Sudan University of Science and Technology
College of Graduate
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Research Submitted in Fulfillment for M. Sc. in Environmental Engineering

Utilization of Vinasse for Biogas Production Using a Pilot Plant

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الآية

بسم الله الرحمن الرحيم

﴿ ٱلَّذِى جَعَلَ لَكُم مِّنَ ٱلشَّجَرِ ٱلْأَخْضَرِ نَارًا فَإِذَآ أَنتُم مِّنْهُ تُوقِدُونَ ﴾

سورة يـس

الآية 80

Dedication

I DEDICATE THIS MODEST WORK TO WHOM PURIFY MORE THAN EVERYONE

"**Glorious December revolution Martyrs**"

The Acknowledgement

First of all, I thank **ALLAH** for giving me the strength to complete this work. but;

OH ALLAH; HOW CAN I THANK YOUR GIFTS FOR ME & EVEN MY THANKS IS A GIFT FROM YOU …

I greatly acknowledge the Environmental Departments in Sudan University of Science and Technology & Al_Neelain University, for giving me this opportunity to perform this work.

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المستخلص

هدفت الدراسة إلى انتاج الغاز الحيوي من الفيناس وصناعة نموذج لهاضم لاهوائي مبسط بأقل التكاليف الممكنة يمكن استخدامه منزلياً سواء كان باستخدام الفيناس أو أي مخلفات عضوية أخرى.

تم استخدام روث الأبقار بخلطه مع الفيناس بنسب مختلفة ولفترات زمنية مختلفة في هواضم بسعة 2400 مل، حتى توصلنا من خلال التجارب العملية والتي استمرت في مجملها 175 يوم إلا أن أكثر نسبة ملائمة لخلط الفيناس مع روث الأبقار في الظروف الطبيعية ودرجة حرارة من 30 – 40 درجة مئوية، حيث كانت نسبة (2:1:1) على التوالي (Vinasse: Cow Dung: Inoculum) هي الأنسب لإنتاج الغاز الحيوي، انقسمت فترة التجارب إلى الخطة (أ) وكانت نسبة الخلط فيها بتخفيف الفيناس إلى ثلاثة درجات مختلفة على تسعة هواضم لا هوائية، بالإضافة إلى ثلاثة هواضم أخرى بدون تخفيف للكونترول، استمرت التجربة 60 يوم، ولما لم يكن هناك انتاج للغاز تم تبديل نسب الخلط في هواضم الاختبار وعكسها في الخطة (ب) بزيادة نسبة الفيناس ومضاعفتها بدلاً عن تخفيفها، واستمرت هذه التجربة (EX_2) فكان أول انتاج للغاز في فترة 9 أيام وأعلى انتاج 500 مل بعد مرور 16 يوم، بعد مرور 60 يوم توقف انتاج الغاز، فتم عمل تجربة تأكيدية (EX_4) باستخدام نسبة الخلط الوحيدة التي أنتجت الغاز (2:1:1)، فكان أول انتاج للغاز بعد مرور 2 يوم، أما الكمية الأكبر خلال يوم واحدة فقد كانت 700 مل وذلك بعد مرور 21 يوم على الخلط. وتوقف انتاج الغاز هذه المرة بعد مرور 64 يوم، مخلفاً حجم تراكمي من الغاز بمقدار 9960 مل، ما يعني أن الهاضم اللاهوائي أنتج متوسط 156 مل/اليوم، وأن كل جرام من الخليط أنتج 25.2 مل من الغاز في متوسط درجة حرارة 35 درجة مئوية.

وجد أن نسبة تواجد غاز الميثان هي (60% – 55) ونسبة غاز ثاني أكسيد الكربون (35 – 40 %)، مع وجود غازات أخرى بنسب ضئيلة جداً.

بناءً على ذلك تم تصميم هاضم لا هوائي بحجم أكبر ليتحمل 20 كلجم من المخلفات العضوية (الفيناس) وبالتالي زاد انتاج الغاز الحيوي في فترة (60) يوم إلى (5833) مل كما أمكن نظرياً إنتاج كهرباء من هذا الحجم من الغاز قدرها 67.5 كيلو واط.

Abstract

The study aimed to produce biogas from Vinasse and to manufacture a model of a simplified anaerobic digester at the lowest possible costs that can be used at home, whether using Vinasse or any other organic waste.

Cow dung was used by mixing it with vinasse in different proportions and for different periods of time in digesters with a capacity of 2400 ml, until we reached through practical experiments, which in total lasted 175 days, that the most appropriate ratio for mixing vinasse with cow dung under natural conditions and a temperature of (30-40) $^{\circ}$C, where the ratio was (2:1:1) which is respectively (Vinasse: Cow Dung: Inoculum), the experiment period was divided into plan (A) and the mixing ratio was by diluting the Vinasse to three different degrees on nine Anaerobic digesters, in addition to three other digesters without dilution of the control, the experiment lasted 60 days, and since there was no gas production, the mixing ratios in the test digesters were changed and reversed in plan (B) by increasing and doubling the proportion of vinasse instead of diluting it, and this experiment continued (EX_2) was the first gas production in a period of 9 days, and the highest production was 500 ml after 16 days. After 60 days the gas production stopped, so a confirmatory experiment (EX_4) was carried out using the only mixing ratio that produced gas (2:1:1), the first gas was produced after 2 days, and the largest quantity in one day was 700 ml, after 21 days of confused. Gas production stopped this time after 64 days, with a cumulative volume of gas by 9960 ml, which means that the anaerobic digester produced an average of 156 ml/day, and that each gram of the mixture produced 25.2 ml of gas in Average temperature 35°C.

Samples of the gas were analyzed and it was found that the percentage of methane gas is (55-60%) and the percentage of carbon dioxide gas is (35-40%), with the presence of other gases in very small percentages.

Accordingly, a larger size anaerobic digester was designed to bear 20 kg of organic waste and thus increase the amount of gas production for domestic use, with the possibility of converting it into electrical energy in the future.

Accordingly, a larger anaerobic digester was designed to bear 20 kg of organic waste (vinasse), and thus the production of biogas was increased in a period of 60 days to 5833 ml, and it was theoretically possible to produce electricity from this volume of gas of 67.5 Kw.

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Chapter One

1. Introduction

Energy is considered one of the most important issues in the lives of peoples and nations. As it provides man with his need for warmth in winter, and it illuminates him at night and dispels the darkness. This manage machineries, cars, factories and all the various modes of transport.

The discovery of oil has had an important role in human life. The world has witnessed many changes and developments. The pace of scientific and industrial progress has greatly accelerated, the Arab region-especially the Arab Gulf -contains large reserves of oil and natural gas. Though the Sudan is rich in solar energy, where the sun shines on them most days of the year.

Energy sources are divided into two types, renewable sources and non-renewable sources. The renewable energy, is that Energy produced from unconventional natural sources. What distinguishes it from the rest of energy sources, it is continuous and inexhaustible? In order people to exploit. Wind can be converted into electrical energy, as the solar energy and other forms of renewable energy.

The nature surrounds mankind works continuously to produce energy in huge and unlimited quantities, and exploits in fact a very small part of this energy. The sun for example, gives humans enormous amounts of energy, as well as waterfalls, which studies have shown that if waterfalls are exploited in the world gave humans 80 percent of their daily energy needs.

The same applies to wind, which produces an amount of energy many times what a person needs. As for tidal wave energy, it can give a person half of his energy needs. As for nonrenewable energy sources, they mean those sources of energy were formed in the ground millions of years ago and the stock of non-renewable energy is limited and must end within the next few decades, and the most important non-renewable energy sources are oil (petroleum) and natural gas.

Biogas is a clean and renewable energy may be substituted to the natural gas. Biogas is a by-product of the decomposition of organic waste by anaerobic bacteria.

In some areas in Sudan, water pollution and access to energy resources present challenges to human health, environmental pollution and economic development. Less than 10% of the population of 21 sub-Saharan African countries have no access to electricity. The need for alternative renewable energy sources from locally available resources cannot be over emphasized. Besides, the alarming population explosion in Africa and its concomitant effect on natural resources due to increased wood charcoal fuel production and consumption is not sustainable in the long term.

Therefore, any reduction in wood fuel consumption as a result of biogas production might be expected to have favorable effect on reduction in deforestation.

1.1. Problem Statement:

The organic waste Resulting from the sugar industry is a major problem and harms the environment and human health if it is not disposed of in a safe and effective manner. Therefore, the current research is looking for ways to take advantage of this waste (Vinasse) and convert it into biogas by finding the best percentage mix (%) after mixing it with catalysts that increase the productivity of Vinasse. One of the most important problems that the researcher seeks to solve is the design of a suitable digester that meets the requirements of fermentation of vinasse in an anaerobic situation to produce biogas for all uses, so that the digester is characterized by ease of use in terms of filling and unloading.

1.2. Objectives:

1.2.1. General Objective:

Based on the above background, the current research is trying to manufacture a Lab Scale model of a biogas production unit for the sugarcane waste (Vinasse).

1.2.2. Specific Objectives:

1. converting Vinasse sugar cane industry waste to CH_4 and then into electrical energy in a simple way
2. creating a model of a biogas production unit for home use is easy to use to create a socio-economic leap.
3. producing biogas at the lowest possible financial costs.
4. comparison of the mixing ratios of different materials to get the best percentage of biogas.
5. modification of the digested system easy to Manufacture, operate and maintain.

1.3. Hypothesis:

The researcher assumed the possibility of producing biogas from vinasse after mixing it with Cow Dung inoculum and then relying on a mixing ratio that is the best among others, with the possibility of designing a digester to do this task, and gas can be converted into electricity in the future.

Chapter Tow

2. Literature Review

2.1. Background:

Sudan is the 3rd largest country in Africa with a good sugar and sugarcane production. There are 6 sugar mills in Sudan of which 5 are in Public Sector and one is in Co-operative Sector. The Department of Sugar was formed in the year 1969, in order to devote special attention to the development of sugarcane and to regulate and oversee the establishment of sugar mills in the Co-operative and Private sector (Sudan, 2007). The average mill size crushes less than 15 tons of sugarcane per day. From each ton of sugarcane, 30 to 35 kg of dry matter is 3% of mill sugar cane is obtained. The 5 mills crush about 360 million tons of sugarcane and generate 120 million tons of filter mud per annual (Elfadil, 2008).

Filter mud, also known as press-mud or filter cake or cane mud or cane filter, is a by-product consisting of components including fiber which can be used as an animal feed or a source of energy generation, lignin, beta carotene, oil containing a high content of phytosterol, refined wax which is a resource of policosanol and which can also be used for many other established purposes, and resin which can be used an additive in asphalt mixtures and tire manufacturing, with sand and other debris or can be recycled back into the sugar milling. Within 24 hours of production, filter mud is normally returned to the field as “manure”. However, if the filter mud is an aerobically digested, biogas can be produced, a higher-grade fertilizer generated and pollution is better controlled.

The Sugar Industry in the Sudan is an important agro-based industry. It plays a major role in the economic development of rural areas in the Sudan. The Sugar Industry generates large-scale direct employment, apart from providing indirect employment to thousands of persons in rural areas who are involved in cultivation, harvesting, transport of cane and other services.

Sugarcane or Sugar beet is processed to produce crystalline sugar, pulp and molasses (Illinois, 2017). The latter are further processed by fermentation to ethanol, ascorbic acid or other products. Juice sugarcane can also be processed directly by ethanol fermentation. After the removal of the desired product (alcohol, ascorbic acid, etc.) the remaining material is called Vinasse.

2.2. What is the Vinasse?

The waste liquid from the distillery after recovering alcohol by distillation is called spent wash (Vinasse) and gives highly obnoxious smell and is a dangerous pollutant of the aquatic life and general air. It has very high BOD, COD and TS and any single conventional treatment technology is not able to bring down BOD values to 50 mg/L, which is the standard limit from health point of view. (Isni Utami, 2015).

This process is mostly applied in industrial waste with an organic load of the medium, which has a concentration of COD in the range of 3000-7000 mg /l. (Lettinga, 1991).

Vinasse, the liquid fraction generated from the rectification and distillation operations of ethanol, is a sulfur-rich, low pH, dark-colored, and odorous effluent, produced at volumes as high as 20-fold of ethanol. (Hu, 2017).

Vinasse is the final byproduct of biomass distillation, mainly from ethanol production from sugar and starch crops or cellulosic material. Its composition is predominantly 93% water and 7% solids. For each liter of alcohol produced in the sugarcane industry, 15 L of Vinasse may be generated. (E.N.V.M.Carrilho, 2016).

Vinasse has variable chemical composition, which depends mainly on the raw material used in the bioethanol production, and its main features are dark brown color, acidic pH 3.5 – 5.0, and high temperature 80 – 100 °C, organic matter concentration COD 50 – 150 g/L, and salinity K, Ca & Mg. (Bianca, 2017). As By-products, for its chemical and organoleptic characteristics becomes An excellent agricultural fertilizer when biologically treated. (ECO Bio-Farm Solutions).

ethanol is produced through a classic fermentation process, in which yeasts transform sugarcane juice, molasses, or a molasses-juice mixture into ethanol. This is a biological process that can be represented by the stoichiometric equation of Gay Lussac:

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6 \text{ (a)}$$

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2 + 23{,}5 \text{ kcal (b)}$$

(Sydney, 2013)

physicochemical components of vinasse vary considerably. Vinasse have high value of biological oxygen demand and chemical oxygen demand, this indicates its high organic matter content, the high organic matter content causes heavy pollution of water and soil if the residues are being disposed untreated. Appreciable amounts of minerals and mineral salts were found in vinasse, indicating that it can be used as raw material to produce fertilizers like urea. In addition, vinasse can be used as a raw material to produce animal feed, as it is free from microorganisms. However, to solve the problem of environmental pollution as a result of the high contents of BOD and COD. (Sulieman, 2013). Vinasse is byproduct waste from the ethanol fermentation industry which still contains high enough organic matter, so that it can be used as raw material for biogas production. (Isni Utami, 2015).

2.3. What is The Biogas?

Biogas is a carbon-neutral source one of renewable energy, generated from the anaerobic digestion process of biodegradable waste, plant biomass, crop residues and manure.

Biogas is a gas mixture, mainly consisting of methane and carbon dioxide, resulting from the, biological process of anaerobic digestion of various organic material (Paul Dobre, 2014). Released biogas acts as an environmentally sustainable energy source, while providing a way to dispose of Vinasse as a waste from the sugarcane industry to be disposed of biogas contains 50-70% methane and 30-50% carbon dioxide. Small amounts of other gases including hydrogen sulfide. Methane is the component chiefly responsible for a typical calorific value of 21–24 mg/m3 (Tom Bond, 2011) Different appliances can be supplied with biogas, with cookers offering an application Suitable for deployment in developing countries. The widespread digestion of biogas in developing countries dates back to the 1970s, and there are now around four and 27 million biogas plants in India and China respectively (Tom Bond, 2011).

Research on investing in clean forms of energy to preserve the environment has become one of the most important global trends on a Pilot Plant Biogas technology in fermentation of organic materials is considered one of the most promising technologies globally, as it has become popular in many countries of the world. Managing blood bank wastes in a safe and environmentally friendly way. Reducing environmental risks of medical waste. Renewable energy production from biogas and Reducing gas cost (Abdala, 2017), poultry manure is good byproduct for production of biogas. (Abdala, 2017).

2.4. Biogas Formation Process:

Biochemical Process Anaerobic digestion is a complex process that takes place in four biological and chemical stages:

2.4.1. Hydrolysis:

Biomass is normally comprised of large organic polymers proteins, fats and carbohydrates. These are broken down into smaller molecules such as amino acids, fatty acids, and simple sugars. It is the essential first step in anaerobic fermentation; fermentative bacteria hydrolyze the complex organic matter into soluble molecules. Some of the products of hydrolysis, including hydrogen and acetate may be used by methanogens later in the anaerobic digestion process. Majority of the molecules, which are still relatively large, must be further broken down in the process of acidogenesis so that they may be used to create methane. (Iftikhar A Raja, 2017)

2.4.2. Acidogenesis:

Acidogenesis is the next step of anaerobic digestion where acidogenic microorganisms further break down the biomass and organic products after hydrolysis. These fermentative bacteria produce an acidic environment in the digestive tank while creating ammonia, H_2, CO_2, H_2S, shorter volatile fatty acids and organic acids, as well as trace amounts of other byproducts. The principal acids produced are acetic acid, propionic acid, butyric acid etc. (Iftikhar A Raja, 2017)

2.4.3. Acetogenesis:

In general, acetogenesis is the creation of acetate, a derivative of acetic acid, from carbon and energy sources by acetogens. These microorganisms catabolize many of the products created in acidogenesis into acetic acid, CO_2 and H_2. Acetogens break down the biomass to a point to which methanogens can utilize much of the remaining material to create methane. (Iftikhar A Raja, 2017)

2.4.4. Methanogens:

Methanogens constitutes the final stage of anaerobic digestion in which methanogens create methane from the final products of acetogenesis as well as from some of the intermediate products from hydrolysis and acidogenesis. There are two general pathways involving the use of acetic acid and carbon dioxide, the two main products of the first three steps of anaerobic digestion, to create methane in methanogens:

$$CO_2 + 4\ H_2 \rightarrow CH_4 + 2H_2O\ CH_3COOH \rightarrow CH_4 + CO_2$$

While CO_2 can be converted into methane and water through the reaction, the main mechanism to create methane in methanogens is the path involving acetic acid. This stage leads to generation of methane and CO_2, the two main products of anaerobic digestion. (Iftikhar A Raja, 2017)

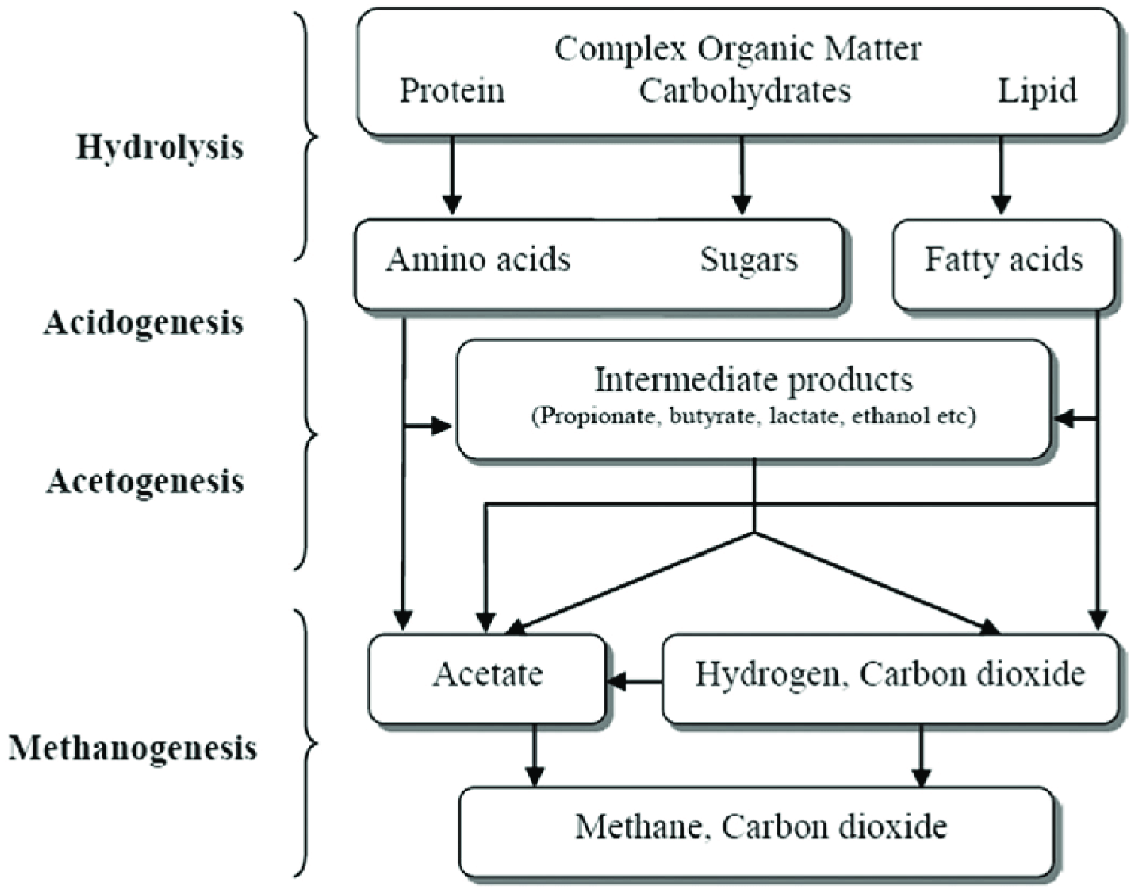


Fig (2.1): Biogas formation process

2.5. Sources of Biogas Production:

a. Animal waste: dung from cattle, poultry, horses, sheep, goats and camels
b. Vegetable waste: firewood, corn, cotton, rice straw, vegetable offerings, greenhouse waste and spoiled fruits.
c. Human waste: sewage, septic tanks, sewage sludge.
d. Household waste: garbage, kitchen waste, food waste, leftovers for preparing vegetables and fruits.
e. Industrial waste: agro-industrial wastes, sugarcane, dairy industry, food, beverages, and all kinds of slaughter house waste.
f. Weeds: wild, aquatic weeds, the Nile rose ... etc.

The characteristics of the waste materials used for anaerobic digestion (AD) are highly dependent on the collection system, and one of the fundamental issues is whether the collected waste is contaminated by inorganic materials. If waste is being segregated at source and collected separately, the quality of this feedstock is increased. The production of biogas from the waste products of the sugar Vinasse waste in particular is very suitable for producing clean energy and protecting the environment from deforestation and desertification, and research is trying to find the best way to produce energy from Vinasse to reach the highest possible productivity of Vinasse waste.

For most people the waste they eject from their bodies is something they don't bother thinking about once they've shut the toilet door behind them. But there are some who think human waste could be a major part of a stable gas supply. Just as long as we can overcome our prejudices (Shah, 2010)

The produced biogas was used in cooking stove for cooking different types of food. It found the consumption of biogas is proportionally changes with change of cooking time and the pressure inside the digester. (Ahmed, Ibrahim and Omer, 2017).

2.6. Biogas Uses:

The English scientists were among the first to use biogas in the 1890s to get rid of its damage and benefit from its economic return. by developing septic tanks to allow gas to be collected and used in street lighting. It is certain that it is a great economic return that should not be wasted, thirty years later, in 1920 AD, Denmark collected gas from sewage treatment plants to reduce the volume of sludge on the one hand and for the great economic return on the other.

Biogas is flammable and therefore can be used in energy production, will be. The simplest use of gas is in a gas boiler, as the gas produces usable heat for heating purposes. The method currently used is only on Smaller plants.

Than the total energy content of biogas 30 - 40% is normally converted into electricity that can be sold to the grid and 45-55% converted to heat (less than the heat used in the process) can sold, for example, for smaller central heating Factory.

The relationship between how much is converted to electricity and how much heating depends on engine size. Overall The conversion efficiency is usually about 85%. In This level of efficiency, biogas can replace coal in power plants and fuels used by heating Factory (oil, natural gas or biomass).

Biogas can also be used in transportation and for this purpose, carbon dioxide is often removed from the gas to reduce its volume. This is the end use replaces liquid fuels such as gasoline or diesel. (Peter Jacob, 2009)

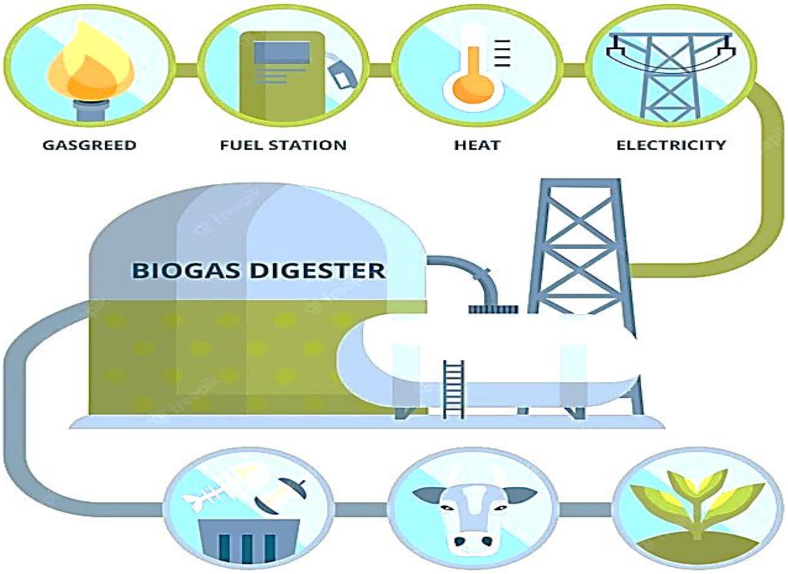


Fig (2.2): Industry Biogas Infographic

2.7. History of Biogas:

- As long ago as the 10th century B.C There are suggestions that biogas was used for heating bathwater in Assyria. and that anaerobic digestion of solid waste may well have been applied in ancient China. (Michael R. Templeton, 2011)
- 1630, Van Helmont recorded the arising of an inflammable gas from breakdown of organic matter. (Peyruze Özmen, 2009)
- 1770 The Italian Volta collected marsh gas and investigated its burning behavior. (Segupta, 2013)
- 1821 Avogadro identified methane (CH4). (Morselli, 1984)
- 1875 Prop off states that biogas is produced under anaerobic conditions. (Energypedia, 2015)
- 1884 Pasteur researched on biogas from animal residues. He proposed the utilization of horse litter to produce biogas for street-lighting. (Peyruze Özmen, 2009)
- 1890s, well documented attempts to harness the anaerobic digestion of biomass by humans date from the mid-nineteenth century, when digesters were in constructed in NewZealand and India, with a sewage sludge digester built in Exeter, UK to fuel street lamps. (Michael R. Templeton, 2011)
- 1906 First anaerobic wastewater-treatment plant in Germany, by the German sanitary engineer Karl Imhoff proposed the so-called “Imhoff tank,”. (Group, 2015)
- 1913 First anaerobic digester with heating facility. (Stefan Habermehl, 1999).
- 1920 First German sewage plant to feed the collected biogas into the public gas supply system.

- 1921, In Guangdong Province, China, commercial use of biogas has been attributed to Guorui Luo, he constructed biogas tank fed with household waste and later that decade founded a company to popularize the technology. (Michael R. Templeton, 2011)
- 1940 Addition of organic residues (fat) to increase sewage gas production.
- 1940s. First biogas plants were built in china by the prosperous families.
- 1950 Installation of the first larger agricultural biogas plant in Germany.
- 1950s in Germany, nearly 50 biogas plants were built, fed by litter mixed with water and dung. Low oil prices and technical problems led to the shutdown of all but two plants. (Stefan Habermehl, 1999)
- 1950s in India, the development of simple biogas plants for rural households started. (Stefan Habermehl, 1999)
- 1970s massive increase in the number of biogas plants took place through strong government backing. Meanwhile, more than one million biogas plants exist in India. The historical experiences in Germany, China and India demonstrate clearly, how biogas development responds to favorable frame conditions. In Germany, biogas dissemination gained momentum through the need for alternative energy sources in a war-torn economy and during an energy crisis or later by the change of electricity pricing. In India and China was a strong government program that furthered the mass dissemination of biogas technology. (Stefan Habermehl, 1999). The fastest growth of biogas use in many Asian, Latin American and African countries (Michael R. Templeton, 2011)
- 1974 After the first ’energy crisis’, increased promotion of research on and implementation of agricultural biogas technology by the EC and federal departments.
- 1980s Chinese government promoted “biogas use in every rural family and facilitated the installation of more than seven million digesters.
- 1988, only 4.7 million household biogas digester-swere reported in China. (Michael R. Templeton, 2011)
- 1997 More than 400 agricultural biogas plants exist in Germany.
- Currently; biogas digesters have been constructed, over 20 million persons use biogas as a fuel. (Stefan Habermehl, 1999)
- 1999 there were over three million family sized biogas plants in India.
- 2007 there were 26.5 million biogas plants.
- 2007, the Indian government had provided subsidy for the construction of nearly four million family sized biogas plants (Michael R. Templeton, 2011).

2.8. Social and Environmental Benefits of Biogas Technology:

Using biogas technology in rural areas is associated with improved quality of life in terms of both health and economic status. Firewood is associated with health-related problems, eye problems, coughs, and pneumonia, while using biogas to meet the cooking needs provides a clean environment.

This means that trees will be saved when using biogas for cooking, and this promotes sustainable development. The social status of rural dwellers can be improved by using biogas technology. This refers to sanitation, better kitchen conditions, and social welfare. Fuelwood is considered a dirty source of energy because after it is burned, it leaves ash behind, and unattended animal waste can be breeding grounds for insects that carry diseases.

It has been proven that using biogas to meet the cooking and heating energy reduces the risks of eye irritation and coughing and improves sanitation. Collecting fuelwood from long distances has become a daunting task, especially for women and children, and it has been estimated that they spend around 2 – 6 h daily to collect fuelwood. The time used for collecting fuelwood could be used to better lives and engage in income-generating activities. (T.E.Rasimphi, 2021).

Significantly reduces carbon dioxide emissions and firewood demand, Sludge can be used as a fertilizer to increase yields and therefore farm incomes. Methane release is mitigated, manure and waste are kept in a confined area. (Technical Notes on Biogas Production, 2018)

2.9. The Main Types of Simple Biogas Plants:

a) balloon plants
b) fixed-dome plants
c) floating-drum plants (Stefan Habermehl, 1999)

2.9.1. Balloon Biogas plants:

A balloon plant consists of a heat-sealed plastic or rubber bag (balloon), combining digester and gas-holder. The gas is stored in the upper part of the balloon. The inlet and outlet are attached directly to the skin of the balloon. Gas pressure can be increased by placing weights on the balloon. If the gas pressure exceeds a limit that the balloon can withstand, it may damage the skin. Therefore, safety valves are required. If higher gas pressures are needed, a gas pump is required. Since the material has to be weather- and UV resistant, specially stabilized, reinforced plastic or synthetic caoutchouc is given preference. Other materials which have been used successfully include RMP (red mud plastic), Trevira and butyl. The useful life-span does usually not exceed 2-5 years. (Stefan Habermehl, 1999)

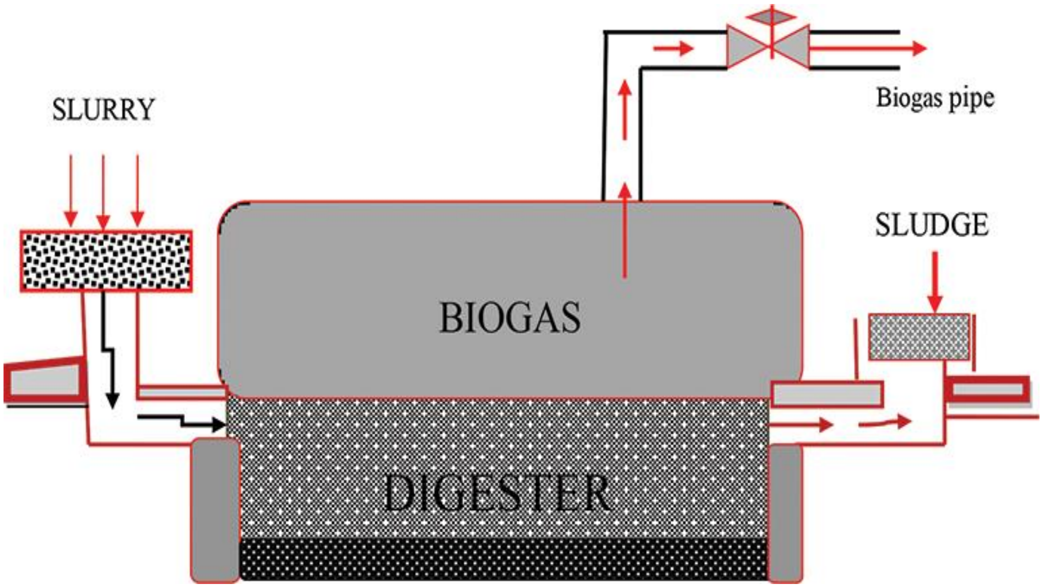


Fig (2.3): Balloon Biogas Plant

Advantages:

- Standardized prefabrication at low cost
- low construction sophistication
- Ease of transportation
- Shallow installation suitable for use in areas with a high groundwater table
- High temperature digesters in warm climates
- Uncomplicated cleaning
- Emptying and maintenance
- Difficult substrates like water hyacinths can be used Balloon biogas plants are recommended, if local repair is or can be made possible and the cost advantage is substantial.

Disadvantages:

- Low gas pressure may require gas pumps.
- Scum cannot be removed during operation.
- The plastic balloon has a relatively short useful life-span and is susceptible to mechanical damage and usually not available locally. In addition, local craftsmen are rarely in a position to repair a damaged balloon. There is only little scope for the creation of local employment and, therefore, limited self-help potential.

2.9.2. fixed-dome Biogas plants

It has a curved bottom and hemispherical top which are joined at their bases with no cylindrical portion in between. Displaced slurry following digestion moves to the outlet displacement chamber as there is no displacement space on the inlet side. An

inlet pipe connects mixing tank with the digester. This type of biogas plant is very cheaper as compared with the other two types of Biogas plants. (Saleh, 2012). The fixed dome digester is the most popular digester; its archetype was developed in China as early as 1936. (Patrick Mukumba, 2017)
The digester is normally constructed using bricks and mortar and ends with a solid fixed dome in the shape of an igloo. Although this is the most well-known digester design and the most widely used, it has a number of inherent disadvantages.

Advantages:
Low initial costs and long useful life-span; no moving or rusting parts that require replacement; basic design is compact, saves space and is well insulated; construction creates local employment.

Disadvantages:
Masonry gas-holders require special sealants and high technical skills for gastight construction; gas leaks occur quite frequently; fluctuating gas pressure complicates gas utilization; the amount of gas produced is not immediately visible; plant operation is not easily understandable; fixed dome plants need exact planning of levels; excavation can be difficult and expensive in bedrock. (Technical Notes on Biogas Production, 2018)

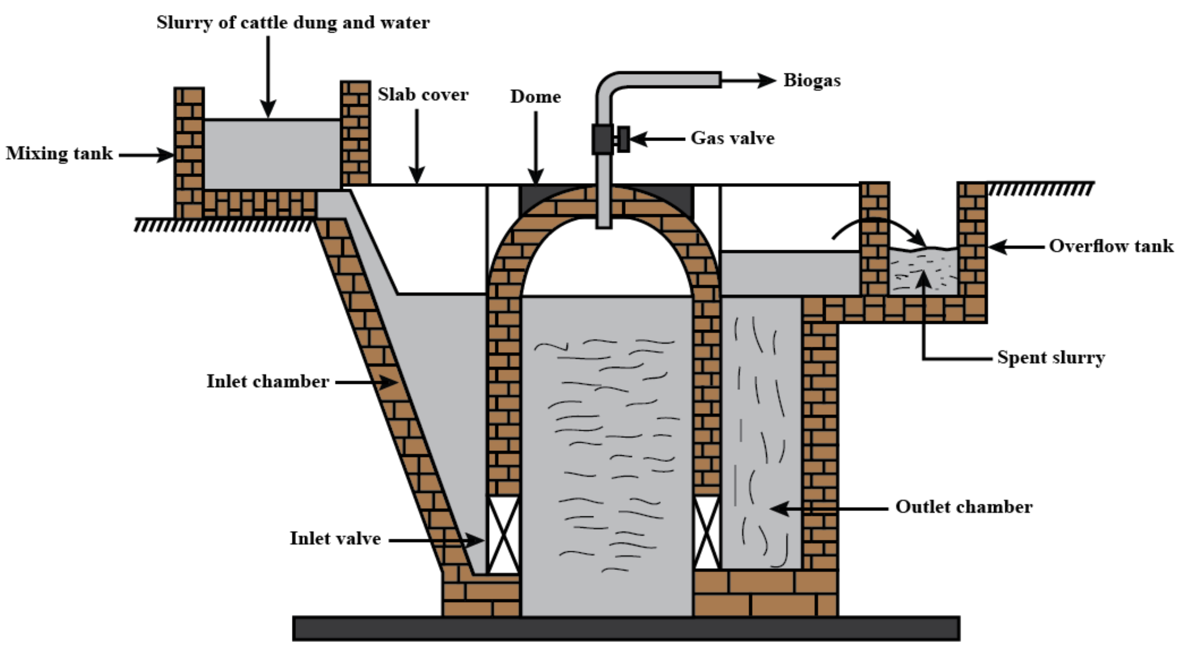


Fig (2.4): fixed-dome Biogas plants

2.9.3. floating-drum plants

in 1956, Jashu Bhai J Patel from India designed the first floating drum biogas plant, popularly called Gobar gas plant. Floating-drum plants consist of an underground digester (cylindrical or dome-shaped) and a moving gas-holder. The gas-holder floats either directly on the fermentation slurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. The gas drum is prevented from tilting by a guiding frame. When biogas is produced, the drum moves up, and when it is consumed, the drum goes down. (Absar, 2015)

Advantages:

1. Very easy to operate
2. Provides constant gas pressure
3. Volume of stored gas can be directly recognized.

Disadvantages:

1. High construction cost
2. Steel parts may lead to corrosion
4. Results in regular maintenance costs due to painting.

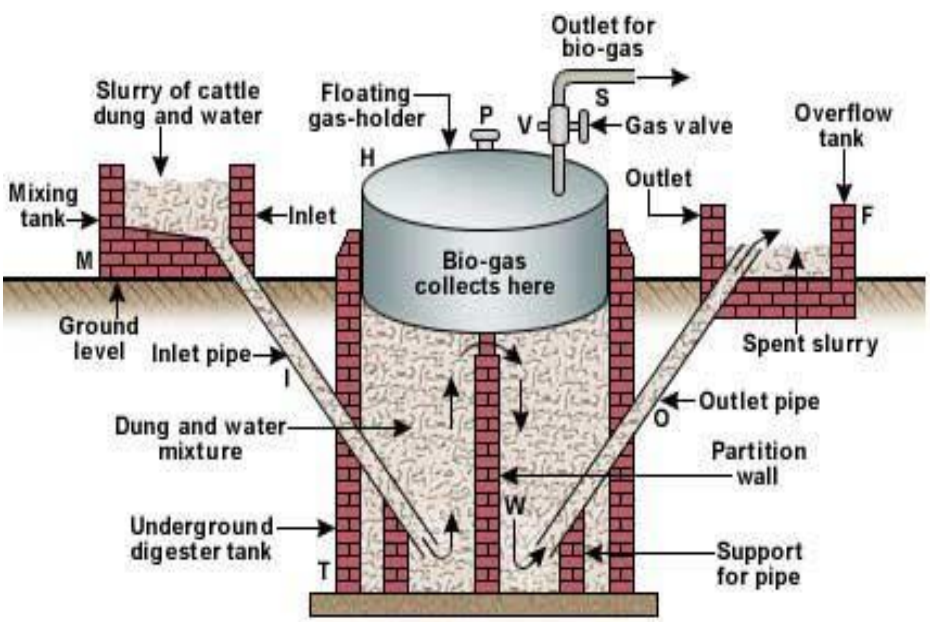


Fig (2.5): floating Drum Biogas plant

Table (2.1): Comparison table of different models of biogas plants:

Properties	Floating	Fixed Dome	Balloon
Experimental Setup	The digester of this Plant is a deep well shaped masonry structure. In these is a partition in middle of the digester	Digester of this plant is a shallow well shaped masonry structure. No partition wall is provided.	The digester consists of only one part .
Biogas Holder	Gas Holder is generally made of the mild steel. It is inverted into the digester and goes up and down with the formation and utilization of gas.	Gas holders the integral part of the masonry structure of the plant. Slurry from the gas storage portion is displaced out of the digester with the formation of gas and comes back when it is used.	The structure described above includes the digester and a gas storage chamber. Gas is collected at the top of the balloon .
Maintenance	Cost of maintenance is high because gas holder is to be prevented from corrosion	Cost of maintenance is low	Cost of maintenance is low.
Life Span	Life span is short	Life span is comparatively long.	Life span is between the other two plants
Extra features	Identifying the defects in gas holder is easy.	Space above the gas holder can be used.	There is no moving part so no recurring expenditure
Required work place	Requires relatively less excavation.	Requires more excavation work	No excavation required, works above ground .

Construction	Digester can be constructed locally. The gas holder needs sophisticated workshop facilities.	A trained mason using locally available materials can build entire plant.	It is prefabricated and cannot be manufactured without consulting the manufacturer
Installation Cost	Installation cost is very high.	It is Cheaper then previous and the plant costs.	It is much Cheaper than both plants and its plant design costs

2.10. Classification of biogas plants:

Classification of biogas plants depends upon the plants design and mode of working. One common way to classify them is:

a. Batch type plant.
b. Continuous type plant.
c. Movable type drum plant.

2.10.1. Batch Type Biogas Plant:

Batch type biogas plants are appropriate where daily supplies of raw waste materials are difficult to be obtained. A batch loaded digester is filled to capacity sealed and given sufficient retention time in the digester. After completion of the digestion, the residue is emptied and filled again. Gas production is uneven because bacterial digestion starts slowly, peaks and then tapers off with growing consumption of volatile solids.

This difficulty can overcome by having minimum to digester so that at least one is always in operation. This problem can also minimize by connecting batch loaded digester in series and fed at different times so that adequate biogas is available for daily use. The salient features of batch-fed type biogas plants are:

a. Gas production in batch type is uneven.
b. Batch type plants may have several digesters for continuous supply of gas.
c. Several digesters occupy more space.
d. This type of plants requires large volume of digester, therefore, initial cost becomes high.
e. This plant needs addition of fermented slurry to start the digestion process. (Ashu, 2010)

2.10.2. Continuous Type Biogas Plant:

In continuous type biogas plant, the supply of the gas is continuous and the digester is fed with biomass regularly. Continuous biogas plants may be single stage, double stage or multiple stage. Digestion of waste materials in a single chamber or digester is called single stage process, in two chambers or digester is called multi stage process. In double stage process, acidogenic and methanogenic stage are physically separated into two chambers. Thus, the first stage of acid production is carried out in a separate chamber and only diluted acids are fed into the second chamber where biomethanation takes place.

In single stage, acidogenic and methanogenic stage are carried out in the same chamber without barrier. These plants are economic, simple and easy to operate. these plants are generally for small and medium size biogas plants. However, the two stage biogas plants are costlier, difficult in operation and maintenance but they produce more gas. These plants are preferred for larger biogas plant system. The important features of continuous type biogas plants are:

a. Gas production is continuous.
b. Retention period is less
c. Less problems as compared to batch type.
d. Small digestion chambers are required (Ashu, 2010)

2.10.3. Movable Drum Type Biogas Plants:

This also known as floating dome type biogas plants. The conventional movable drum type comprises a masonry digester with an inlet on one side for feeding slurry and an outlet on the other side for removing digested slurry. The gas collects in a steel gasholder which is inverted over the slurry and moves up and down depending upon accumulation and discharge of gas guided by a central guide pipe. This movable gas holder is made of steel.

The gas holder is painted by anticorrosive painting at least once in year. This plant helps in consistent pressure which can be adjusted by regulating weight. The main drawback of this is that metal cost is large and maintenance cost is also high. To tackle this problem the scientist have created high density polyethylene.

Advantages:

a. Constant gas pressure.
b. No problem of gas leakage
c. Higher gas production
d. Scum problem is less (Ashu, 2010)

Chapter Three

3. Materials and Methods

3.1. Materials:

3.1.1. Collecting Sample and Analysis:

Vinasse was obtained from (Kenana sugar factory), by Al_Neelain University, department of environmental sciences. And stored at the university for more than two years before starting experiments.

3.1.2. Study of Raw Material (Vinasse):

There are a number of factors that affect the fermentation process of vinasse and must be studied and analyzed before and after the fermentation process and the production of biogas from vinasse, which are:

(pH, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended Solid (TSS) and Carbon to Nitrogen Ratio C:N).

3.1.3. Consumption of the materials:

The work on the experiments was divided into two stages, the beginning was with plan (A) by diluting the vinasse by adding water each time, then it was moved to plan (B), which was by adding cow dung and the Inoculum in varying proportions to the vinasse, so the mixing ratios were for each of the plan (A). Plan B is as shown below:

Plan A		Plan B		
Vinasse	**: H_2O**	Vinasse	: Cow Dung	: Inoculum
1	1	1	1	1
1	2	2	1	1
1	3	3	1	1

3.1.4. Anaerobic Digester Lab Scale Design:

The implementation of this research started from the process of lab scale of Anaerobic Digester, Fig (3.1), with 10% Inoculation from old Digester Plant

1. Bottle 2.5 liters.
2. Cork
3. Glass Tube
4. Rubber Tube
5. beehive shelf
6. Tub
7. Measuring cylinder

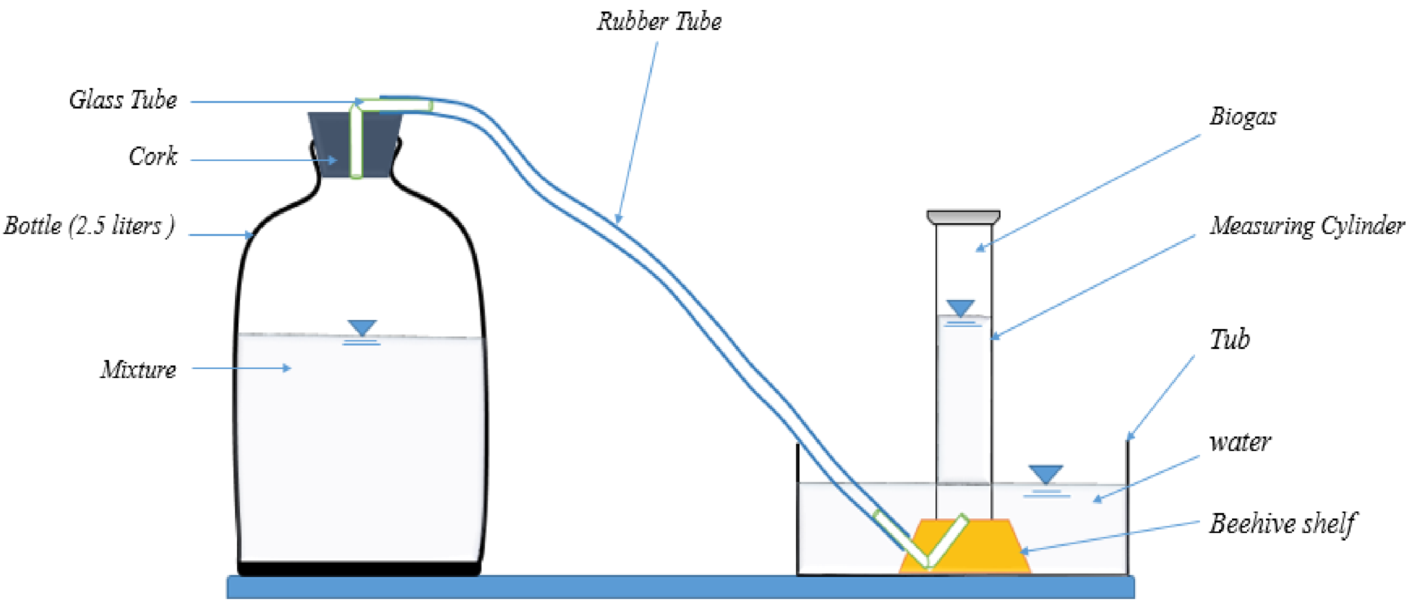


Fig (3.1.A): Schematic Lab Scale of Anaerobic Digester

Fig (3.1.B): The Lab Scale of Anaerobic Digester

3.1.5. Anaerobic Digester Pilot Plant:

After practical application of the Lab Scale model, larger plant was designed to be easy to operate maintain and cost effective, to be modified according to the need. The biogas produced was measured and analyzed using (Laser Induced Breakdown Spectroscopy (LIBS)). The slurry was analyzed for the N.P.K and supplied to the farmer to increase the plant productivity finally a good Pilot plant to be used as digester was fabricated to suit this process easy to operate, maintain and lower cost plant. in Pilot Plant Biogas plant attempt to produce electricity for the local people. Slurry displacement inside digester, depends on gas usage pattern. As cooking is usually done two times in a day

3.1.6. Anaerobic Digester Pilot Plant Design:

1. Main digester (height = 60 cm & diameter = 58 cm).
2. Gas Collection Drum (height = 35 cm & diameter = 57 cm)
3. Row materials Inlet (diameter = 3 inch).
4. Slurry Out let (diameter = 2 inch).
5. Biogas outlet valve (diameter = 0.5 inch).
6. Rod to shake the mixture.
7. Joint Between the two Drums.

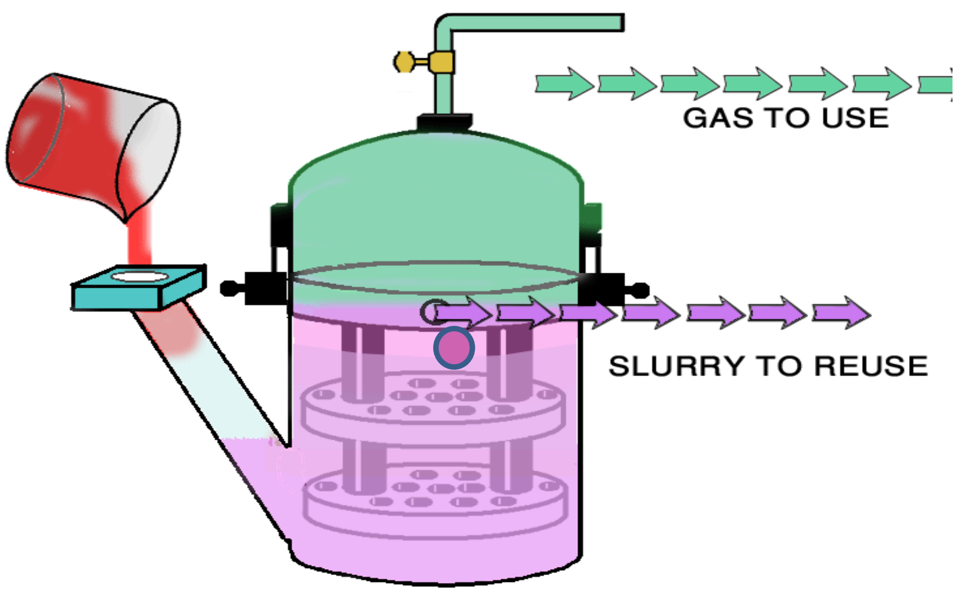


Fig (3.2.A): Pilot Plant Design Illustration

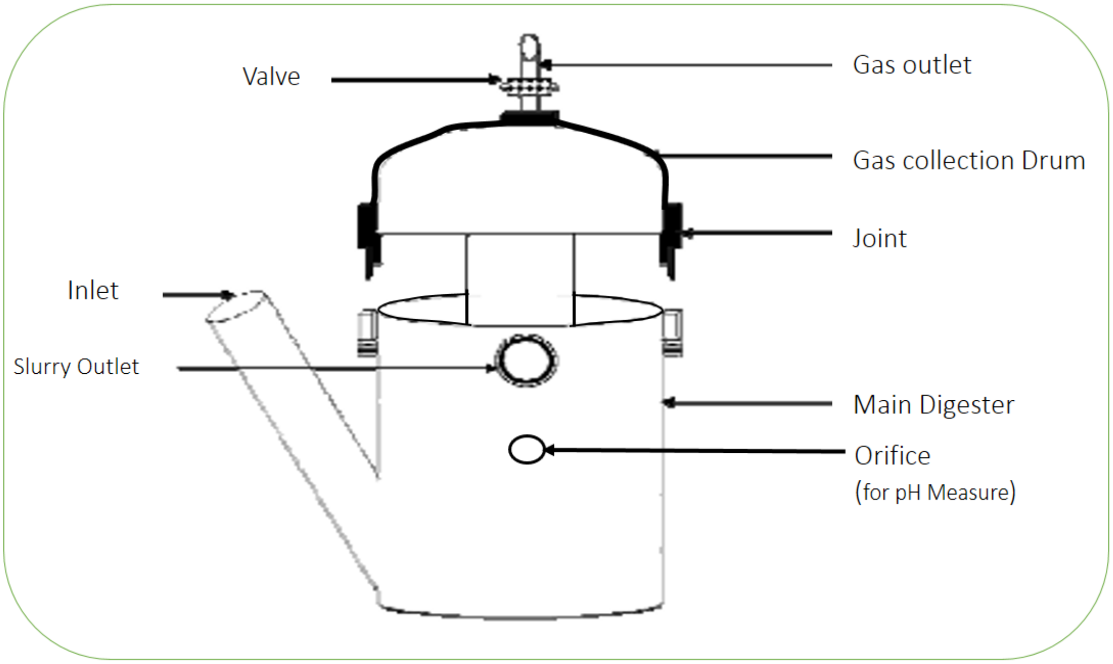


Fig (3.2.B): Pilot plant outside look

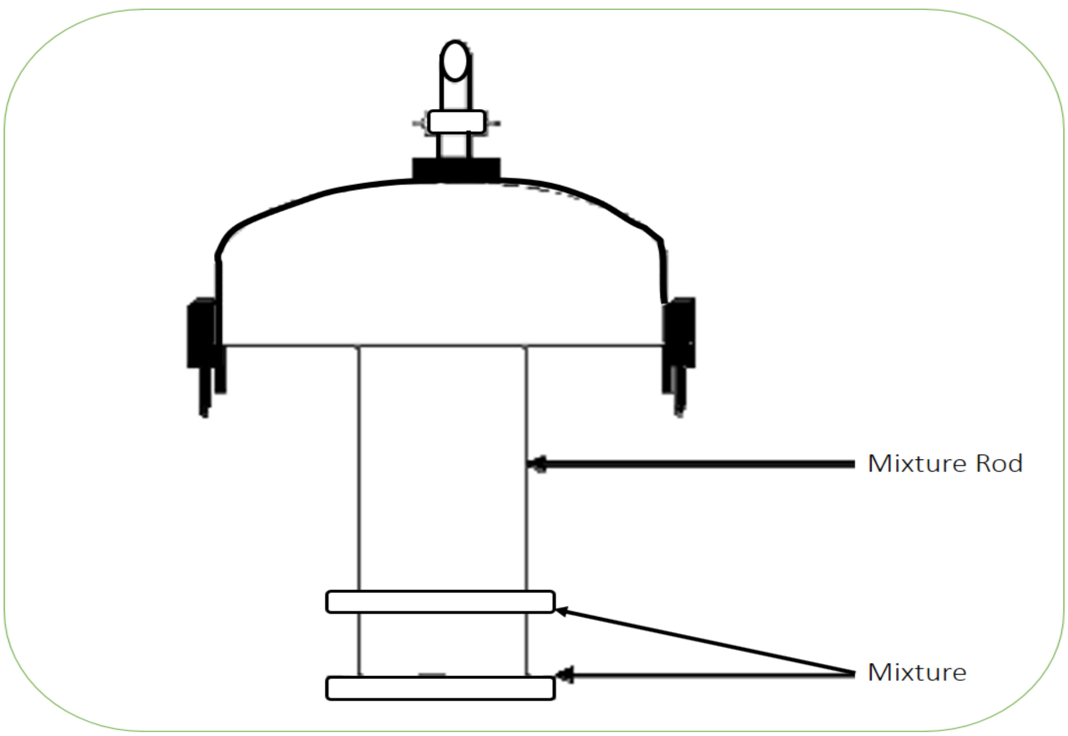


Fig (3.2.C): Pilot plant inside look

3.2. Methods:

To determine the appropriate mixing and mitigation ratio of Vinasse with water, laboratory experiments were conducted in which the mixing ratio was divided into three groups 1:1, 1:2 and 1:3, table (3/1).

The sludge was activated by the addition of human water taken from the sewage levels of Al_Neelain University, and was added by 10% of the total volume of mixing (vinasse: water: 0.1 inoculum) in each bottles, after 18 days there was no trace of produce gases so (10%) of the homogenous cow dung solution was added.

A number of mixing ratios and dilution with water were tried, accompanied by a lack of gas production or a weak production volume in some of them. Accordingly, a group of mixtures with different ratios were used between (vinasse: cow dung: activated sludge), The activated sludge was obtained from the waste of a digester in operation in (Khartoum - Jabra area), until the appropriate ratio was reached.

3.2.1. Factors Effecting:

1) Biochemical Oxygen Demand (BOD)
2) Carbon to Nitrogen Ratio (C:N)
3) Chemical Oxygen Demand (COD)
4) Hydraulic Retention Time (HRT)
5) Inoculum Level
6) Loading Rate
7) pH
8) Total Suspended Solids (TSS)
9) Temperature

1) <u>Biochemical Oxygen Demand (BOD)</u>:

BOD is the amount of oxygen, expressed in mg/L or parts per million (ppm), that bacteria take from water when they oxidize organic matter. The carbohydrates (cellulose, starch & sugars), proteins, petroleum hydrocarbons and other materials that comprise organic matter get into water from natural sources and from pollution. They may be dissolved, like sugar, or suspended as particulate matter, like solids in sewage. (Clifford C. Hach, 1997)

2) Carbon to Nitrogen Ratio (C:N):

- **Nitrogen**

  Nitrogen is required by all organisms for the basic processes of life to make proteins, to grow, and to reproduce. Nitrogen is very common and found in many forms in the environment. Inorganic forms include nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), and nitrogen gas (N_2). Organic nitrogen is found in the cells of all living organisms and is a component of proteins, peptides, and amino acids.

- **Organic Carbon:**

  Organic Carbon is measured using a carbonaceous analyzer. This instrument converts the organic carbon in a sample to CO_2 by either catalytic combustion or wet chemical oxidation. The CO_2 formed is then either measured directly by an infrared detector or converted to CH_4 and measured by a flame ionization detector. The amount of CO_2 or CH_4 in a sample is directly proportional to the concentration of carbonaceous material in the sample. (EPA, METHOD 9060A Total Organic Carbon, Nov 2004)

  The relationship between the amount of carbon and nitrogen in organic materials is represented by the C:N ratio. The C:N ratio is an important parameter in estimating nutrient deficiency and ammonia inhibition. (Hartmann, 2002) Optimal C:N ratios in anaerobic digesters are between 16 and 25 (Deublein D, 2011).

3) Chemical Oxygen Demand (COD):

COD testing is used to determine the amount of oxidation that will occur and the amount of organic matter in a water sample. and also used to determine the amount of inorganic chemicals in a sample. The COD test is usually done with a strong oxidizing chemical. Organic matter is oxidized to CO_2 and H_2O in an acidic state. The amount of organic matter or oxygen demand is calculated by determining the amount of oxidizing chemicals that were consumed during the test. A lot of organic matter can have a negative impact on the environment in which the waste is discharged. (EPA, Standard Operating Procedure, 2013). The difference between BOD and COD is that COD measures everything that can oxidize, while BOD measures only the oxygen required by living things. (Ashish, 2014).

COD/BOD ratio is normally in the range of 1.3 to 1.5. When the result of a COD test is more than twice that of the BOD test, there is good reason to suspect that significant portion of the organic material in the sample is not biodegradable by ordinary microorganisms. (idpowerstation, 2020)

4) Hydraulic Retention Time(HRT):

HRT) affects the contact between substrates and microorganisms which also favors toward higher treatment efficiency. HRT depends on the biodegradable nature of waste. (Bolzonella David, 2019) Retention time of 14 days was optimum for biogas production from cow dung. (I. J. Dioha, 2013)

5) Inoculum Level:

inoculum is added only at the start of the process, the nutrients provided by the inoculum are diluted with time due to addition of feedstock lacking required ratio of nutrients, which may adversely affect the process (Asad Ayub Rajput, 2019). The inoculum source is very important when digesting complex substrates with high organic content, like the case of vinasse. (Monica, 2018). Not effective as control, became rapidly too acidic (Prince, 2012).

The use of an optimum inoculum ratio is essential for the best energetic valorization of this type of organic waste because the ratio of inoculum is impacting. (Ouahid Elasri, 2018)An active inoculum can provide extra methane producing microorganisms (Asad Ayub Rajput, 2019). Digestant from anaerobic project can also provide extra nutrients source during the AD of agriculture waste. Micronutrient concentration in an inoculum can increase the enzyme activity and biogas yield. (Asad Ayub Rajput, 2019).

6) Loading Rate:

This is usually expressed as kilograms of volatile solids (kg VS) fed to the digester per day per cubic meter of digester volume. Thus a 5 m3 biogas plant with 50 kg of dung fed per day should have loading rate of around 1.4 kg VS/day m3. Temperature – controlled – mechanically stirred large biogas plants can have loading rates as high as 5 kg VS/day m3. It is to be mentioned that if loading rate is too high, pH of the digester content tends to fall due to its becoming acidic following inability of micro-organisms to biodegrade all feed materials (Ketut Adi Atmika, 2019)

The actual loading rate depends on the types of wastes fed into the digester (Hiya Dhar, 2015) optimize the organic loading rate in AD followed by application of statistical tools. (Rus, 2003)

7) pH:

The term (pH) stands for the power of Hydrogen and is the measurement of the hydrogen ion activity in a solution (Albert, 2003). The optimum environment is a pH of between 6.5 and 8, and the preferred level is 7.2. When the process is in balance, the acidity in the reactor will be within this range and as the buffer capacity in the reactor is very large, it takes a lot to alter it. The system is, in other words, very robust and stable. Slurry-based plants often have a somewhat higher pH (8-8.3) due to a higher ammonium content. (Nilsen & Bendixen, 2009).

8) Total Suspended Solids (TSS):

Total Suspended Solids (TSS) are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life. TSS is visible to the naked eye and can absolutely be reduced (eComply, 2021)

TSS testing measures the total concentration of suspended (non-soluble) solids in the aeration stabilization basin (ASB) or in effluents. The total suspended solids (TSS) data is critical in determining the operational behavior of a waste treatment system. (EBS, 2021).

$$TSS\left({}^{mg}/_{l}\right) = \frac{\left(Wpost\ (g) - Wpre\ (g)\right) \times 1000}{V\ (L)}$$

(Rodger B. Baird, 2017)

Where:

TSS	=Total suspended solid. (mg/L).
W post	= Weight of filter paper after filtration.
W pre	= Weight of filter paper before filtration.
V	= Volume of filtered sample.

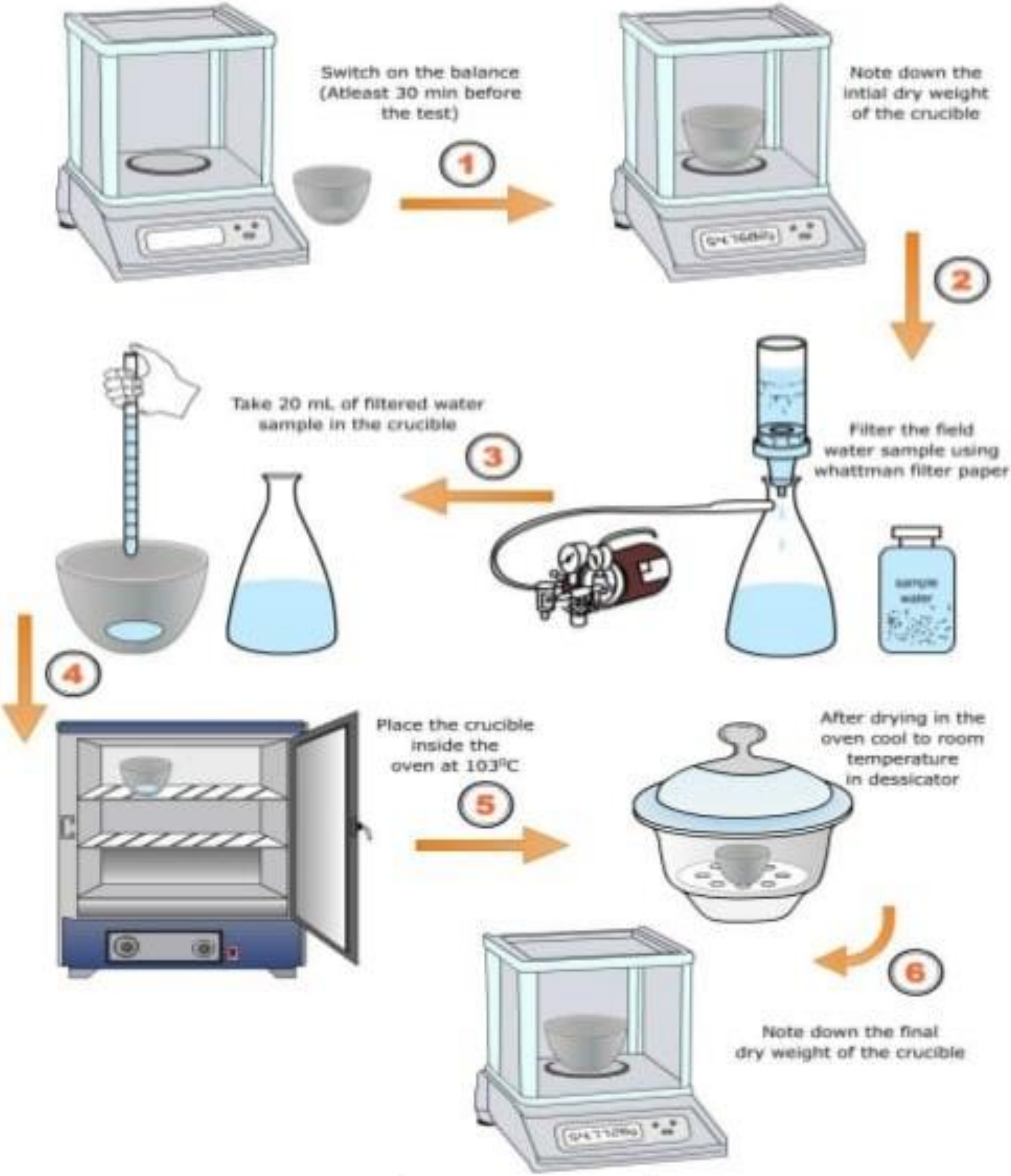


Fig (3.3): Method of TSS Test

9) **Temperature:**

Temperature is one of the most important factors in the succession of composting micro-organisms, and it is relatively easy to ascertain the microbial succession from mesophilic to thermophiles, or conversely from thermophiles to mesophilic, using different incubation temperatures. (Nakasaki K, 2005). The rate of biochemical processes generally increases with temperature. Several types or strains of bacteria involved that have adapted to the different temperatures, psychrophilic 0 – 20°C, mesophilic 15 – 45°C and thermophiles 40 – 65°C. Common to the bacteria is that they are very sensitive to changes in temperature. This sensitivity increases with temperature. In practice, biogas plants are run at either a mesophilic level of around 37°C, where fluctuations of approx. ± 2°C is tolerated, or at a thermophilic level of around 52°C, where fluctuations of only approx. ± 0.5°C (Nilsen & Bendixen, 2009)

3.2.2. Experiments Stages:

The production of biogas from Vinasse was tested in four phases:

1. Plan (A) mixing ratio.
2. Plan (B) mixing ratio
3. Confirmatory Experiment.
4. Pilot Plant Design

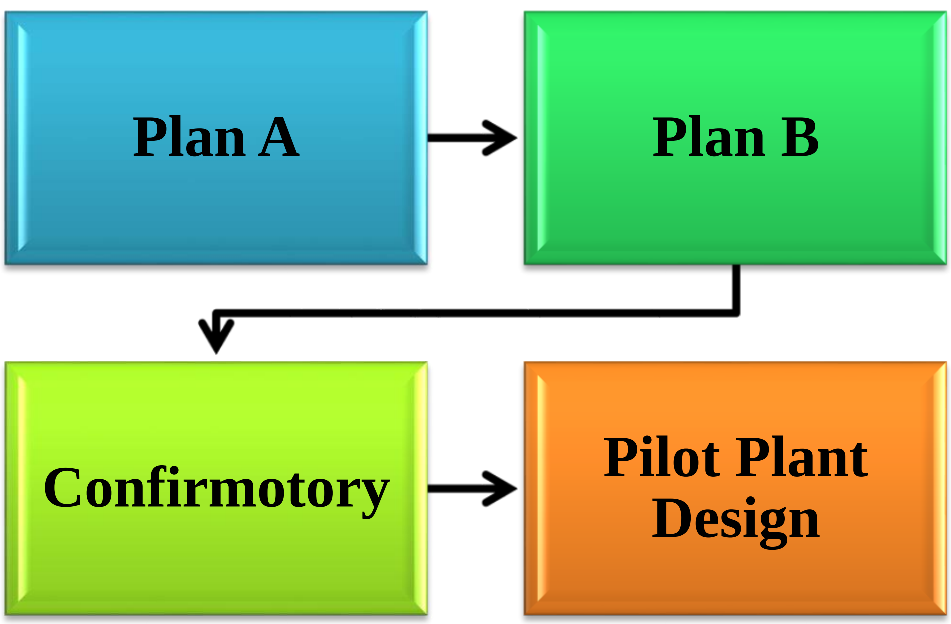
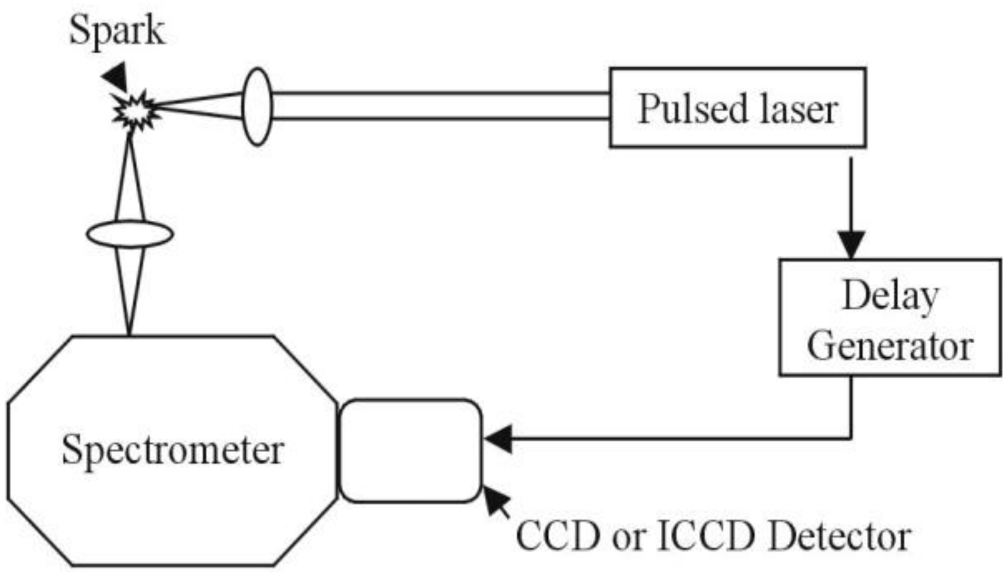


Fig (3.4): Vinasse Biogas Production Experiment

3.2.3. <u>Laser Include Breakdown Spectroscopy (LIBS)</u>:

LIBS is an atomic emission spectroscopy technique which uses highly energetic laser pulses to needle optical sample excitation. The interaction between focused laser pulses and the sample creates plasma composed of ionized matter. Plasma light emissions can provide “spectral signatures” of chemical composition of many different kinds of materials in solid, liquid, or gas state. LIBS can provide an easy, fast, and in situ chemical analysis with a reasonable precision, detection limits, and cost. Additionally, as there is no need for sample preparation, it could be considered as a “put & play” technique suitable for a wide range of applications. (Anabitarte F., 2012)



Charge

Fig (3.4): Schematic of LIBS system

3.2.4. Gas chromatography (GC):

Gas chromatography is a separation technique based on partitioning analyst between two immiscible phases: gaseous mobile phase (Carrier gas) and a stationary solid or immobilized liquid phase (packed or hollow capillary column). (Taha, 2018)

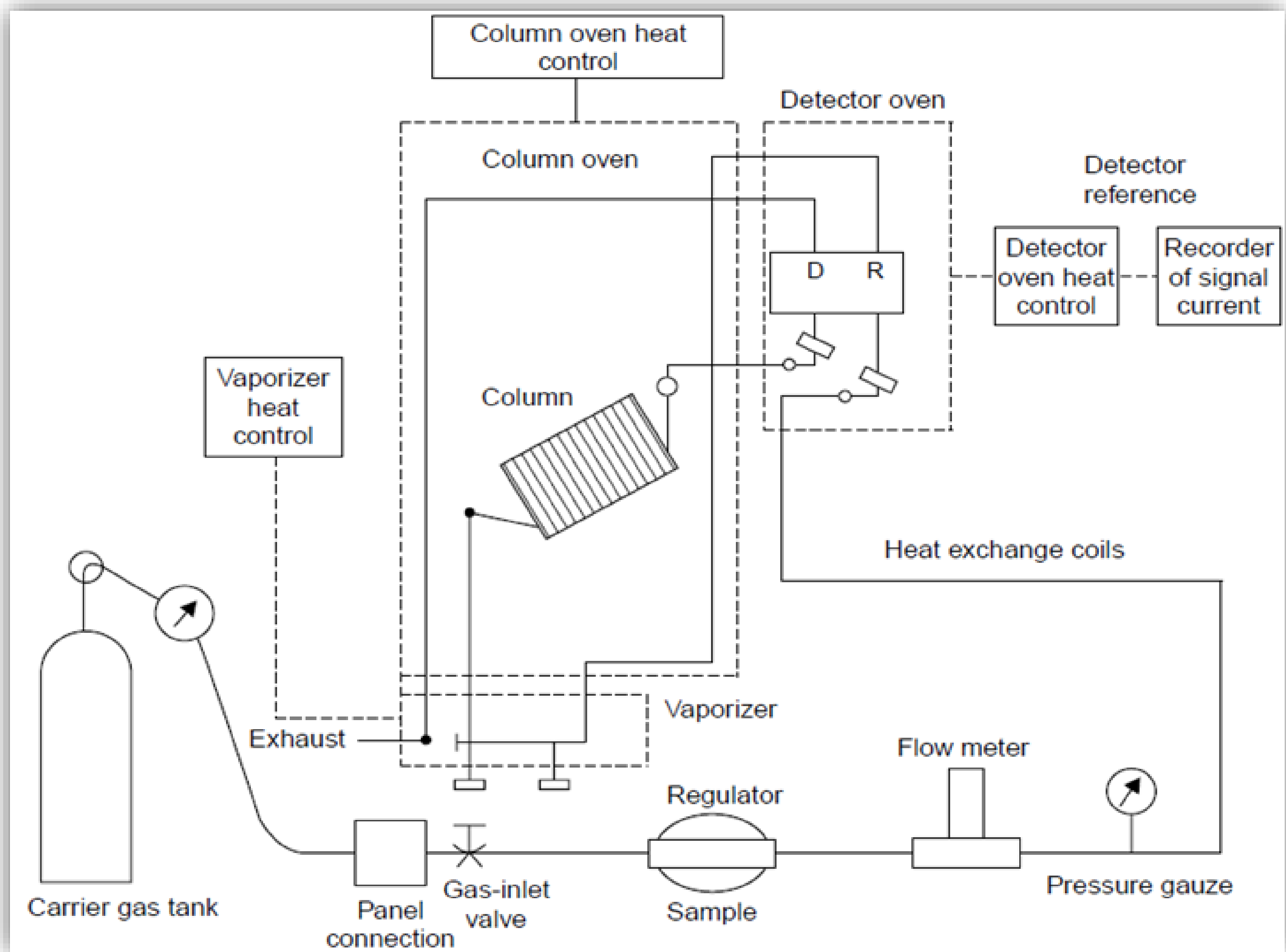


Fig (3.5): Gas Chromatography

Chapter Four

4. Results and Discussions

4.1. Results:

By following plans (A) and (B), respectively, with a total of three experiments in each stage, and each experiment contains three digesters (lab scale model) with the same mixing ratio each time (EX_1, EX_2 & EX_3), with a total of 9 digesters, and by taking the average of each of the three groups of experiments it was found that EX_2, which contains a ratio of (2: 1: 1), is the most productive for biogas, so we moved to the third stage of work, which is the confirmatory experiment (EX_4), so (vinasse: cow dung: Inoculum) was mixed with the same ratio of (EX_2), to confirm the mixing ratio. The results of the analysis of factors affecting the fermentation process and biogas production from vinasse before and after the experiments (Vinasse as raw material before the fermentation process, (EX_2) after the fermentation process, confirmatory (EX_4) after fermentation), were recorded as shown in Table (4.1).

Table (4.1): Vinasse analysis before and after digestion:

Factors	Before Digestion	Digestion		Units
		(EX2)	(EX4)	
BOD	213333	160000		mg/l
C:N	11.433	0		
COD	320000	240000		mg/l
Days of Largest produce		9	21	days
Gas produced per days	-	42.8	156	ml/day
Gas produced per weight	-	30.6	25.3	ml/g
Inoculum level (%)		25	25	%
Largest volume		500	700	Ml
Largest volume/ mixture volume		20	29	%
Loading rate (dry weight)		84	396	G
Mixture volume		2400	2400	Ml
pH	4.31	7.3	7.4	
Ratio of mixture	-	2:1:1	2:1:1	
Retention time	-	60	64	days
Starting of the gas production	-	48	48	hours
T.S.S	65	2680		mg/l
Temperature	28.33	36.4	35.5	◦ c
Total volume of gas produced	-	9890	2570	Ml
Total volume of gas/ mixture volume	-	1.07	4.1	Ratio

4.2. Discussions:

4.2.1. Plan A:

To determine the appropriate mixing and dilution ratio of Vinasse with water, laboratory experiments were conducted, during which the mixing ratio was divided into three groups (1:1, 1:2 and 1:3).

Activated sludge by adding sewage water taken from the sewage manholes of Al_Neelain University, and it was added by 10% of total volume of mixing water with Vinasse in each of the ratio test bottles, after 18 days from the start of the experiment, there was no effect of the appearance of gases, so a cow dung solution was added homogeneous by 10% of the total volume of the bottle.

Plan (A) mixing: (Vinasse: Water: Inoculum): (EX_1 = 1:1:0.1), (EX_2 = 1:2:0.1) & (EX_3 = 1:3:0.1).

The control bottles is: (C_1 = 1 Vinasse), (C_2 = 2 Vinasse) & (C_3 = 3 Vinasse)

- After 7 days of adding Cow dung; no gas Produce.
- Cause of the relative humidity in the Basement lab; temperature is very low in the Basement lab (the place of the experiment), where the temperature ranged 20 - 25 °C, So we transferred the experiment to outside place, where temperature 30 - 40 °C, that resulted in gas production in less than 48 hours.
- The gas produced in top of the measuring cylinders (displacing water), the large production in (EX_2R_1) which was the mixing ratio is (1:2).
- Volume of gas produced on (EX_2R_1) is 4 times more than others (less than 10 ml).
- After 30 days it was found that the production of gas stopped at 8 ml, no increase.

4.2.2. Plan (B)

It was found that the volume of gas in plan (A) is very weak, and the switch was made between the two plans after 60 days. with the mixing ratios shown in Table (4.2).

Table (4.2): Plan (B) mixing ratio (Vinasse: Cow dung: Inoculum)

	Mix	EX. No.	Vinasse (ml)	Cow Dung (ml)	Activated Sludge (ml)
EX_1	1:1:1	R_1	800	800	800
		R_2	800	800	800
		R_3	800	800	800
EX_2	2:1:1	R_1	1200	600	600
		R_2	1200	600	600
		R_3	1200	600	600
EX_3	3:1:1	R_1	1440	480	480
		R_2	1440	480	480
		R_3	1440	480	480
Control	1:1:1	C_4	100	100	100

- The table was designed so that the remaining space after adding the mixture in each bottle is 100 ml, where gas is formed, and then it is increased to work on displacing the water from the measuring cylinders inverted on the water Tub.
- According to Table (4.2) and the moisture content of Vinasse 93.3 Found that the dry weight of Vinasse in each bottle as in Table (4.3)

Table (4.3): Dry weight of mixture according to moisture content:

Bottles	wet. Weight (g)	Dry. Weight (g)
	1	**0.07**
EX_1	800	56
EX_2	1200	84
EX_3	1440	100.8

- Gas was produced in (C_4) after (4 days equivalent to four times the gas produced on other measuring cylinders, but every time an attempt was made to burn the resulting gas it did not ignite, and instead turned off the lighter; We conclude from this that the resulting gas is carbon dioxide.

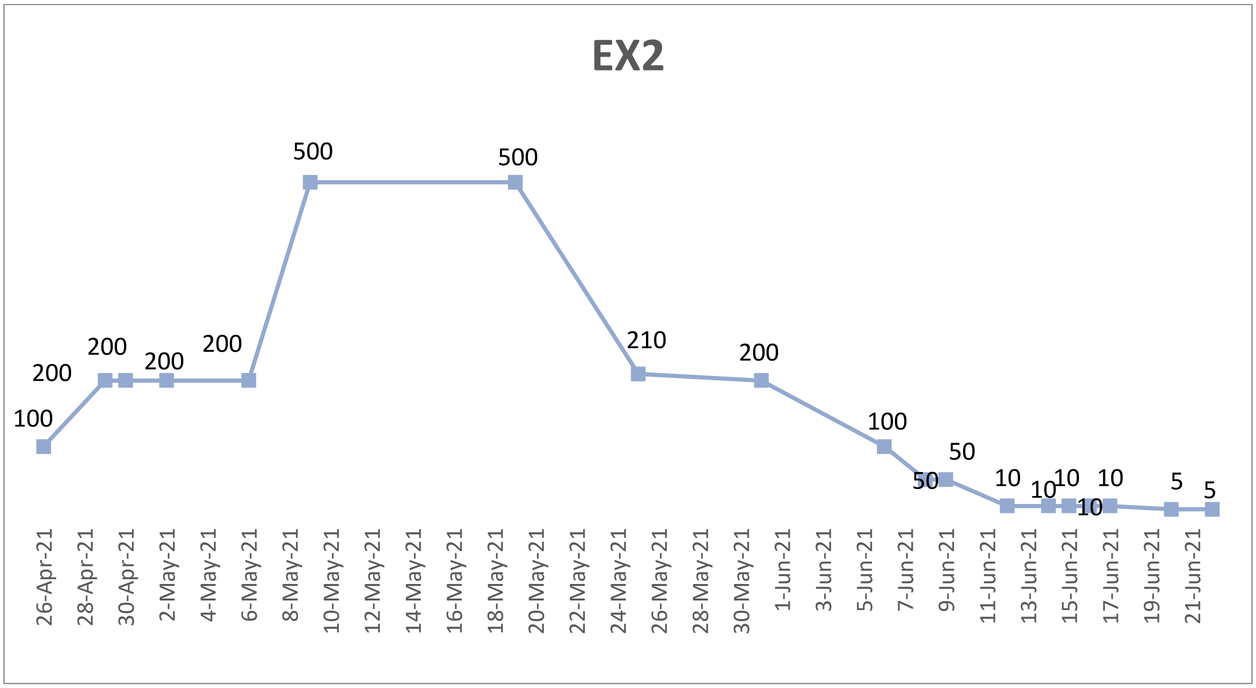


Fig.: (4.1): (EX_2) Volume of production gas vs dates

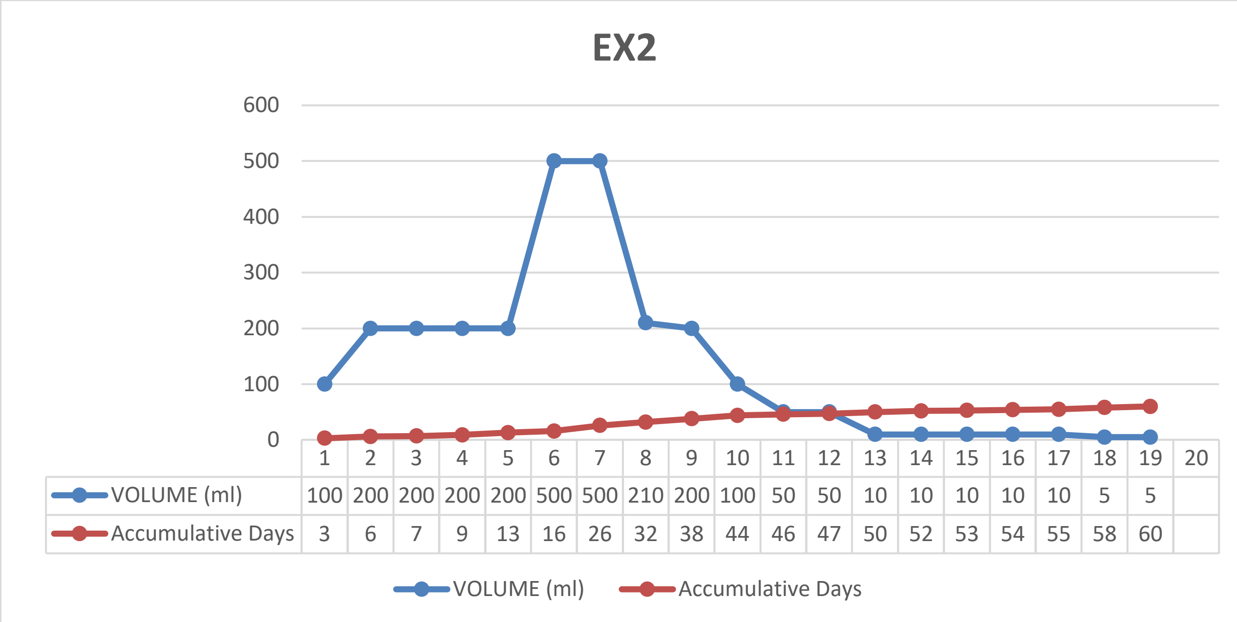


Fig.: (4.2): (EX_2) Volume of production gas vs accumulated days

We conclude from the above figures that the ratio (2: 1: 1) is the most suitable for the formation of gas produced by Vinasse fermentation at an average temperature of 35 °C, by adding cow dung and activated sludge in normal conditions, where the specifications of the homogeneous mixture for this ratio were: COD = 240000 mg/L, BOD =160000 mg/L, volume 2.4 L, and this result was after 60 days of fermentation for mentioned ratio, the gas produced at 9 days.
The gas produced 2570/84 = 30.6 ml/g.
The volume of gas was steady at the highest levels 500 ml in 15 - 30 days, then the amount of product gas began to decline 31 day until it reached its lowest level 5 ml after 60 days of fermentation.

In the study of (Isni Utami, 2015) Vinasse was used as a raw material for biogas production. The period of gas production in the current study is less than in that study, But the production started in a shorter period 48 hours and the maximum production of gas was after 9 days = 500 ml. The volume of activate sludge was 25% of the volume of mixture lower than in the previous study.

The ratio of the largest volume of gas produced in experiment (EX_2) to the volume of the mixture in the bottle was 500/2400 equal 20%, Total Volume of Gas were produced in (EX_2) is 9890 ml in (64) days.
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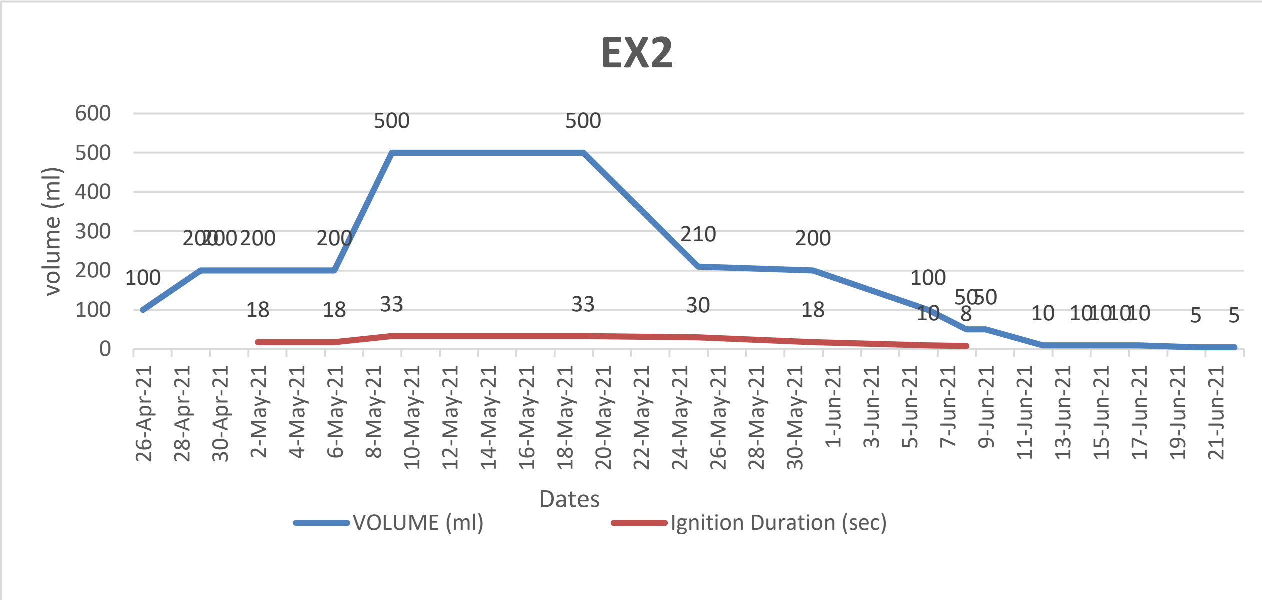

Fig.: (4.3): (EX_2) Ignition duration (sec) vs dates of productions

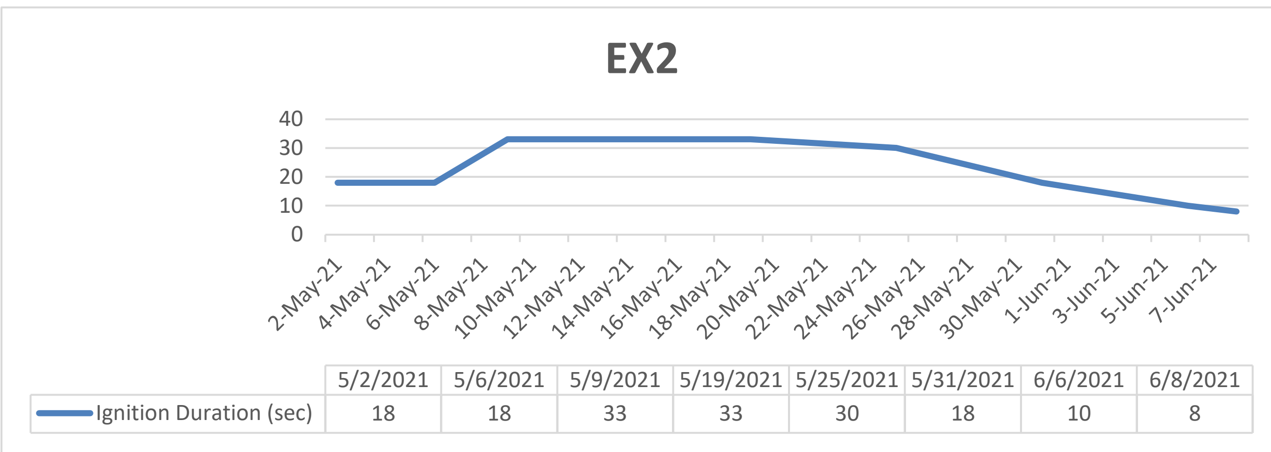

Fig.: (4.4): (EX_2) Volume of production Gas vs ignition duration (sec)

The maximum ignition duration is 33 sec with 500 ml of gas.
Due to COD, BOD & TSS there for these factors have influence the production of biogas. Imbalance can occur due to excessive organic loading or changes in operating conditions (Isni Utami, 2015).

4.2.2.1. Changing in pH (EX_2)

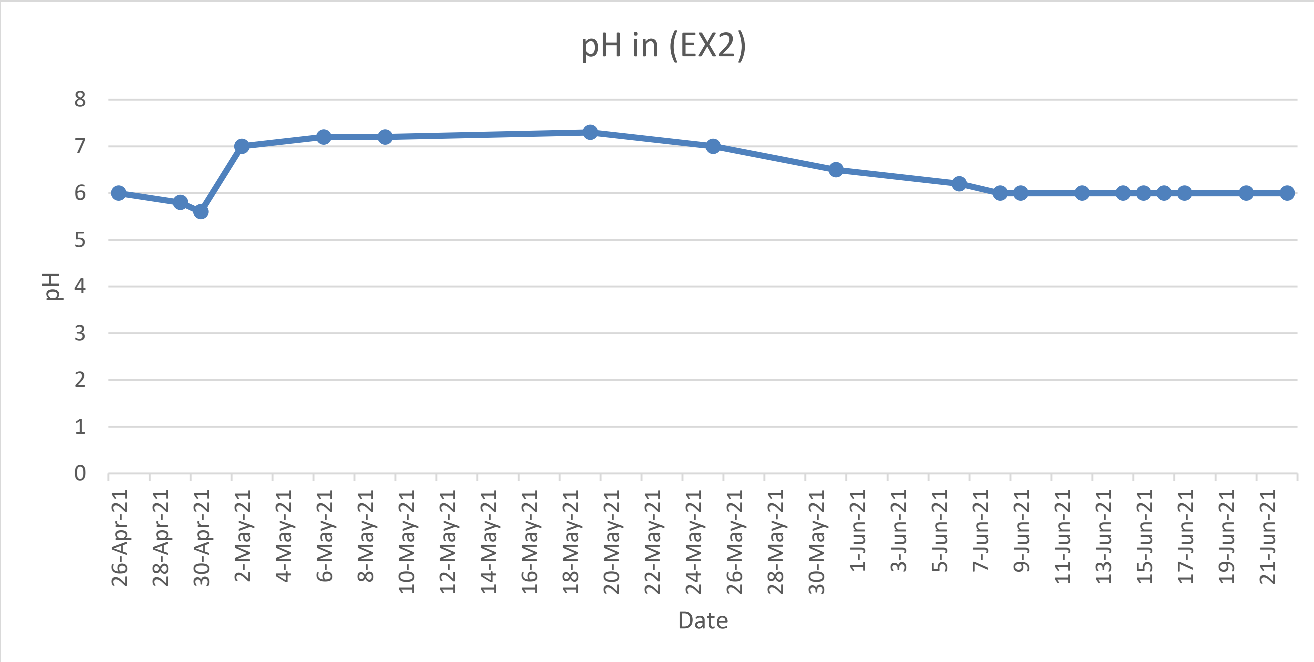

Fig (4.5): (EX_2) Changing in pH per Day

The change occurred in the pH of the mixture since the start of the experiment continuously, where he was 6 on the first day and then began to decline during the first week until he arrived at 5.6, to work until the pH increased to 7, the volume of gas production was then 200, to reach the pH to its highest level after 26 days of the start of the experiment, and gas production was also at its highest level 500 ml. The pH began once again after passing 38 and took the decline until he settled at 6 after 46 days, and this means that the bacteria has consumed the food.

4.2.3. Confirmatory Experiment (EX_4).

- **(**EX4) were mixed as (2:1:1) = (EX2), as the only experiment that produced gases, The moisture content of the experiment was measured in (EX2 = 77.7%).
- Found that the dry weight of Vinasse is as shown below:

Table (4.4): Vinasse Dry Weight on (EX_2):

EX_2	Wet. W (g)	Dry. W (g)
Vinasse	1	0.33
EX_2R_1	600	198
EX_2R_2	1200	396
EX_2R_3	1440	475.2

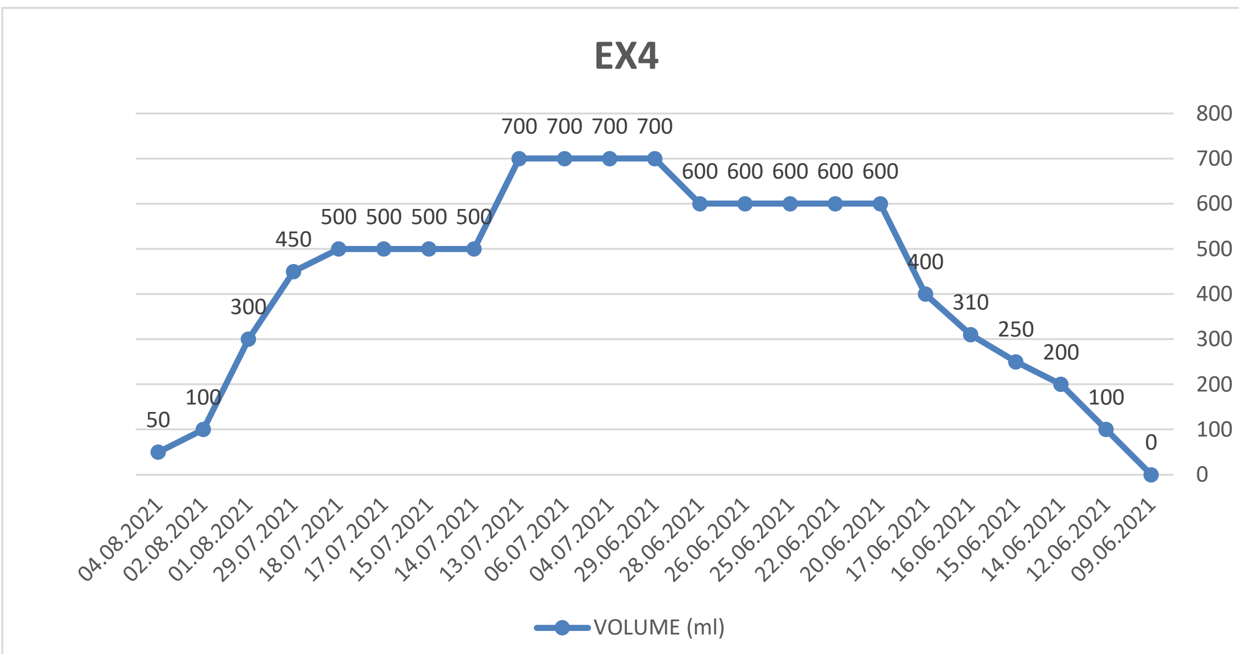

Fig.: (4.6): (EX_4) Volume of Production Gas vs Date

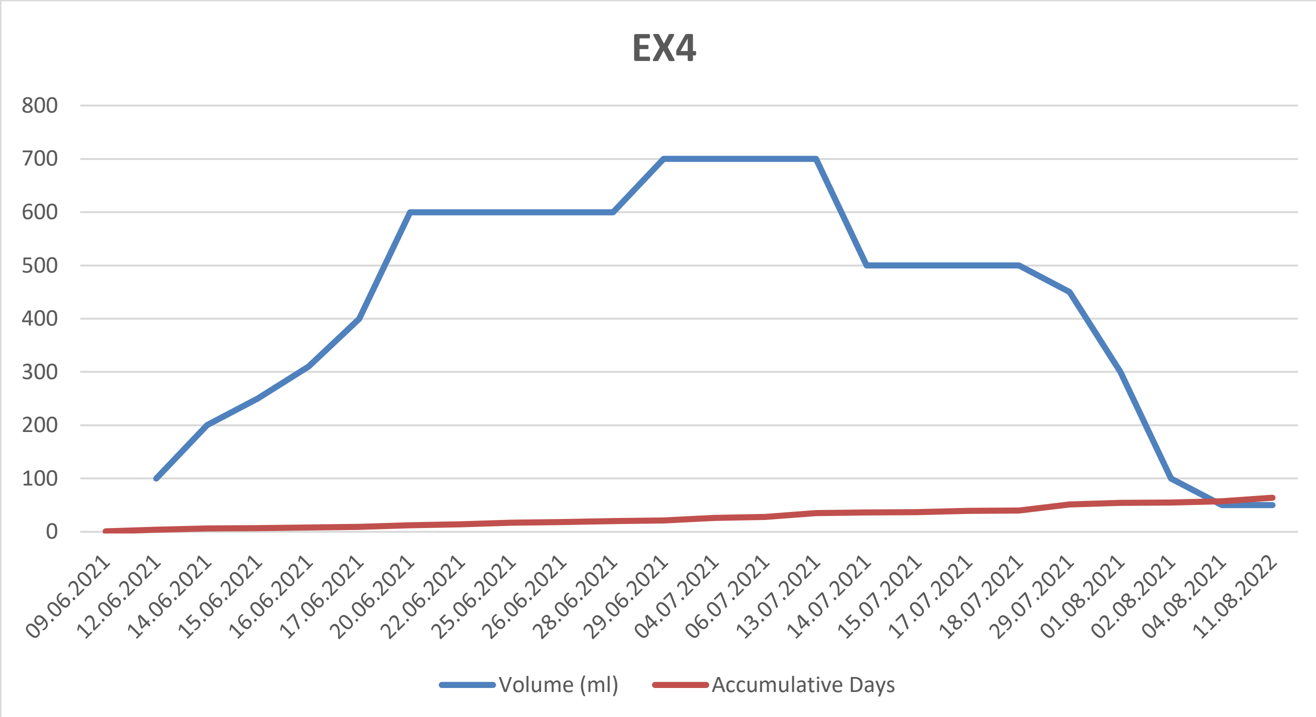

Fig.: (4.7): (EX_4) Volume of production gas vs accumulated days

Affirmative Experiment (EX_4) Confirmed that the mixing ratio (2: 1: 1) working on biogas production in less than 48 hours, and connect the volume of gas to 500ml after 9 days from the start of fermentation, but the largest size was recorded is 700 ml during 21 days from the start of fermentation, which indicates that the increase in dry weight had the effect of accelerating the fermentation process and producing gas in a shorter period.

The fermentation process in (EX_4) In the proportion of the size of the largest gas producer in which the size of the mixture in the bottle 700/2400 equal 29%.

Also the percent of inoculum volume 600 ml to the total volume of the mixture 2400 ml was equal to 25% of the volume of the mixture. Total Volume of Gas were produced in (EX_4) is 2570 ml in 60 days.

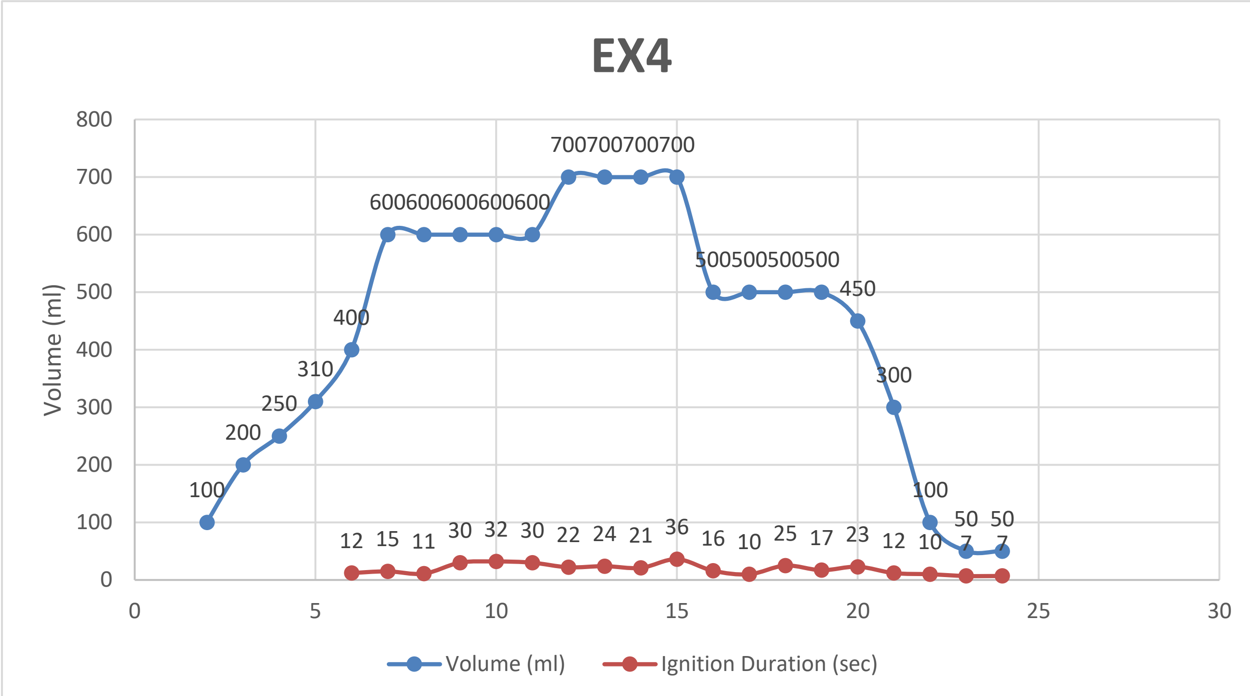

Fig.: (4.8): (EX_4) Volume of production gas vs ignition duration time (sec)

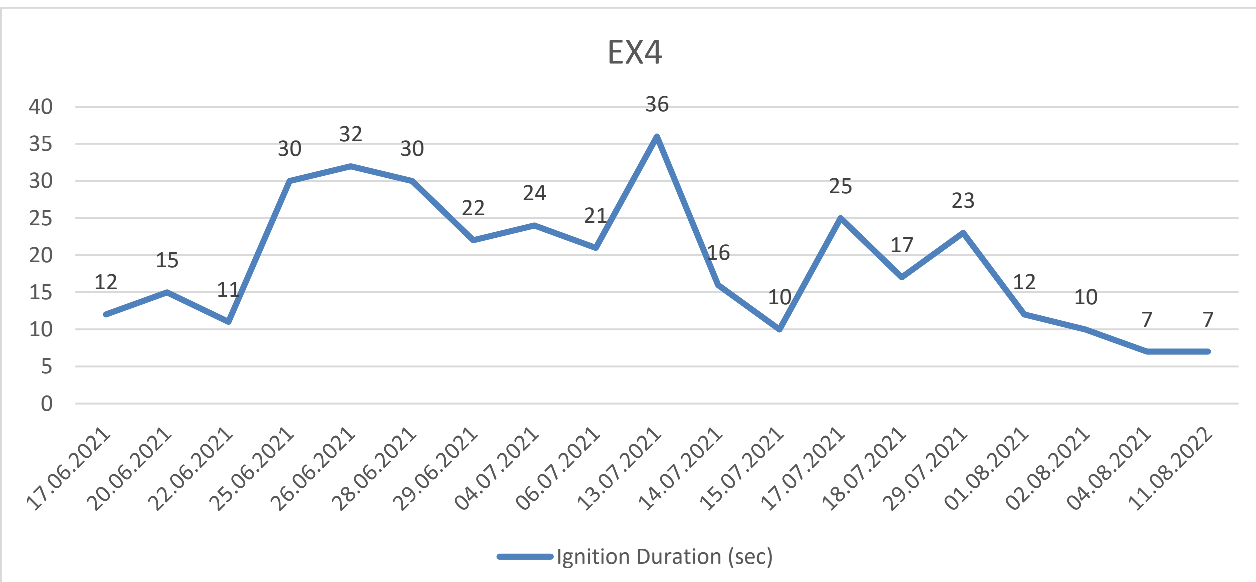

Fig.: (4.9): (EX_4) Ignition duration (sec) vs dates of productions

The ignition time is proportionally to the amount the of the gas produced. As retention time increased the gas produce increased, 32 second per 700 ml.

C:N Ratio of Vinasse was 11.343, pH of mixtures was increased in (Raw Vinasse, EX1, EX2 and EX3) by the following values (4.31, 7.3, 7.5 & 7.9) respectively, and it was 7.9 in the slurry, (N.P.K) in output slurry was increased (0, 13.148, 386.631).

That means pH of (EX_2) in the optimum range. Nitrogen in the (EX_2) was zero, Due to the fact that the analysis for the Nitrogen estimation was don late, there for oxidation reduction reaction to place Nitrogen converted to ammoniac form (NH_3), The digested slurry can be used to increase the productivity of the plant

In the study of (Paul Dobre, 2014) concluded that the raw material used to produce biogas through the anaerobic fermentation process must meet the requirements that the material is biodegradable, in (Budy Rahmat, 2019) Study A heat-operated biogas digester was designed as a pre-treatment of thermophilic raw materials (banana waste), and the most important conclusions were that the thermophilic heat treatment could shorten the processing time to 3 days.

This is what was also concluded in the current study, as after changing the location of the experiment from the Basement lab to the outer room, the gas productivity changed within 48 hours. However, the current experiment relied on room temperature in natural conditions without thermal interference, as the temperature ranged 30 – 40 ˚C.

In Studies of (Ahmed .O, 2013) and (Bianca, 2017) Vinasse had a very high BOD and COD values, vinasse samples were devoid of all microbial groups. COD/BOD ratio of 1.34 in (Bianca, 2017) indicates high biodegradability and that the vinasse constituents may be used by bacteria as substrate for bio-surfactant production.

The remaining fermentation media was submitted to anaerobic biodegradation under mesophilic conditions. The residual medium derived from fermentation with vinasse diluted to (1:1), without adding nitrogen, C:N= 21 and for 168 hours, resulted in 63.2% of COD.

The current Study was also carried out in Mesophilic temperature conditions, cow dung is 0.25% of mixture, COD/BOD = 240000/160000 = 1.5, Total volume of Gas per volume of mixture in (EX_2) is 1.07, but in (EX_4) is 4.12, This is due to the change in the dry weight of the mixture from 84 g in (EX_2) to 396 g in (EX_4), Due to the changes in the TSS and C:N the Experiment had resulted in highest biogas production in the (2:1:1) ratio.

The increase in carbon content will give rise to more carbon dioxide formation and lower pH value, while high value of nitrogen will enhance production of ammonia gas that could increase the pH to the detriment of the micro-organisms. (I. J. Dioha, 2013)

4.2.3.1. Changing in pH (EX_4)

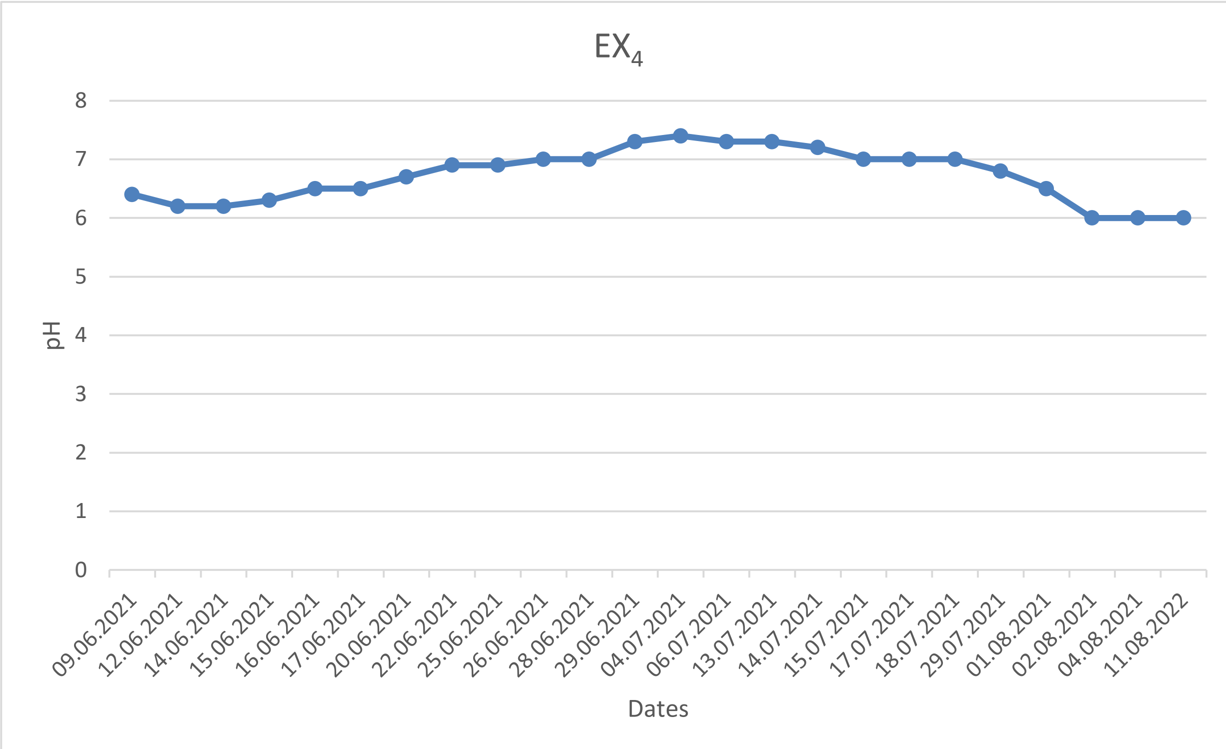

Fig (4.10): (EX_4) Changing in pH per Day

The confirmatory experiment (EX_4) went through similar changes in the pH level with the experiment (EX_2) where the change in the pH was also continuous, it was 6.4 on the first day and then began to decline during the first week until it reached 6.2, due to the lack of Feeding anaerobic bacteria in the digester, but as soon as the anaerobic bacteria began to work, the pH increased to 7, and the volume of gas production at that time was 600 ml, bringing the pH to its highest level 7.4 after 26 days from the start Experiment, gas production was also at its highest level 700 ml.

The pH started decreasing again after 28 days and started declining until it settled at 6 after 55 days, which means that the bacteria had consumed the food.

4.3. Anaerobic Digester Pilot Plant:

I designed and built an anaerobic digester with a capacity of 10 liters vinasse. Was designed from simple raw materials in a way that is easy to use by housewife and applicable to commercial purposes.

Jashu Bhai from India designed the first floating drum biogas plant, popularly called Gobar gas plant. Floating-drum plants consist of an underground digester (cylindrical or dome-shaped) and a moving gas-holder. The gas-holder floats either directly on the fermentation slurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. (Basnet, 2015)

A Chinese inventor designed a one-unit system built underground. Have low construction cost, no moving parts, no rusting steel parts, hence long life (20 years or more), underground construction, affording protection from winter cold and saving space, creates employment locally. But the Plants often not gaslight (porosity and cracks), gas pressure fluctuates substantially and is often very high, low digester temperatures. (Biogasplant, 2014)

- For both the Gobar and Chinese digesters, comparatively high investment and maintenance costs, and poor solids movement through the system were drawbacks, which quickly led to their obsolescence (Elfadil, 2008)

4.4. Laser Induce Breakdown Spectroscopy (LIBS):

By analyzing two samples of the produced gas by (LIBS) method, the following elements were obtained according to their wavelengths.

Sample (1):

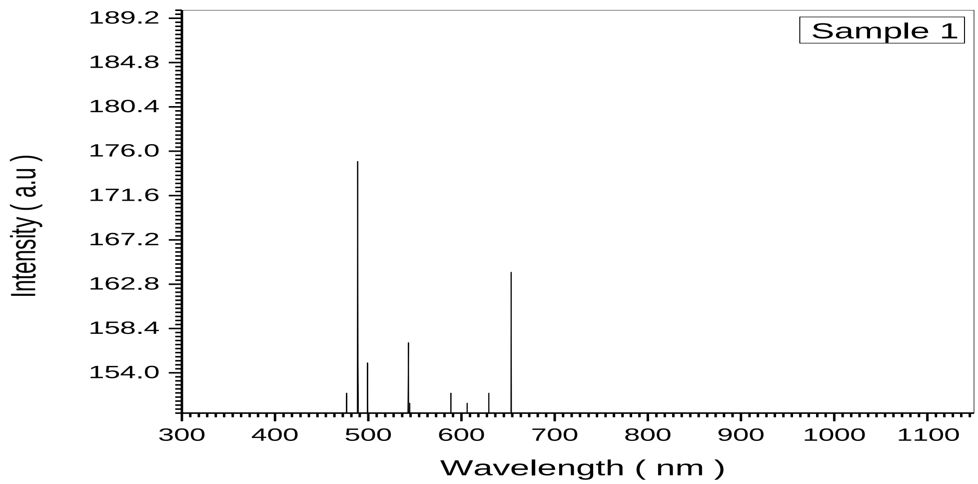

Fig.: (4/11): Sample (1) (Gas production), Wavelength vs intensity

The elements: (Cl, Cl_2, Xe_2, Ti_1, Na_2, Na_1, Eu_1, Ce_1 and Cs_2) respectively.

Sample (2):

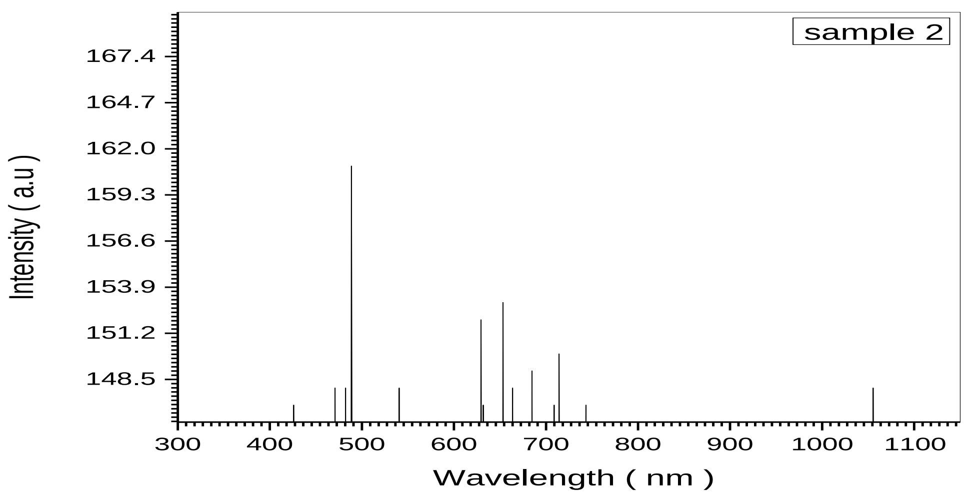

Fig.: (4/12): Sample (2) (Gas production), wavelength vs intensity

The elements**:** (Cf_1, Gd_1, Tc_1, Ar_1, C_1, Ce1, Cs_2, Ar_2, Pm_1, F_1, Zr_1, Cs_2, Cl_1, U_1 and Ce_1) respectively.

In addition to this, the result of the gas liquid chromatography as it has been depicted in table (4.5).

- Table (4.5): Chemical Analysis of the Biogas Production

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 – 20.000 ppm (2%)
Ammonia (NH_3)	0 – 0.05 %
Nitrogen (N)	0 – 2 %
Oxygen (O_2)	0 – 2 %
Hydrogen (H)	0 –1%

Methane gas is flammable and has a very hot, faint blue flame, but its presence with a mixture of gases limits its heat, as it gives a calorific value of "3170-4777" kilocalories/m3. Biogas is used in cooking food, lighting, heating, and operating internal combustion engines and electricity generators. What remains after biogas production is an organic fertilizer rich in plant fertilizing elements, and some countries provide it as fodder for livestock after drying and granulating it. (Mahmoud, 2014)

It will be benefited from adapting the idea. Biogas has economic value; it is cheaply produced by farmers at rates sufficient for daily cooking and lighting needs of a rural family.

4.5. The process of converting into electrical energy:

Advanced biological methods are potentially less expensive and more efficient. Biogas electricity production can be a very efficient way to produce electricity from a renewable energy source. However, this applies only if the heat generated from the power generator can be used in an economically and environmentally sound manner. (Elfadil A. G., 2017).

It is theoretically possible to produce electricity. Biogas could be converted directly into electricity using a fuel cell. However, very clean gas and an expensive fuel cell are essential to this process. So this is still a matter of research and is not currently a viable option. While the use of gas for direct combustion in household stoves or gas lamps is common, electricity is produced from biogas. The energy content of a gas mainly depends on its methane content. (Elfadil A. G., 2017).

The average calorific value of biogas is about 21-23.5 MJ / m^3, which means that 1 m^3 of biogas corresponds to 0.5 - 0.6 liters of diesel fuel or an energy content of about 6 kWh. However, due to conversion losses, larger biogas plants are generally more cost-effective than smaller plants. However, biogas electricity generation is a suitable technology even for relatively small applications in the 10-100 kWh range. (FNR, 2009), Gas was measured by using the physical method [burning].

4.5.1. Simulation Used to Convert Biogas to Electricity in EX_2:

1 m^3 → 1000 liter

Based on this formula the following equation has been emerge

84 g (dry weight) → 10010 ml (amount of gas)

$84\ g \times 10010\ ml/g = 840840\ ml = 840.84\ L$

1 m^3 → 1000 L

X → 840.84 L

$(840.84\ L \times 1\ m^3) / 1000\ L = 0.84\ m^3$

Percent of $CH_4 = 0.6 \times 0.84 = 0.504\ m^3$

0.5 to 0.6 (Diesel) = 0.504 m^3 (biogas)

X (Diesel) = 0.504 m^3

$(0.6\ m^3 \times 0.504\ m^3) / 1\ m^3 = 0.304\ L$

0.5 to 0.6 L (Diesel) → 6 kWh

0.5 → 6 kWh

0.304 → X

X = 3.63 kWh

0.504 m^3 (Biogas) → 3.63 KWh

1 m^3 (Biogas) → 7.202 KWh

4.5.2. Simulation Used to Convert Biogas to Electricity in EX_4:

1 m^3 → 1000 liter

Based on this formula the following equation has been emerge

396 g (dry weight) → 2570 ml (amount of gas)

396 gram × 2570 ml/gram = 1017720 ml = 1017.72 liter

1 m^3 → 1000 liter

X → 1017.72 liter

(1017.72 liter × 1 m^3) / 1000 liter = 1.0177 m^3

Percent of CH_4 = 0.6 x 1.0177 = 0.6106 m^3

0.5 to 0.6 (Diesel) = 0.6106 m^3 (biogas)

X (Diesel) = 0.6106 m^3

(0.6 m^3 × 0.6106 m^3) / 1 m^3 = 0.3664 L

1 m^3 Diesel → 6 kWh

0.3664 Diesel → X

X = 0.06 × 6 = 2.1984 kWh

2.1984 kWh this is amount of electricity produce from 1017720 ml of biogas.

1 m^3 biogas = 0.5 to 0.6 Diesel = 6 kWh.

X (Diesel) = 2.1984 m^3

(0.6 m^3 × 2.1984 m^3) / 1 m^3 = 1.319 L

0.5 to 0.6 L (Diesel) → 6 kWh

0.5 → 6 kWh

1.319 → X

X = 15.828 kWh

0.6106 m^3 (Biogas) — 15.828 KWh

1 m^3 (Biogas) → 25.695 KWh

4.5.3. Electricity from Pilot Plant:

Using 20 liters of Vinasse mixture in a mixing ratio (2:1:1), and based on the methane produced (50 - 60)%, and using the simulation result (0.504 m^3 of biogas gives 3.63 KWh in 60 days of fermentation, the results are as shown in the table (4.6).

Table (4.6): Cumulative conversion of biogas into electricity at the Pilot Plant:

Days	Volume (ml)	Methane (50 - 60)%	Volume (m^3)	Diesel (L)	Electricity (Kw)
10	3333.33	1666.67	1.67	0.83	10
20	5000	2500	2.5	1.25	15
30	5833.33	2916.67	2.92	1.46	17.5
40	4166.67	2083.33	2.08	1.04	12.5
50	3750	1875	1.86	0.94	11.25
60	416.67	208.33	0.21	0.10	1.25
Total In 60 Days	22500	11250	11.24	5.62	67.5

The maximum volume of biogas production in one day was after 30 days with a quantity of 5833 ml, while the cumulative production for the whole period 60 days reached 22500 ml, the electricity was produced from The Pilot Plant in 60 Days = 67.5 kWh.

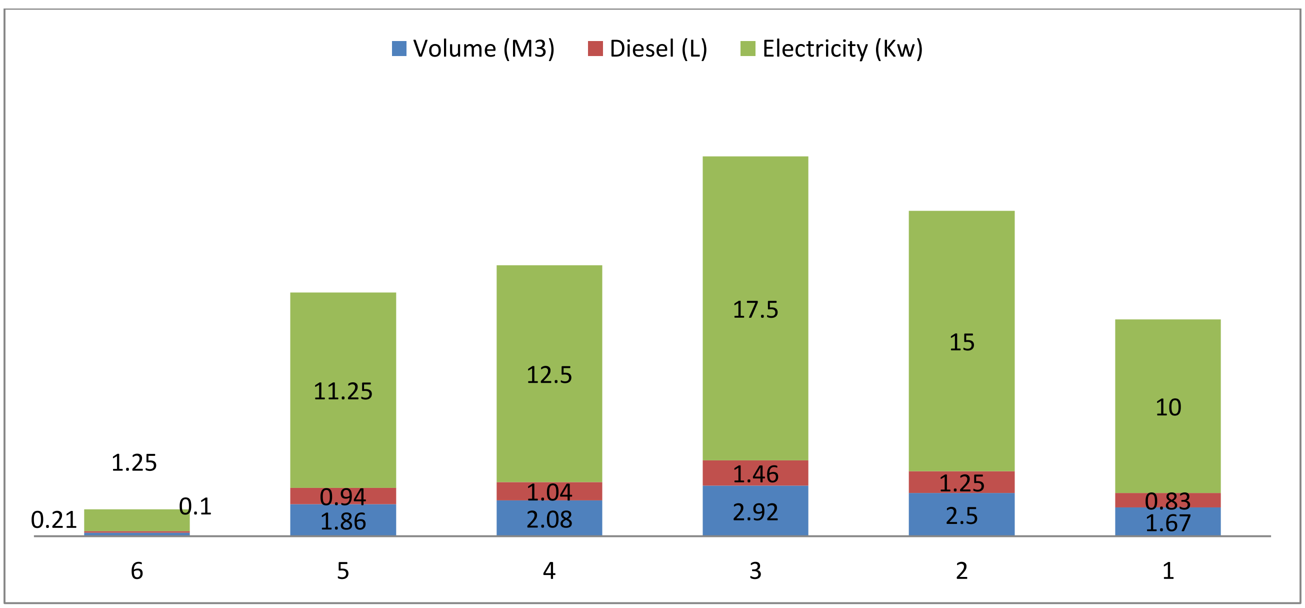

Fig (4/13): Cumulative conversion of biogas into electricity at the Pilot plant.

Chapter Five
5. Conclusion and Recommendation

5.1 Conclusion:

The study aimed to take advantage of Vinasse to produce biogas and then convert the waste into organic fertilizer.

The experiments were designed on a 2.5 liter digester and blending of Vinasse with cow manure and active sludge from the digester producing biogas in a ratio of 2:1:1 respectively. The result was that the production of biogas started after 48 hours at an average temperature of 30-40 degrees Celsius, then the gas reached its highest levels after 15 days with a volume of 500 ml, and daily biogas. Production continued at this rate for another two weeks 30 days from the start of the experiment, as the experiment relied on burning gas on a daily basis. To allow the formation of new gas, the volume of production started to decrease until it reached its lowest level 5 ml after 60 days from the start of the experiment, which means that the ratio of the volume of gas produced to the volume of components 2400 ml is 0.2%. The burn time of the torch increases and decreases according to the gas volume, and the highest was 36 seconds with a volume of 500 ml.

The experiment was repeated with the same volume and mixing ratio, and the result was that biogas production started after 48 hours, then the gas volume reached 500 ml after 10 days with an average temperature between 30 to 40 degrees Celsius, then Link. Highest levels 700 ml 20 days from the start of the experiment, the burning duration of the remaining flame increased and decreased according to the volume of gas produced per day; The highest level was 36 seconds, and the lowest level was 10 ml after 64 days from the beginning of the experiment.

Accordingly, a Pilot plant was designed to accommodate 20 kg of the mixture, which in turn produced a greater amount of biogas that reached in 60 days to 5833 ml which resulted in the maximum benefit of raw materials with low production cost and ease of use at home by housewives, The use of production residues as fertilizer.

5.1. Recommendation:

The recommendations were based on the results obtained:

- The study recommends expanding the biogas production from Vinasse using the model that was designed, to produce biogas by mixing Vinasse with organic products in homes and restaurants to achieve the economic benefit of these restaurants and reduce the waste generated from them.
- The study recommends further studies on the waste generated from digesters when producing biogas and converting it into organic fertilizer.
- The study recommends using the model that is designed to ferment all the organic waste that can be used to produce methane where vinasse can be replaced by other agricultural waste products like water hyacinth, poultry, animals dung, human waste, and kitchen wastes
- Creation of jobs for all genders and small businesses, improved living standards, and a healthier.

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Appendix

Appendix (Table -1): Plan (A): mixing ratio of (Vinasse: Water: 0.1 Inoculum):

	Mix	EX. No.	Vinasse (ml)	Water (ml)	Inoculation (ml)
EX_1	**1:1**	R_1	500	500	100
		R_2	500	500	100
		R_3	500	500	100
EX_2	**1:2**	R_1	500	1000	150
		R_2	500	1000	150
		R_3	500	1000	150
EX_3	**1:3**	R_1	500	1500	200
		R_2	500	1500	200
		R_3	500	1500	200

Appendix (Table -2): Plan (A): mixing ratio of (Vinasse: Water: Cow Dung).

	Mix	EX. No.	Vinasse (ml)	Water (ml)	Cow Dung (ml) (10% from Total Volume)
EX_1	1:1:0.1	R_1	500	500	100
		R_2	500	500	100
		R_3	500	500	100
EX_2	1:2:0.1	R_1	500	1000	150
		R_2	500	1000	150
		R_3	500	1000	150
EX_3	1:3:0.1	R_1	500	1500	200
		R_2	500	1500	200
		R_3	500	1500	200
Control	1:1	C_1	500	500	0
	1:2	C_2	500	1000	0
	1:3	C_3	500	1500	0

Appendix (Table -3): Time line of Gas production in (EX_2R_2, EX_2R_3, EX_4 & C_4):

Date	No. of Days			Volume of Gas Production (ml)				Ignition Time (sec)				Temp (◦C)
	Plan A	Plan B	EX4	EX_2R_2	EX_2R_3	EX_4	C_4	EX_2R_2	EX_2R_3	EX_4	C_4	
17.02.2021	01			Start Plan (A) mixture (Appendix-1)								28
28.02.2021	11											29
03.03.2021	14											27
07.03.2021	18											29
15.03.2021	26											28
16.03.2021	27			The location of the experiment was changed from an Basement lab to an external room with a metal roof (zinc).								35
18.03.2021	29			8				The volume of gas produced during this period is cumulative that has not been burned on a daily basis				36
20.03.2021	31			8								35
22.03.2021	33			8								30
23.03.2021	34						15					30
24.03.2021	35						25					36
28.03.2021	39						30					35
31.03.2021	42						30					30
01.04.2021	43						30					30
08.04.2021	50						40					33
21.04.2021	63						50					35
23.04.2021	65						50					33
24.04.2021	66	01		Moved to plan (B) with a new mixture (Table 4/3)								32
25.04.2021	67	02										33
26.04.2021	68	03		100	100		Stoped					30
27.04.2021		04					10					34
29.04.2021		06		200	150							
30.04.2021				200	200							
02.05.2021		**09**		**300**	**400**			18	17			
06.05.2021		13		200	150			18	15		No gas	
09.05.2021		16		500	200			33	21			40
19.05.2021		26		500	300		200	36			CO_2	
25.05.2021		32		210	100			30				
31.05.2021		38		200	150			18				40
06.06.2021		44		100	100			10				40
08.06.2021		46		50	50			8				38

09.06.2021		47	01	10	10	**Start Confirmation Experiment (EX$_4$)**						
12 .06.2021		50	04	10	4	100		The volume of gas produced during this period is cumulative that has not been burned on a daily.				42
14.06.2021		52	06	10	6	200						36
15.06.2021		53	07	10	7	250						36
16.06.2021		54	08	10	8	310						36
17.06.2021		55	09	10	10	400				12		35
20.06.2021		58	12	10	5	600				33		36
22.06.2021		60	14	5	5	600				11		38
25.06.2021			17	Stoped Produce		600				30		35
26.06.2021			18			600				32		35
28.06.2021			20			600				30		36
29.06.2021			**21**			**700**				22		34
04.07.2021			26			700				24		35
06.07.2021			28			700				21		36
13.07.2021			35			700				20		36
14.07.2021			36			500				16		36
15.07.2021			37			500				10		36
17.07.2021			39			500				25		37
18.07.2021			40			500				17		36
29.07.2021			51			500				23		35
01.8.2021			54			300				12		33
02.08.2021			55			100				10		33
04.08.2021			57			50				7		35
11.08.2021			58			50						30

Appendix (Table - 4): (EX_2R_2 & EX_2R_3) Volume of Gas & Ignition Duration per Day:

DATE	Volume (ml)	Ignition Duration (sec)	Days	Accumulative Days	pH
4/26/2021	100		3	3	6
4/29/2021	200		3	6	5.8
4/30/2021	200		1	7	5.6
5/2/2021	200	18	2	9	7
5/6/2021	200	18	4	13	7.2
5/9/2021	500	33	3	16	7.2
5/19/2021	500	33	10	26	7.3
5/25/2021	210	30	6	32	7
5/31/2021	200	18	6	38	6.5
6/6/2021	100	10	6	44	6.2
6/8/2021	50	8	2	46	6
6/9/2021	50		1	47	6
6/12/2021	10		3	50	6
6/14/2021	10		2	52	6
6/15/2021	10		1	53	6
6/16/2021	10		1	54	6
6/17/2021	10		1	55	6
6/20/2021	5		3	58	6
6/22/2021	5		2	60	6

Appendix (Table -5): Results of the confirmatory experiment (EX_4):

Date	**Volume (ml)**	**Ignition Duration (sec)**	**Days**	**Accumulative Days**	**pH**
09.06.2021			1	1	6.4
12.06.2021	100		3	4	6.2
14.06.2021	200		2	6	6.2
15.06.2021	250		1	7	6.3
16.06.2021	310		1	8	6.5
17.06.2021	400	12	1	9	6.5
20.06.2021	600	15	3	12	6.7
22.06.2021	600	11	2	14	6.9
25.06.2021	600	30	3	17	6.9
26.06.2021	600	32	1	18	7
28.06.2021	600	30	2	20	7
29.06.2021	700	22	1	21	7.3
04.07.2021	700	24	5	26	7.4
06.07.2021	700	21	2	28	7.3
13.07.2021	700	36	7	35	7.3
14.07.2021	500	16	1	36	7.2
15.07.2021	500	10	1	37	7
17.07.2021	500	25	2	39	7
18.07.2021	500	17	1	40	7
29.07.2021	450	23	11	51	6.8
01.08.2021	300	12	3	54	6.5
02.08.2021	100	10	1	55	6
04.08.2021	50	7	2	57	6
11.08.2022	50	7	7	64	6

Appendix (Table - 6): Sample (1) Gas production, Wavelength vs intensity:

Elements	λ(nm)	Intensity(a.u)
CL	475.3125	151.888563
CL_2	543.53	156.932
Xe2	655.528	163.771
Ti_1	499.627	154.62
Na_2	541.787	156.838
Na_1	588.918	152.2057
Eu_1	608.3293	151.102639
Ce_1	629.375	151.912023
Cs_2	653.894231	163.8768

Appendix (Table -7): Sample (2) Gas production, Wavelength vs intensity:

Elements	λ(nm)	Intensity(a.u)
Cf_1	424.230769	146.90088
Gd_1	469.795673	147.928446
Tc_1	482.055288	148.048094
Ar_1	489.002404	160.96305
C_1	538.040865	147.928446
Ce_1	629.375	151.912023
Cs_2	653.894231	152.876246
Ar_2	664.314904	148.048094
Pm_1	666.153846	147.928446
F_1	685.360577	149.139003
Zr_1	709.879808	146.90088
Cs_2	715.192308	148.470381
Cl_1	714.550481	147.027566
U_1	1055.19231	147.928446
Ce_1	631.009615	146.844575

Republic of Sudan
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بسم الله الرحمن الرحيم

جمهورية السودان
وزارة التعليم العالي والبحث العلمي
المركز القومي للبحوث
معهد أبحاث البيئة والموارد الطبيعية والتصحر

4/8/2021

الطالب / محمد حمد عبدالله

الموضوع / تحليل عينة (Vinass)

N %	O.C %	C:N	T.S.S mg/L
0.140	1.588	1:11.343	65.000

Done by: Magdi Hashim	Supervisor/ Dr. Omer M.
Sign:	
Date: 4/8/2021	4/8/2021

الخرطوم – شارع محمد نجيب – ص. ب. 6096 – فاكس 0188463416 – هاتف 0188463441
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Appendix (Fig – 1): Analysis of Raw vinasse sample (N, O.C, C:N & TSS)

ENVIRO-LAB

المجلس الأعلى للبيئة والترقية الحضرية و الريفية

إدارة المختبر البيئي

Date: *9/8/2021* **No:** W.21/8/3

Source: سكر كنانة

Sample Type waste water

Collected by: *Customer*

Methodology*: standard methods for the examination of water and waste water 20th edition 1998*

SSMO*: Sudanese Standards and Metrology Organization for Liquid Waste after Final Treatment.*

Test Results

Test \ Source	Vinas 1	Vinas 2	unit	STD *SSMO*
COD	320000	240000	mg/L	75
BOD	213333	160000	mg/L	15

Salma Hamid
Chem. lab.Head

Dr. Um Elkheir Mokhtar
Laboratory manager

Appendix (Fig - 2): Analysis of vinasse sample (COD & BOD)

- Vinasse 1= Raw Vinasse
- Vinasse 2 = (EX_2) = (2 Vinasse: 1 Cow Dung: 1 Inoculum)