A Review on Advancements in Biogas Technologies

Thokchom Subhaschandra Singh*
M.E Thermal Engineering,
J.J College of Engineering and Technology,
Tiruchirapalli, Tamilnadu, India

P. Sankarlal
Assistant Professor, Dept. of Mechanical Engineering.
J.J College of Engineering and Technology,
Tiruchirapalli, Tamilnadu, India

***Abstract*— The aim of this paper is to bring out the various methodologies applied in generating biogas and technologies used in improving the quality. Various feed materials are used as a biomass, ranging from MSW to kitchen waste is provided in detail. The usage of AD reduces the GWP considerably. 100% reduction in green house gases may be possible by using biogas in incineration process. 95% methane content is made possible and the efficiency comes close to natural gas fueled systems, hence Biogas up-gradation methods are highlighted. Usage of sludge as a natural fertilizer had an added advantage of reduction in Abiotic Depletion Potentials. Lower NO_x and SO_x are found in biogas fuelled engines. In the duel fuel mode, it gave 26% (biogas+ diesel) efficiency close to that of diesel. Less modification is required for S.I engine to utilize biogas fuel, hence suitable for I.C engines. The applicability of Biogas as fuel from rural to urban areas with the availability of biomass, demonstrates the possibility of the nation to improve its economy and generate employment for the mass.**

Keywords—Biogas, Anaerobic Digestion(AD), Gas upgrade, CHP.

I. INTRODUCTION

Biogas is an important renewable source of energy, which is generated by the action of *methanogenesis* bacteria on organic matter. It is produced by the decomposition of organic matter in anaerobic, damped and oxygen depressed environments. The constituents of biogas include Methane, as the main component and other gases such as carbon-dioxide, H_2S, water vapor, NO, SO etc. It has been stated that biogas is one of the most leading source of clean renewable energy which can replace fossil fuels, hence reducing the environment problems affected by the non-renewable sources [1]. The basic composition of biogas is given herewith. MSW have been reported to have a huge potential for biogas generation throughout the states of India [2, 34]. Even though, a biogas may be a clean fuel, an upgraded biogas proves to be better than the untreated one. Upgrading includes various processes and one such important is the reforming of biogas into Syngas [3]. Other known sources of biogas up-gradation include CO_2 capture and storage, as given by Renato B et al [6].

Anaerobic Digester or simply AD is the controlled degradation of biodegradable wastes in the absence of oxygen and presence of different groups of bacteria which catalyze a series of complex microbial actions. Main important aspects of using biogas, produced through AD's include- depletion of GWP, continuous energy production without dependence on external sources, reduced the dependency of artificial fertilizers as the by-product of AD's produce natural and eco friendly fertilizers. This has been agreed by various researchers over time. The bacterium grows and acts on the organic matter effectively under mesophillic conditions and thermophillic conditions. This has been illustrated by M.H Geradi et al.[5]

The paper provides insight knowledge in biogas production, utilization and end usage technologies. Findings from various researchers upon feed material of AD's, expertise in gas production tools and methodologies in application of the gas in various Combined Heat and Power (CHP) process have been illustrated.

Table. 1 Composition of Biogas

Compound	Molecular formula	% Content
Methane	CH_4	50–75
Carbon dioxide	CO_2	25–50
Nitrogen	N_2	0–10
Hydrogen	H_2	0–1
Hydrogen sulphide	H_2S	0–3
Oxygen	O_2	0–0

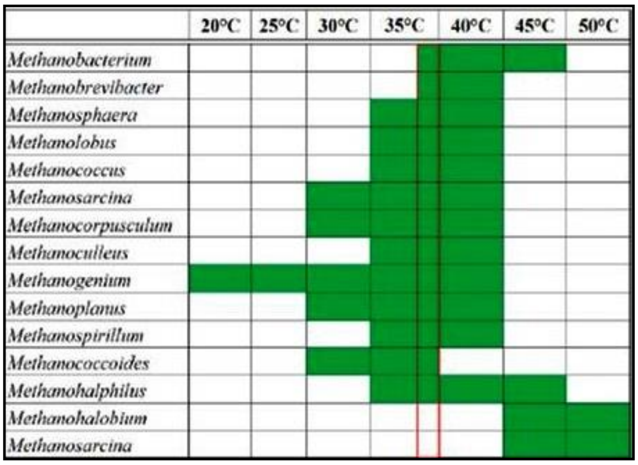


Fig.1. Temperature range for optimal growth of bacteria [5]

II. FEED MATERIALS OF AD'S

Cow dung, pig dung, fresh rumen and water were utilized as feed material for biogas production by Aremo M.O et al. They have performed the experiment under mesophilic conditions with temperature ranging from 27-35 °C. The pH value for the whole experiment from feeding of materials to the end of the gas production varies from 6.2-6.8. Plastic bio-digesters were utilized. They have concluded that cow dung and pig dung were a good energy source, which can later be purified and stored [7].

Poultry droppings with corn hub and waste paper as co-substrate, under temperature range of 29-34 °C, with pH ranging from 4.2-8.0, was found to be suitable for good production of biogas. All the substrate, except the poultry droppings were pretreated as they are lingo-cellulosic materials, physical treatment by milling to reduce particle size and thermal hydrolysis were employed. The AD's with treated co-substrates proved to yield better results than the ones untreated. [8]

Chompoonut A et al. [9] have reported to have used inoculums seeds and waste water from various agro industrial wastewaters, based on carbohydrate, protein and lipid manufacturers, including a concentrated rubber factory, Cassava starch factory, Palm oil mill factory, Swine farm and Soymilk processing factory. Most of the waste water was found to be acidic nature while swine manure is neutral. Methane production is found to be highest with combinations including-Rubber seeds with Cassava wastewater, Cassava starch seeds with Soy milk wastewater, Palm oil seeds with Soy milk wastewater, Swine seed with Palm oil wastewater and Soy milk seeds with Palm oil wastewater.

The possibility of mixing water-hyacinth with sheep waste in different combinations for anaerobic co-digestion, for biogas generation and digested sludge as an important agricultural product has been illustrated by Jagadish H. P et al. [10] Pretreatment of water-hyacinth was performed by alkali method. Mesophilic conditions were followed with 8% total solids, retention time of 60 days and pH of 6.7 and 6.4 for sheep waste and water-hyacinth. The fermentation slurry (Mixing ratio- 4:12.01:83.90 for Water-hyacinth: Sheep waste: Water) was found to be optimum with maximum biogas yield with composition of 60.81% CH_4, 21.53% CO_2 and 17.63% (H_2, N_2, H_2O, H_2S etc.)

Anaerobic co-digestion of canned seafood wastewater with glycerol waste (GW) and *wolffia arrhiza*(WA) was performed in Up-flow Anaerobic Sludge Blanket reactor (UASB). It has been found that by using GW and WA as co-substrate, a good biogas with methane content of 62.3% can be obtained [11].

Rafiq Kumar M et al.[12] have suggested in using of Weed Ipomoea in extraction of volatile fatty acids(VFA), comprising mainly of acetic acid and lesser quantities of propionic ad butyric acids. They are feed with *methanogens* under anaerobic conditions to produce biogas. The extraction of VFA was achieved by the usage of acid phase reactors and charging the leaves along with water inoculated with cow dung. The reactors are stirred intermittently and a conversion of 10% of biomass into VFA is observed.

Wild and Cultivated varieties of reed canary grass for biogas production and comparing the efficiencies of gas production of the two varieties have been suggested by Marta O et al[13]. The plant material were analyzed by Fourier Transform Infrared Spectroscopy (FTIR), which have shown that the wild variety have higher lignin content than the cultivated one as evident by absorbance values of 0.0071 and 0.0062 a.u respectively at wave frequency of 1512 cm^{-1} to 898 cm^{-1}.The biogas yield was found to be higher in cultivated variety than the wild one, which led to the conclusion by the authors that high dry matter content and indigestible fraction of crude fiber have significant reducing effect on biogas quality and quantity.

Biogas production from food waste have been evaluated by Ojikutu A.O et al.[14] which include yam peels, plantain peels, orange rind and fish waste. The experiment was conducted under a temperature range of 30-37 °C and total solid concentrations of 8%. The mixture and individual waste digesters were studied and it has been found that the highest biogas yield was from the digester containing the mixture and the least from the fish waste alone.

Ravi P.A et al[15] have recommended the usage of kitchen waste as the best alternative for biogas production in a community level biogas plant. Different ratios of kitchen waste with water and manure were compared in a metal made portable floating type biogas plant. It has been suggested that aluminum metal is more efficient as it increases the temperature inside the digester, which in-turn increase the biogas production rate. High production of gas has been observed at ratio of 1:2 of waste and water.

Biogas from Waste Activated Sludge (WAS) using cattle inoculums was investigated by Maamri S et al[16]. Thermophilic conditions with temperature of 55 °C and retention period of 15 days have been applied. The authors found out that with increase in TS concentration, biogas production potential and gas production rate have been increased. This may be due to rich contents of Hydrogen, Nitrogen, Phosphorous, Calcium, Magnesium and a number of trace elements which are essential for anaerobic growth.

Brewery wastes (BW) and Cattle dung (CD) have been reportedly used for biogas production, with mixing ratio of 30:70 of BW and CD as optimum ratio [17]. At maximum organic loading rate, of 3.3kgVS/m^3.day in semi continuous mode, there was no clogging of the reactor. The stability of the process has been justified by the gradual reduction of the VFA reduction.

Pennisetum pururem cv. Pakchong 1 grass and layer chicken manure have been used in completely stirred tank, for biogas production [18]. The experiment was carried out to check the effect of carbon to nitrogen (C/N) ratio and organic loading rate (OLR). The authors, through preliminary investigation have found out that grass and manure ratio of 50:50 and 70:30 by weight yield C/N ratio of 20 and 30 respectively. The average pH value was found to be 6.80 to 7.20. The average alkalinity of effluent was higher than 3000 mg/L. the VFA concentrations are found to be low throughout the experiment and the highest methane yield was found in C/N ratio of 20.

III. GAS PRODUCTION TECHNOLOGIES

Dasgupta B.V et al [19]. conducted an experiment to convert the organic fraction of Varanasi's Municipal Solid waste into biogas. They have preferred anaerobic digestion since the organic fraction have very good moisture content of about 85% and C/N ratio ranging from 25 to 30. Sodium hydroxide is added to the substrate in the hydrolysis phase. The fraction of municipal waste used for this process includes vegetables, fruits, food waste, paper, grass, leaves and biodegradable textile fibers like wool, silk, cotton etc. and shredded to reduce particle size. Nitrogen gas is subjected into the anaerobic digester to maintain inert atmosphere, and the experiment was carried out in room temperature.

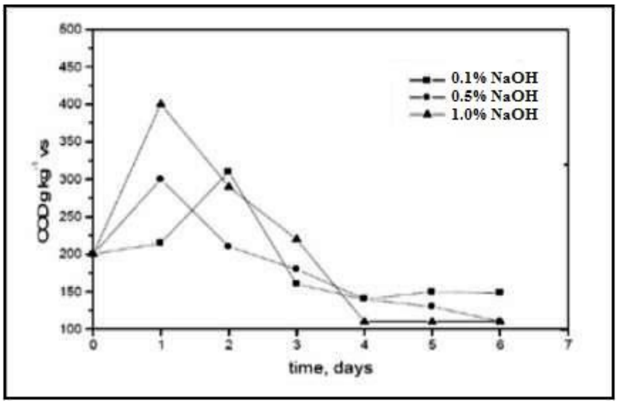


Fig.2. Variation of COD with different concentrations of NaOH in hydrolysis[19].

The Chemical Oxygen Demand (COD) value increased initially and decreases, which result in 30% COD solubilization in 0.1 NaOH solution. Correspondingly, high values of COD in 0.5% and 1% of NaOH were observed at the 1st day, and decreased, giving constant value of 60% and 70% respectively.

The effect of NaOH on pH of the samples are evaluated and reported to be 5.97 after the alkali addition, rose to 8.7, 10.4 and 12 respectively for 0.1, 0.5 and 1%. The VFA production showed maximum value with addition of 1% NaOH on 4th day, while the pH value decreases with increase in VFA. Addition of Sodium bi-carbonate was made to regulate the pH of 6.8-7.4 which is ideal for *methanogenesis*. Slurry with 0.1% NaOH produced the greatest yield while slurry with 1% shows the least production with retention time of 15 days. It has been found that the addition of NaOH did not improve the conversion of soluble COD into biogas, as high concentrations of NaOH must have unfavorably affected the digester performance. Sludge with 0.5% NaOH has reduced volatile solids by up to 80%.

A research survey has been taken up by Debadayita R et al. [20] on the implementation of decentralized biogas plants in the state of Assam. Family sized AD (<6m^3) and a community sized AD (>25m^3) have been analyzed. A wide range of data collection methods including semi structured interviews with family members of the villages, ethnographic observations and pictorial evidence and semi-structured interviews with institutional actors in the reason , have been taken up. It has been found out that biogas plants have great impact on the lively hood on the villages of Assam. It helps in developing the economy of the general public while cutting down the usage of fire woods/manure cakes etc. resulting in reduction in pollution.

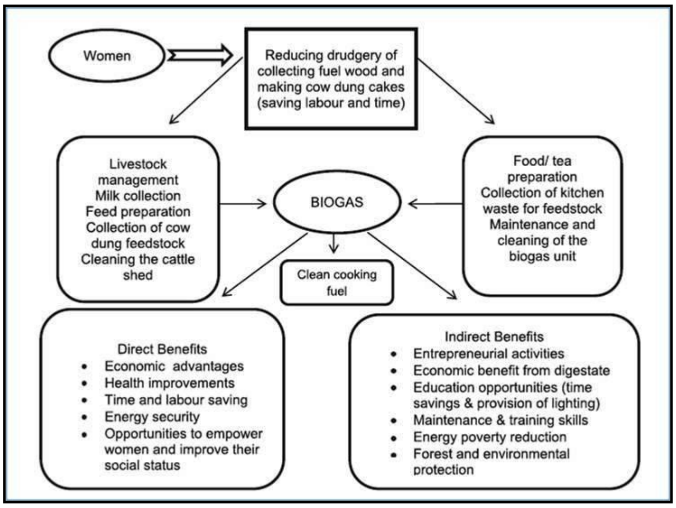


Fig.3. Role of women in feeding, maintaining and usage of household biogas systems [20].

Wheat bran, sugarcane bagasse, Rice bran and rape straw were crushed and the sizes were reduced (particle size<180µm). The biomasses are pretreated in two ways- one in 2-3% H_2SO_4 and the other in 0.1mL of α-amylase enzyme. At pH 5 and 30 °C, the enzyme pretreatment was found to be optimum for fermentation, while 3% acidic pretreatment is found to be most favorable for further process. [22].

While Emil Nutiu et al[23]. have provided a solution that does not consume energy from external sources. Animal and Bird wastages are used as feed material for the digester. The authors have presented that by the usage of these type of anaerobic fermentation techniques, external energy requirements have been eliminated, excessive production of mud is restricted, high degree of purification of 80-90% in a period of 15-20 days and a biogas with a calorific value of 5.500Kcal/Nm^3 can be obtained.

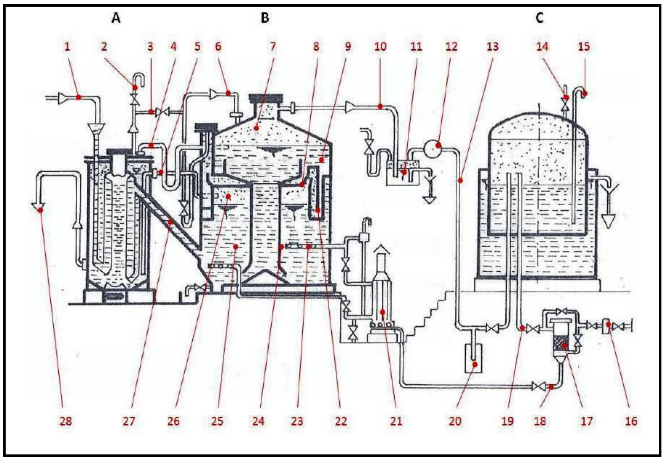


Fig.4. AD concept by Emit Nutiu et al.[23].- Radiator (A), Bioreactor(B) and Gas Storage (C)

The bioreactors are made with metal and can be buried halfway underground, requiring less manual labor for maintenance. Electrical energy is found to be utilized for lightening and raw material feed into the fixture.

The need for thermal stabilization of digesters of biogas plants by optimization of surface radiative properties of gasometer domes have been emphasized by Alberto M et al.[24].

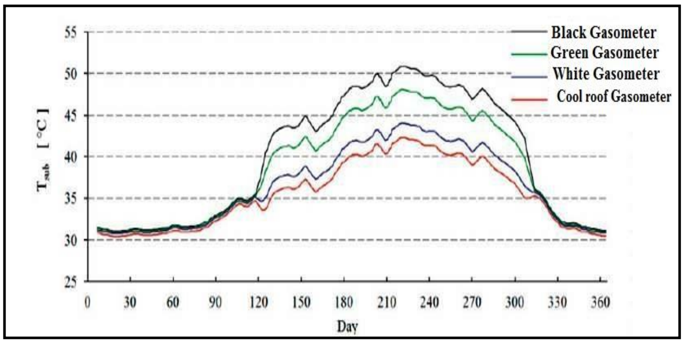


Fig.5. Temperature of Digester bath for different domes color – Black (5%), Dark green (10%), White(78%) and White cool roof(85%) [24].

	Dome color	Solar reflectance [%]	$Q_{in,hottest\ day}$ [kW]	$T_{sub,max}$ [°C]
	Black	4.8	75.4	46.2
	Dark green	10.3	70.4	44.1
	White	77.6	39.3	38.7
	Cool roof white	85	5.5	37.0

Fig.6. Solar reflectance of gasometer domes [24].

The calculation model have been performed with *Energy Plus*, as a productive tool to check the impact on the change in solar reflectance of gasometer domes over the temperature of the digester bath. The findings yield a result that these gasometer domes have lower specific profitability and stability than larger plants. A solution to overcome may be rectified by providing the gasometer dome by cool roof materials having high solar reflectance, as without it may affect the production of biogas by affecting the lives of *methanogenesis* bacteria or the vent of biogas, due to overheating. For smaller plants, it has been specified that, every aspect should be carefully designed during operation in order to make certain of the adequate performance and in return of investments.

The method of carbon dioxide removal for up-gradation of biogas has proved to be efficient using Alkali Absorption with Regeneration (AwR) [6]. In this process, the CO_2 gas gets separated from the biogas by alkali aqueous solution, and the used absorption solution is again regenerated for repeating the process.

The chemical reaction which is in support of the investigation is given below, denoted as (1) and (2).

$$2KOH + CO^2 = K_2CO_3 + H_2O \qquad (1)$$

$$Ca(OH)_2 + K_2CO^3 = CaCO_3 + 2KOH \qquad (2)$$

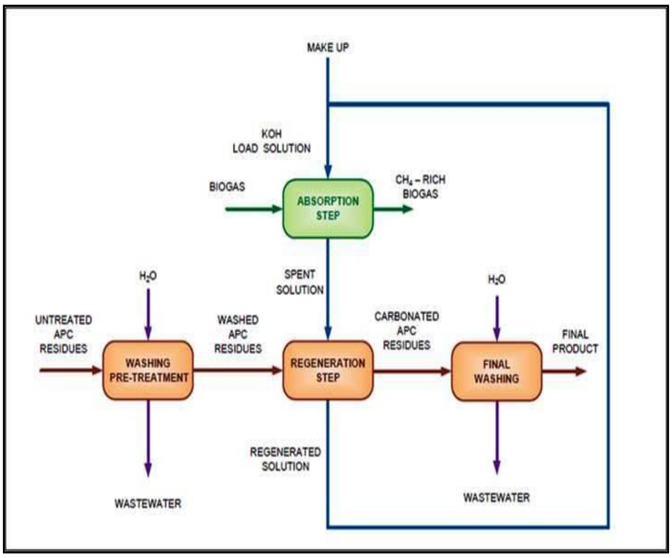


Fig.7. Scheme of absorption with regeneration of biogas upgrading with CO_2 storage process [25].

Special importance in studying the optimization hydrolysis substrate retention time and augmentation in order to increase biogas production using two-stage digester from *Jatropha curcas* Linn. Capsule husk is demonstrated by Hendroko Roy S et al [25]. Glass wool is used as immobilized growth into the *methanogenesis* digester, under mesophilic conditions. With a pH value of 6.20, a retention time of 14 days is not ideal for gas production at optimal condition. This is due to the formation of NH_3 in the hydrolysis digester, increasing the solution pH. The highest biogas yield has been found with a retention time of 4 days, but does not differ significantly with 7 days, at 90% NH_4. While a retention time of 14 days produced least biogas.

Another important aspect of biogas upgrading is the production of Syngas using an Al-based Ni Catalyst. Syngas is produced by dry reforming reaction using methane and carbon dioxide, which are actually the main components of biogas[3]. A chemical model was being implemented for prediction of dry reforming reaction, followed by experiment. Two ratios of biogas have been taken into consideration, CH_4:CO_2 =1:1 and CH_4:CO_2 =1.5:1, in temperature range of about 300-1000 °C at atmospheric pressure. For the dry catalyst reaction, γ-Al_2O_3 catalyst with 10% Ni is used.

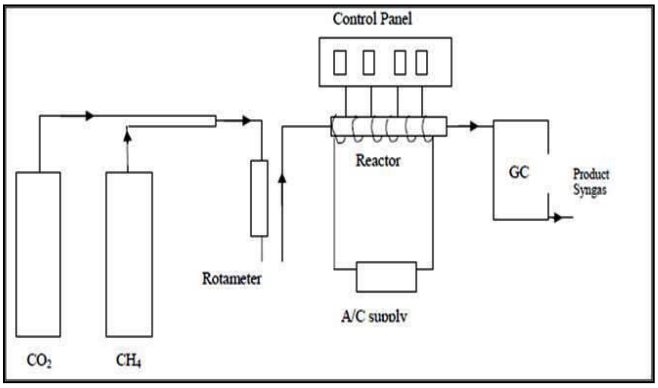


Fig.8. Syngas using reforming reactor [3].

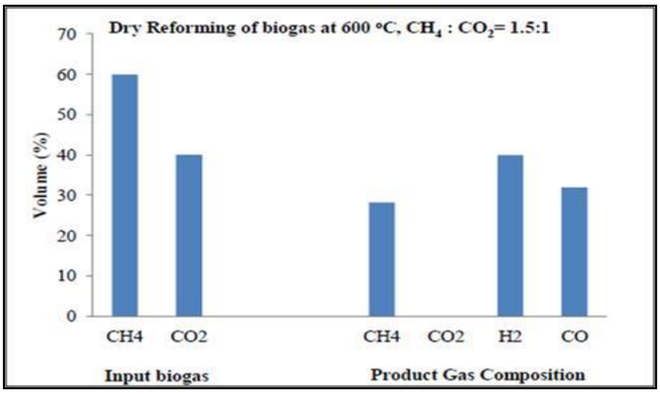
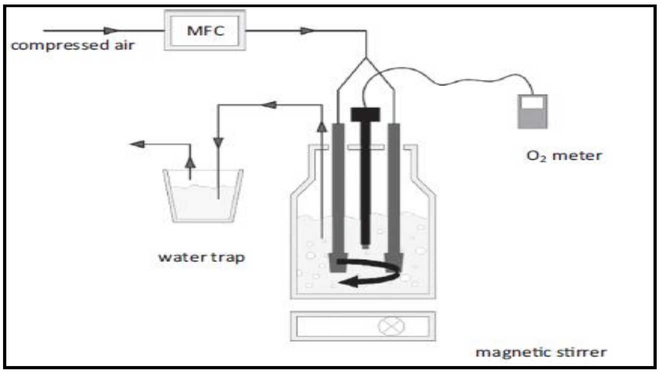


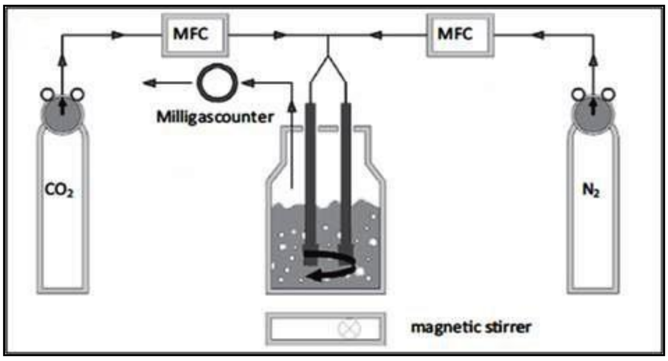
Fig.9. Product gas composition at CH_4:CO_2 =1.5:1 and flow rate 2.5 LPM, 600 °C [3].

With increase in temperature, CH_4 and CO_2 conversion increases, which result in lower CH_4 and CO_2 in the product gas. CO_2 was not present in product gas but higher amount of CO was observed, with considerably rich H_2. The carbon footprint will get reduced due to the presence of high H_2, and this enables the fuel to be used as a better option for automobiles applications, with concurrent reduction in pollution.

Cartmell E et al.[26] have portrayed the enhancement of biogas by carbon capture through carbon dioxide enrichment in AD treating food waste or sewage sludge. CO_2 is injected at 0, 0.3, 0.6 and 0.9M fractions, into batch ADs treating the wastes.



(a)



(b)

Fig.10. Author's experimental rig for (a) absorption test (b) operation of AD enriched with CO_2 [26].

The injected CO_2 have been utilized to the levels prior to the enrichment or to other substrate limitation. The recovery of any initial acidification during first 24-48 hours of the digestion may point to the fact that CO_2 was consumed up-to the levels, preceding the enrichment. CH_4 production was found increasing by 96-138%, indicating the probability of AD's to consume more CO_2.

IV. END USE TECHNOLOGIES

Life Cycle Assessment (LCA) is used as a tool to calculate the environmental impacts of AD-CHP system, following the ISO 14040/14044 methodology [27]. The authors took two common alternatives- Natural gas CHP and Electricity supplied from grid and heat generated by either oil or gas boiler. It has been estimated that 17 tones of Ammonium Sulphate and Nitrate mix per year have been saved. For, *Abiotic Depletion Potentials*, there has been huge savings due to displacement of artificial fertilizers by the digestate.

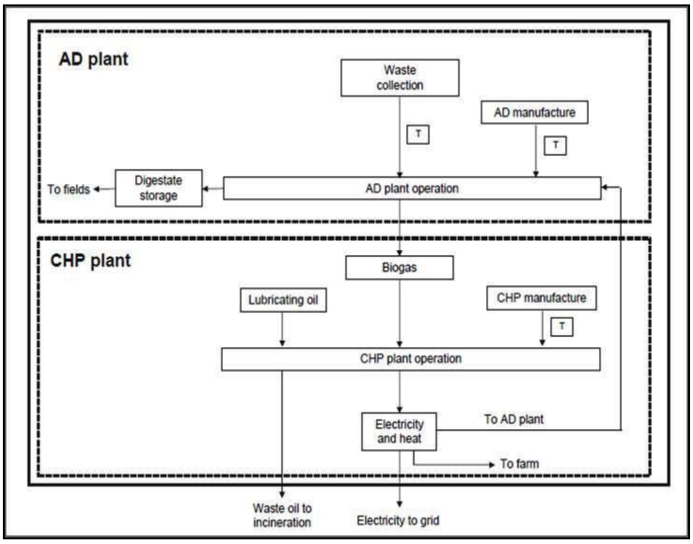


Fig.11. Author's AD-CHP system[27].

In *Acidification & Eutrophication potentials (AP and EP)*, ammonia emissions are responsible for 95% *AP* and 97% *EP*. The ammonia is produced in the liquid digestate and escapes through its open air storage.

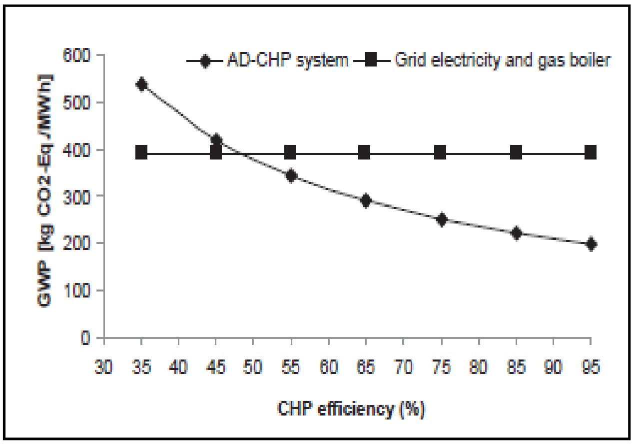


Fig.12. GWP comparison [27]

The *Global Warming Potential (GWP)* is estimated at 222 kg of CO_2 eq. /MWh, the vast majority(86%) of which is due to methane emissions from the digestate. CO_2 emissions from the biogas combustion in CHP are not considered as they are biogenic in nature. *Ozone Depletion Potential (ODP)* of 0.8 mg R11 eq. /MWh are caused by the release of halons such as bromotrifluoromethane during the combustion of biogas in CHP process (about 57%).

By using covered storage, large reduction in GWP and POCP occur (80% and 60%) owing to the avoided methane emissions. There is also 18% fall in both AP and EP, owing to reduction in ammonia emissions. It has been established that three most important parameters- feedstock type and source, digestate storage and its application on land, if regulated properly, can lower the majority of impacts compared to fossil fuels and even natural gas.

Bakul R et al.[28] have performed a multi criteria analysis of alternative biogas technologies by using Analytical Hierarchical Process (AHP) tool, with a perspective of overall self reliance of India for biogas technologies promoted by Govt. of India. The author performed the case study for a small biogas plant ($2m^3$). The tool has been used for ranking and analyzing six biogas alternatives- Khadi and Village Industries Commission (KVIC) Digester, KVIC with ferro-cement digester, KVIC with Fiber Reinforced Plastic (FRP) gas holder, KVIC with FRP gas holder and digester, Deenbandhu digester and Bi-phasic digester. The analysis proved that, KVIC with FRP gas holder and digester has the highest ranking, owing to corrosion resistance, leading to less maintenance cost, ease of transport (high strength to weight ratio) and unskilled labor can be utilized with minimum training.

The need of portable electrification using biogas technology, as a means of providing Off-grid power supply system, has been emphasized by Calvin A.C et al[29].. Portable Energy Storage Device (PESD) is used for charging the electricity generated by using biogas in an I.C engine. The study was taken up at Uganda, where less than 10% of the populations have access to electricity, however 50% of them owns a mobile phone. Two scenarios have been taken into consideration- a large biogas system with relatively long distant from customer and a smaller system which is situated close to the customer locations and waste source. It has been found that, small and portable off-grid power source must be constructed close to the waste sources and customers, as it provides lower initial and operating cost. The assumption "bigger is always better" has been proved to be not suitable in all the conditions.

Another important milestone in the field of biogas technology is the conversion of a gasoline engine into a biogas engine to power an electric generator [30]. A single cylinder, 4 stroke S.I engine is considered for conversion methodology. Emphasis has been given to the fact that, for use of the gas as a fuel in the engine, it must be upgraded to zero H_2S and H_2O content. The experiment aims at designing a controlled algorithm to adjust the fuel and air ratio in order to attain lower NO_x emission and higher generation efficiency. The study revealed that upgraded biogas contains almost 95% methane, which produce efficiency close to natural gas powered engine. For biogas, the reduction in Green House emission can be as much as 100%. Lower NO_x and SO_x have been reported to be found in usage of biogas in engines.

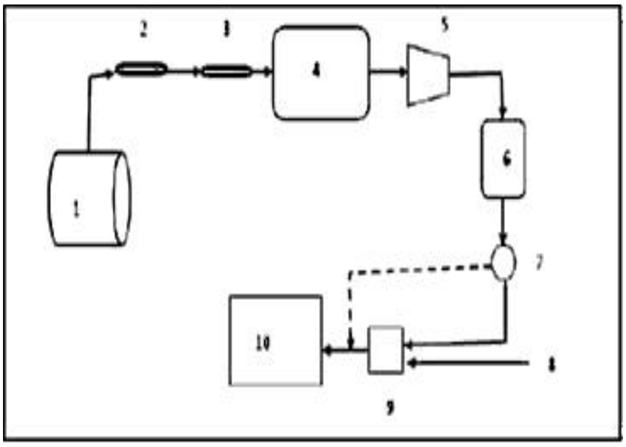


Fig.13. Schematic representation of biogas powered I.C engine. (1-digester, 2-desulphurizer, 3-dehumidifier, 4-gas holder, 5-compressor, 6-gas container, 7-Vaccum opened valve, 8-air intake, 9-air+biogas mixture, 10-engine) [30].

In the 4 stroke, 196 cc, compression ratio of 8.5:1, and ignition system of Non-contact Transistor Ignition, the authors have found that biogas can fueled the engine without much modification. LPG mixing with biogas has also been investigated and mixing ratios of 95%, 90%, 85% and 80% (biogas: LPG) were performed. With 100% biogas, the maximum rpm was found to be 1500 rpm. Addition of 5% LPG increase the speed to 1600 rpm and maximum rpm was found to be 3600 rpm at 20% LPG.

Omid R et al. [32] have provided the technologies implemented in usage of usage of biogas in an I.C engine. The author presented the impacts of biogas contaminants to the I.C engine. H_2S has been found to be the main problem in an I.C engine as it causes wear and tear. During combustion H_2S reacts and forms SO_2 and H_2O, further reacting forms H_2SO_4. Silixocanes can form thick silicate deposit in combustion chamber of the engine, exhaust manifolds, turbochargers and stacks. Ammonia is another component found in biogas (AD feed with poultry droppings), which when reacts with H_2O forms NH_4OH, thereby corroding the metals such as Al, Cu. The presence of high amounts of Diluents in biogas lowers the Wobble Index and lower heating value, causing lower flame temperature. The heat produced inside the engine chamber during combustion has been reported to be absorbed by CO_2. In order to use biogas in I.C engine, certain modifications may be performed such as-usage of more corrosion resistant materials, forged steel pistons etc. The author reported that, biogas engines have reached 64000 working hours before major overhaul. Although there were many biogas fuelled power plants available today, research in this field is lot lesser than other technologies and hence theoretical and experimental works are required to understand the exact combustion mechanisms.

Murugan S et al. [33] have studied the emission characteristics and performance evaluation of a CI engine coupled with gasifier running in dual fuel mode. A downdraft gasifier was designed and developed and a Single cylinder, 4 stroke, CI engine is used, running at 1500 rpm. Diesel (DF) and Producer gas (PG) (or Syngas) were used in dual fuel mode. The maximum efficiency achieved by a diesel engine was found to be 27.5%, while in dual fuel mode maximum efficiency was close to 26%. The exhaust gas temperature was found to be 330 °C at full load with diesel, and 388 °C at dual fuel conditions. The CO emission was found to be increasing in dual fuel mode compared to Diesel alone, which may be due to incomplete combustion. No emission is found to be lower in Dual fuel mode, compared to diesel. The smoke density is found to be 32% in dual fuel mode, while in Diesel alone accounts to 25%. The experiment yields important results and the authors concluded that, with the use of Syngas gas in CI engine in dual fuel mode, diesel fuel can be saved, although HC and CO emissions are increased at full load conditions compared to diesel, indicating to the insufficient amount of oxygen available in combustion chamber.

Thus the ideology of biogas powered I.C engine has been agreed by many researchers [29, 30, 31, 32 and 33].

V. CONCLUSION

This paper has presented approaches in usage of various feed materials for use in anaerobic digestion purpose. Various technologies which may be implemented for biogas upgrading and cleaning purpose were presented. Biogas may be used effectively for production of heat and power. The possibility of ceasing of all the non-renewable resources by 2020 provides a new regime in research of advanced renewable energy harnessing methods. Biogas is one among the top renewable resources, after solar, which might play a crucial role in energy production. Researchers must be encouraged to take up various proposals in Biogas sector, as there are many problems which hinder the establishment of biogas systems in today's world. Use of sophisticated tools such as CFD, *Energy Plus* etc must be initiated for research and development purpose.

Addition of 0.1% of NaOH produced a great yield of slurry, but is it advisable not to use in high concentrations as it affected the digester performance. Pre-treatment of wastes in 2-3% H_2SO_4 or 0.1mL of α-amylase enzyme was found to be optimum at pH of 5 and 3°C., in fermentation and further processes. By using specific techniques, biogas with high degree of purification of 80-90% with a retention time of 15-20 days, can be obtained. Gasometer domes provided with cool roof materials having high solar reflectance provides a solution in improving stability and profitability in AD's. Up-gradation by conversion into Syngas lowers the CO_2 from 40% to almost 0%, at 600°C. While CO_2 injection techniques with various fractions increases the CH_4 content by almost 96-138%. *Acidification Potentials* and *Eutrophication Potentials* have fallen by 18%, owing to ammonia reductions. The applicability of biogas in I.C engines have proved to be another important milestone in Biogas technologies.

Hence, biogas technology may expand our supply of energy, reduce our reliance on imported fuels, improve the atmosphere by reducing harmful gases and GWP, progress the economy of the Nation, creating jobs for the population, improving the conventional cooking methods and reduce the dependency on artificial fertilizers.

REFERENCES

[1] Gupta P., Singh S.R., Sachan A., Vidyaarthi A.S., Gupta A. A re-appraisal on intensification of biogas production. Renewable and Sustainable Energy review, 2012; 16(7): 4908-4916

[2] Samir Saini., Prakash Rao., Yogesh Patil. City based analysis of MSW to energy generation in India, calculation of state wise potential and tariff comparison with EU. Procedia- Social and behaviour Sciences, Elsevier, 2012; 37: 407-416

[3] Vikram Rathod., Purnanand V. Bhale. Experiment Investigation on Biogas Reforming for Syngas Production over an Alumina Based Nickel Catalyst. Energy Procedia. Elsevier, 2014;54: 236-245.

[4] McInerney M J., Bryant M P.,Stafford A D. Metabolic stages and energetics of microbial anaerobic digestion. In: Satfford DA, Wheatley BI, Hudges DE (eds) Anaerobic Digestion. Applied Science, London, 1980;91-98.

[5] M.H. Gerardi. The microbiology of anaerobic digesters,2003

[6] Renato Baciocchi., EnnioCarnevale., GiuliaCosta., Lidia Lombardi., Tommaso Olivieri., Alessandro Paradisi., Laura Zanchi., Daniela Zingaretti. Pilot-scale investigation of an innovative process for biogas upgrading with CO_2 capture and storage. Energy Procedia. Elsevier, 2013; 37: 6026-6034.

[7] Aremo M.O.,Agarry S.E. Comparison of Biogas from Cow dung and Pig dung under Mesophilic condition. IRJES,2012; 1(4): 16-21

[8] Aremo M.O., Agarry S.E. Enhanced Biogas Production from Poultry droppings using Corn-hub and waste paper as co-substrate. IJEST, 2013;5(2): 247-253

[9] Chompoonut Auphimai., Warin Rukruam.,Pawinee Chaiprasert. Efficacies of various inoclum on methane production from agro-industrial wastewaters. Energy Procedia. Elsevier,2014;52: 167-172

[10] Jagadish H Patil.,MAL AntonyRaj., Shanker BB.,Mahesh Kumar Shetty., BP Pradeep Kumar. Anaerobic Co-digestion of water Hyacinth and Sheep waste. Energy procedia. Elsevier,2014;52:572-578

[11] Kiattisak Panpong., Galaya Srisuwan., Sompong O-Thong., Prawit Kongjan. Enhanced Biogas Production from Canned Seafood wastewater by Co-digestion with Glycerol waste and *Wolffia arrhiza*. Energy Procedia. Elsevier, 2014;52:337-351

[12] M. Rafiq Kumar., S.M Tauseef., Tasneem Abbasi., S.A. Abbasi. Control of amphibious weed ipomoea (*Ipomoea carnea)* by utilizing for the extraction of volatile fatty acids as energy precursors. Journal of Advanced research (*in Press*); 2014.

[13] Marta Oleszek., Aleksandra Krol., Jerzy Tys., Mariusz., Mariusz Kulik. Comparison of biogas production from wild varieties of reed canary grass. Biogas Technology. Elsevier, 2014; 156: 303-306.

[14] OjikutuAbimbola O., Osokoya Olumide O. Evaluation of biogas Production from food waste. IJES, 2014; 3(1): 01-07.

[15] Ravi P. Agrahari., G.N Tiwari. The Production of biogas using Kitchen waste. IJES, 2013; 3(6): 408-413

[16] S. Maamri., M. Amrani. Biogas production from waste activated sludge using cattle dung inoculums: Effects of total solid contents and kinetics study. Energy Procedia. Elsevier, 2014; 50: 352-359.

[17] Samuel Tewelde., K. Eyalarasan., R. Radhamani., Kaliyaperumal Karthikeyan. Biogas Production from Co-digestion of Brewery Waste (BW) and Cattle Dung (CD). IJLTAFS, 2012; 2(2): 90-93

[18] W. Wiliwan., P. Pholchan., P. Aggrangsi. Biogas Production from Co-digestion of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure using completely stirred tank. Energy procedia. Elsevier, 2014;52:216-222.

[19] B.V Dasgupta., M.K Mondal. Bio Energy Conversion of Organic fraction of Varanasi's Municipal Solid Waste. Energy Procedia. Elsevier, 2012; 14: 1931-1938.

[20] Debadayita Raha., Pinakeshwar Mahanta., Michele L. Clarke. The implementation of decentralized biogas plants in Assam, NE India: The

impact and effectiveness of the National Biogas and Manure Management Programme. Energy Policy. Elsevier, 2014; 68: 80-91.

[21] Ratih Novi Listyawati., Christia Meidiana., Mustika Anggraeni. Evaluation of energy self-sufficinet village my means of energy indices. Procedia Environmental Sciences. Elsevier, 2014;20: 30-39.

[22] Devendra Pratap Singh., Rakesh Kumar Trivedi. Biofuel from wastes an economic and environmentally feasible resource. Energy Procedia. Elsevier, 2014;54:634-641

[23] Emil Nutiu. Anaerobic purification installation with production of bogas and liquid fertilizers. Procedia technology. Elsevier, 2014;12:632-636.

[24] Matteo Bavutti., Luca Guidetti., Giulio Allesina., Antonio Libbra., Alberto Muscio.,Simone Pedrazzi. Thermal stabilization of digesters of biogas plants by means of optimization of the surgace radiative properties of the gasometer domes. Energy Procedia. Elsevier, 2014;45:1344-1353

[25] Roy Hendroko S., Satriyo K. Wahono.,Praptiningsih G.A., Salafudin., Agus S. Yudhanto.,Imam Wahyudi., Salundik Dohong. The study of Optimization Hydrolysis Substrate Retention time and Augmentation as an effort to increasing biogas productivity from *Jatropha curcas* Linn. Capsule Husk at two stage digestion. Energy Procedia. Elsevier,2014; 47: 255-262

[26] Y. bajon Fernandez., A Soares., R. Villa., P. Vale., E. Cartmell. Carbon capture and biogas enhancement by carbon dioxide enrichment of anaerobic digesters treating sewage sludge or food waste. Bioresource technology. Elsevier, 2014;159: 1-7

[27] Andrew Whiting., Adisha Azapagic. Life cycle emvironmental impacts of generating electricity and heat from biogas produced by anerobic digestion. Energy. Elsevier, 2014;70: 181-193

[28] Bakul Rao., Archana Mane., Anand B. Rao., Vishal Sardeshpande. Multi-criteria analysis of alternative biogas technologies. Energy Procedia. Elsevier, 2014;54: 292-301

[29] Calvin A. Cherry., Michael Rios., Aleia McCord., Sarah Stefanos., Giri Venkataraman. Portable Electrification suing Biogas systems. Procedia Engineering. Elsevier, 2014;78: 317-326

[30] I Wayan Surata., Tjokorda Gde Tirta Nindhia., I Ketut Adi Atmika., Dewa Ngakan Ketut Putra Negara., I Wayan Eka Permana Putra. Somple Conversion method from Gasoline to Biogas Fueled small engine to power electric generator. Energy Procedia. Elsevier,2014;52: 626-632

[31] Jaroslaw Milewski., Lukasz Szablowski., Jerzy Kuta. Control Stratergy for an Internal Combustion engine fuelled by Natural gas operating in distributed generation. Energy procedia. Elsevier, 2012;14:1478-1483

[32] Omid Razbani, NimaMirzamohammad, Mohsen Assadi. Literature review and road map for using biogas in internal combustion engines. 3rd International Conf. on Applied Energy, Italy. 2011

[33] Vinay Shrivastava., Abhishekh Kumar Jha., Arun Kumar Wamamkar., S. Murugan. Performance and Emission Studies of a CI Engine Coupled with Gasifier running in dual fuel mode. Procedia Engineering. Elsevier,2013;21: 600-608

[34] T. Blenkinsopp., S.R Coles., K. Kirwan. Renewable energy for rural communities in Maharastra, India. Energy Policy. Elsevier, 2013;60: 192-199.

[35] C.H Pharm., J.M. Triolo., T.T.T Cu., L. Pederson., S.G. Sommer. Validation and recommendation of methods to measure Biogas production potentials of animal manure. Asian Australas J. Anim. Sci. 2013; 26(6): 864-873.

[36] Carmelia Abagnale., Maria Cristina Cameretti., Luigi De Simio., Michele Gambino., Sabatino Iannaccone., Raffaele Tuccillo. Combined numerical-experimental study of dual fuel engines. Energy Procedia. Elsevier, 2014;45: 721-730.

[37] Swami Nathan S., S. Mallikarjuna J.M., Ramesh A. An experimental study of the biogas-diesel HCCI mode of engine operation. Energy Conservation and Management, 2010;51:1347-1533.

[38] Chandra R., Vijay V.K., Subbarao P.M.V., Khura T.K. Performance evaluation of a constant speed IC engine on CNG, methane enriched biogas. Applied Energy, 2011;88: 3969-3977.

[39] D. Devakumar., S. Semple., D. Osrin., S.K Yadav., O.P Kurmi., N.M. Saville., B. Shrestha. D.S. Manandhar., A. Costello., J.G Ayres. Biomass fuel use and the exposure of children to particulate air pollution in southern Nepal. Environmental International. Elsevier, 2014;66: 79-87.

[40] Dilip Kumar De., Muwa Nathaniel., Olukunde Olawole. Cooking with minimum energy and protection of environement and health. IERI Procedia. Elsevier,2014;9:148-155.

[41] Divya D., Gopinath L.R., Merlin Christy P. A review on trends and prospects for biogas production in developing countries. International Research Journal of Environmental Sciences, 2014;3(1): 62-69.

[42] Dayananda B.S., Sreepathi L.K. An experimental study on gasification of chicken litter. Int. Res. J. Environment Sci,2013; 2(1): 63-67.

[43] Dr. Vadirajacharya., Dr. P.K Katti. Rural Electrication through Solar and Wind hybrid system: A self sustained grid free electric power source. Energy Procedia. Elsevier, 2012; 14: 2081-2087.

[44] F. Moedinger., F. Ast., M. Ragazzi., E.C Rada., C. Callegati. The use of renewable and alternative fuel in the heavy clay industry. Energy procedia. Elsevier, 2013;36: 68-75.

[45] Julia Terrapon-Pfaff., Carmen Dienst., Julian Konig., Willington Ortiz. A cross sectional review: Impacts and sustainability of small scale renewable energy projects in developing countries. Renewable and Sustainable Energy Reviews. Elsevier, 2014;40: 1-10.

[46] Kiattisak Panpong., Galaya Srisuwan., Sompong O-thong., Prawit Kongjan. Anaerobic Co-digestion of canned seafood wastewater with glycerol waste for enhanced biogas production. Energy Procedia. Elsevier, 2014;52:328-336

[47] Kifayat Ullah., Mushtaq Ahmad., Sofia., Vinod Kumar Sharma., Pengmei Lu., Adam Harvey., Muhammad Zafar., Shazia Sultana., C.N. Anyanwu. Algal biomass as a global source of transport fuels: Overview and development perspectives. Progress in Natural Science: Materials International. Elsevier, 2014; 24: 329-339.

[48] M. Njenga., N. Karanja., H. Karlsson., R. Jamnadass., M. Liyama., J. Kithinji. Additional cooking fuel supply and reduced global warming potential from recycling charcoal dust into charcoal briquette in Kenya. Journal of cleaner Production. Elsevier, 2014; 81: 81-88.

[49] Mostafa S. Elshahed. Microbiological aspects of biofuel production: Current status and future directions. Journal of Advanced Research,2010; 1: 103-111.

[50] T.G Narayani., P. Gomathi Priya. Biogas production through mixed fruit wastes biodegradation. Journal of Scientific & Industrial Research, 2012; 71: 217-220.

[51] B. Muruganandam., R. Saravanane., M. Lavanya., R. Sivacoumar. Effect of Inoculum-subtrate ratio on Acclimatization of pharmaceutical effluent in an anaerbic batch reactor. J. of Env. Sci. Engg., 2008;50(3): 191-196.

[52] Sri Atmaja P. Rosyidi., Tjasa Bole-Rental., Surya Budi Lesmana., Jazaul Ikhsan. Lesson learnt from energy needs assessment carried out for the biogas program for rural developemt in Yogyakarta, Indonesia. Procedia Env. Sci. Elsevier, 2014;20:20-29.

[53] Tarek A. Hamad., Abdulhakim A. Agil., Yousif M. Hamad., John W. Sheffield. Solid waste as renewable source of energy: current and future possibility in Libya. Case studies in Thermal Engg. Elsevier, 2014;4: 144-152.