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System Improvement of Biogas Digester using SMS Notification and Methane Production and Monitoring

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Abstract
Anaerobic digestion processes organic maters by decomposition/breaking down into particles from biodegradable wastes using containers to form biogas and organic fertilizers. Biogas technology takes the form of biogas digesters are producing methane which is a flammable gas and organic fertilizer as its by-products. Biogas digester parameters needs proper monitoring to ensure smooth operation and prevent system failure. That include methane yield, loading rate, temperature, retention time and acidity using SMS notification and monitoring.

Index Terms: *biogas technology, biogas digesters, methane, organic fertilizer*

I. INTRODUCTION

Massive amount of solid waste is still a major problem in the Philippines and if not addressed, this will continually have a negative impact on health and environment. Solid wastes typically contain more organic components than other materials. According to National Solid Waste Management Commission (NSWMC), disposed waste is dominated by biodegradable waste with more than 52%.

The significant portion of biodegradable waste indicates that proper method of disposal will have a great impact on reducing solid wastes. Disposal in an open landfills is now controlled and other methods are practiced based on the Ecological Solid Waste Management Act of 2000 (Republic Act 9003). As a result, new methods are emerging to solve problems with bio wastes and one of which is through biogas technology.

Biogas technology takes the form of biogas digesters which consist of large containers that can turn biodegradable waste into biogas and fertilizer by decomposing / breaking down organic matter through a process called anaerobic digestion. Biogas produced inside the digester is mainly composed of methane which is a flammable gas that may be used for cooking as an alternative for Liquefied Petroleum Gas (LPG). In addition, the fertilizer is purely organic and does not contain substances that may harm plants and the environment. Effectively, biogas technology may not only solve problems with bio waste but it will also produce by products for everyday use [1].

In operating a biogas digester there are parameters that needs proper monitoring to ensure smooth operation and prevent system failure [2]. These include methane yield, loading rate, temperature, retention time and acidity. With regards to this, several methodologies are emerging to monitor and control these parameters.

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II. OBJECTIVES OF THE STUDY

A. General Objective

Generally, the study aimed to improve Biogas digester by installing methane production monitoring system and overfeeding notification

B. Specific Objectives

1) To measure and compare the percentage of methane and carbon dioxide produced by biogas digester

2) To monitor the allowed loading rate of biogas digester

3) To ensure smooth operation and prevent complications.

RESEARCH METHODOLOGY

In order to satisfy the objectives of this study, historical research was conducted wherein past data regarding the existing biogas digesters were analyzed and investigated to come up with an improvement.

The researchers used DMAIC method to assess and evaluate the existing biogas digester installed in GMA, Cavite, Philippines.

Five Phases:

1. Define – presents the existing biogas digester installed in GMA, Cavite and problems associated on daily operation.

2. Measure –this phase determines the extent of the problem through data gathering by the researchers at MENRO Dept. of GMA, Cavite for three consecutive months (December, 2018-February, 2019)

3. Analyze – focuses on addressing the significant internal and external factors of the existing biogas digester. It helps the researchers identify possible causes of unmonitored methane content and overfeeding.

4. Improve - the improvement of biogas digester through installation of methane production monitoring system and overfeeding notification is presented in this phase.

5. Control –in this phase the researchers developed an action plan to makes sure that the improvement is well-implemented and maintained.

Table 1

IPO Chart

Input	Process	Output
• Interview • Data Gathering • Observation • Hardware • Biogas digester	• Data Analysis • Research • Process flow chart • Why Why Analysis • SWOT Analysis • System Development • Testing and Evaluation	• Improved Biogas Digester with Notification and Monitoring

III. RESULTS AND DISCUSSIONS

This IBC Water Tank Biogas Digester installed at GMA, Cavite requires 25 kilos of biodegradable waste per day. It has an estimated burning capacity of 30 to 60 minutes per day. This technology offers sustainable solution to the growing garbage problems of the province.

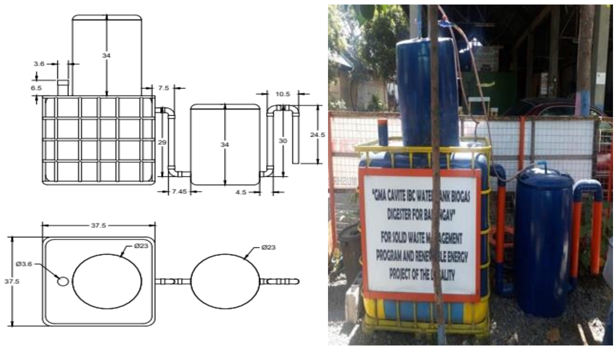

Figure 1. Biogas Digester in GMA, Cavite

The main part of a biogas system is a large tank, or digester. Inside this tank, bacteria convert organic waste into methane gas through the process of anaerobic digestion. The operator of biogas system feeds the digester with bio waste. The methane gas produced inside biogas system may be used for cooking. Waste that has been fully digested exits the biogas digester in the form of organic fertilizer.

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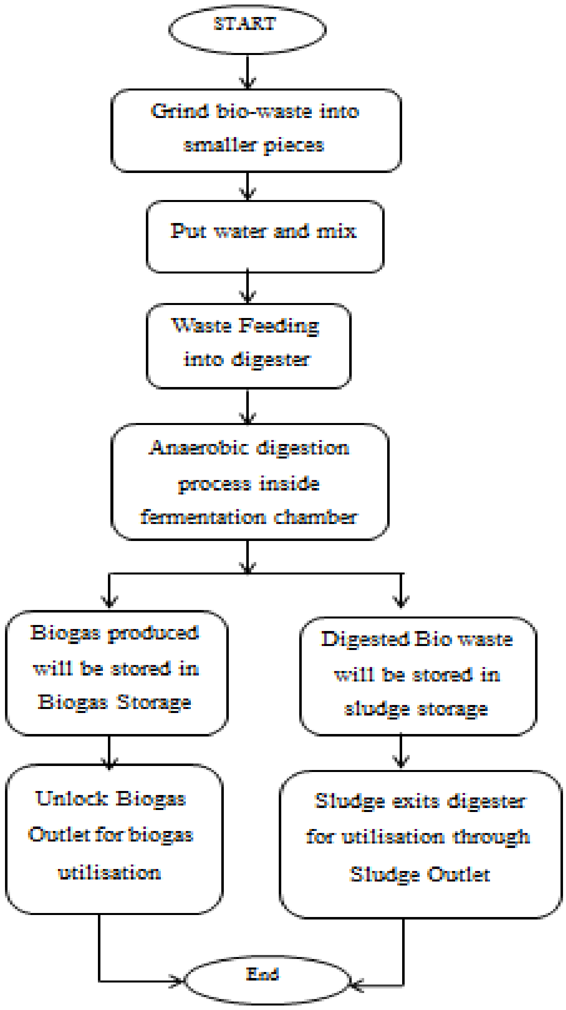

Figure 2.

Process flow chart of Biogas Digester

Table 2

Parts of the Biogas Digester

Parts	Function
1.) Inlet Pipe	enables the bio wastes enter the digester
2.) Fermentation Chamber	where bacteria decompose organic materials to produce biogas
3.) Biogas Storage	biogas is collected and stored until the time of consumption
4.) Biogas Outlet	a way out of biogas for utilization
5.) Sludge Storage	after the digestion process , the remains or sludge will be stored until the time of utilization.
6.) Sludge Outlet	a way out of the sludge for utilization

When organic matter, such as food scraps and animal waste, break down in an anaerobic environment (an environment absent of oxygen) they release a blend of gases, primarily methane and carbon dioxide.

Table 3

Composition of Biogas from World Energy Council [3]

Chemical Component	Concentration(by volume)
Methane (CH_4)	55-60%
Carbon Dioxide (CO_2)	35-40%
Water (H_2O)	2-7%
Hydrogen Sulphide (H_2S)	2%
Ammonia (NH_3)	0-0.05%
Nitrogen (N)	0-2%
Oxygen (O_2)	0-2%
Hydrogen (H)	0-1%

Table 3 shows the typical composition of biogas, where it is mainly composed of methane and carbon dioxide. Based on the table, methane concentration higher than 60% indicates efficient process of anaerobic digestion, in contrast lower than 55% represents needs improvement. Moreover, when carbon dioxide exceeds 40%, potential methane content of bio waste is not fully extracted.

Because the organic material decomposes in a liquid environment, nutrients present in the bio waste dissolve into the water, and create a nutrient-rich sludge, typically used as fertilizer for plants.

This fertilizer output is generated on a daily basis, and therefore is a highly productive by-product of anaerobic digestion which is used by MENRO Department for their plants around the vicinity and other nearby residences.

Figure 3

Organic fertilizer obtained from biogas digester

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Table 4

Weekly Average Burning Capacity (MENRO Department)

Month	Weekly Average Burning Capacity (in mins)				
	Week				
	1	2	3	4	Total
December, 2018	36:38	27:15	48:47	30:45	35:51
January, 2019	42:13	39:25	45:41	40:46	42:01
February, 2019	28:45	29:36	43:37	36:19	34:34
				Ave	37:29

The table 4 shows that from December 2018 to February 2019 there are times that the burning capacity is lower than the minimum of 30 minutes and does not last to its maximum capacity of 60 minutes, this indicates that there is no steady methane production. In this case in order to maintain the effectiveness of biogas digester it is essential to monitor the methane content of biogas.

Table 5.

Methane content of some typical biomass material [4]

Materials	Methane Contents
Poultry manure	60%
Cattle manure	65%
Farmyard manure	55%
Straw	59%
Grass	70%
Leaves	58%
Kitchen waste	50%

Based on Journal entitled "Biogas production: The fundamental processes" the composition of biogas varies with raw materials used. However, the typical composition is given in table 4.

Analyze Phase

This phase focuses on addressing the significant internal and external factors of the existing biogas digester. It helps the researchers identify possible causes of unmonitored methane content and overfeeding.

Table 6

SWOT Analysis of Existing Biogas Digester

Strengths	Weaknesses
Solves biowaste disposal problem Generates gas for cooking; safe and cheap Produces organic fertilizer for plants Eco friendly biowaste disposal method	Limitation on loading rate Low burning capacity No equipment for monitoring important parameters Unfamiliar disposal method to other areas
Opportunities	**Threats**
Monitoring of parameters: Methane yield Loading rate Temperature Retention time Acidity	Blockage of pipes and unnoticed holes can cause system failure Potential gas leaks which could result to damage in digester

Improve Phase

The improvement of biogas digester through installation of methane production monitoring system and overfeeding notification is presented in this phase.

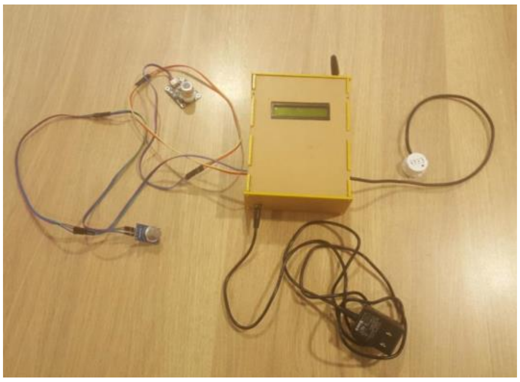

Figure 4. Methane Production Monitoring System and Overfeeding Notification

Figure 5. Device installed on the Biogas Digester

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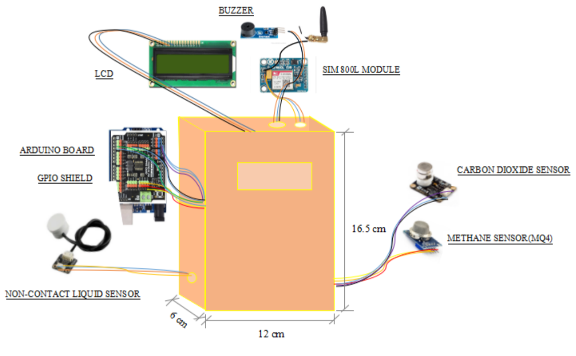

Figure 6. Prototype design

Methane and Carbon Dioxide Content Monitoring System with Real Time Display on LCD and SMS Notification

The researchers developed a monitoring system for methane and carbon dioxide content of the biogas digester. Determining the methane and carbon dioxide concentration levels will give information about the efficiency of the anaerobic digestion process. High value of carbon dioxide and too low methane content indicates that improvement is needed to increase the methane production of the biodegradable waste. Moreover, it may imply if there's already a problem in the process or the biogas digester itself.

Real Time Display on LCD

Two sensors were placed inside the biogas storage; methane sensor and carbon dioxide sensor. Once these sensors recognize the presence of the gases , obtained values will be displayed on the LCD that allows the staff who's in charge on the biogas digester to measure and monitor the methane and carbon dioxide content of the biogas at any time of the day.

SMS Notification

In addition to the real time display of values on the LCD, the system can also send an SMS notification every hour relaying information about methane and carbon dioxide production of the digester. This enables waste management staff to have a daily record even if they neglect to note down the values by just looking on the LCD display.

Overfeeding Notification

The biogas digester is also equipped with overfeeding notification that gives an alarm if the fermentation chamber already reached its allowed quantity of bio waste. Loading rate or the amount of bio waste fed per day in the digester is an important parameter that affects gas yield. If the digester is overfed, acids will accumulate and methane production will be disturbed since micro-bacteria cannot survive in acidic situation.

Table 7.

Parts and Description of Overfeeding Notification

Parts	Description
Non-contact Liquid Level Sensor 	It utilizes an advanced signal processing technology. No contact with liquid makes the module suitable for detecting all kinds of liquid in an airtight container under high pressure
Buzzer 	An electric signaling device that makes a buzzing sound

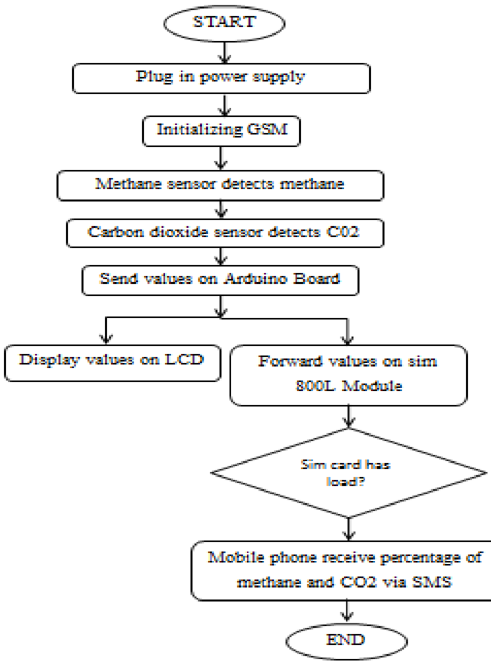

Figure 7. Flow chart for Methane Production Monitoring System

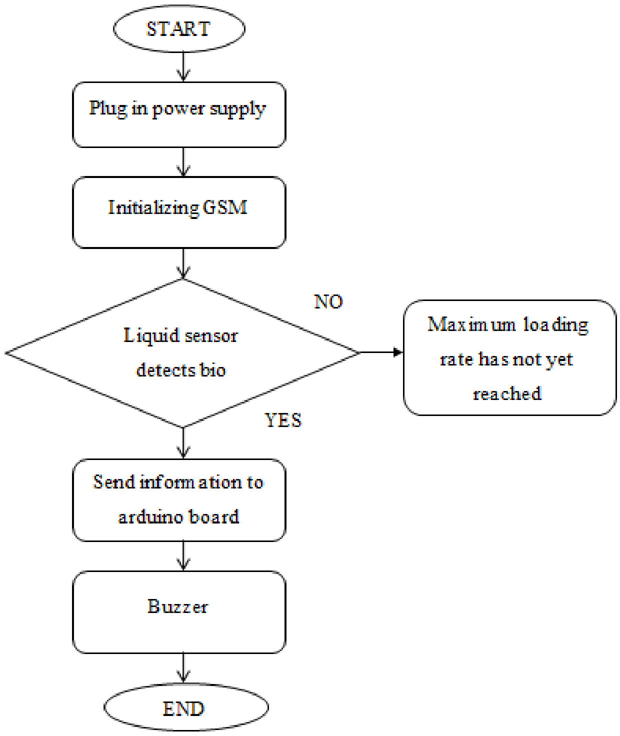

Figure 8. Flow chart for Overfeeding Notification

Testing and Results

Figure 9. Percentage of Methane and Carbon Dioxide display on LCD

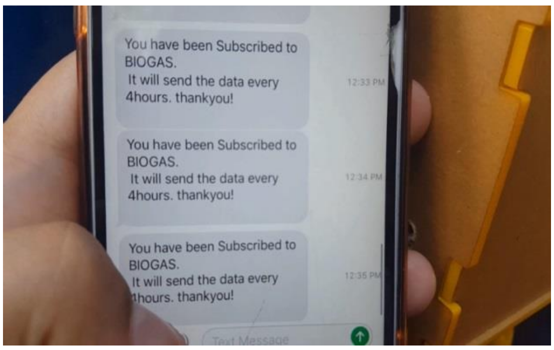

Figure 10. Subscription to Monitoring System through SMS

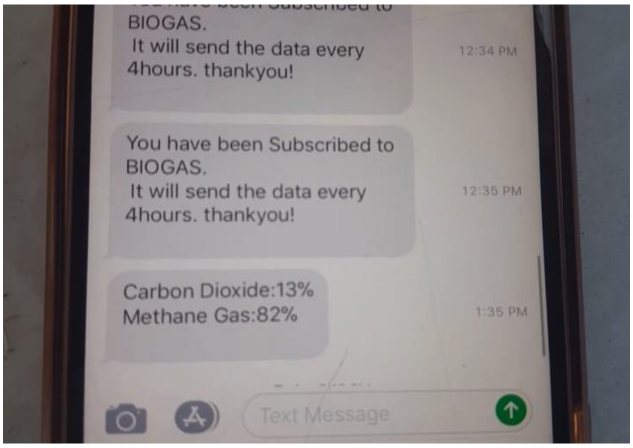

Figure 11. SMS Notification (After 1 hour)

CONCLUSIONS

Methane production and loading rate are important parameters in operating a biogas digester, therefore adequate operational management and process monitoring is necessary in order to prevent upcoming process imbalance of the biogas digester.

By installing methane production monitoring system, MENRO can measure and compare the methane and carbon dioxide content of their biogas digester.

Through overfeeding notification, the allowed loading rate can be control and possible complications due to overfeeding can be prevented.

Improvements for the efficiency of biogas technology are as (1) Compression of Biogas that will separate other gases to produce pure methane for longer burning capacity. (2) Installation of propeller inside the fermentation chamber to activate the bacteria that decomposes biowaste for better biogas production. (3) Application of ergonomics for feeding the digester to lessen human effort and (4) Improvement of pre-treatment process for better production of methane.

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