to clean biogas before use. When hydrogen sulfide gas escapes into the atmosphere, it will then touches oxygen and become sulfur dioxide gas. Underneath oxygen and suitable humidity it will form into mist of vitriol that is spread throughout the atmosphere which is called acid mist. Then, when the air has high humidity it will turn condense which will make these particles fall along with the rain which is called acid rain.

Plug Flow Anaerobic Digester

Plug flow anaerobic [5] is another treatment system that does not use air that is commonly used within animal farms. By which these farms use concrete pits that can control the flow of waste water to be "plug flow" type. The top of the plug flow anaerobic digester has installed a PVC or HDPE plastic dome for the function to confine biogas for beneficial use. In the plug flow anaerobic digester there is an installation of a biogas vascular bundle to gather biogas for other uses. The plug flow anaerobic digester's function is to act as a ferment pit to disintegrate organic substances within waste water, as well as to distribute concentrated waste and clear waste from each other. Concentrated waste or solid dregs will be fermented in the plug flow anaerobic digester for about 40 days to change the organic substances from within the waste water to become organic acids, as well as to change into biogas by air-free bacteria. The results from the fermentation of organic substances will make the wastewater decrease its COD about 70–80%. In the operation of the plug flow anaerobic digester there must be a pulling of garbage which went through complete fermentation around 1% of the plug flow anaerobic digester's capacity per day in order to prevent the accumulation of too much dregs. This makes it necessary for the plug flow anaerobic digester to dig and peel just as the anaerobic covered lagoon. By which the dregs that has been sucked out will be divided into two parts. The first part will be left out to dry on a dregs dryer. The other part will be cycled back into the waste water pit in order to increase the amount of bacteria as well as mix bacteria with waste water which will make the disintegration happen faster. The elements of the plug flow anaerobic digester can be shown in Figure 2. The features of the plug flow anaerobic digester while in actual use in a pig farm can be shown in Figure 1.

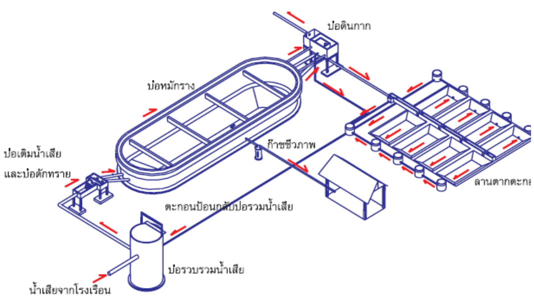

Figure 1 Elements of plug flow anaerobic digester treatment system [6]

Materials and Methods

To study how to adjust the quality of biogas that can be produced from a pig manure gutter pit by air insertion, pig manure from a pig farm was used. Other than taking the pig manure to create fresh fertilizer for farm plants, some of the wastewater that was formed from cleaning the pig stables was released into the river. This resulted in the disturbance of smell to the region. Therefore, we scooped the pig manure out first before cleaning the pig stables. This was meant to speed up reactions for the system in creating a balanced mesospheric condition. By which when starting the experiment for the first raw materials, we used to seeds and pig manure waste water that has been mixed with pig manure and waste water with a proportion of 2% TS and (solid pig manure about 20 Kg. per 100 L of water). After that every time before adding waste water in each day we will mix fresh pig manure with water by using a measuring chart for measuring the amounts and will store the pig manure in a room with a temperature of 0 – 3°C before use. By which each experiment has a different amount of air insertion which can be shown in Figure 2 that shows the adjustment of amount of air according to the proportion of each experiment.

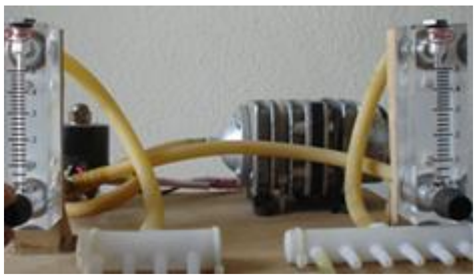

Figure 2 the adjustment of amount of air according to the proportion at Chiang Mai University

Results and Discussion

Air insertion at 4%

From the experiment of reducing the intensity of hydrogen sulfide gas in biogas by adding 4% of air of the amount of biogas, we found that a ferment pit without an air insertion system can produce biogas at an average of 224 and 196 L per day. A pig manure gutter pit with an air mixing system of 2 times per day can produce biogas at an average of 211 L per day and a pig manure gutter pit with a continuously air mixing system can produce biogas at an average of 176 L per day with an average temperature of 37°C as shown in Figure 3.

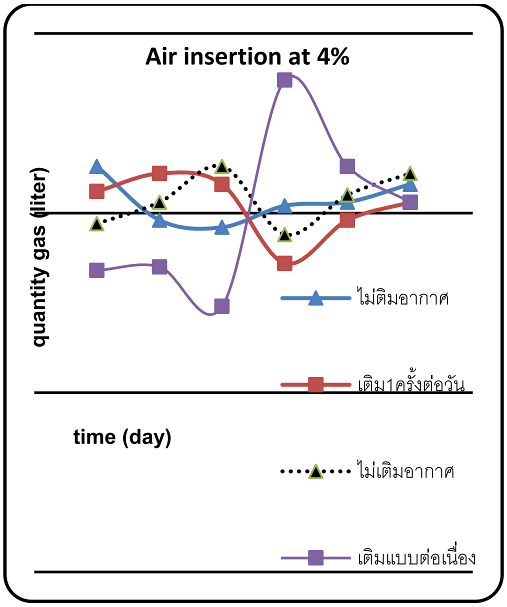

Figure 3 amounts of biogas in air mixing condition of 4%

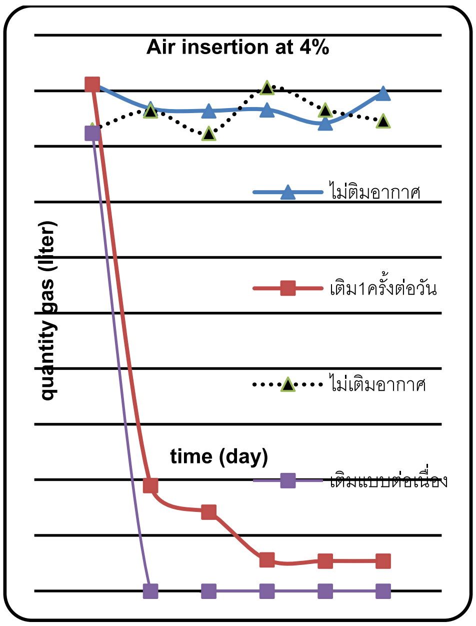

Figure 4 *intensity of hydrogen sulfide gas in air mixing condition of 4%*

A pig manure gutter pit without an air mixing system will have a hydrogen sulfide intensity at an average of 644 within the pig manure gutter pit with an air mixing system of 2 times per day. The intensity will start to decrease to 104 ppm on the second day, 88 ppm on the third day, and 36 ppm on the fourth. After that it will remain stable at 13 ppm on the fifth day of experimentation as well as in the pig manure gutter pit with a continuous air mixing system. The value of intensity reduced to 0 ppm on the fourth day of experimentation, then after that remained stable at 0 ppm as shown in Figure 4.

Conclusion

By continuous air insertion in a proportion of 4% of the capacity of biogas that can produce the average, it is the lowest proportion of adding air that makes the intensity of hydrogen sulfide gas that exited the system reduces from the average value of 644 ppm to an undetectable amount within 48 hours. Biogas that has been produced has the proportion of methane gas reduced from air insertion no more than 3.5% in a level no less than 77% which can be used to produce renewable energy as usual.

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References

[1] Kapdi SS., et al. (2004). Biogas scrubbing, compression and storage:perspective and prospectus in Indian context. *Renewable Energy, 30,* 1195-1202.

[2] Khanal S.K. and Huang J.C. (2005). Online oxygen control for sulfide oxidation in anaerobic treatment of high-sulfate wastewater. *Water Environment Research, 77.*

[3] Khanal S.K. and Huang J.C. (2003). ORP-based oxygenation for sulfide control in anaerobic treatment of high- sulfate wastewater. *Water Research, 37*, 2053–2062.

[4] Pipatmanomai S., Kaewluan S. and Vitidsant T. (2008). Economic assessment of biogas-to-electricity generation system withH2S removal by activated carbon in small pig farm. *Applied Energy, 86,* 669-674.

[5] Saikkonen K.A. (2006). Technical and economic feasibility of upgrading dairy manure-derived biogas for natural gas pipeline: Master's thesis. Cornell University.

[6] Soroushian F., et al. (2006). Development and application of biological H_2S scrubbers for treatment of digester gas. *Water Environment Foundation*, 3541-3547.