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Performance Analysis of Homebiogas 2.0 Plant and Comparison with GGC Modified Model

by

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DEPARTMENT OF AEROSPACE AND MECHANICAL ENGINEERING

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a final thesis entitled **"Performance Analysis of Homebiogas 2.0 Plant and Comparison with GGC Modified Model"** by Bashu Gautam in partial fulfillment of the requirements for the degree of Master in Renewable Energy Engineering.

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ABSTRACT

Homebiogas is a tubular shaped biodigester. The size in research is of 2 cubicmeter. Its digester chamber of size 1200 liters and gas bag of size 800 liters. Homebiogas system has two different compartments, one for digester chamber and another for gas chamber. Pressure for the produced biogas have been created through dead load (Sand bags) placed on the pocket of gas bag. There has been mixed feeding. During experiment cow manure as well as kitchen waste like rice, vegetables, fruit waste, leamon, citrus food and bread was fed to the system. After the system has been stabilized if the input material was only kitchen waste, there has been decrease in pH. So there need to be added cattle manure in order to neutralize the pH. The average gases produced per day have been 201 liters. Homebiogas 2.0 can replace 3.064kg of LPG per month or 37.488kg of LPG per year. Biogas composition has been in good range with methane concentration of 58.1%, carbon dioxide with 37.1% and rests other gases. Energy produced per day has been 1.308kWh. A total solid of inlet and outlet is 44.72 and 12.72 mg/g. The volatile solid of inlet and outlet have been 38.31 and 9.8 mg/g. Percentage reduction in TS and VS have been 71.56% and 74.2% respectively. There have been higher reductions in TS and VS for food waste when anerobically digested with cow manure. Volatile solid had been 85.66% of total solid for feedstock material. When the feedstock was digested anaerobically, outlet slurry has been 77.044% of TS. Co digestion gives higher degradation rate as compared to monodigestion. The biogas produced from homebiogas has been 0.419 m^3/kg of TS and 0.471 m^3/kg of VS. Nitrogen, Potassium and Phosphorus of feedstock has been 0.27%, 0.1%, 0.06% respectively and outlet slurry have been 0.19%, 0.09%, 0.04% respectively. There have been slightly decreases in the value of the NPK because formation of ammonia gas through formation of ammonium ion. Gas output from the HBG 2.0 was 0.44 times the output of GGC modified of $6m^3$. Gas output from the HBG 2.0 has been 8.375L/hour. There need to be used Greenhouses, Compost heap and hot water during colder climate. Using Greenhouses, Compost heap and hot water we can increase the output from the system.

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LIST OF ACRONYMS AND ABBREVIATIONS

AD	Anaerobic digestion
AEPC	Alternative energy promotion center
BSP	Biogas support programme
C/N	Carbon nitrogen
CNG	Compressed natural gas
CO	Carbon monoxide
DS	Dry solid
FRP	Fiber Reinforced Plastic
FY	Fiscal Year
gm	Gram
GGC	Gobar Gas and Agricultural Equipment Development Company Pvt. Ltd
GHGs	Green House Gases
HBG	Homebiogas
HRT	Hydraulic Retentation time
KJ	Kilojoule
KW	Kitchen waste
kWh	Kilowatt hour
LPG	Liquefied petroleum gas
mg	Milligram
MJ	Megajoule
MOF	Ministry of Finance
NAST	Nepal Academy of Science and Technology
NBPA	Nepal Biogas Promotion Association
NPK	Nitrogen, Phosphorus, Potassium
OTR	Oxygen Transmission Ratio
PE	Polyethylene
PP	Polypropylene
PVC	Polyvinyl Chloride
RETS	Renewable Energy Testing Station
SRT	Solid Retention Time
TS	Total Solid
VFA	Volatile Fatty Acid

VS	Volatile solid
VSD	Volatile solid destroyed

CHAPTER ONE: INTRODUCTION

1.1 Background

Energy is a basic need for living beings. Without energy human cannot alive that may be either in their body or the external source for their basic need. In the modern world people cannot live without energy. Socio-economic development of the present world depends upon the energy. There are different sources of energy like fossil fuel, renewable energy and so on. Global energy consumption scenario shows a high supply from the commercial sources like by the petrol, Diesel, Coal and Natural Gas. As we can see that there is gradual decline in use of fossil fuel from 94.55% in 1970 to 80.04% in 2015; the use of renewable source is around 1.64% in world scenario (World Energy Outlook, 2017). Use of biogas skill can reduce the world green house gas emission by 3,290 to 4,360Mt carbon dioxide equivalent. In southern Asia country like India, Nepal and China have large number of domestic bio-digester working around 50 millions (Sarika Jain, Global Potential of Biogas, 2019).

Till now Nepal cannot found the resources of natural gas, coal and oil. Still Nepal is searching these things in his area or periphery. Nepal energy demand is fulfill by the biomass resources like firewood, coal, cattle cake and agricultural residual. These days the consumption of LPG is growing day by day, as we know the LPG is imported from foreign country, during its import in huge amount the economy of country goes outside. Also Nepal electrification rate is increasing day by day, till it hasn’t reached to all Nepalese people. Till now 69% of Nepal energy demand is fulfill by the biomass like firewood, coal and agricultural residual. Nepal has huge potential of hydro resources, but energy to extract the hydro-potential takes long time and huge economy. Also hydro takes transmission line and efficient energy device. Along with hydro resources, solar and wind are other energy resources. We can abstract huge amount of energy from these energy resources. Solar has great potential along with wind energy. If we cannot tie up the energy sector with sustainable resources and successful harnessing of energy from sustainable resources, the economy of country cannot move forward in good path. The higher financial system of a earth require secure admission to at hand source of renewable energy similar to hydropower, solar, biogas to create stronger its growth and increasing wealth. While a lot of built-up countries might be attentive on family energy security. Still southern Asian country like Nepal, Bhutan is seeking for proper energy mix. In the modern world-we need quick access to the energy security, energy access and so on. Energy security helps to be independent and reliable for economic activity all around the country and promote economic growth of human. Mostly electricity is consumed in household sector. Mostly people use firewood to cook food in household sector, as firewood is easily available in the field of farmers. These days people are switching to the LPG because it's easy to use and can be transported in a cylinder with higher compression and higher calorific value. Also these days' people rely on the firewood for about 69%, for meeting daily needs of their cooking. Energy consumption mix for the FY 2018/19 depicts high dominance of traditional fuels (69%), Commercial fuel about 28% and renewable energy 3%.

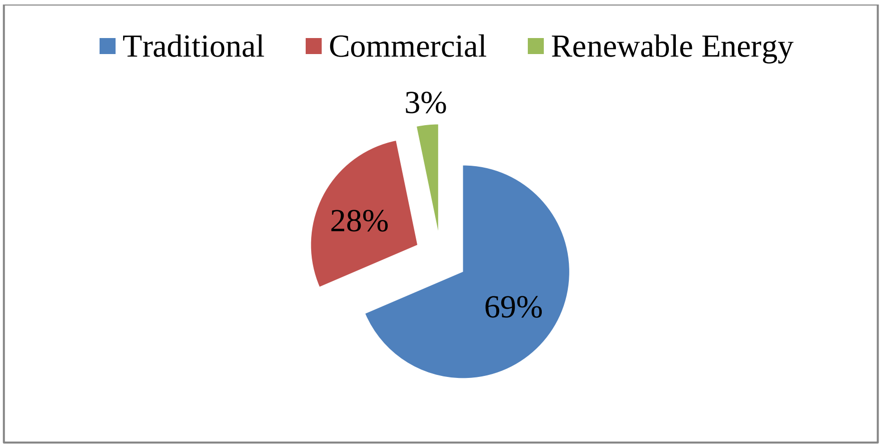

Figure 1.1: Energy consumption by fuel type in first 8 months of FY 2018/19 (MOF, 2019)

Biogas are the sources of renewable energy which takes degradable waste like municipality waste, cattle waste, human waste, agricultural waste and converts it into fertilizer and biogas fuel through AD process. The outlet slurry is rich in fertilizer like nitrogen rich, potassium rich and produced gas is methane with other gases like CO_2, methane, hydrogen sulphide and oxygen. Biogas technologies can be used for cooking purposes rather than using cattle cake and also can be used for treating human waste. Different other input material can be used for biogas plants like food waste; kitchen waste, vegetable waste and agricultural waste. Domestic biogas plants have been constructed in large amount in developing world, mostly in Asia and Africa using cattle manure, kitchen waste and human waste like night soil. A lot of factors for assortment of feedstock, place, and ecological factor have to be researched earlier than deciding to set up a biogas plant. Biogas a basis of renewable energy. It's not the grown-up skill for Nepal. Even though they are not talented to completely exploit it.

Most of the energy needs is fulfill by firewood around 69% in case of Nepal. As we know hydro resources is one of the main component of Nepal's resources but yet we could not fully utilize it due to lack of advance technology and manpower. Also hydro resources takes time and money to built but biogas is environment friendly and low costs. Biogas systems take wastes that are degradable and contain some TS and VS, which finally can take form of Biogas fuel. Biogas is a renewable energy source. AD takes place in closed chamber and in absence of light, presence of microorganism. This microorganism converts TS and VS into methane and other gases for fuel. The enclosed chamber where the light cannot enter and bacteria convert TS and VS to methane gas so called bioreactor or bio-digester. The basic structure of dome type biogas which is widely used is shown below.

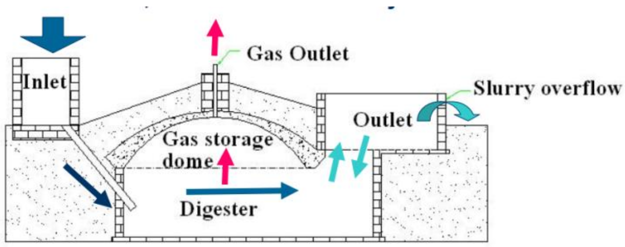

Figure 1.2: Dome type Biogas (BSP)

Biogas is mainly composed of methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulfide (H_2S), moisture and siloxanes. Gas produced from the biogas plants are methane, carbon dioxide and hydrogen can be burned in presence of oxygen. Biogas is free energy available in the environment and cheap fuel, this fuel can be used for cooking and heating purposes. Biogas can be cleaned and upgraded; can be used upgraded fuel to power vehicle and run generator to produce electricity. Electricity can be injected to national grid or can be made mini grid powered by biogas itself. Biogas fuel can be used for diverse purpose like catering, illumination and heating.

We can produce the CNG gas from the biogas produced by AD process, produced biogas need to be filtered; clean and compressed to form CNG. CNG can be used for different purposes like running automotives, running generator to produce electricity and so on. Still there is subsidy mechanism for biogas in different part of world, especially in developing world there is huge amount of subsidy. Bio-methane can be made from biogas produced by anaerobic digestion process up to natural gas standards. Biogas is a system where the degradable organic waste is converted to the methane gas and other gases. Its continuous process, feeding of the material and production of biogas is continuous; it gives no net carbon dioxide. When the organic material breaks down in absence of air, it is transformed to biogas moreover used. The slurry again grows the plants and finally biogas and cycles repeats. Fertilizer produced from the biogas technology can be used for growing crops and organic material can be used for converting into biogas again. Biogas plants are of different size from smaller to larger scale. Smaller scale are used for the cooking purposes in rural and urban area while larger scale are used for waste treatment, producing biogas from the organic material and so on. Feedstock provided to the biogas is transformed to the biogas and slurry. Co-digestion helps to produce the proper amount of biogas from the waste residual from industrial waste. From the co-digestion there is higher yield of biogas. Biogas produced from the different substrate is of varities composition and also this factor is affected by temperature, pH and pressure and so on. Gas produced from the landfill consists of methane around 50%. As produced, biogas contains water vapor. The amount of water vapor depends on the temperature, pressure and pipeline. Most of the produced biogas contains siloxanes. They are formed from the anaerobic decomposition of materials commonly found in soaps and detergents.

For the first time, Nepal has been introduced with drum model biogas plant by late father B.R Saubolle in Godavari, Kathmandu Nepal. Biogas installation programmed got energized after energy crises in world by 1973, due to this there was global interest in this sector. In case of Nepal 1975/76 was considered as agricultural year, biogas was promoted at the same time for prevention of forest from burning log of wood. The bank office presents in different parts of the country played a great role for promotion of biogas sector in case of Nepal and till now they are promoting these things to end users. In 1977 the Gobar Gas and Agricultural Equipment Development Company Pvt. Ltd was formed to promote the technology all over the Nepal with different branches and offices. Research on various design of biogas plants such as floating drum, concrete fixed dome, precast tunnel, plastic bio-digester, ferro-cement gas holder, brick mortar dome were carried out and experimented. Biogas Support Programme was initiated in July 1992 to develop and promote the use of biogas in Nepal with the financial support of Netherlands Development Organization (SNV). After the establishment of BSP, the pace of biogas plant installation has increased in an accelerating rate. There was highest biogas installed in FY 2013/14 and 2014/15 for last 12 years. There was installation of average 20,407 plants per year in Nepal for last 12years.

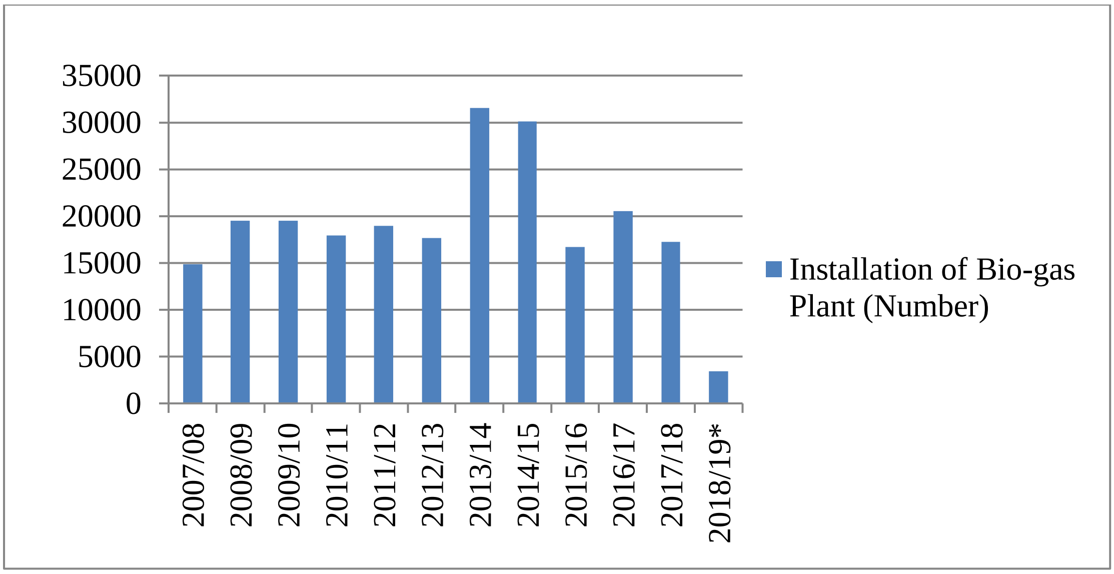

Figure 1.3: Biogas plant installed in Nepal year wise (MOF, 2019)

Table 1.1 shows the Domestic biogas and large biogas plant installed in Nepal till now. In Nepal four lakh twenty five thousand five hundred and eleven domestic biogas systems are installed in Nepal and two hundred and forty seven systems for large scale. Regarding urban type biogas model, there were installed some plants in past years.

Table 1.1: Biogas Plant installed In Nepal (AEPC, 2019)

SN	Plant	Number
1	Domestic Biogas	425511
2	Large Biogas	247

The system which is implemented by AEPC in urban area of Nepal is called Gharelu Biogas Plant. The size of GBPs is up to 4m^3. It is designed to be urbanized and endorse in the middle of the city and semi-urban household of big cities. To run the organic kitchen waste like food waste, vegetable waste at the households converting them into biogas and natural fluid fertilizer is the major center of this scheme. GBPs use the daily household organic wastes, such as food leftovers like rice, pickle, bread etc, vegetable waste, cuttings and trimmings, etc to create biogas for cookery purpose. It is additional suitable for maintaining household hygiene and it also reduce the inside and external contamination. From figure 1.4, there can be seen that waste produced from individually household mainly composed of degradable organic waste of 71%. Rest other waste like plastic 12%, paper and paper product 7.50%, metals 0.5%, glass 1.3%, rubber and leather 0.3%, textiles 0.9%,dirt and construction debris 5%,hazardous waste 1% and other waste 0.7%.

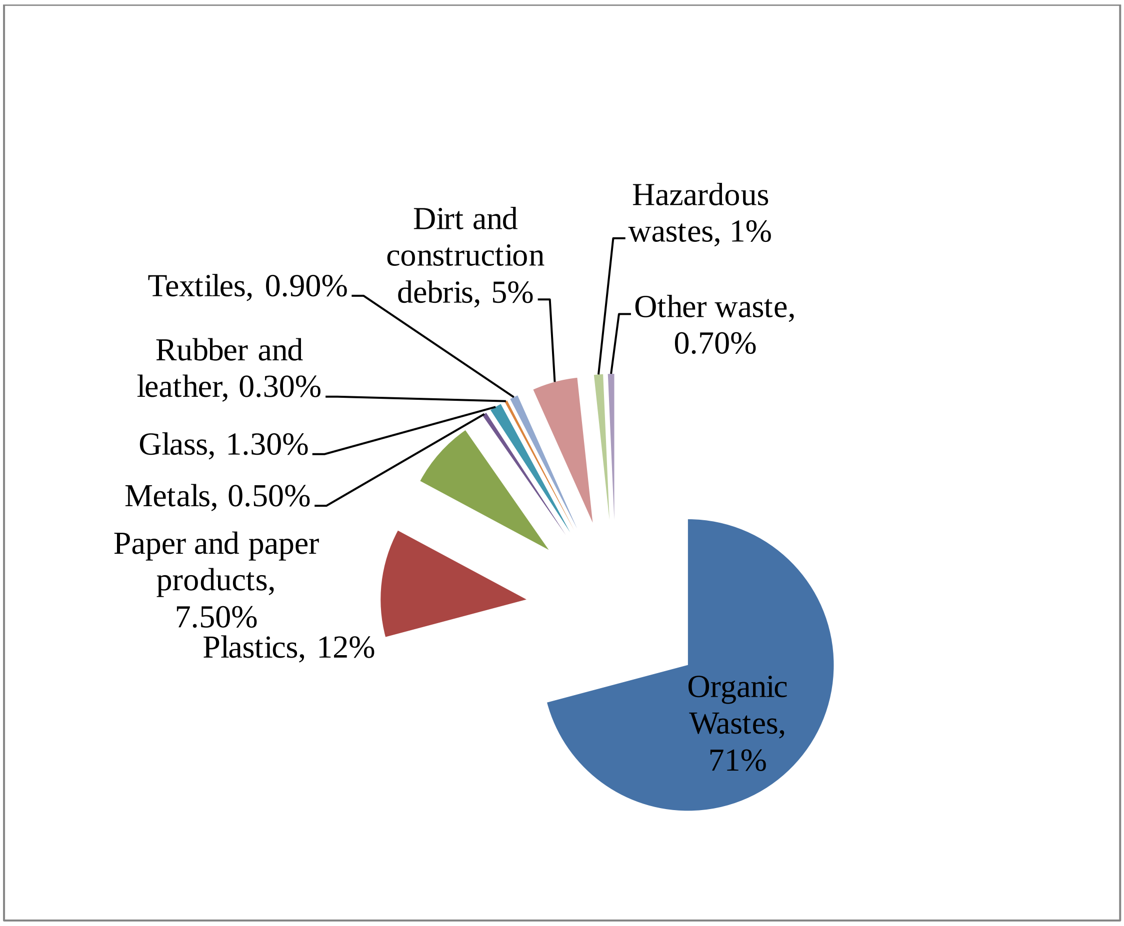

Figure 1.4: Waste produced from household in Kathmandu municipality (Mohan B. Dangi, 2011)

1.2 Problem Statement

More than four hundred thousand biogas plants have been installed in Nepal. Most of them are fixed dome model. As we know that Nepal lies in the prone of earthquake region. Earthquake can damage the fix dome digester. Also it is very difficult to construct the fixed dome model in urban area, as it consumes more space and time to construct. People rapidly migrate here and there in urban area. So there is need for optional model for the fixed dome structure. Also there is need for less space consuming, portable model for the urban area. So that we can solve the waste management problem of urban area converting into clean cooking gas and natural liquid fertilizer at source itself. HBG bio-digester can solve waste problem of individual house providing clean cooking gas and natural liquid fertilizer. Fertilizer obtained from the HBG can be used to grow flowers, vegetable at the top of building in urban area. HBG biodigester saves the consumption of LPG. Liquefied petroleum gas is imported from the foreign country, so during its import in large amount economy of country goes outside. By using natural liquid fertilizer people can grow vegetables, flowers so that they can save their expenses. HBG cannot be damage by natural disaster like earthquake.

1.3 Objective

The main objective of the thesis is:

Performance analysis of Homebiogas 2.0 and comparison with GGC-Modified model.

The main objectives will be accomplished with the following auxiliary objectives:

- To determine biogas generation, its composition and LPG substitution.
- To find Reduction in TS, VS and NPK of inlet Feedstock and outlet slurry.
- To compare gas output of HBG2.0 with GGC-modified ($6m^3$).
- To find the colder climate modification.

1.4 Limitations

Limitations of research are

- Inner middle part temperature of digester tank cannot be taken due to lack of advance thermometer.
- All necessary data are taken at ambient conditions.
- Leakage of gas from the system and pipeline is not considered.
- Microbiological analysis couldn’t be performed due to lack of advance laboratory.
- All research is based in colder season.
- Laboratory and instrumental error is not considered.
- Dimension and size of system is considered based upon the measurement.

CHAPTER TWO: REVIEW OF LITERATURE

The huge use of the petrol, diesel, coal and the natural gases has degraded the environment too much. Due to its use GHGs are produced, GHGs will create at blanket at lower surface of earth, finally raising the temperature of the earth. Among GHGs, CO_2 is one of the main factors produced by emissions of crude oil in the world. Most of the GHGs are produced from developed country like china, India, USA and some other parts of the world. From the energy scenario of world we can see that most of the energy sources are fossil fuels, nearly around 88% of energy demand is fulfils by fossil fuels like oil, coal and gas. Most of these fossil fuels are found on those parts of world where politically there is most unstable or changing political stability continuously. Waste is produced all over the globe. Waste production is a continuous cycle and its evergreen. We can convert biodegradable waste to produce biogas and nutrient rich fertilizer. Energy from the waste can play a great role in present scenario as well as in future scenario. Energy produced from the biogas is environment friendly and no effect in ecology of globe or country. Produced biogas from the waste can be used for bio-methane production. Modern study suggest that the energy produced from AD as comparison to others bio-energy, AD process is easy, energy-efficient and environment friendly process. The main use of domestic scale biogas plants is due to Clean cooking, fast cooking, easy cooking, Easy to use & install, Nutrient rich Organic Fertilizer for vegetables and usable fertilizer instantly available, less load for collection of firewood, no issues in family about cooking food, children can cook also (no smoke, no danger of explosion), gas availability can be seen with naked eyes, Monthly money savings, Stove is good, less dependency on LPG, no problem during pandemic / strike and so on. Biogas systems offer the more stable way of treating organic waste. The proper use of biogas technology reduces the liberation of CO_2 and methane gases; methane gases are about 21 times more efficient than CO_2 for trapping the heat in the surface of earth. So we need to avoid the liberation of CH_4 in the environment, the better way of doing it using in cooking by trapping through AD process. Biogas can reduce odours, insects and pathogens associated with manure. To choose correct type of biogas plants is very difficult task, we need to understand fluid dynamics, structural strength, and so on. Among many type of bio-digester, egg-shaped vessel is the best solution for it. Egg shaped bio-digester is expensive as comparison with others, so mostly used in sewage treatment plants. The fixed dome model is similar to egg shaped but cheaper and can be built with locally available material like cement, rod stones and gravel. Some of fixed dome model contain conical bottoms for storage of stones and mud's and some are flat for easy flow of slurry in outlet tank. This type of biogas plants are easier to built and sometimes can be found in ready-made in market. AD can reduce GHGs emission from the environment as comparison with use of fossil fuel. AD can provide the high value organic fertilizer to the plants also there are certain way of slurry management in biogas plant. Actually customer can construct the pit and put residual straw, grasses over there in order to make high value fertilizer. From every living beings biogas can be produced, just there are ways to produce biogas from certain feedstock in certain way. Lignocelluloses are present in most of waste like agricultural waste, municipal waste.

Table 2.1: Production amount and energy for the different feedstock (Spyridon Achinas a, 2017)

Type	Biogas yield per ton of fresh manure(m^3)
Animal Manure	55 – 68
Chicken manure	126
Food wastes	110
Fruit wastes	74
Horse manure	56
Municipal waste	101.5
Pig manure	11
Sewage sludge	47

AD is a sequence of processes by which microorganisms break down biodegradable material in the absence of oxygen. Much of the fermentation used industrially to produce food and drink products, as well as home fermentation, uses AD. Anaerobic digesters can also be fed with purpose grown energy crops, such as maize, wheat. AD is widely used as a source of renewable energy in developing world. The AD process produces a biogas, consisting of methane, carbon dioxide, ammonia and traces of other contaminant gases. This produced biogas can be used directly as fuel, in combined heat and power gas engines or upgraded to natural gas quality biomethane to produce power. The nutrient rich digestate slurry also produced can be used as fertilizer. Degradable organic waste present in waste provides the measurement of biochemical oxygen demand, and, in turn, be able to be used as a metric designed for the in general efficiency of an anaerobic digester. The amount of oxygen present in sludge sample can be known by chemical oxygen demand i.e., inspired in a response by means of oxidizing agent. Many microorganisms affect anaerobic digestion, including acetic acid-forming bacteria and methane-forming bacteria these organisms promote a number of chemical processes in converting the biomass to biogas. There are four key biological and chemical stages of anaerobic digestion:

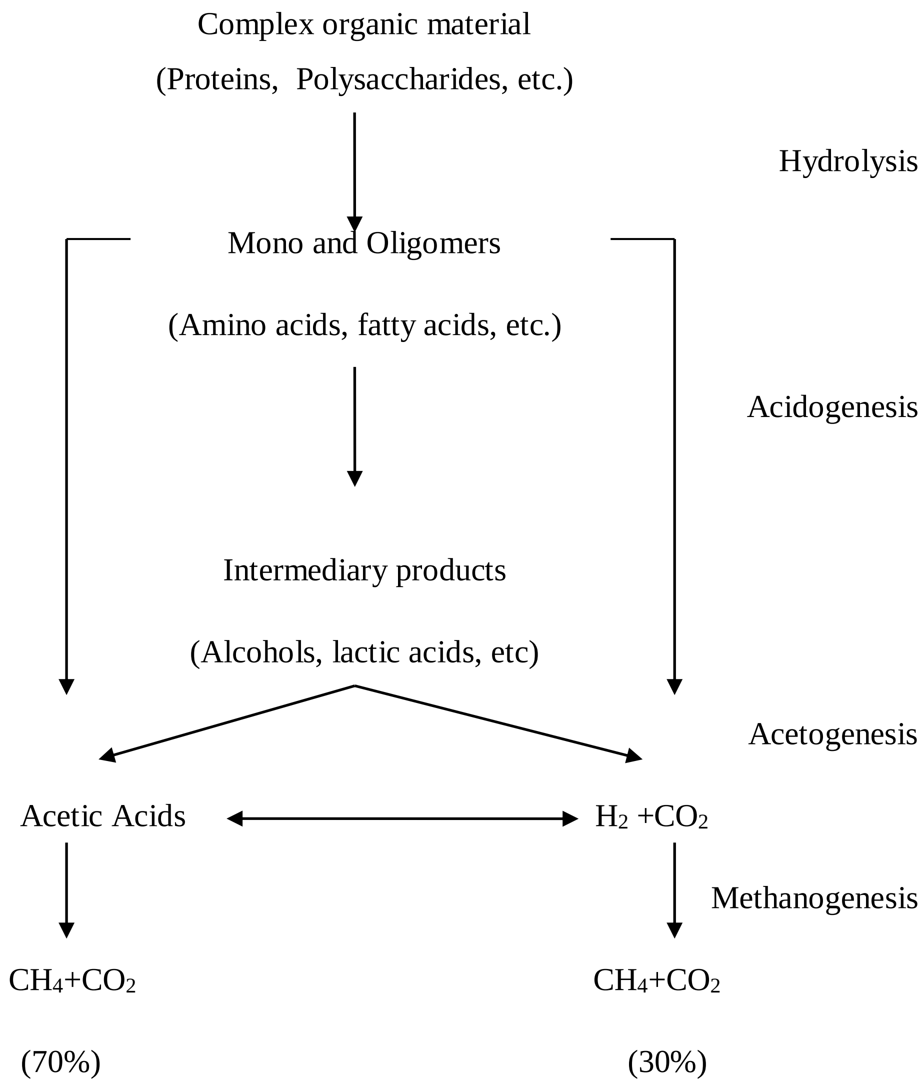

Figure 2.1: Pathways of Anaerobic Digestion (Serna, 2009)

1. Hydrolysis

Hydrolysis is meaning by breaking of bonds by water addition. While breaking the with water molecules anion and cations are formed. It is first stage of AD process. Hydrolysis is very slow step when we see other steps; it can affect the limit rate of AD process. The response connected by means of this pace is known in Equation

(2.1). Cellulose is converted to the glucose as a primary product and giving off hydrogen.

$(C_6H_{10}O_5)_n + n\ H_2O \rightarrow n\ C_6H_{10}O_5 + n\ H_2$ Equation(2.1)

2. Acidogenesis

This is the second stage and also known by fermentation stage. Equations (2.2)-(2.4) in attendance the response series that summarize the acidogenic stage of AD. During this stage the output from the hydrolysis is converted to carbon dioxide and hydrogen.

$C_6H_{12}O_6 \leftrightarrow 2CH_3CH_2OH + 2CO_2$ Equation(2.2)

$C_6H_{12}O_6 + 2\ H_2 \leftrightarrow 2CH_3CH_2COOH + 2H_2O$ Equation(2.3)

$C_6H_{12}O_6 \rightarrow 3\ CH_3COOH$ Equation(2.4)

3. Acetogenesis

This is the third stage in AD process. This stage is also called dehydrogenation stage. The response series linked by means of this phase of AD are representing by Equations (2.5)-(2.7). in this stage hydrogen is given off with others catanion and anion.

$CH_3CH_2COO^- + 3H_2O \leftrightarrow CH_3COO^- + H^+HCO_3^- + 3H_2$ Equation(2.5)

$C_6H_{12}O_6 + 2\ H_2O \leftrightarrow 2\ CH_3COOH + 2CO_2 + 4H_2$ Equation(2.6)

$CH_3CH_2OH + 2\ H_2O \leftrightarrow CH_3COO^- + 3H_2 + H^+$ Equation(2.7)

4. Methanogenesis

This is the fourth and final stage of the AD process. In the final stage the produced acid is converted to hydrogen and carbon-dioxide and methane gas. Bacteria active in this stage is highly poisonous with oxygen. This is also a very slow step and bacteria responsible for this are highly sensitized with temperature and environment. They can attract and absorb the simplest shape of feedstock. Equation from (2.8) to (2.10) represents the methanogenesis stage. Equation (2.8) shows the conversion of acid to methane gas and carbon dioxide. Finally CO_2 is converted to methane and hydrogen in the following equation.

$CH_3COOH \rightarrow CH_4 + CO_2$ Equation(2.8)

$CO_2 + 4H_2 \rightarrow CH_4 + 2\ H_2O$ Equation(2.9)

$2CH_3CH_2OH + CO_2 \rightarrow CH_4 + 2CH_3COOH$ Equation(2.10)

2.1 Types of Biogas

2.1.1 Fixed Dome Digester

Fixed dome model biogas plants are widely used in developing world. This can be constructed from the local material available in the local area of the community. It consists of inlet, dome and outlet tank (compensation tank). Inlet tank is provided with mixture, mixture machine can be used manually in order to mix the cattle manure, KW with water. After mixing in the inlet tank the slurry inters to the digester chamber so called dome. After certain number of days i.e., HRT gas starts production and gets collected in upper part of dome via through pipeline gas is used at stoves. As the gas volume gets increased in digester chamber it starts displacing the slurry as a result slurry gets out of inlet tank-finally to the compost pit. We know that the fixed dome model biogas plant is constructed inside the earth surface so there is no fluctuation of day/night temperature-almost constant temperature for bacteriological process. Fixed dome model biogas plants creates local level employment-specially people who have great idea of masonry work. Construction of these types of biogas plants need good supervisor form the experienced people otherwise it may lead to failure. Special care should be taken during construction of dome because leakage at these parts creates leakage of produced gas-ultimately releasing methane gas to environment and failure of system. Fixed dome model biogas plants have life of 20 years or even more.

Varaties of fixed dome digester are found in world in present existence namely fixed dome, Janata model, Deenbanhdu model & Camartec model. Among all, Fixed dome digester was the oldest and all other originate from the fixed dome digester. Janata model was introduce in India, having number of faulty design and material this plant don’t came in existence or became failure in their earlier stage. Having modified on the janata model, deenbanhdu bio-digester came in existence-it has slope in bottom part of digester for easy flow of slurry and hemispherical dome for produced gas collection. Another popular design was named as camartec-it has simplest design among all digester. We can see that development partner like GIZ, SNV are promoting mainly fixed dome bio-digester. This is being promoted in different part of world mostly in south Asia and African country.

Table 2.2: Gas output per day from GGC 2047 (Bijaya Raj Khanal, 2014)

Date	Flow Meter Reading(Liters)	Every Day gas Production(Liters)
Wednesday, October 08, 2014	22563	
Thursday, October 09, 2014	23150	587
Friday, October 10, 2014	23701	551

Saturday, October 11, 2014	23850	149
Sunday, October 12, 2014	24003	153
Monday, October 13, 2014	24866	863
Tuesday, October 14, 2014	25403	537
Wednesday, October 15, 2014	25984	581
Thursday, October 16, 2014	26674	690
Friday, October 17, 2014	27412	738
Saturday, October 18, 2014	27552	140
Sunday, October 19, 2014	27715	163
Monday, October 20, 2014	28053	338
Tuesday, October 21, 2014	28380	327
Wednesday,October 22, 2014	28891	511
Average		452

The digesters of fixed dome plants are usually masonry structures, structures of cement and ferro-cement exist. The basic part of fixed type biodigester is dome, outlet, mixture, gas pipe, pipe, mixture, main valve. Table 2.2 shows the gas output of 6 cubic meter of GGC plant install at Khumaltar, Lalitpur, and NAST Compound. This was built on 2010. 40kg of cow manure was feed to the system each day. Gas produced from this system was used by RETs canteen. The average gas production from that particular system was four hundred and fifty two-average ambient temperatures of 18.75℃ (Bijaya Raj Khanal, 2014).

2.1.2 Floating Drum Digester

The mostly used, portable bio-digester is floating drum. Mostly this type of plants is used in south Asia. This type of bio-digester is built in India. This was first built by Patel in 1956. It was the first floating drums biogas plant built ever. Mostly this type of plant ranges for domestic scale-household purposes. Basically there are two parts in floating drum model biogas plant, fixed cylindrical part and floating cylindrical or conical parts. The fixed cylindrical part can be kept inside the earth surface in order to maintain the constant temperature of the slurry-helps for bacteriological process. Gas compartment floats on the water jacket either or slurry made up of kitchen waste or cow manure. When the volume of gas gets collected, the gas tank gets upward while there is no gas it sits on the top of the digester. Gas chamber gets protected and guided from the sloping and declining on the frame. As we know water has low viscosity as comparison to the slurry, so floating chamber gets stuck when used in high viscosity substances. The cost of the floating drum model is very high as comparison to the fixed dome model, so after there is construction of fixed dome model, floating drum model became absolutely discouraged. So these days the construction of floating drum dome model is slowed down as comparison to earlier days.

2.1.3 Tubular Digester

The tubular polyethylene digester is bended at each end PVC drainpipe and is wound with rubber strap of recycled tire or tubes. With this method a hermetic isolated tank is obtained. One of the PVC drainpipes acts as inlet and the other one as the outlet of the digested slurry. In the tubular digester finally, a hydraulic level is set up by itself, so that as much quantity of added feedstock matter (the mix of dung and water) as quantity of digested slurry leave by the outlet. Because the tubular polyethylene model is flexible, it is necessary to construct cradles which will occupy the reaction tank, so that a trench is excavated. There are different types of tubular model biogas plant. Mostly this type of plants is made up of plastic with good mechanical & thermal properties. In case of Nepal there have been promoted this type of model in the past but the continuation hasn't been done. Basically it's long in length and can be seen with naked eyes. Tubular model bio-digester is easy to install and use. Also it has low cost as comparison with others type of bio-digester.

2.1.4 Tubular Model Biogas Plant in World

The figures of tubular model biogas plant are attached in APPENDICES B. Different types of tubular model biogas plant available in world are:

A) Balloon plants: Balloon plants consist of polyethylene bag at the top, which is strong and heat-sealed. The digester sits in bottom and the gas gets collected in the upper parts of the chamber.

B) Earth-pit plants: Actually this type of plants sits on top of the soil. The plants sit in incline wooden frame. In order to prevent the plants from the seepage, plastered is done with wire mesh fixed. The end of the plants is attached with the help of the ring which helps as an anchorage for the parts of gas holder. Gas chamber can be manufacture from the metal or the plastic. When we made the bag of plastic, it is attached with wooden frame which expands down to the end with slurry. The required gas pressure is obtained from the weight kept on the gas chamber; actually this provides the pressure to the gas. With the help of pressure provided by the weight, gas flows to the stoves.

C) Bio Bowser: These plants are available in household use worldwide.

D) Flexi Biogas: Flexi Biogas is manufacture in Nairobi, Africa. Flexi biogas is a tubular shape, mostly used for the household's purposes in rural part of the world. We can place the system in the greenhouses and maintain the constant temperature.

F) Sim Gas: This system is made in Kenya and Tanzania. Sim Gas has a different range of biogas digesters.

G) Huamei International Green Energy: This Company manufactures tubular representation biogas plant. These types of plants are of different sizes ranging from the 6 cubic meters - 100 cubic meters. Due to easiness this system can be installed in rural area with semi-skilled technician and can be transported easily to those parts of world where it is needed the most.

H) Sistema Biobolsa: Actually, this biogas plants is manufacture in Mexico-Latin America. This company produces the tubular model biogas plants with good resistance membrane as a material. On this system there is a continuous flow mechanism, it's modular, flexible and high quality bio-digester. Actually this category of plants is used for the small household's farmers to cook morning and evening food. Numbers of biogas plants have been installed in different parts of world and these plants are used well by farmers for their energy demand.

I) Ecofys Plastic Bag Digester: The Ecofys plastic bag digester is prefabricate and in particular calculated designed for grower households. This scheme is inexpensive, simple to fit, and simple to convey keen on distant area, as yielding enough gas for food preparation, illumination and heat wants.

J) BiogasSA: BiogasSA is situated in South Africa. BiogasSA Company specialize in the plan, fitting and preservation of a variety of type of biogas kits for together the home as well as the profitable market.

K) Taiwanese PVC Bag Digester: This kind of bag digester was calculated in Taiwan. It has extended, channel fashioned bio-digester-made up of PVC. System has to be position within the earth. There is inlet in single side and opening on one more side. Slurry is store in subordinate fraction of tube and gas gets composed in higher fraction.

2.1.5 Tubular Model Biogas Plant in Nepal

Some of tubular shaped biogas plants were installed by BSP in case of Nepal in past years. This bag digester was light and easy to install and use. As comparison with GGC model, this model was cheap and easy to install with short period of time. Basically this type of plants was installed in mid hill of Nepal because GGC was very difficult to construct on that place due to lack of highways for transportation and difficult to dig holes for dome. Outlet blockage was common problem for bag digester introduce in Nepal by BSP Nepal.

2.2 Homebiogas

Homebiogas system is manufacture in Israel. Homebiogas is a biotechnology Company. The company produces the system of size $2m^3$, $4m^3$ and $7m^3$ household biodigester. The Homebiogas household biogas system turns organic waste like food scraps and animal manure into biogas, which can be used for cooking, and natural liquid fertilizer, which can be used for gardening. This is an Israel product. The system operates as a continuous-flow system: organic waste is fed into one end, and gas and fertilizer are emitted constantly from the other as long as the system is active and being fed. Fertilizer is produced whenever liquid & wastes are added into the system. The Homebiogas household system processes organic matter including food waste, animal manure, and human waste, turning the organic waste into biogas that can be used for cooking as well as natural liquid fertilizer. Biogas is a gas generated through the anaerobic digestion (digestion without oxygen) of organic matter. Biogas is a flammable gas that is lighter than air, composed mainly of methane and carbon dioxide. Performance may therefore depend on environmental conditions and may vary due to physical location and ambient temperature. The system works most efficiently in a warm climate which enables the bacteria to actively engage in the digestion process.HomeBiogas2.0 has a life of more than 15 years. Homebiogas can be rapidly deployed to urban, peri-urban, and rural environments. The Homebiogas system can be complemented with a bio-toilet system for human waste management. The homebiogas system is a domestic-scale biogas system that has the capacity to treat all organic waste (kitchen waste, animal manure and toilet waste), as well as to produce cooking gas and liquid fertilizer daily. The systems can be assembled in about two hours by anyone and requires no digging, no building, and no infrastructure. The systems operate mechanically. A safe, low gas pressure is maintained by our patented solution - enable gas to flow directly to the connected stove. The stove ignites without delay, and provides a constant flame for healthy cooking. Both the biogas and the liquid fertilizer are filtered by the system. Lastly, the system tanks are completely sealed and contained. The system has the European CE approval for safety. There has been formation of a committee for the guidelines of domestic size biogas plant; Homebiogas Company is leading these things.

2.2.1 Technical Specification

HBG2.0 has the system volume of 2000liters, gas tank volume of 800liters & digester tank of 1200liters. The length, width & height of system is 2.1m, 1.15m and 1.25m.The technical Specification of homebiogas2.0 is shown in table 2.3.

Table 2.3: Technical Specification of HBG2.0 (Homebiogas, 2020)

System volume	2 m^3
Gas tank volume	0.8m^3
Digester tank volume	0.12m^3
Dimension assembled	2.1m*1.15m*1.25m
Weighted assembled	1270kg
Gas pipe length	Up to 20meter
Daily kitchen waste input	6 liter(max)
Daily animal manure input	20liters(max)

The general layout of Homebiogas 2.0 is shown in figure 2.4.

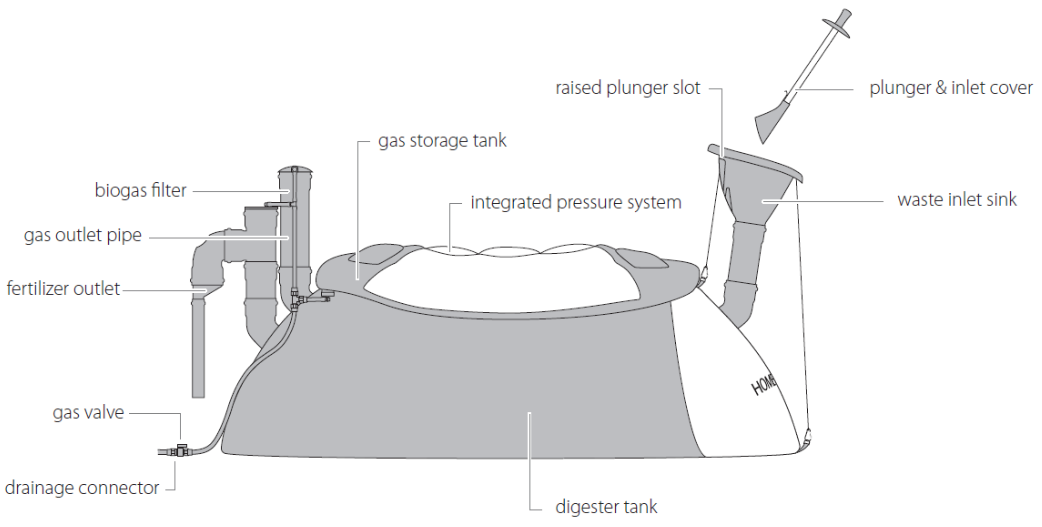

Figure 2.2 :Homebiogas Showing different parts (Homebiogas, 2020)

2.2.2 Working Principle

For the activation of system there need to fill 100 kilogram of cow manure with water .The mixture should be in 2:1 ratio, 2 part water and one part cow manure. Rest part of digester tank need to be filled by water until there is flow from the fertilizer outlet. Depending upon the ambient temperature of environment the gas starts collecting in gas bag. Once the gas bag is full then there need to be addition of cow manure (20L) or kitchen waste (6L) per day. Cow manure or kitchen waste needs to be mix with water and put in the system. Mixing process is done in bucket with the help of stick. Organic matter is fed through a collection sink into the digester tank full. The organic matter is biodegraded through anaerobic bacteria in the water which digests it. The biogas is created during the anaerobic fermentation process. Another product of the system is nutritious and natural liquid fertilizer. The system operates as a continuous-flow system, i.e. waste is fed in one end, and the gas and fertilizer are emitted from the other. A unique patented mechanism regulates the gas pressure, enabling the gas to be delivered at a constant and predictable pressure, as is required for stable use. The generated biogas is filtered through a special-purpose activated carbon filter to remove any unpleasant odors and toxic gases such as hydrogen sulfide (H_2S). There is optional to use a chlorine tablet in the output for the liquid fertilizer in order reduces the amount of active bacteria in the effluent. The homebiogas household system processes organic matter including food waste, animal manure, and human waste, turning the organic waste into biogas that can be used for cooking as well as natural liquid fertilizer. The 2.0 system is a 2 cubic meter system that provides 2 hours of cooking gas per day. This system operates in mesophiles range. In order to create the pressure for gas in the system sand bags are put in the pocket of gas bag. One kilogram of sand needs to be put inside the sand bag, and put in the pocket of gas bag as shown in figure2.5. Sand bags are properly distributed so that there is equal pressure from full of gas bag to empty of gas bag. Forty eight sand bag of 1kilogram is put in gas bag. This creates pressure of 1 kilopascal. System operates at pressure of 1kilopascal to 1.5kilopascal. There is a pressure release mechanism for the safety issue. Once the gas bag gets full and there is no use of gas, excess biogas is released through pressure release mechanism (fertilizer Outlet).

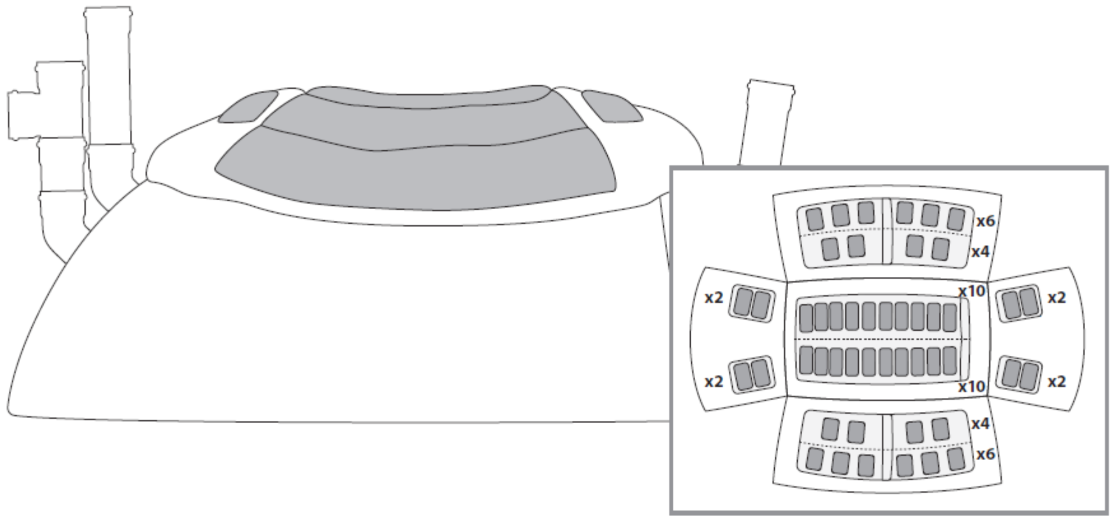

Figure 2.3: Sand bags arrangement in gas bag (Homebiogas, 2020)

2.2.3 Material of HBG 2.0

Homebiogas systems are made of:

1. Homebiogas is made up of polyethylene and polypropylene.

2.3 Factor that Effect the Production of Biogas

Biogas production from AD is affected by various elements. Production of biogas from organic waste will get better fit surroundings from side to side the killing of the pathogens, during AD. This provides liquid fertilizer extremely wealthy in NPK.

The main components that fluctuate the methane gas production are:

1) Temperature

2) Hydraulic Retention Time

3) Sublayer Composition

4) pH of System

5) Reactor Pressure (Digester Pressure)

6) Light Effect

7) C/N Ratio (Feeding Material)

2.3.1 Temperature

Temperature is crucial parameters for biogas production through AD process. Different factors effects the biogas production, among them temperature is one of the main governing factors. Produced methane gas is influenced by the temperature by quality was well as quality. Temperature categories are of 3 types, namely cryophilic, Mesophiles and Thermophiles. Crophilic operates in the range of 12-24°C, at lower temperature. 22-40°C are known by mesophiles stage, also known as intermediate stage. Stage operating between 50-60°C is known by thermophiles. Temperature largely fluctuates in open environment while in case of underground, almost constant temperature can be found. Different bacteria colonies are activate at different temperature and different stage. Microorganism also plays vital role for biogas production and AD process. Acidogenic and methanogenic phases are largely effected by lower temperature but temperature above 25°C are more favorable for biogas production. (Shiwei Wang, 2019).

2.3.2 Hydraulic Retention Time

The average time the slurry stages in the digester chamber are called HRT. HRT depends upon the feedstock, temperature and other different parameters. Mathematically, HRT is equal to the digester volume to the input material per day. HRT plays great role for bacterial mass control. HRT is one the main points taken during designing of the digester. It also affects the TS and VS of the material or feedstock. Some of the large digester has stirrers for mixing and maximum removal of solids. For very high HRT, we need big digester (volume) therefore for continuous feeding it's not feasible for higher HRT.

2.3.3 Sub layer Composition

The input material used for the biogas system through AD should have favorable atmosphere for bacteria to digested the input solids and finally for methane production. Different things effect for favorable environment. The AD circumstances have to complete a number of significant circumstances: -

- Should have organic matter.
- System pH should be 6.8-7.3.
- Feedstock C/N in among 15 and 25
- There should not be presence of chemicals, soap, antibiotics.

2.3.4 pH Value

Biogas is produced at definite value of pH. For optimum biogas production, system pH should be in range of neutral value. Value below 6, biogas production is inhibitive. Alt low value of pH in digester there is creation of VFA. It affects the microorganism at different stage. Almost constant ph is found in cattle manure but in case of food waste we can see higher acidic feedstock as a result lowering the value the slurry inside the digester. Temperature also affects the pH of digester. CO_2 solubility is higher in thermophilic stage than mesophilic stage, so carbonic acid is formed at higher temperature increasing acidity. We can maintain the pH value by addition of cow manure or bicarbonate. Cow manure or bicarbonate provides the sufficient amount of buffering capacity for pH variation. Most of the waste produce from industrial area has low pH, so we need to add lime for controlling the digester pH(Chunlan Mao, 2015).

2.3.5 Reactor Pressure

There is always pressure inside the digester chamber of biogas. Pressure has negative impact on the biogas production. Pressure also has negative impact on different microorganism. Produced hydrogen pressure when exceeds 40Pa, without buffering materials in chamber, production of biogas slows down. (Paul dobre, 2014).

2.3.6 Light Effect

Light inside the digester chamber has negative effects on bacteria, methanogenic bacteria favors' darkness.

2.3.7 C/N Ratio

Feedstock has both nitrogen and carbon. Both are essential component for biogas production. Proteins and amino acids are synthesis by nitrogen and also nitrogen is converted to ammonia, produced ammonia can neutralize volatile acids. Having higher quantity of nitrogen in feedstock helps in formation of ammonia, ammonia is toxic agents for AD process. That why nitrogen present in feedstock has important function. Components present in feedstock has significant role for AD and growth of bacteria, biogas manufacture. CN ratio should be in between of 20:1-30:1, and for optimal 25:1 for bacteria growth (Maria M. Estevez, 2012). If there isn't correct C/N ratio, ammonia is released and VFAs can accumulate. Both the components TAN and VFAs are significant intermediates and possible inhibitors in the AD procedure. The best C/N ratio varies with the kind of contribution material to be digested in the bio-digester. Algae has high nitrogen concentration, in order to stabilize it waste paper need to add on it during AD, C/N ratio for the co-digestion was 20 to 1 to 25 to 1 (Yen, 2007). Onion juice and digested sludge can be digested at 15 to 1. (Rowena T. Romano, 2008).

2.3.8 Total Solid and Volatile Solid

The biogas produced from a specific organic material is not the fixed value but depends upon the number of parameters like temperature; HRT. Total solid is the sum of organic material and inorganic material present in the feedstock while volatile solid is the organic material present in the feedstock. The biogas is produced from the organic material present in the feedstock. Table 2.4demonstrate the some of the feedstock which are being used widely today. Biogas production is in a straight line connected awake by means of the bio-digestion course. Waste material can be categorized in terms of three basis which are Dry-TS above 15%, Semidry-TS ranging from 15% to 10% and wet digestion- TS below 10% (Yebo Li, 2011) (Flavia Liotta, 2014). Food waste has higher VS reduction capacity (District, 2008). Among 9.54 g VS/L, 20.12 g VS/L, and 39.99 g VS/L, the concentration of 20.12 g VS/L under thermophilic circumstances have the most excellent anaerobic digestion presentation in the middle of every one the kitchen waste. The most exact methane gives way of 591 ± 30 mL/g VS was obtained as of dinner (Junfeng Jianga L. L., 2018). Biogas manufacture in the digester was steady at 642 m^3 $tonne^{-1}$ VS wherever accumulation equilibrium accounted for in excess of 90% of the material incoming the plant send-off as gaseous. (Charles J Banks, 2011)

Table 2.4: Amount of biogas yield per kg of TS and VS (Peter Jacob Jørgensen, 2009)

Biomass	Typical gas yields	
	m^3 biogas/kg TS	m^3 biogas/kg VS
Pig slurry	0.37	0.32
Cattle manure	0.24	0.21
Mink slurry	0.4	0.35
Deep bedding	0.24 to 0.37	0.21 to 0.32
Chicken manure	0.4	0.35
Floating sludge from sewage treatment plant	0.41 to 0.86	0.36 to 0.75
Offal	0.49 to 0.57	0.40 to 0.46
Primary sludge	0.38	0.33
Biological sludge	0.11 to 0.23	0.10 to 0.20
Source separated households waste	0.43	0.35
Maize	0.61	0.37
Grass	0.57	0.35

2.4 GGC vs Homebiogas

Modified GGC 2047 model is widely implemented in case of Nepal. In different size it can be constructed 2, 4 and 6, 8, 10 and so on. Fixed dome bio-digester consists of five main structures or components: a) Inlet Tank b) Digester Vessel c) Dome d)

Outlet Chamber and e) Compost Pits. The necessary amount of input material and water is mixed in the mixture and the slurry is discharged to the digester chamber for digestion. The biogas shaped from side to side by methanogenesis in the digester is composed in the higher fraction of dome. Afterward digested slurry flows to the outlet hall from side to side of the manhole. The slurry after that flows from side to side the run over opening in the outlet chamber to the compost ditch. The gas is supplied from the top of dome to the point of request through a pipeline.

Table 2.5: Comparison of GGC 2047 modified with Homebiogas

Category	Homebiogas 2.0	GGC 2047 modified
Type	It is a tubular model, made in Israel.	It is a fixed dome biogas plants, can be made from locally available material like sand, stone, bricks, rod, cement.
Material	Made from PE and PP.	This is made from stones, bricks, cement, gravel, rod, sand.
Life span	It has life span of more than 15 year.	It has life span of more than 20 years.
Orientation of System	It has to be put on E-W direction, facing outlet east.	It has to be put on N-S direction, facing outlet south pole.
Upgrading of Biogas Produced	It has biogas filter made up of activated carbon.	Filter mechanism has not been introduced in GGC 2047 model.
Skill Required for installation	It requires less skill manpower for installation.	It requires skilled manpower for installation (Skill in masonry work).
Feedstock Mixing Technique	Feedstock has to mix in bucket or drum and pour in the system.	GGC have mixture, manually the cow manure can be mixed in mixture.
Slurry in Pipeline	Digester bag and gas bag are separated so there is no chance of entering slurry in gas pipe.	Gas is directly collected upward of digester, so there is chance of entering slurry in gas pipe.
Pressure	Produced biogas gets pressure from dead weight	Produced biogas gets pressure from the outlet slurry level.

	(sand bag) kept on gas bag.	
Pressure of Biogas	It has pressure 1 to 1.5kilopascal.	It has pressure 5 to 15 kilopascal.
Handling	This is very portable.	It cannot be moved from one place to another (Fixed).
Maintenance	There is less maintenance part except the filter has to be replaced every six month.	There is more maintenance part on GGC model.
Damage from earthquake	Homebiogas have to be installed on the surface of earth, so there is no affect from earthquake on this system.	GGC 2047 Modified is installed inside the earth surface, so earthquake can damage this system.
Length of Pipe	It can supply biogas upto 20m placed stoves.	It can supply biogas longer distant than HBG.

CHAPTER THREE: RESEARCH METHODOLOGY

The research has been performed in certain steps. The steps performed during the research are shown in figure 3.1.

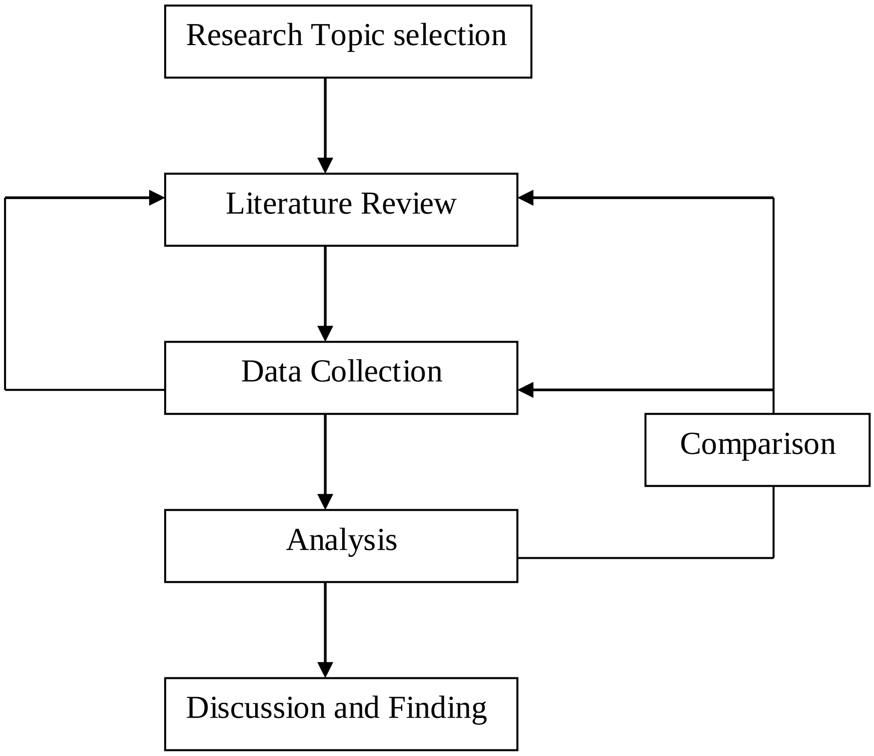

Figure 3.1: Research Methodology

3.1 Thesis Topic Selection

First of all, a topic selection has been perform for the research work. The energy demand has been increasing in Nepal. The use of LPG for cooking is increasing in urban and rural area. The shortage of LPG has caused several problems in urban area. The use of biogas energy mainly for cooking (in place of LPG) can be solution for this. The waste produce by human beings in home is mostly degradable. From degradable waste we can run biogas. Biogas system helps to produce clean cooking gas and natural liquid fertilizer. So construction of Homebiogas in urban area helps to reduce consumption of LPG, also it provides solution of waste management. So in this research a portable biogas (Homebiogas 2.0) have been chosen for study.

3.2 Review

The literature related to biogas, domestic biogas, types of waste and other necessary literature has been reviewed. The Domestic size biogas, portable biogas has been studied in detailed. The several organization which works in field of biogas sector was visited like AEPC, NBPA, and SNV. Also the data and research that has been done in portable biogas model was studied.

3.3 Data Collection

The research was performed by taking the relevant data of system installed in the alternative energy promotion center which has been situated in Godawari Sadak, Lalitpur. The data has been taken after the system is stabilized (well running condition). The system has been visited once in a week and relevant data was taken from it. Beside these several other locations like BSP, NBPA and other organization was also visited. The cost of installation of homebiogas 2.0, subsidy mechanism, and material required for installation of plant, material it made up of, life time was studied. Other necessary data was taken from the internet. Research plant was located at lalitpur district of Nepal. The latitude and longitude of experiment was 27.655 and 85.332. The plant was installed on 8th October 2019. For the activation of system there need to put 100 kg of cow manure with water. The mixture should be in 2:1 ratio, 2 part water and one part cow manure. Rest part of digester tank has been filling by water until there is flow from the fertilizer outlet. The system was left until there has seen gas in the gas bag. Gas has been seen after 10 days of installation. The feeding has started 21st day of installation with kitchen waste. The experimental system figure is attached in APPENDICES C.

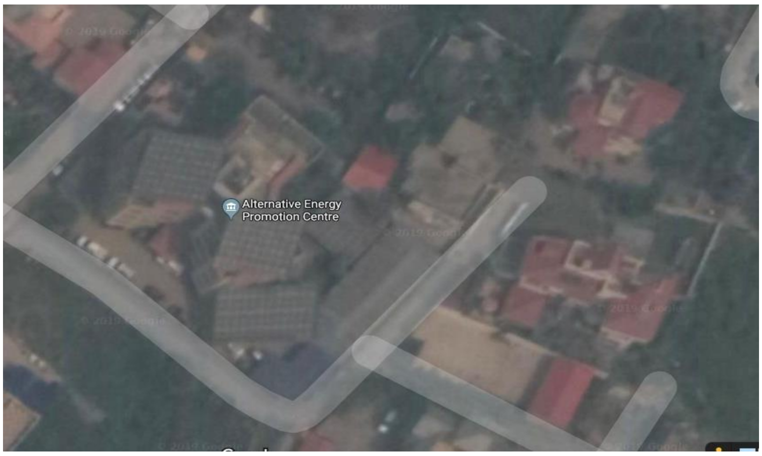

Figure 3.2: Location of Homebiogas 2.0 systems.

The system covers the area of 6.6 m^2 areas. Every day waste produced from kitchen of AEPC is around 4-5 liters. Waste includes rice, vegetables, dal, bread, pickle, fruit waste, leamon etc. Above photograph shows the location of system in AEPC backyard. Sun can fall on system in early sunshine only. After 12 pm sunshine cannot fall on system due to tall building of AEPC. This distance of pipeline is 12 meter from the system to stoves. Beside KW, cow manure has been fed on the system. Codigestion of kitchen waste with animal manure has been done in the system.

3.3.1 Gas Flowmeter

Gas flow meter have installed in the system in which the experiment has to be performed. Customer has been using the gas earlier morning (7:00-9:00 AM) to cook food. A stove was used once in a day to cook food from 7:00 to 9:00 AM. The reading from Gas Flow meter (Zhejing Chint instrument and meter co.ltd) has been taken from the AEPC canteen every day at 12:00PM. Gas flows from system to burner through pipeline. Gas flow meter has been placed between system and burner as shown in figure 3.3. A log sheet has been provided to the person who uses the stoves; on the daily basis the data have recorded. All data have been recorded in a cubic meter. Reading was taken at normal atmospheric pressure. 4.536 m^3 is the first reading on the flow meter as on 10^{th} of November 2019. Reading from the gas flow meter has been taken from the 10/11/2019 to 18/1/2020. The final reading of the flow meter has been 16.082m^3. The photograph of gas flow meter is attached in APPENDICES C.

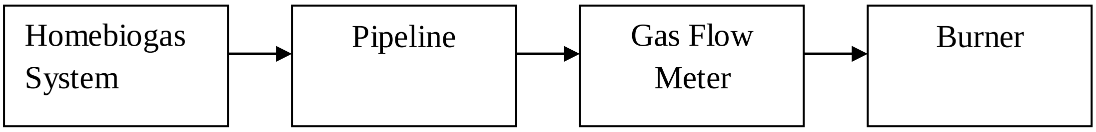

Figure 3.3: Experiment Setup

3.3.2 pH

Every week the pH meter (HM Digital) have used in order to measure the pH of system. Initially pH meter has been calibrated and used for testing output slurry. The standard of pH meter has been maintained on regular basis by calibrating it with the help of standard buffer solutions of pH 4, 7. A small amount of digested slurry from the system has taken in a beaker and pH meter is dipped on it until constant reading was obtained, pH of digested slurry has tested. Test has started on Tuesday, November 12, 2019 and end on Tuesday, December 17, 2019. Every week on Tuesday the pH have been measured. The photograph of pH meter is attached in APPENDICES C.

3.3.3 Temperature

Every day 12:00 PM the ambient temperature of system surrounding has taken. The maximum temperature and minimum temperature of surrounding the systems environment have been taken. Temperature has been taken at Degree centigrade.

3.3.4 Feeding

System has been feed with semi-continuous feeding. Food waste, cow manure was fed on the system. Food waste or cow manure was mixed with water in 1:1 ratio in the plastic bucket and put in system. As per availability of food waste like rice, vegetable waste, bread, pickle, fruit waste was fed to the system. Every week the system has fed with cow manure after there was decrease in pH value of system. The amount of feeding was noted in log sheet in daily basis. Feeding was done at 11:00AM.

3.3.5 Sample Preparation

Sample preparation has been another important and crucial task performed during research period. Among total sample it contains 75% cow manure and 25% kitchen waste. They all are mixed and sample has been taken for testing TS, VS and NPK. 10L of cow manure has been made from the ratio of 1:2-cow manure: water. The obtained slurry was mixed with 3.33L of kitchen waste. From the mixture of cow manure and kitchen waste, one liters of sample has been taken as a feedstock sample and other 1 liter have been taken from outlet slurry.

The photograph of sample preparation is attached in APPENDICES C.

3.3.6 Calculation of TS, VS and NPK

Prepared sample has taken to lab Nepal Environment and scientific services pvt.ltd. The sample has taken to this lab, located to Thapathali, Kathmandu Nepal.

First of all the dirt free, dehydrated and pre-weighed watch glass has taken and small amount of the sample was place on top of it, was precisely weigh. It have dehydrated in burning air oven at 105°C for 5 hours, chilled in desiccators and weighed. The same process was frequent awaiting achieving a set consequence. In order to measure VS, ignite a clean watch glass at 550°C for 1 h in a furnace.

Mass of unfilled watch glass = A

Mass of watch glass + sample = B

Mass of watch glass + sample after drying at 105°C = C

Mass of watch glass + remains after ignition at 550°C=D

Total solids = $\frac{C-A}{B-A}$

Volatile reduction = $\frac{C-D}{C-A}$

Table 3.1 Method was adopted in order to measure the TS, VS, NPK of feedstock and outlet slurry.

Table 3.1: Method used at lab to test NPK, TS &VS

SN	Parameters	Test Methods
1	Nitrogen (%)	Modified Kzeldahl, FAO, Fertilizer and Plants Nutrition Bulletin No.19
2	Total Phosphorous as P_20_5 (%)	Venadomolybdophosphric acid, FAO, Fertilizer and Plants Nutrition Bulletin No.19
3	Total potassium as K_2O (%)	Flame Absorption, AAS, FAO, Fertilizer and Plants Nutrition Bulletin No.19
4	Total solids(mg/g)	Oven Drying,Gravimetric,2540 C,APHA
5	Volatile solids(mg/g)	Ignition & Gravimetric,2540 C,APHA

3.3.7 GGC-Modified Model

The GGC-2047 is a modified version of Chinese model fixed dome model bio-digester. The BSP also have given approval to the GGC-2047 as the only standard model for construction and promotion in Nepal. GGC-2047 design has been derived from the Chinese fixed dome model plant and has been modified over the years to adopt it to the local demands and conditions. Data related to the GGC-Modified ($6m^3$) has taken from plants installed at RETS. Data includes the gas production per day and feeding amount per day. The result of GGC Modified has been compared with HBG 2.0.

3.4 Thesis Writing and Presentation

Finally the obtained results have compared with the past research; thesis writing work and presentation have done after consulting the supervisor, expert and friends related to the field.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 pH Variation

When the system starts running well, we have started the testing the pH of a system- after stabilization of the system. Testing of pH has performed for a month, on a weekly basis. Initially, it has been performed on 11/12/2019 and end on 12/17/2019. The pH of system can be seen in figure 4.1. The pH has been low for system, first two week. This was due to feedstock-feeding of input material for the system with food waste, pickle, citrus food and vegetable waste only. If there is gradual decrease in pH, composition of produced biogas varies, ultimately biogas production may stop. In order to neutralize the pH of the system there have to be added cow manure-so same has done during research period. When there have addition of cow manure, pH value increased to 7(Neutral). After 2^{nd} week of starting measuring pH, every week the system has been fed with cow manure. The pH of the input feedstock acts very significant position in methane creation. When biogas manufacture has been stabilize, the pH choice remains buffered between 7 and 8. When we use food waste only, we cannot successfully run AD process (Jia Lin, 2011). When co-digestion is done between press water, food waste, it gives higher buffer capacity and digestion can be carried at high loads without Ph control. (Nayono, 2010). When we add cattle manure to the food waste, AD process stabilized and higher output is obtained. (Cunsheng Zhang, 2013). Co-digestion provides more steadiness than mono-digestion for food waste (Yue Zhang, 2012). Co-digestion of food waste with cow manure balances the nutrients in the anaerobic digester and thus provides a more stable environment for anaerobic bacteria (L. Neves, 2009)

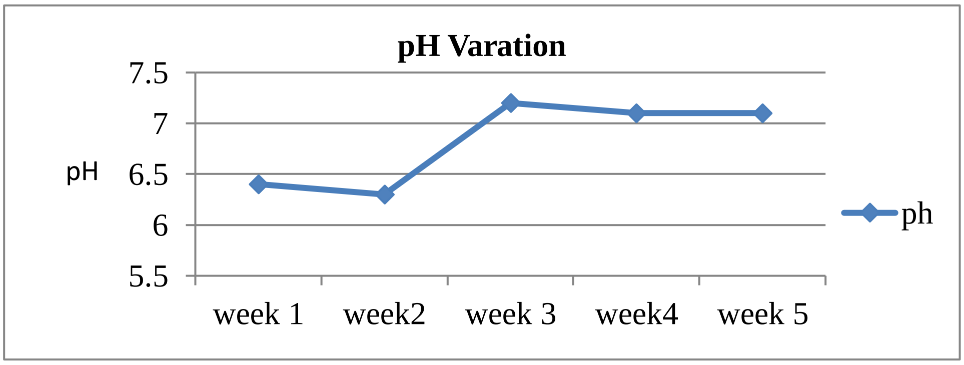

Figure 4.1: pH variation of output slurry

4.2 Gas Output

The gas output has been taken for 70days. It has started from Sunday, November 10, 2019 till Saturday January 18, 2020.

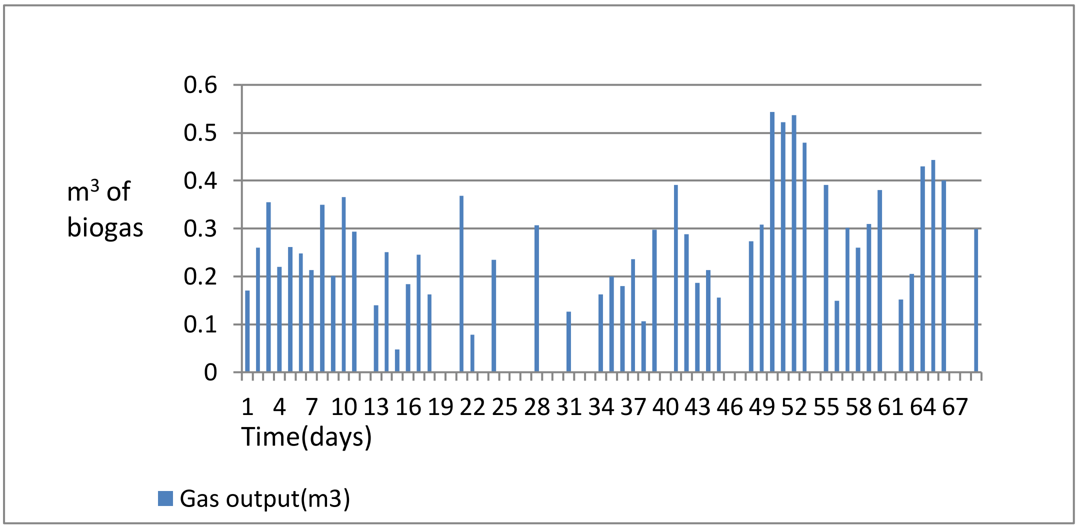

Figure 4.2: Gas output from the system

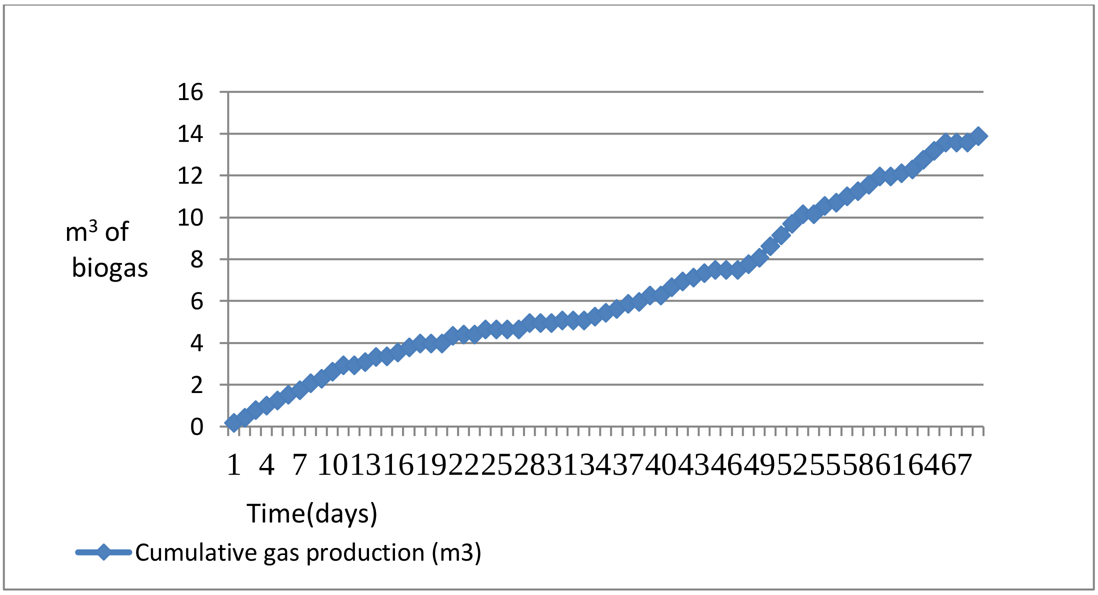

Figure 4.3: Cumulative gas production from the system

The average gas output per day has been 0.201 m^3.The average energy produced per day have been 1.308 kWh. Semi continuous data have taken from the meter because AEPC itself is a government body so there was no use of gas from the system during holiday. Gas production varies from 79 liter to 543 liter per day. Biogas produced per hour has been 8.735L. This has been due to temperature of system and feeding material supplied to the system. Cumulative gas output from the system follow increasing linear relationship with time as shown in figure 4.3. Cumulative graph have been increasing every day. From the 1.75m^3 of ARTI model biogas plant, gas output per day 0.182m^3 with 2kg of kitchen waste feed per day (Harka Man Lungkhimba, 2010).

4.3 Gas Composition and LPG Substitution

Gas composition has been measured with the help of geotech biogas 5000 portable biogas analyzer for the produced gas from the system. Percentage of methane content is good with 58.1%, while concentration of H_2S is 40ppm very low. Concentration of CO_2, CO, NH_3, was 37.1%, 0ppm, 28ppm. The CH_4 & CO_2 concentration of food waste, animal, manure & sewage waste has concentration of 65, 60, 70% and 35, 40, 17.5% respectively (Ramya Selvaraj, 2017). The Biogas shaped from KW and cattle manure provide work consists of 60% CH_4, 18% CO and 22% other gases (Farzana Tasnim, 2017).

Table 4.1: Biogas Composition

Gas Component	Mean Concentration
Methane(CH_4)	58.1%
Carbon dioxide(CO_2)	37.1%
Carbon monoxide(CO)	0ppm
Ammonia(NH_3)	28ppm
Hydrogen Sulphide(H_2S)	40ppm

Energy value = 6.5kWh/m^3 (AEPC)

Average gas used per day = 0.201 m^3

Total Energy per day = energy value × average gas used per day

= 6.5 × 0.201

= 1.308kWh

LPG

Calorific value of LPG = 46.1MJ/kg (American Society of Testing and Material)

Gas in one LPG tank = 14.2 kg

Total energy in LPG tank = 14.2*46.1

= 654.62

= 181.84kWh (1MJ=0.27778 kWh)

Equivalent LPG tank = 181.84/(1.308*30)

= 0.22

System can replace 3.55kg of LPG/month or one-fourth of LPG tank.

4.4 Reduction in TS and VS

When a feedstock or the outlet slurry is dried off i.e., humidity is dried off it gives total solids of a substance while the VS shows the organic part of the total solids. TS and VS of feedstock is greatly effects the production of biogas. Every matter contains TS and VS; the presence of TS and VS depends upon the matter on it. While calculating TS and VS, first of all we need to calculate the TS, during calculation of TS-all moisture have dried off by adding heat at 105 Degree Centigrade. After calculating the TS, we can calculate the VS of the material. VS can be calculated by drying it at higher temperature at about 550 Degree Centigrade. Both TS and VS affect the microbial activity of the AD process. For maximum biogas production, the total solid content of material should be around 10.16%-this is the optimum value for biogas production for maximum category of material (Ejiroghene Kelly Orhorhoro, 2017). One sample of feedstock as mentioned earlier and another sample of outlet slurry have taken. The taken sample has been taken to lab. The laboratory report of the sample prepared is attached in APPENDICES D. Based on this sample the following data has been obtained:

Table 4.2: TS AND VS of inlet feedstock and outlet of HBG 2.0

Parameter	Inlet(mg/g)	Outlet(mg/g)
Total Solid(TS)	44.72	12.72
Volatile Solid(VS)	38.31	9.8

Average Daily Feeding = 15kg

Average Daily gas production = 201 liters =0.201m^3

Table 4.3: Percentage change of TS and VS after digestion

Parameters	Inlet(mg/g)	Outlet(mg/g)	Difference(inlet-outlet)	% Change
Total Solid content(TS)	44.72	12.72	32	71.56
Volatile Solid Content(VS)	38.31	9.8	28.51	74.42

Total Solids per day (Inlet) = 15*4.4/100

= 0.67 kg of TS

Volatile Solids per day (Inlet) = 15*3.831/100

= 0.57 kg of VS

Total Solids per day (Outlet) = 15*1.272/100

= 0.19 kg of TS

Volatile Solids Per day (Outlet) =15*0.98/100

= 0.147 kg of VS

Amount of TS used per day = (0.67-0.19) kg of TS

= 0.48 kg of TS

Amount of VS used per day = (0.57-0.14) kg of VS

= 0.42 kg of VS

m^3 of biogas/kg of TS = Average Gas produced per day (Cubic meter)/TS per day used

= 0.201/0.48

=**0.419 m^3 of biogas/kg of TS**

m^3 of biogas/kg of VS = Average Gas produced per day (Cubic meter)/VS per day used

= 0.201/0.42

= **0.471 m^3 of biogas/kg of VS**

There has been good degradation rate for the total solid content, 71.56% and VS with 74.42%. Biogas produced has been 0.419 m^3 of biogas/kg of TS and 0.471 m^3 of biogas/kg of VS. Total solid and Volatile solid destroyed have been higher for food waste when anaerobically digested. Volatile solid is 85.66% of total solid for feedstock. After the feedstock has been digested anaerobically outlet slurry had VS 77.044% of TS. Co-digestion allows higher organic loading rate and gives a more stable anaerobic digestion process (Yue Zhang, 2012). Organic mixtures of kitchen waste and black water gives output of maximum 0.520 m^3 CH_4/kg VS (Maria Cristina Lavagnolo, 2017). The methane potentials for Fruit and Vegetable Waste (FVW) and Food Waste (FW), which has been 0.30, 0.56 m^3 CH_4/kg VS, respectively (Jia Lin, 2011). The highest methane potential of food waste have been in the range of 0.3-1.1 m^3 CH_4/kg VS added, generally higher than other anaerobic digestion substrates such as lignocellulosic biomass, animal manure and sewage sludge (Chunlan Mao, 2015).

4.5 Biogas Slurry

When the feedstock takes place inside the digester, it is converted to the biogas. Also the biogas helps to control odour of the material. The biogas output material both the methane gas and fertilizer are good for the environment. Fertilizer has high quality nutrient value for plants growth. Digested slurry has both the macro and micro nutrient contain of the fertilizer for crops growth and nourishments. Digested slurry has very low toxic material and also low amount of metals as compared to the synthetic fertilizers. Fertilizers have sufficient amount of nutrients for soil, to improve its soil capacities and crops yielding capacity. The Output from the different crops increases that actually farmers grows like rice, vegetables, and banana and so on. If we can combine in the use of the digested slurry to the synthetic fertilizer, we can even more increase the output from the crops. Plants growth favors for the combination of digested slurry and the synthetic fertilizer. From the shown table it can be concluded that there has been decrease in value of nitrogen. During anaerobic digestion most of the nitrogen has converted to ammonium, which is readily available for plant growth. Some phosphorus had changed to ortho phosphorus (a soluble form) in the digester. When household waste is anaerobically digested, digested slurry has N, K_2O_5 and P_2O_5 are 3.1, 1.7, and 3.2% respectively (Voca, 2005).

Table 4.4: Fertilizer contain in slurry

Parameter	Inlet (%)	Outlet (%)
Nitrogen(N)	0.27	0.19
Potassium(K_2O_5)	0.1	0.09
Phosphorus(P_2O_5)	0.06	0.04

4.6 Comparison of HBG2.0 with GGC Modified

GGC Modified model (Fixed dome digester) biogas plant of size 6m^3 have taken which is situated in khumaltar, lalitpur Nepal. This plant belongs to Renewable Energy Testing Station. With an average feeding of 40kg cow dung in GGC model of 6 m^3, gas output per day was 452 liter. The average temperatures during testing is 18.75^{o}C (Bijaya Raj Khanal, 2014).While in case of homebiogas it was 201 liters with average ambient temperature of 13.84^{o}C. The average feeding in system has 15kg per day (Combination with outlet slurry). Feeding includes food waste and cow manure. There was more gas production from the food waste as comparison with cow manure. Food waste contains more VS for production of gas.

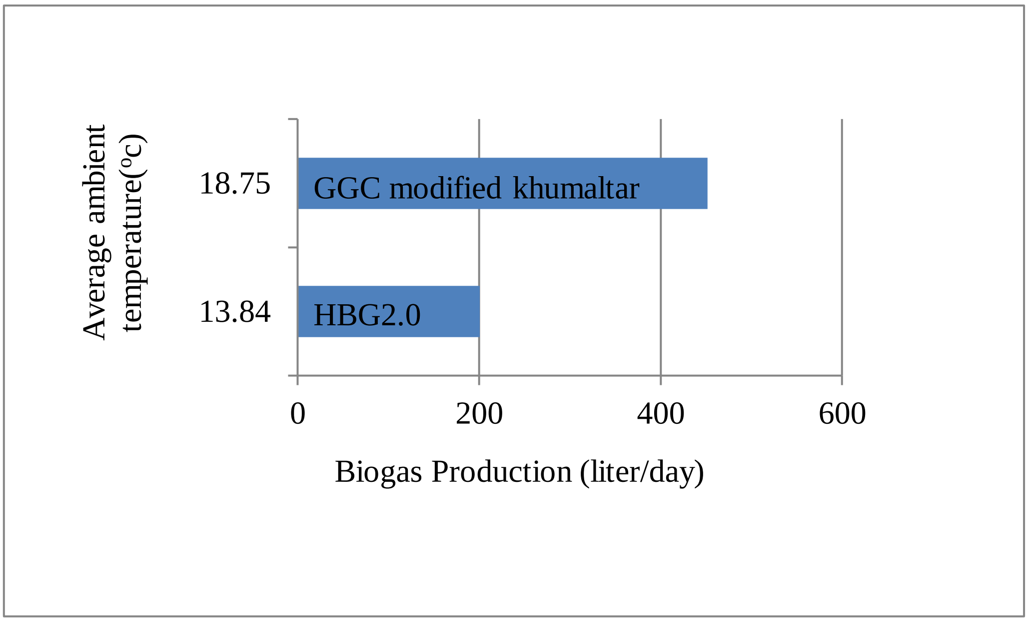

Figure 4.4: Comparison of biogas production from HBG2.0 and GGC model of 6 m^3

For GGC modified model the average Nitrogen (N) 1.6%, Potassium (K_2O_5) 1.55%, Phosphorus (P_2O_5) 1% for outlet slurry (Amrit B. Karki, 2015).

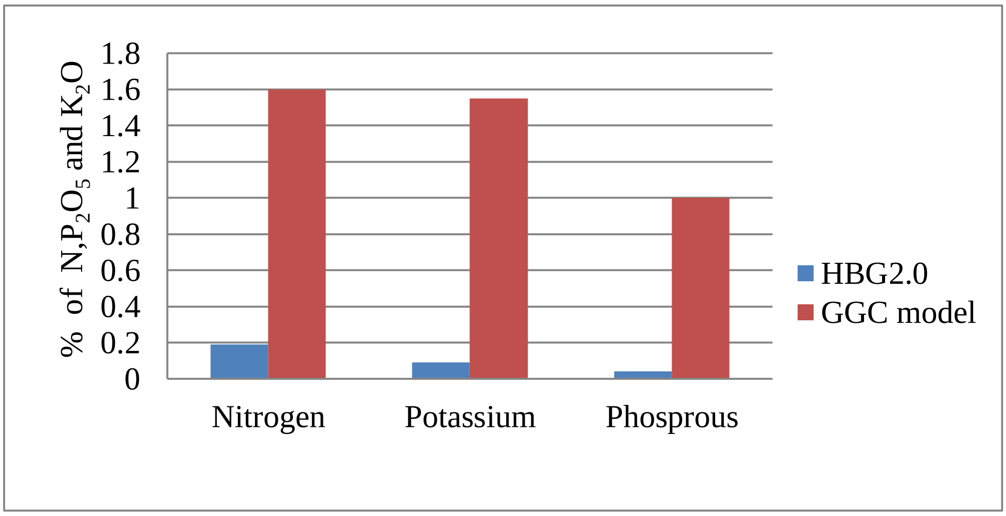

Figure 4.5: NPK Comparison for HBG and GGC Model

4.7 Colder Climate Modification

Increase in temperature of system also increases the output from biodigester. There needs to be maintained favorable temperature for biogas system. In order to maintain the constant temperature we can adopt heat conservation system which includes using heap composting and green houses.

Calculation of theoretical heat requirement

Total Digester Heating Requirement, $Q_1 = Q_T + Q_L$

Where,

Q_T=Rate of heat transfer to the raw manure influent.

Q_L=Rate of heat loss through digester walls.

Calculating the influent heating

The energy required to heat the influent manure to reach the required temperature of the digester is calculated as:

$Q_T = m \times C \times (T_2\text{-}T_1)$

C=specific heat of the influent.

m=mass of influent inside digester.

T_1= average slurry Temperature.

T_2= desired slurry Temperature.

Now,

Specific heat of cow dung, C_1=2.79925KJ/kg°C (Nayyeri et al, 2009)

Specific heat of water, C_2=4.186KJ/kg°C

Average specific heat of manure, $C = \frac{C_1+C_2}{2}$

=3.4926KJ/kg°C

Mass of influent inside digester=1200Kg

Average slurry Temperature, T_1=13.84°C

Desired slurry Temperature, T_2=35°C

Mass of the influent inside the digester=1200kg

Heat required heating the influent to desired temperature,

$Q_T = m \times C \times (T_2\text{-}T_1)$ Equation(4.1)

= 1200*3.4926*21.16

= 88396.5 KJ

Parameters for Heat Loss

Thickness of Polypropylene, L_{PP} = 3.57mm

Thickness of Polyethylene, L_{PE} = 0.13mm

Thermal Conductivity of Polypropylene, K_{PP} = 0.16W/mK (Ineos olefins & polymers USA, 2019)

Thermal Conductivity of Polyethylene, K_{PE}=0.33 W/mK (Ineos olefins & polymers USA, 2019)

Thermal Resistance in Series is given by below formula,

$$\frac{1}{R_{series}} = \frac{K_{PP} \times A_{PP}}{L_{PP}} + \frac{K_{PE} \times A_{PE}}{L_{PE}}$$ Equation(4.2)

Where,

R_{series}=Total thermal resistance in series

A_{PP}=Area normal to polypropylene material through which heat passes.

A_{PE}=Area normal to polyethylene material through which heat passes.

L_{PP}=thickness of polypropylene through which heat passes.

L_{PE}=Thickness of polyethylene through which heat passes.

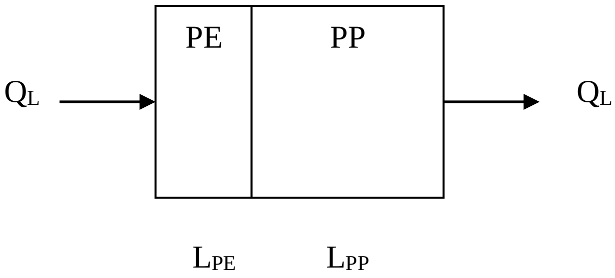

Figure 4.6: Heat lost from the system

Dimension of bag Digester (HBG 2.0),

Length of bag digester (L) = 210cm

Width of bag digester (W) = 115cm

Height of digester bag (H) = 64cm

Normal area through which heat passes in bag digester

Table 4.5: Surface area of digester

SN	Particular	Area(m^2)
1	Bottom surface area	2.415
2	Top surface area	2.415
3	Inlet side area	0.763
4	Outlet side area	0.763
5	Left side wall	1.344
6	Right side wall	1.344

Calculation of thermal Resistance,

Table 4.6: Thermal resistance

SN	Particular	Thermal Resistance(°K/W)
1	Bottom surface area	0.00016
2	Top surface area	0.00016
3	Inlet side area	0.000507

4	Outlet side area	0.000507
5	Left side wall	0.000287
6	Right side wall	0.000287

Heat Loss calculation

Heat Loss = $\frac{T_{slurry} - T_{ambient}}{Thermal\ resistanace}$ Equation(4.3)

Where,

Desired slurry temperature, T_{slurry} =35°C

Ambient temperature, $T_{ambient}$ = 13.84°C

Now heat loss,

$= \frac{21.16}{Thermal\ Resistance}$

Now putting the thermal resistance of each surface area,

Table 4.7: Heat loss from different part of digester

SN	Particular	Heat Loss(Watt)
1	Bottom Surface Area	132044.9612
2	Top Surface Area	132044.9612
3	Inlet side Area	41718.55
4	Outlet Side Area	41718.55
5	Left Side Wall	73485.89
6	Right Side Wall	73485.89
	Total Heat Loss	494498.81

Therefore total heat loss from the system, Q_L = 494498.8114watt

= 494498.8114 joule

Total Heat Required = $Q_T + Q_L$

= 88396.5 + 494498.814

= 88.89 MJ

Homebiogas is mostly used for the urban area where there is availability of electricity. Instant tap heater can be connected to tap near by the system. It is made up of Nylon and glass fiber, Size of 21mm, length of 80mm. internal diameter of tap is 21mm, Pitch 1.814, and Tap drill diameter of 19mm. It has Patent heating technology, much longer service life. Electric instant heating hot water has to be connected to tap near to the system. Hot water (35°C) can be used during mixing with cow manure or kitchen waste. After having mixing with hot water in bucket. It can be poured down to the system from inlet side of homebiogas2.0. When the handle is moved towards to off the appliance keep closed mode. When handle is moved towards to blue icon, cold water will come out from the tap. Handle in the position of red icon, hot water will come out from the tap. From the Led digital display, the outlet temperature of water is clear at glance. We can set the outlet temperature to 35°C by pressing the bottom provided in tap heater. Power cord can be connected to the board near by the tap. The Specification of instant tap heater is as follows:

Table 4.8: Specification of instant tap water heater

Model Number	TA33D
Voltage	220-240V
Rated Frequency	50/60 Hz
Power	3.3Kw

4.6.2 Compost heap

When substances are degraded, it liberates heat. Due to liberation of heat, temperature of air, water surrounding environment increases. Water presence in the substrate evaporates liberating water vapor. The energy liberate through the decomposition of substrate essential takes two form energy that increases the temperature and energy associated with an increase in water vapor. Enthalpy accounts for both the sensible and latent heat of a mass of air. When air passes through a composting substrate, by convection, air takes heat released during composting. There can be adaptation of compost heap for the system in order to increase the temperature of the system.

The conditions for the heap by Berkley are:

1. The temperature is maintained for compost heap at 55-65degree Celsius.
2. The carbon to nitrogen ratio for the material to be used in compost heap is around 25-30:1.
3. Heap needs to be around 1.5 meter width and height in all sides of homebiogas.
4. Material should be balanced for the carbon and nitrogen, if they are large they need to be broken, and mulched.
5. Compost is turned from outside to inside and vice versa to mix it thoroughly.

The ratio of carbon to nitrogen in the compost substrate needs to be between 25 to 30 parts carbon to one-part nitrogen by weight. Materials that are very high in carbon are typically dry and brown materials, such as sawdust, dried leaves, straw, branches and other woody or fibrous materials that rot down slowly. Materials that are high in nitrogen are typically moist containing water, green materials, such as lawn/grass clippings, fruit and vegetable scraps, animal manure and green leafy materials that rot down very quickly. By mixing different ingredient we can make compost heap. We can use roughly 1/3 green parts materials and 2/3 brown parts material. There need to be maintain one bucket nitrogen rich material and two bucket dry carbon containing material (Deep Green Perm culture). Compost heap should be 1 meter wide and 1.5 meter height around the system. The CN ratio for different material is attached in APPENDICES E.

4.6.3 Green House

A greenhouse is a man made structure with walls, window, door and roof made chiefly of transparent material, such as glass and plastic. The higher temperature inside a greenhouse occurs because incident sun radiation passes through the transparent roof, window, door and walls and is absorbed by the floor, air, earth, and contents, which become warmer. The structure is not open to the enviroment; the warmed air cannot escape via convection, so the temperature inside the greenhouse rises. The greenhouse can provide control environment for microbiological process. There needs to be constructed a green houses of size length 3.5 meter, Width 3 meter and height of 2 meter. Wooden structure can be used in order to construct the house. Covering materials like plastic are the important component of the greenhouse structure. They have direct influence on greenhouse effect, inside the house and they alter the air temperature inside. The types of structure and method of fixing also varies with covering material. Hence based on the type of covering material following can be used:

a) Glass glazing.

b) Fibre glass reinforced plastic (FRP) glazing

  i. Plain sheet

  ii. Corrugated sheet.

c) Plastic film

  i. UV stabilized LDPE film.

  ii. Silpaulin type sheet.

  iii. Net house

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the research carried out following conclusion was obtained:

1. From the research we can analyze that this system is feasible for urban area of Nepal. We can solve the problem of degradable waste at home itself. After the biodigester was stabilized, if feeding material was only kitchen waste like vegetable waste, food waste, pickle, citrus food outlet slurry pH goes on decreasing. As a result methane concentration goes on decreasing and difficult to ignite the gas in stoves. So there have to be added cow manure in order to neutralize the acid produced in the system. Cow manure brings the pH to neutral value or around 7. The average gas production per day was 0.201 m^3.
2. TS of feedstock were 44.72mg/g and outlet slurry was 12.72mg/g. There was good degradation rate in TS with 71.56%. Food waste has high degradation rate when anaerobically digested with cow manure. VS of inlet feedstock were 38.31 mg/g and outlet slurry was 9.80mg/g. There was good degradation rate in volatile solid with 74.42%. VS were 85.66% of total solid for Feedstock material. After the feedstock was digested anaerobically outlet slurry has VS 77.044% of TS. 0.419m^3 biogas/kg of TS and 0.471m^3 biogas/kg VS was produced from system. NPK of Feedstock was 0.27%, 0.10%, and 0.06% and outlet was 0.19%, 0.09%, 0.04% respectively.
3. Per hour gas production from Homebiogas 2.0 was 8.375liter while in GGC of 6m^3 were 18.75 liters. The ambient temperature of GGC was 18.75°C and 13.84°C for Homebiogas 2.0.
4. There need to be used instant tap heater near by the system for colder climate. There need to be mix the water from the instant tap heater with the feeding material. By doing so we can increase the output from the system & come over from the winter climate. Also we can put the system in green house gases and hot composting.

5.2 Recommendations

Based on the research carried out following recommendations was carried out,

1. Research should be done whole year in order to get proper output. So that we can get proper results in all seasonal variations.
2. During testing of TS, VS and NPK, more sample needs to be tested in order to get exact results.

3. There needs to be carried out more detailed study for colder climate modification. Heating can be done with solar. Solar heating methods need to be carried out in future.
4. Their needs to be carried out research in cow manure only, kitchen waste only.
5. Microbiological activity need to be carried out through advance laboratory.
6. There need to have close control on temperature parameters for further study.

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APPENDICES A: PUBLICATION

1. Gautam B, Jha A.K. (2020). Performance Analysis of Homebiogas and Comparison with Modified GGC-2047 Model Biogas Plant, Artech Journal of Effective Research in Engineering and Technology, 1, 1-6.

APPENDICES B: TUBULAR MODEL BIOGAS PLANT IN WORLD

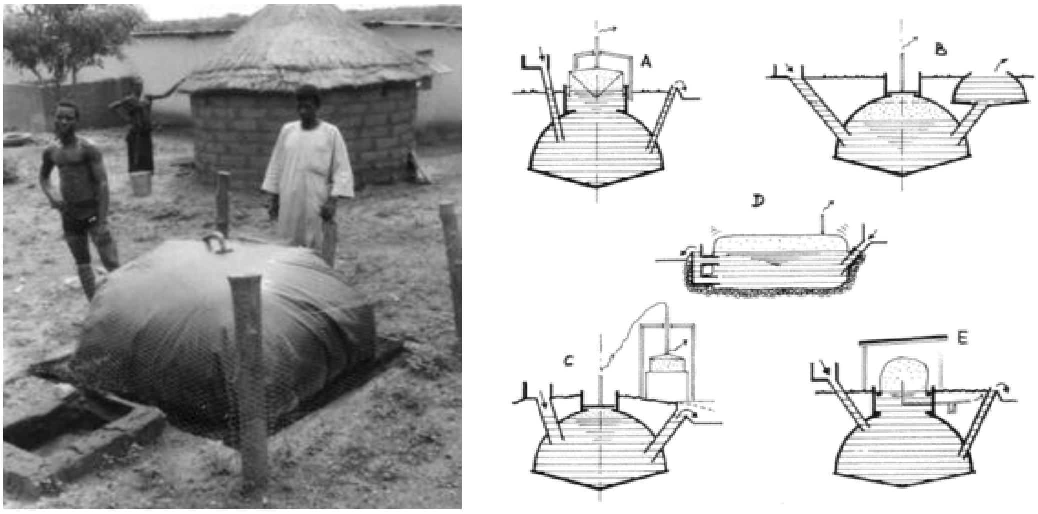

Fig: Ballon Digester

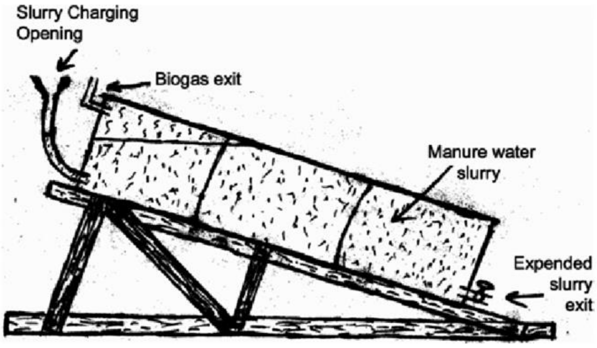

Fig: Earth Pit Plant

Fig: Biobrowser

Fig: Flexi Biogas

Fig: Simgas

Fig: Huamei International Green Energy

Fig: Sistema Biobolsa.

Fig: Ecofys Plastic Bag Digester.

Fig: Agama Biogaspro Digesters.

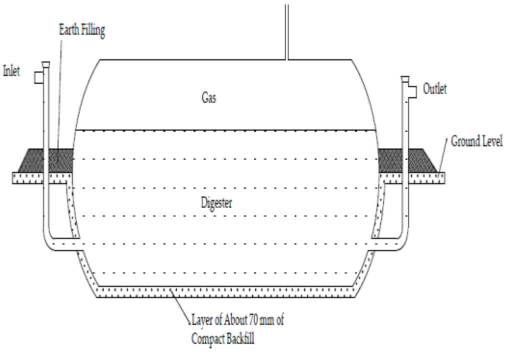

Fig: Taiwanese PVC Bag Digester.

Fig: Bag Digester in Nepal (BSP Nepal).

APPENDICES C: EXPERIMENT SETUP

Fig: Homebiogas in backyard of AEPC.

Fig: Gas flow Meter.

Fig: pH meter.

Fig: Sample preparation.

Fig: Sample Preparation.

APPENDICES D: LABORATORY REPORT

NESS

Nepal Environmental & Scientific Services (P) Ltd.

G.P.O. Box: 7301, Thapathali, Kathmandu, Nepal

Phone : +977-1-4244989, 4241001, Fax No.: +977-1-4226028, Email: ness@mos.com.np

http:\\www.nesspltd.com

Page 1 of 1

NESS/Lab, M-03/R1.1

QS Test Report / Certificate

NS Accreditation No. Pra. 01/053-54

Entry No. : NCL -365 (Oth) (2) - 12 - 2019   Date Received : 29 - 12 - 2019

Sample : Biogas Slurry   Date Completed : 19 - 01 - 2020

Client : Bashu Gautam   Sampling Date : 28 - 12 - 2019

Sampled By : Client   Location : Khumaltar

S. N.	Parameters	Test Methods	Observed Values	
			Inlet	Outlet
1.	Nitrogen, (%)	Modified Kzeldahl, FAO, Fertilizer & Plant Nutrition Bulletin No. 19	0.27	0.19
2.	Total Phosphorous as P_2O_5 (%)	Vanadomolybdophosphoric acid, FAO, Fertilizer & Plant Nutrition Bulletin No. 19	0.10	0.09
3.	Total Potassium as K_2O, (%)	Flame Absorption, AAS, FAO, Fertilizer & Plant Nutrition Bulletin No. 19	0.06	0.04
4.	Total Solids, (mg/g)	Oven Drying, Gravimetric, 2540 C, APHA	44.72	12.72
5.	Volatile Solids, (mg/g)	Ignition & Gravimetric, 2540 C, APHA	38.81	9.80

Note: The gravimetric analysis was carried out in controlled temperature condition (20°C).
FAO: Food and Agriculture Organization; APHA: American Public Health Association; AAS: Atomic Absorption Spectrophotometer.

(Analyzed By)   (Checked By)   (Authorized Signature)

Note:
1. This report/certificate is in reference to Laboratory Quality Control Manual, QS (017), section OPT.
2. The result listed refer only to the tested samples & applicable parameters. Endorsement of products is neither inferred nor implied.
3. Liability of our institute is limited to the invoiced test parameters & amount only.
4. Samples will be destroyed after one month from the date of issue of test certificate unless otherwise specified.

APPENDICES E: CN RATIO FOR DIFFERENT MATERIAL

CN ratio for different material (Planet Natural Research Center, 2020)

SN	Particulars	CN Ratio
1	Wood Chips	400:1
2	Saw Dust	325:1
3	Newspaper, shredded	175:1
4	Corn stalks	75:1
5	Straw	75:1
6	Leaves	60:1
7	Fruit Waste	35:1
8	Peanut shells	35:1
9	Ashes, wood	25:1
10	Garden waste	30:1
11	Weeds	30:1
12	Green woods	25:1
13	Hay	25:1
14	Vegetable Scrap	25:1
15	Clover	23:1
16	Food waste	20:1
17	Grass clippings	20:1
18	Seaweed	19:1
19	Horse Manure	18:1
20	Cow manure	16:1
21	Chicken Manure	12:1
22	Pigeon Manure	10:1
23	Fish	7:1
24	Urine	1:1

APPENDICES F: SIMILARITY REPORT

1. Agyeman, F. a. (2014). Anaerobic Codigestion of Food Waste and Dairy Manure: Effects of Food Waste Particle Size and Organic Loading Rate. Journal of enviromental management , 133, 268-274.
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APPENDICES G: DATA SHEET

S.N	Date	Feeding (Ltrs or kg)	Gasflowmeter Reading ,m^3	EveryDay Gas Production/Consumption,m^3	Cumulative Gas Production,m^3	Cooking Hrs Everyday	pH	Ambient Temperature(Tmax),Degree Centigrade	Ambient Temperature(T_{min}),Degree Centigrade	Average Ambient Temperature(T_{av}),Degree Centigrade
1	Sunday, November 10, 2019	10	4.536					26	12	19
2	Monday, November 11, 2019	10	4.706	0.17	0.17			26	11	18.5
3	Tuesday, November 12, 2019	10	4.966	0.26	0.43	0.867	6.4	25	11	18
4	Wednesday, November 13, 2019	10	5.321	0.355	0.785	1.183		25	11	18
5	Thursday, November 14, 2019	10	5.541	0.22	1.005	0.733		25	11	18
6	Friday, November 15, 2019	10	5.803	0.262	1.267	0.873		25	11	18
7	Saturday, November 16, 2019	10	6.051	0.248	1.515	0.827		25	10	17.5
8	Sunday, November 17, 2019	10	6.264	0.213	1.728	0.710		25	10	17.5
9	Monday, November 18, 2019	10	6.614	0.35	2.078	1.167		24	10	17
10	Tuesday, November 19, 2019	10	6.815	0.201	2.279	0.670	6.2	24	10	17
11	Wednesday, November 20, 2019	10	7.181	0.366	2.645	1.220		24	10	17
12	Thursday, November 21, 2019	10	7.475	0.294	2.939	0.980		24	9	16.5
13	Friday, November 22, 2019	30	7.475	0	2.939	0.000		24	9	16.5
14	Saturday, November 23, 2019	10	7.615	0.14	3.079	0.467		24	9	16.5
15	Sunday, November 24, 2019	10	7.866	0.251	3.33	0.837		24	9	16.5
16	Monday, November 25, 2019	10	7.914	0.048	3.378	0.160		23	8	15.5
17	Tuesday, November 26, 2019	10	8.098	0.184	3.562	0.613	7.1	23	8	15.5
18	Wednesday, November 27, 2019	10	8.343	0.245	3.807	0.817		23	8	15.5
19	Thursday, November 28, 2019	10	8.506	0.163	3.97	0.543		23	8	15.5
20	Friday, November 29, 2019	30	8.506	0	3.97	0.000		23	8	15.5
21	Saturday, November 30, 2019	20	8.506	0	3.97	0.000		23	8	15.5
22	Sunday, December 01, 2019	10	8.875	0.369	4.339	1.230		22	7	14.5
23	Monday, December 02, 2019	10	8.954	0.079	4.418	0.263		22	7	14.5
24	Tuesday, December 03, 2019	20	8.954	0	4.418	0.000	7.2	22	7	14.5
25	Wednesday, December 04, 2019	10	9.189	0.235	4.653	0.783		22	7	14.5
26	Thursday, December 05, 2019	10	9.189	0	4.653	0.000		22	6	14
27	Friday, December 06, 2019	30	9.189	0	4.653	0.000		22	6	14
28	Saturday, December 07, 2019	20	9.189	0	4.653	0.000		21	6	13.5
29	Sunday, December 08, 2019	10	9.496	0.307	4.96	1.023		21	6	13.5
30	Monday, December 09, 2019	10	9.496	0	4.96	0.000		21	6	13.5
31	Tuesday, December 10, 2019	10	9.496	0	4.96	0.000	7.1	21	6	13.5
32	Wednesday, December 11, 2019	10	9.622	0.126	5.086	0.420		21	6	13.5
33	Thursday, December 12, 2019	10	9.622	0	5.086	0.000		22	6	14
34	Friday, December 13, 2019	60	9.622	0	5.086	0.000		22	6	14
35	Saturday, December 14, 2019	6	9.785	0.163	5.249	0.543		21	6	13.5
36	Sunday, December 15, 2019	10	9.985	0.2	5.449	0.667		21	6	13.5
37	Monday, December 16, 2019	10	10.165	0.18	5.629	0.600		21	6	13.5
38	Tuesday, December 17, 2019	10	10.401	0.236	5.865	0.787	7.1	21	6	13.5
39	Wednesday, December 18, 2019	10	10.507	0.106	5.971	0.353		21	6	13.5
40	Thursday, December 19, 2019	10	10.804	0.297	6.268	0.990		21	5	13
41	Friday, December 20, 2019	60	10.804	0	6.268	0.000		20	5	12.5
42	Saturday, December 21, 2019	10	11.195	0.391	6.659	1.303		20	5	12.5
43	Sunday, December 22, 2019	10	11.483	0.288	6.947	0.960		20	5	12.5
44	Monday, December 23, 2019	10	11.669	0.186	7.133	0.620		20	5	12.5
45	Tuesday, December 24, 2019	10	11.882	0.213	7.346	0.710		20	5	12.5
46	Wednesday, December 25, 2019	10	12.038	0.156	7.502	0.520		20	4	12
47	Thursday, December 26, 2019	10	12.038	0	7.502	0.000		21	5	13
48	Friday, December 27, 2019	40	12.038	0	7.502	0.000		20	5	12.5
49	Saturday, December 28, 2019	10	12.312	0.274	7.776	0.913		20	5	12.5
50	Sunday, December 29, 2019	10	12.62	0.308	8.084	1.027		20	5	12.5
51	Monday, December 30, 2019	10	12.855	0.543	8.627	1.810		20	5	12.5
52	Tuesday, December 31, 2019	10	13.142	0.522	9.149	1.740		20	5	12.5
53	Wednesday, January 01, 2020	10	13.392	0.537	9.686	1.790		20	4	12
54	Thursday, January 02, 2020	10	13.621	0.479	10.165	1.597		20	4	12
55	Friday, January 03, 2020	40	13.621	0	10.165	0.000		20	4	12
56	Saturday, January 04, 2020	10	14.012	0.391	10.556	1.303		20	4	12
57	Sunday, January 05, 2020	10	14.161	0.149	10.705	0.497		19	4	11.5
58	Monday, January 06, 2020	10	14.313	0.301	11.006	1.003		19	4	11.5
59	Tuesday, January 07, 2020	10	14.421	0.26	11.266	0.867		19	4	11.5
60	Wednesday, January 08, 2020	10	14.623	0.31	11.576	1.033		19	4	11.5
61	Thursday, January 09, 2020	10	14.801	0.38	11.956	1.267		19	3	11
62	Friday, January 10, 2020	40	14.801	0	11.956	0.000		19	3	11
63	Saturday, January 11, 2020	10	14.953	0.152	12.108	0.507		19	3	11
64	Sunday, January 12, 2020	10	15.158	0.205	12.313	0.683		19	3	11
65	Monday, January 13, 2020	10	15.383	0.43	12.743	1.433		19	3	11
66	Tuesday, January 14, 2020	40	15.601	0.443	13.186	1.477		19	3	11
67	Wednesday, January 15, 2020	10	15.783	0.4	13.586	1.333		18	3	10.5
68	Thursday, January 16, 2020	40	15.783	0	13.586	0.000		18	3	10.5
69	Friday, January 17, 2020	20	15.783	0	13.586	0.000		18	3	10.5
70	Saturday, January 18, 2020	10	16.082	0.299	13.885	0.997		18	3	10.5
Average		14.94		13.715	18	0.672		21.4	6.27	13.84

APPENDICES H: PUBLISHED RESEARCH PAPER

Artech Journal of Effective Research in Engineering and Technology (AJERET)
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Performance Analysis of Homebiogas and Comparison with Modified GGC-2047 Model Biogas Plant

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Pulchowk Campus, Institute of Engineering, Tribhuvan University, Kathmandu, Nepal

Abstract: *Homebiogas is a tubular model biodigester. The size in research was of 2 m^3. Its digester chamber of size 1200 L and gas bag of size 800 L. Outer bag made of high-quality Polypropylene sheet laminated with Polyethylene. Gas liner made from multilayer Polyethylene. Digester bag made from advanced Polyethylene co-extruded PA barrier cover film. There was mixed feeding. Cow manure as well as Kitchen waste like rice, vegetables, fruit waste and bread was feed to the system. After the system was stabilized if the feedstock was only food waste there was decrease in pH. So there need to be added cow manure in order to neutralize the pH. The average gas produced per day was 201 L. Homebiogas2.0 can replace 3.064 kg of lpg/month. Energy produced per day was 1.308 kWh. Percentage reduction in TS and VS was 71.56 and 74.2%. There was higher reduction in TS and VS for food waste when anerobically digested. Biogas produced was 0.419 m^3/kg of TS and 0.471 m^3/kg of VS. Nitrogen, Potassium and Phosphorus of feedstock was 0.27, 0.1, 0.06% respectively and digested slurry was 0.19, 0.09, 0.04% respectively. Gas output from the homebiogas2.0 was 0.44 times the output of GGC modified of 6 m^3.*

Key words: Anaerobic digestion, feedstock, total solid, volatile solid, homebiogas2.0

INTRODUCTION

A biogas plant is an anaerobic digester of organic material for the purposes of treating waste and generating biogas. The treated organic waste is a nutrient rich while the biogas is mostly methane gas with inert gases including carbon dioxide and nitrogen. Biogas plants are a preferred alternative to burning dung cake as a fuel. Other feedstock which can be used includes household waste like vegetable waste, food-wastes and most types of animal manure. In large amount biogas plants have been constructed in the developing country for treatment of organic wastes and animal manure, alternative energy supply to direct burning in the kitchen and overall improvement of human health and the environment. Biogas is a source of renewable energy. In case of Nepal large number of fixed dome model biogas plant are installed. Most of these biogas plants are installed in rural area. A few of plants are in urban area.

Homebiogas is a tubular model(bag digester) biogas plant. Homebiogas2.0 has digester chamber of 1200 L and gas chamber of 800 L. The length, width and height of homebiogas2.0 is 2.1 and 1.15 and 1.25 m, respectively and it is designed to operate in more than 20°C. Outer bag of homebiogas made of high-quality Polypropylene sheet laminated with Polyethylene for both UV protections. Gas liner made from multi layer Polyethylene. Digester bag made from advanced Polyethylene co-extruded PA barrier cover film. For the activation of system there need to fill 100 kg of cow manure with water. The mixture should be in 2:1 ratio, 2 part water and one part cow manure. Rest part of digester tank need to be filled by water until there is flow from the fertilizer outlet. In order to create the pressure for produced gas in the system sand bags are put in the pocket of gas bag. The 1 kg of sand needs to be put inside the sand bag. Sand bags are properly distributed so that there is equal pressure from full of gas bag to empty of gas bag. The 48 sand bag of 1 kg was put on gas bag. GGC-2047 modified plant is a fixed dome model biogas plant.

Most of biogas plant that are install in Nepal is fixed dome model. As we know that Nepal lies in the prone of earthquake region. Earthquack can damage the fixed dome digester. Also, it is very difficult to construct the dome type model in urban area, as it consumes more space and time to construct. People also migrate here and there in urban area. So there is need for optional model for the dome structure. Also there is need of less space consuming, portable model for the urban area. So that we can solve the problem of organic waste of urban area converting into clean cooking gas and natural liquid fertilizer at source itself (**Fig. 1**). Liquid fertilizer can be

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Citation: Gautam, B., A.K. Jha, 2020. Performance analysis of homebiogas and comparison with modified GGC-2047 model biogas plant. Artech J. Eff. Res. Eng. Technol., 1: 1-6.

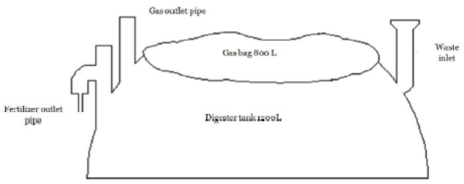

Fig. 1: General Layout of Homebiogas2.0 (HBG2.0)

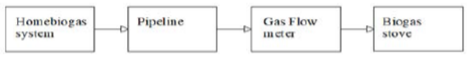

Fig. 2: Experimental setup at AEPC for homebiogas2.0

used for the roof top farming, gardening. Use of this biodigester saves the consumption of Liquefied Petroleum Gas (LPG). LPG is imported from the foreign country, so during its import in large amount economy of country goes outside. So using this we can save the economy of country too. This research was performed to analysis the performance of homebiogas2.0 and compare the gas output with GGC-2047 modified of 6 m^3.

MATERIALS AND METHODS

For the research a homebiogas plant of size 2 m^3 was chosen which was installed in latitude and longitude 27.655, 85.332 respectively. A selected plant belongs to Alternative Energy Promotion Center (AEPC), khumaltar, Lalitpur, Nepal (**Fig. 2**). Selected plant was installed in October 2019. Research was started after the system was stabilized. Gas flowmeter was placed between the system and stove. Gas flows from gas bag to pipeline, gas flowmeter and finally to stove. A stove was burn at 9:00 a.m. everyday during research period till the gas bag is empty. Gas flowmeter (zhejing chint instrument and meter Co., Ltd. China) data was taken from the system every day at 12:00 p.m. All data was recorded in a cubicmeter. Reading was taken at normal atmospheric pressure.

Every week the pH meter (HM Digital) was used in order to measure the pH of system. Initially pH meter was calibrated and used for testing output slurry. The quality of pH meter was maintained regularly by calibrating it with the help of standard buffer solutions of pH 4, 7. A small amount of slurry from outlet was taken in a beaker and pH meter was dipped on it until constant reading was obtained. Test was started on Tuesday, November 12, 2019 and end on Tuesday, December 17, 2019. Every week on Tuesday the pH of outlet slurry was measured. Ambient temperature of surrounding the system was taken. It was noted down in degreecentigrade. System was feed with continuous feeding. Food waste, cow manure was feed in the system. Food waste was collected from the AEPC canteen itself and cow manure from the cow farm near by the city. Food waste or cow manure was mixed with water in 1:1 ratio and put in system. Food waste like vegetable waste, rice, bread, pickle, fruit waste was put in the system. In order to measure the TS, VS and NPK of feedstock and fertilizer there need to be taken sample. A 20 L bucket was taken. According to codigestion sample was prepared by mixing 75% cow manure and 25% kitchen waste. First of all 10 L of slurry was prepared from cow manure and water from 1:2 ratios (cow manure:water). Prepared cow manure was mixed with 3.33 L of kitchen waste like vegetable waste, bread, fruit waste. All the material was mixed with each other and sample was taken for inlet feedstock. Another sample was taken from outlet slurry.

Calculation of TS, VS and NPK: TS is defined as the sum of organic and non-organic matters in primary feedstock.VS is a part of TS which represents the available organic matters for microorganism. The amount of methane generated in an AD system is directly related to the amount of VS. A clean, dry and pre-weighed watch glass of weight A was taken. A small amount of sample was taken in watch glass. It was dried in hot air oven at 105°C for 4.5 h, cooled in desiccators and weighed. In order to measure VS, ignite a clean watch glass at 550°C for 1 h in a furnace.

Weight of empty watch glass = A
Weight of watch glass + sample = B
Weight of watch glass + sample after drying at 105°C = C
Weight of watch glass + residue after ignition at 550°C=D

$$\text{Total Solid (TS)} = \frac{C - A}{B - A}$$

$$\text{Volatile Solid (VS)} = \frac{C - D}{C - A}$$

Listed method was adopted in order to measure the TS, VS, NPK of feedstock and outlet slurry (**Table 1**).

RESULTS AND DISCUSSION

pH variation: The pH variation of system can be observed from the graph (**Fig. 3**). During 1st 2 weeks pH was low; it was low for a 2 weeks. This was due to feeding of kitchen waste with more acid contain. So addition of cow manure started in system in order to neutralize the pH of system. After addition of cow manure pH value increased to 7. Anaerobic digestion process for

Table 1: Method adopted at lab

Parameters	Test methods
Nitrogen (%)	Modified kzeldahl, FAO, Fertilizer and Plants Nutrition Bulletin No.19
Total Phosphorous as P_2O_5 (%)	Venadomolybdophosphric acid, FAO, Fertilizer and Plants Nutrition Bulletin No.19
Total potassium as K_2O (%)	Flame absorption, AAS, FAO, Fertilizer and Plants Nutrition Bulletin No.19
Total solids (mg/g)	Oven drying, Gravimetric, 2540 C, APHA
Volatile solids (mg/g)	Ignition and Gravimetric, 2540 C, APHA

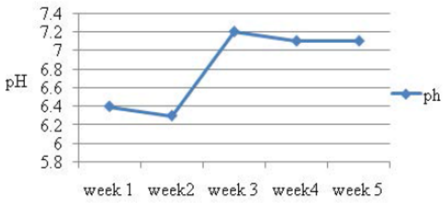

Fig. 3: Variation in pH

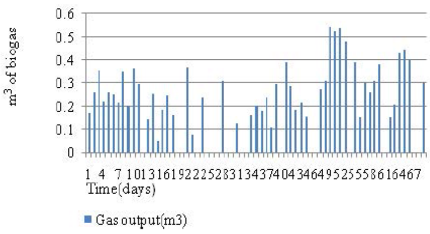

Fig. 4: Gas output from the homebiogas2.0 (HBG2.0)

food waste only fails due to acids accumulation (Lin *et al*., 2011). Addition of press water or food waste to biowaste digester lead to high buffer capacity and Digestion could be carried out at high loadings without pH control (Nayono *et al*., 2010). There is a higher stability of the co-digestion system due to the increased buffer capacity, showing that the addition of cattle manure to food waste could stabilize anaerobic system (Zhang *et al*., 2013). The long-term process stability of co-digestion with cattle slurry and card packaging compared to mono-digestion of food waste (Zhang *et al*., 2012). Co-digestion of food waste with cow manure balances the nutrients in the anaerobic digester and thus provides a more stable environment for anaerobic bacteria (Neves *et al*., 2009).

Gas output: The gas output was taken for 70days.it was started from Friday, December 27, 2019 till Saturday January 18, 2020 (**Fig. 4**). The average gas output per day was 201 L. The average energy produced per day was 1.308 kWh. Semicontinous data was taken from the meter. Gas production varies from 79-543 L/day. Cumulative gas output from the system follow nearly increasing linear relationship with time. The average gas

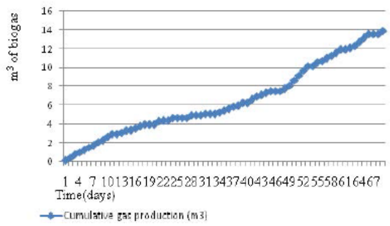

Fig. 5: Cumulative gas output from the homebiogas2.0 (HBG2.0)

output from ARTI Model compact of 1.75 m^3 is 182.78 L/day with average feeding of 2 kg of kitchen waste (Lungkhimba *et al*., 2010).

Gas composition and LPG substitution: Gas flow analyzer (Geotech biogas 5000 portable biogas analyser) was used to measure the composition of gas produced from the system. Percentage of methane content was good with 58.1%, while concentration of H_2S was 40 ppm very low. Concentration of CO_2, CO, NH_3, O_2 was 37.1%, 0, 28 ppm, 11.7% respectively. Homebiogas2.0 can replace 3.064 kg of LPG per month. The average CH_4 gas concentrations for different feed-stocks, food-waste, animal manure and sewage waste was to be around 65, 60 and 70%, respectively and average CO_2 concentrations for different feedstocks, food-waste, animal manure and sewage were estimated to be around 35, 40 and 17.5%, respectively (Selvaraj *et al*., 2017). Biogas produced from kitchen waste and cow manure provide composition consists of 60% CH_4, 18%CO and 22% other gases (Tasnim *et al*., 2017) (**Fig. 5**).

Reduction in TS and VS: One sample of feedstock and another sample of digested slurry were taken. The taken sample was tested in lab. Total solid of inlet feedstock and digested slurry was 44.72 and 12.72 mg/g, respectively. Volatile solid of inlet feedstock and digested slurry was 38.31 and 9.8 mg/g, respectively. There was good degradation rate for the total solid content 71.56% and VS with 74.42%. Biogas produced was 0.419 m^3 of biogas/kg of TS and 0.471 m^3 of biogas/kg of VS. Total solid and volatile solid destroyed was higher for cow manure and food waste when anaerobically digested. Volatile solid was 85.66% of total solid for feedstock. After the feedstock was digested anerobically outlet slurry

Table 2: N, K_2O_5, P2O5 of inlet feedstock and digested slurry

Parameters	Inlet feedstock (%)	Outlet slurry (%)
Nitrogen (N)	0.27	0.19
Potassium (K_2O_5)	0.10	0.09
Phosphorus (P_2O_5)	0.06	0.04

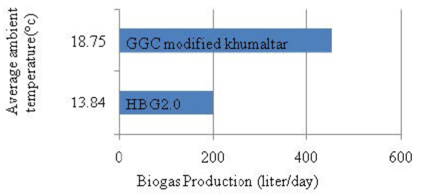

Fig. 6: Gas output from GGC-2047 modified model of 6 m^3 and HBG2.0

had VS 77.044% of TS. Average organic loading rate per day was 0.475 kg VS/m^3. Co-digestion allows higher organic loading rate and gives a more stable anaerobic digestion process (Zhang *et al*., 2012). Organic mixtures of kitchen waste and black water gives output of maximum 0.520 m^3 CH_4/kg VS (Lavagnolo *et al*., 2017). The methane potentials for Fruit and Vegetable Waste (FVW) and Food Waste (FW), which is 0.30, 0.56 m^3 CH_4/kgVS, respectively (Lin *et al*., 2011). The highest methane potential of food waste is in the range of 0.3-1.1 m^3 CH_4/kg VS added, generally higher than other anaerobic digestion substrates such as lignocellulosic biomass, animal manure and sewage sludge (Mao *et al*., 2015). Fruit and vegetable waste like leaves, peels, pomace, skins, rinds, cores, pits, pulp, stems, seeds, twigs and spoiled fruits and vegetables contains 7.4-17.9% TS, VS/TS is 83.4-95.3%, methane yield is 0.16-0.35 $m^3/kgVS_{feed}$ (Labatut *et al*., 2011; Lin *et al*., 2011; Bouallagui *et al*., 2004; Shen *et al*., 2013). Household and restaurant food waste contains 4-41.5% TS, 88.7-95.1% VS/TS and 0.46-0.53 m^3/kg VS_{feed}. (Agyeman and Tao, 2014; Brown and Li, 2013; Meng *et al*., 2015; Zhang *et al*., 2011, 2013; Zhen *et al*., 2016; Wu *et al*., 2015; Han and Shin, 2004; Browne and Murphy, 2013; Carucci *et al*., 2005; Rao and Singh, 2004).

Outlet slurry: There was decrease in value of nitrogen. During anaerobic digestion most of the nitrogen was converted to ammonium, which was readily available for plant growth. Some phosphorus had converted to ortho phosphorus (a soluble form) in the digester. When household waste is anerobically digested, digested slurry has N, K_2O_5 and P_2O_5 are 3.1, 1.7, 3.2% respectively (Voca *et al*., 2005) (**Table 2**).

Comparison of HBG2.0 with GGC modified: GGC model biogas plant of size 6 m^3 was taken which is located in khumaltar, lalitpur Nepal. This plant belongs to Renewable Energy Testing Station (**Fig. 6**). With an average feeding of 40 kg cow dung in GGC Model of 6 m^3, gas output per day was 452 L and average temperatures during testing was 18.75°C (Khanal and Jha, 2014). While in case of homebiogas2.0 it was 201 L with average temperature of 13.84°C. The average feeding in system was 15kg/day which includes both kitchen waste, cow manure.

CONCLUSION

This system is feasible for urban area of Nepal. It can solve the problem of waste, provides manure for rooftop farming and clean cooking gas. After the biodigester was stabilized, if feeding material was kitchen waste like vegetable waste, food waste, pickle used, pH of system goes on decreasing. There have to be added cow manure in order to neutralize the acid produced in the system. The average gas production per day was 0.201 m^3. Total energy in a month was 39.24 kWh. The gas composition was methane 58.1%, carbondioxide 37.1%, oxygen 11.7%, ammonia 28 ppm, carbonmonooxide 0 ppm and hydrogen sulphide 40 ppm. It can replace 3.064 kg of LPG per month or 36.768 kg of LPG per year. TS of feedstock was 44.72 mg/g and outlet slurry was 12.72 mg/g. TS includes the organic as well as inorganic matter in the feedstock. There was good degradation rate in TS with 71.56%. VS of inlet feedstock was 38.31 mg/g and outlet slurry was 9.80 mg/g. There was good degradation rate in VS with 74.42%. Volatile solid was 85.66% of total solid for Feedstock. After the feedstock was digested anerobically outlet slurry has VS 77.044% of TS. The 0.419 m^3 biogas/kg of TS and 0.471 m^3 biogas/kg VS was produced from system. NPK of Feedstock was 0.27, 0.10 and 0.06% and outlet was 0.19, 0.09, 0.04% respectively. Per hour gas production from homebiogas2.0 was 8.375 L.

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APPENDICES I: PLAGIARISM REPORT

Basu_IV

ORIGINALITY REPORT

19%	15%	8%	15%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Seoul National University Student Paper	1%
2	camping-in-thailand.com Internet Source	1%
3	www.aepc.gov.np Internet Source	1%
4	Submitted to J S S University Student Paper	1%
5	hal.inrae.fr Internet Source	<1%
6	mafiadoc.com Internet Source	<1%
7	Submitted to University of Newcastle upon Tyne Student Paper	<1%
8	i-rep.emu.edu.tr:8080 Internet Source	<1%
9	www.chuka.ac.ke Internet Source	<1%

APPENDICES J: PERMISSION LETTER

HOMEBIOGAS

RIDDHI SIDDHI OVERSEAS (PVT) LTD.

(Exclusive Representation of HomeBiogas In Nepal) Pan No: 302598966

Date: 8/10/2020

To,

Department of Mechanical & Aerospace Engineering,

Pulchowk Campus, Lalitpur, Nepal

Subject: Permission Allowed.

Dear Sir/Madam,

We would like to inform you that we have given permission to use data of user's manual (owner's manual) and the data related to the AEPC system located at Khumaltar, Lalitpur Nepal (HBG 2.0 system) to Mr. Bashu Gautam for his thesis study of Master of Science in Renewable Energy Engineering at Pulchowk Campus, Lalitpur and also this permission is granted for academic (study) purpose only. All the best for his future study.

Thank you!

Regards,

Salina KC

Kathmandu, Nepal

Dillibazar, Kathmandu, Nepal
Phone: 01 - 4422162, 4418435