FLOW ANALYSIS OF BIOGAS IN A BURNER FOR DOMESTIC APPLICATION

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***Abstract*—**

Matured biogas production technology has led to the development of a number of biogas appliances for lighting, power generation, and cooking. The most promising among them is the biogas stove, to meet the energy requirement for cooking application at domestic as well as at the community level. Biogas, being based on a renewable fuel and it is a gas which is used as a fuel in biogas stove. For the modelling of biogas stove , its flow analysis in the burner is analysed by ANSYS simulation and biogas stove is to be fabricated. For the flow analysis various parameters are analysed such as velocity, pressure, flame temperature.

***Index Terms*—Biogas stove, Flow analysis, Burner, Cooking**

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1. Introduction

In recent years the interest in bio fuels has been increasing, motivated on the one hand by the need for reducing greenhouse gas emissions and on the other hand by the desire to improve energy security by reducing our dependence on imported fossil fuels. Biomass energy is more and more attention world wide because it is a potentially carbon di oxide neutral and renewable energy source[1].

Conditions that must be satisfied in burner tests in order to preserve comparable operating conditions as in the real application are stressed. Last part provides an outline of the utilisation of statistical analysis methods and modelling by computational fluid dynamics (CFDs) including the formation
of pollutants. One of the most important factors influencing burner design is the fuel properties. Choice of fuel depends on specific demands of the technology, as well as on availability, legislative restrictions and economic assessment. Due to announced legislative restrictions, it is necessary to include the possibility of future payment for the greenhouse gas carbon dioxide in economic calculations.

One of the most widespread types of burners is gas burners. This is caused mainly by their availability and by the relatively favourable price of natural gas, investment costs and maintenance of the combustion units, compared to other fuels. Availability of natural gas is supported by a long-term systematic activity in the construction of gas lines. Other gaseous fuels used in the industry are mixtures of various combustible and incombustible gases (hydrogen, methane, propane, nitrogen, carbon monoxide and dioxide, etc.). Such fuels are generally available only locally as by-products of chemical processes, e.g. mining gas in former mining areas. It may be concluded that gaseous fuels are also favoured, thanks to their low emissions, low investment and maintenance costs, when compared to liquid and solid fuels.

There are different classifications of burners with regard to certain important features as for example the type of fuel, the way combustion air is supplied to the burner and the position of the burner within the combustion chamber . Among these factors, the most fundamental are the type of fuel and the air supply system. Each of the basic burner classes may be further structured, e.g. according to the number of fuel or air stages, possibility to fire various fuels, velocity of reactants ejected from the burner etc[2].

1.1 Biogas

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Organic wastes such as dead plant and animal material, animal dung and kitchen waste can be converted into a gaseous fuel called biogas .Biogas originates from biogenic material and it is a type of bio fuel.

Characteristics

Biogas is a clean fuel – non toxic in nature, odourless and smokeless. Chemically it contains 55-70 per cent methane 35-40 per cent carbon dioxide and less than 5 per cent of other gases, such as ammonia, hydrogen, carbon monoxide, nitrogen, etc. On complete combustion of biogas, the amount of energy released is about 20-24 MJ/m3. Biogas, which is produced from cattle dung, pig manure and other organic wastes in a specially designed anaerobic digester, commonly called as 'biogas plant', is a methane-rich fuel. Since biogas contains primarily methane and carbon dioxide, their physical and chemical properties and quantities will determine over all properties of biogas and in turn the choice of combustion device. Biogas produced in individual households can be used for cooking and/or lighting purposes. It burns as soot-less blue flame. Characteristics of biogas important from the viewpoint of designing an efficient stove.

Biogas stove designing parameters which is achieved for high efficiency,the important factors to be considered as

- Gas composition
- Gas pressure
- Flame speed(velocity)
- Pan to burner distance

In general the stove should meet the criteria mentioned below:

- Gas inlet pipe should be smooth to minimize the resistance to flow of gas and air.
- Size and Shape of the burner.

Table 1 Typical details of biogas

Composition	55-70%Methane,30-45 % carbondioxide,traces of other gases
Energy content	6.0-6.5 kW m^{-3}
Fuel equivalent	0.6-0.65L oil/ m^3
Explosion limits	6-12% biogas in air
Ignition temperature	650-750°C
Critical pressure	75-89 bar
Critical Temperature	-82.5°C
Normal Density	1.2 kg m^{-3}
Odour	Bad Eggs(the smell of hydrogen sulphide)

- Spacing and size of air holes should match with the requirement of gas combustion.
- Volume of burner manifold should be large enough to allow complte mixing of gas with air.
- Size,shape and number of burner port holes should allow easy passage of the gas-air mixture,forming of stabilised flame and complete combustion of gas,without causing

lifting up of flame,off the burner port or flash from burner portto as mixing tube and injector jet.The flame should be self stabilizing i,e., flameless zones must reignite automatically within 2 to 3 seconds.

Table 2 Properties of biogas relevant to design a stove

1.2 Biogas Stove

Biogas stove is a relatively simple appliance for direct combustion of biogas. Its burner is a premix and multi-holed burning ports type and operates at atmospheric low pressure. A typical biogas stove consists of gas supply tube, gas tap/valve, gas injector jet, primary air opening(s) or regulator, throat, gas mixing tube/manifold, burner head, burner ports (orifices), pot supports and body frame. Biogas reaches with certain speed at the stove, depending on inlet gas pressure and diameter of gas supply pipe. With the help of an injector jet at the inlet of the stove, the gas speed is increased to produce a draft to suck primary air. The gas and air get mixed in the mixing tube and the diffused gas mixture goes into the burner head. The cone of the diffuse and the shape of the burner head are formed in such a way as to allow the gas pressure to equal everywhere before the mixture of gas and air leaves the burner through the ports with a speed only slightly above the specific flame speed of biogas. For the complete combustion of biogas, more oxygen is drawn from the surrounding air, called secondary air.

1.3 Heat recirculating domestic gas burner

Existing designs of most conventional domestic burners (CB) have typically relied on open combustion flame, where a large amount of energy loss with the flue gas arises, resulting in relatively low thermal efficiency (<30%). Against this background, a novel semi-confined porous radiant recirculated burner (PRRB) concept based on heat-recirculating combustion using the porous medium technology was developed for energy savings in domestic use and in the small-scale food processing industry. Performance of the new burner using the same ring burners as those in the CB, i.e. the PRRB(CB) were evaluated by comparing thermal efficiencies and the combustion characteristics with those of the conventional one (CB). Operating parameters such as heat input, flow type of the ring burners (conventional radial flow (CB) or swirling central flow (SB)) were clarified. PRRB(CB) is very effective in establishing a heat-recirculation mechanism from the hot exhaust gas to the combustion air, resulting in efficient combustion air preheating with maximum combustion air temperature of 300 _C. Thermal efficiency of the proposed PRRB(CB) is increased to about 12% higher than that of the conventional one (CB). Further improvement in thermal efficiency of the burner can be realized by combining the PRRB with the swirling central flame ring burner (SB), i.e. the PRRB(SB), yielding a maximum thermal efficiency of about 60% and, thus, energy saving of about 50% in average over the operating range[3].

Most conventional domestic burners have typically relied on an open combustion flame, which loses a large amount of energy through the flue gas, leading to relatively low thermal efficiency[5]. Most natural flames are diffusion flames. However, most arranged flames are premixed. Premixed flames are affected
by pressure and initial temperature significantly. This is because chemistry plays a strong role in their combustion scheme. The final temperature they attain on combustion depends on equivalence ratio. The flame speed depends on the equivalence ratio, pressure and initial temperature. In the present work, a producer gas fired premixed burner is tested and optimized.

Premixed burners are those in which fuel and oxidizer are mixed before the combustion zone. Premixing has less pollutants and combustion can be expected to be better completed as elements are available in immediate vicinity. Flame stabilization could be achieved by many mechanisms
such as formation of local low-velocity regions by solid objects (bluff body) and hydrodynamics (counter flows) or by generation of local high-temperature regions using pilot flames and ignitors. The optimal performance with respect to uniform and stable flame is achieved with conventional bluff body having blockage ratio of 0.65.The blockage ratio above 0.8 is not desirable for producer gas fired premixed burner as it gives rise to condition of flash back. The maximum flame temperature is achieved when the bluff body is kept near burner tip.The study reveals that the maximum temperature is at the center of flame and the temperature thereafter gradually reduces in radially outward direction[6].

Property	Value
Methane and Carbondioxide content	60% and 40% (v/v)
Calorific value	22 MJ/m^3
Specific gravity	0.940
Flame speed factor	11.1
Air requirement for combustion	5.7 m^3 / m^3
Combustion air	4. cm/sec
Inflammability air	6-25%

2. Project Description

2.1. Burner

A burner is a mechanical device that supplies required a0mount of fuel and air creates condition for rapid mixing of fuel and air produces a flame which transfers thermal energy to furnace and charge . In liquid fuel burner, oil is heated and atomised either mechanically or by high speed gaseous jet.In mechanical methods oil is atomised by means of a rotating disc or cup or by swirler. A gaseous fuel burner could either be of premixed type or diffusion type. In a pre-mixed type gas and air are mixed prior to passing through the nozzle. In diffusion type fuel and some amount of air is mixed and the mixture is passed through the burner. Rest air for combustion is supplied in the furnace chamber. Combustion of fuel is controlled by the rate of mixing of air and fuel. In these burners small portion of air is mixed with fuel as primary air and the rest amount, known as secondary air is supplied in the furnace. Industrial burners for gaseous fuel are diffusive type.

Mixture of air and gaseous fuel

In diffusion burner air and gaseous fuel are supplied separately in the furnace. In modt combustion systems mass of air is at least 8 to9 times than fuel. When air and fuel pass through the burner, the momentum flux of air is several times greater than fuel. Some fraction of total air is mixed with the fuel and this air is known as primary air. Rest amount of air, known as secondary air is supplied in the furnace through appropriate locations. Mixing and combustion take place simultaneously.

When a mixture of air and gaseous fuel passes through the burner, a free jet is produced downstream the burner. If the air fuel mixture is discharged in the furnace then a confined jet is produced because of the furnace walls. The difference between the free jet and confined jet is that in the former the amount of surrounding is unlimited whereas in the later the amount is limited. Mixing of secondary air in the jet is important for complete and efficient combustion. In the absence of mixing the chances of formation can not be ruled out.

2.2. Modified System

The proposed system which is design analysis of burner which is used for gaseous fuel is flow.For designing of burner Flow analysis is to be analysed by using ANSYS flotran CFD.According to this Modelling and meshing process undergone.From this Temperature distribution,velocity distribution,pressure distribution is obtained.

2.3. Methodology

The following methods occurred from the project right up to the finish:

(1) Analyzing using ANSYS 13.
(2) Burner is designed.
(3) Fabrication of biogas stove.

2.4. Design equation of burner

The force which drives the gas and air into the burner is the pressure of gas in the pipeline. The key equation that relates gas pressure to flow is Bernoulli's theorem (assuming incompressible flow)

$P/\rho + v^2/2g + z = \text{constant}$

where

p is the gas pressure (N/m^2),
r is the gas density (kg/m^{-3}),
v is the gas velocity (m/ s),
g is the acceleration due to gravity (9.81 m/s^2) and
z is head (m).
For a gas, head (*z*) can be ignored.

Injector orifice or jet:

The gas flow rate (*Q*) is related to the gas velocity (*v*) by the area(*A*) of the pipe through it is flowing:

$Q = v A$

where

Q is flow rate ($m^3 h^{-1}$)

V is gas velocity(m s^{-1})
A is area(mm^2)
For gas flow through an orifice, the area of the hole is not necessarily the area of the flow. A sudden change in flow area causes a "vena contracta",
a narrowing of the flow to an area smaller than that of the hole itself:

Gas flow through an injector orifice (jet)

$Q = 0.0467\ Cd\ A_0$

where
Q is gas flow rate ($m^3\ h^{-1}$),
A0 is area of orifice (mm^2)
p is gas pressure before orifice (mbar)
s is specific gravity of gas
Cd is coefficient of discharge for the orifice.
The coefficient of discharge for the orifice takes into account the vena contractor and friction losses through the orifice. It usually has value between 0.85and 0.95.

2.5 FORMULAE:

- $Q = v\ A$
- $Q = 0.0467C_d\ \sqrt{P/S}$
- $d_0=\sqrt{(Q/0.036C_d)^4}\ \sqrt{S/P}$
- $V_0=Q/3.6*10^{-3}\ A_0$
- $V_t=V_0*A_0/A_t=Vo*d_0{}^2/d_t{}^2$
- $P_t=P_0-\rho\ V_0{}^2/2g[1-(d_0/d_t)^4]$
- Entrainment ratio $r=\sqrt{S}(\sqrt{(A_t/A_0)}-1)$

2.6 Typical calculation:

Using a suitable injector with a Cd of 0.9,

1. **The injector size is**:

$d_0=\sqrt{Q/0.036C_d{}^4}\sqrt{S/P}$
$=\sqrt{0.471/0.036*0.9^4}\sqrt{0.94/10}$
$=2.1mm$

2. **The velocity of the gas orifice is**

$V0=Q/3.6*10^{-3}\ A_0$
$=37.8m/s$

3. If the stochiometric air requirement is 5.5, then **the entrainment ratio r** should be

$r= 5.5/2 = 2.75.$

4. **Using Prigg's formula**:

$dt = (r/\sqrt{s}+1)d_0$
$=(2.75/\sqrt{0.94}+1)*2.1$
$=8.1mm$

5.**Gas pressure in the throat**:

$P_t=P_0-\rho V_0{}^2/2g[1-(d_0/d_t)^4]$
$P_t=10^5-1.0994(37.82/(2*9.81)[1-(2.1/14)^4]$

$=10^5$-80pa

6. **Mixture flow rate at optimum aeration**:

Q_m=Q(1+r)/3600

=0.471(1+2.75)/3600

=4.91*10^{-4} m^3/s

7. **Flow Rate**:

$Q = 0.0467C_d \sqrt{P/S}$

=0.0467*0.9* √10/0.94

=0.1370 m^3 h^{-1}

8. **Throat size** :

The flow rate of the mixture in the throat (Qm) is then given by:

Q_m =Q(1+r)/(3600)

with Q_m in m^3/s and Q in m^3 h^{-1}.

9. The pressure drop due to the flow of the mixture down the mixing tube should be checked, by first calculating the **Reynolds number**:

$Re= \rho\, d_t V_t / \mu = \rho\, d_t / \mu * 4\, Q_m / \pi\, d_t^{\,2}$

$= 4\, \rho/ \pi\, \mu * Q_m/ d_t$

10. **The pressure drop (Δp)** is then given by:

Δp = $(f/2)\rho\, V_t^{2}\,(L_m / d_t) = (f/2)\rho(16Q_m^{2} / \pi^2 d_t^{5})\, L_m$

Where f=64/Re, when Re< 2000 and f=(0.316/ $Re^{(1/4)}$ when Re>2000

11. The pressure drop in the mixing tube which should be atleast 140mm long (10 *d_t) can be calculated:

$Re= \rho\, d_t V_t / \mu = \rho\, d_t / \mu * 4\, Q_m / \pi\, d_t^{\,2}$

$= 4\, \rho/ \pi\, \mu * Q_m/ d_t$

Re=(4* 1.15*4.91*10^{-4}) / 3.14*1.71*10^{-5}*0.014

=3003

Re >2000, so f=(0.316/ $Re^{(1/4)}$

F=(0.316) /(3003 $^{(1/4)}$ =0.0427

Δp= $(f/2)\rho(16Q_m^{2} / \pi^2 d_t^{5})\, L_m$

=0.0427*1.15*[(8*(0.000491)^2 / (π^2 *0.014^5)]*0.14

=2.5 Pa

This is much lower than the driving pressure in the throat (80 pa)

12.**Diameter of mixing pipe** d=6 d0

D=6*1.6 ;

D=9.6

13. **Length of air intake holes**

L max=7d

= 7*9.6

=67.2

L min =1.35*d

=1.35*9.6

=12.96

14. **Mixing chamber diameter**

$D=1.30d$

$=1.30*9.6$

$=12.48cm$

15. **Length of mixing chamber**

$L=1.50d$

$=1.50*9.6$

$=14$ cm

16. **The total burner port area** can be chosen:

$A_p > Q_m /(0.25) > 0.00196\ m^2$,say $0.02\ m^2$

Using 5 mm diameter holes,the total number required will be:

$N_p = (4 A_p)/(\pi d_p^2)= 4*0.002/(\pi *0.005^2)=102$

Using flame stabilisation,it should be possible to reduce this number of burner ports ,by upto 1/5,so 20 holes may be sufficient.Diameter of mixing pipe d=6 d0

3.Biogas Combustion:

Biogas burns in oxygen to give carbon dioxide and water:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

- One volume of methane requires two volumes of oxygen, to give one volume of carbon dioxide and two volumes of steam.
- Since there is 58% methane in biogas and 21% oxygen in air:
- 1/0.58=1.72 Volumes of biogas require 2/0.21=9.52 volumes of air or
- 1 volume of biogas requires 9.52/1.72=5.53 volumes of air or
- 1/(1+5.53)=0.153=15.3% biogas in air (stochiometric air requirement).

4.Flow Analysis Of biogas in a burner

The modeling of the flow analysis is made using the designed values of length, diameter, pressure and velocity obtained from above calculations. From these values used to provide the flow analysis of biogas burner. Using the properties as biogas.

For modeling is created by using keypointswith dimensions from calculation. Meshing the areas as created and loads are defined. velocity value as 20m/s. Pressure at wall is zero.

4. Analysis Results and Discussion

The flow analysis of biogas stove were analyzed using the ANSYS 12. This chapter explains analysis conducted followed by the results obtained.

1. Temperature distribution

2. Pressure distribution
3. Velocity distribution

4.1 Contour solution for Temperature

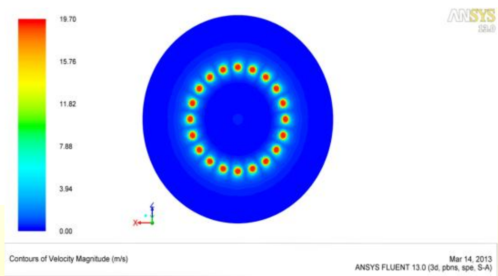

Fig 4.1 Temperature distribution

4.2 Contour solution for pressure

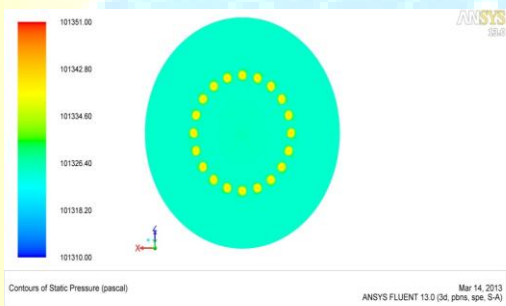

Fig 4.2 Pressure distribution

4.3 Contour Solution for Velocity

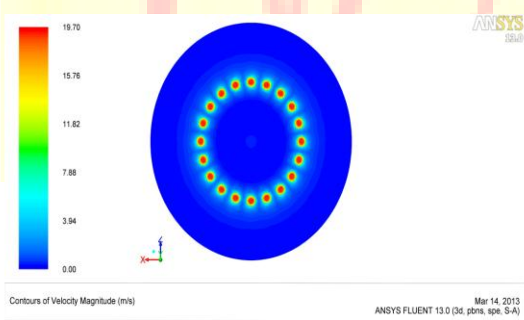

Fig 4.3 Velocity distribution

5. Fabrication of Stove

Gas burner components are usually made of cast metal, as they must take high temperatures, be very robust and withstand corrosion. Many parts can be made from aluminium, except for those parts which might reach temperatures above its softening point (600°C). Cast iron is used for parts that reach higher temperatures, as it is fairly resistant to corrosion. However, it is brittle and can shatter if dropped onto a hard surface. Mild steel can take high temperatures, is not brittle, is easily welded and is very strong, so can be used for many components. However steel is susceptible to corrosion, so must be coated with a corrosion inhibitor that can withstand the temperature in which the steel is being used. There are aluminium based paints that are designed for high temperature use, as well as vitreous enamels that are baked onto the metal surface. Gas burner parts can also be made from ceramics, which are much cheaper than metals, easy to mould and can be baked in a furnace to give a hard material that can withstand high temperatures and is not susceptible to corrosion. The main disadvantage is that they are brittle and can shatter if dropped on a hard surface. Biogas burners have been made almost entirely from ceramic, apart from the orifice and injector tube.

6. Conclusion

This project will provide cheap energy resource to backward people in villages and will help the government to deal with energy crises This will lead to sustainable development. Moreover, the project will also contribute for the reduction of explosion risks in the case of occurrence of high gas concentrations in landfill interior.The production of energy from wastes generates great opportunities for the landfill construction and operation market that starts to have a net recipe.So, the landfill operator will have financial resources for applying in pollution control equipment and initiatives, reducing landfill environment impact. This project will illustrates cooking and biogas consumption rates for boiling water and cooking rice compared to results obtained from other countries and sources. The cooking rate for water and rice was lower for this stove than the values obtained from India and the other sources. This resulted in higher biogas consumption rates for this stove when compared to the values obtained from India and the other sources. This also played a major role in the biogas consumption rate as it determined the duration of the cooked material on the stove.

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References

[1]N.L.Panwar,B.L.Salvi,V.SivaReddy,"Performance evaluation of producer gas burner for industrial Application",Biomass and Bio energy,vol 35,pp. 1373-1371,2011.

[2] V.Kermes, Petr Belohradsky,Jaroslav Oral, Petr Stehli, “Testing of gas and liquid fuel burners for power and process industries”,Energy,vol 33,pp.1551-1561,2008.
[3] Sumrerng jugjai,Natthawut Rungsimuntuchart, “High Efficiency heat re-circulating domestic gas burners”,Experimental thermal and Fluid Science,vol 26,pp. 581-592,2002.
[4]P.R.Bhoi,S,A.Channiwala, “Emission characteristics and axial flame temperature distribution of producer gas fired premixed burner”,Biomass and Bioenergy ,vol 33,pp.469-477,2009.
[5] Shuhn-Shyurng Hou,Chien-Ying Lee,Ta-Hui Lin, “Efficiency and Emissions of a new domestic gas burner with a swirling flame”,Energy Conversion and Management,vol 48,pp.1401-1410,2007.
[6] P.R.Bhoi,S.A.Channiwala, “Optimization of producer gas fired premixed burner”,Renewable enegy,vol 33,pp.1209-1219,2008.
[7]Golam ,M.M Hussain,□ improved cook stoveand bio gas programs in Bangladesh” ,Sustainable development
[8]. Hari katuwal,Alok.et.al, “Biogas: A promising renewable technology and its impact on rural households in Nepal”, Renewable and Sustainable Energy Reviews ,vol. 13, pp. 2668-2674,2009.
[9]. Heinimo et.al,J.,”Production and trading of biomass for energy – An overview of the global status”, bio mass and bio energy,vol. 33,pp.1310-1320,2006.
[10].Hui Feng.et.al,”The Resource Utilization of Anaerobic Fermentation Residue”, Procedia envi.Sci.,vol. 11,pp 1092-1099,2011.
[11]. Itodo I N and Agro G E , “Performance analysis of bio gas stove for cooking in Nigeria”journal of energy in south Africa,vol.18.pp.14-18,2007.
[11].Natarajana,R.,Karthikeyana N.S., Avinash Agarwaala,Sathiyanarayananb,K. ”Use of vegetable oil as fuel to improve the efficiency of cooking stove”,Renewable Energy,vol. 33,pp.2423–2427,2008.
[12].Panwar N.C, “ Design and performance evaluation of 5KW producer gas stove”,Bio mass and bio energy,vol 32.pp.1349-1352,2008.
[13].ZHOU Xiao zhu, OU She liang,” Problems and Solutions Based on Comprehensive Utilization of Biogas”,Energy Procedia,vol. 5,pp. 42-47,2011.
[13].Anil k.Rajvanshi .et.al, “Low concentration of Ethanol stove for cooking in rural areas in india”,Ene.for.Sus..Development,vol.11, pp 94-99, 2007.
[14].Golam ,M.M Hussain, “improved cook stove and bio gas programs in Bangladesh” ,Sustainable development, vol 14, pp 1341-1352, 2009
[15].Hui Feng.et.al, “The Resource Utilization of Anaerobic Fermentation Residue”, Procedia envi.Sci., vol. 11,pp 1092-1099, 2011.
[16].Itodo I N and Agro G E , “Performance analysis of bio gas stove for cooking in Nigeria”journal of energy in south Africa, vol.18.pp.14-18, 2007.
[17].Omar mossera,Hilda Zamora ,“ Adaption and sustainable use of improved cookstoves”,Energy policy , Vol .39. pp.7557-7566, 2011.
[18].B. V. Dasgupta, M. K. Mondal, “Bio Energy Conversion of Organic Fraction of Varanasi’s Municipal Solid Waste”, Energy Procedia ,vol 14 ,pp 1931 – 1938,2012
[19].Hari Katuwal , Alok K. Bohara, “Biogas: A promising renewable technology and its impact on rural households in Nepal”, Renewable and Sustainable Energy Reviews,vol 13,pp 2668–2674,2009

[20].Rajeeb Gautama, Sumit Baralb, Sunil Herat, “Biogas as a sustainable energy source in Nepal: Present status and future challenges”, Renewable and Sustainable Energy Reviews ,vol 13 ,pp 248–252,2009

[21].Nathan Curry , Pragasen Pillay, “Biogas prediction and design of a food waste to energy system for the urban Environment”, Renewable Energy ,vol 41,pp 200-209,2012

[22].Hui Feng,Guang-fei Qu,Ping Ning,Xiang-feng Xiong, Li-juan Jia, Yu-kunShi,Jun Zhang, “ The Resource Utilization of Anaerobic Fermentation Residue”, Procedia Environmental Sciences ,vol 11,pp 1092 – 1099,2011

[23].Ewa Klimiuk,Tomasz Pokoj,Wojciech Budzyn ski,Bogdan Dubis, “ Theoretical and observed biogas production from plant biomass of different fibre contents”, Bioresource Technology ,vol 101 ,pp 9527–9535,2010

[24].Wen-Chien Kuo, Wen-Lung Lai, “Treatment of kitchen waste using a mobile thermophilic anaerobic digestion system”, Renewable Energy ,vol 35,pp 2335-2339,2010

[25].Beatriz Molinuevo-Salces, Cristina Gonzalez-Fernandez, Xiomar Gomez,Maria Cruz Garcia-Gonzalez, Antonio Moran, “ Vegetable processing wastes addition to improve swine manure anaerobic digestion: Evaluation in terms of methane yield and SEM characterization”, Applied Energy ,vol 91,pp36–42,2012.