Design of Floating Biogas Digester and Production of Biogas using Kitchen Waste

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***Abstract*:- In Vishwaniketan [Vimeet] collage, there are two canteens, and both having their own individual mess, where daily a large amount of kitchen waste is obtained which can be utilized for better purposes. Biogas production requires anaerobic digestion. This project is to create an Organic Processing Facility to create biogas which will be more cost effective, eco-friendly, cut down on landfill waste, generate a high quality renewable fuel, and reduce carbon dioxide and methane emissions. Kitchen (food) waste will be collected from two canteens of Vimeet as feedstock for the reactor which works as anaerobic digester system to produce biogas energy. The anaerobic digestion of kitchen waste produces biogas, a valuable energy resource. Anaerobic digestion is a microbial process for production of biogas, which consists of primarily methane (CH4) and carbon dioxide (CO2). The continuously fed digester requires addition of sodium hydroxide (NaOH) to maintain the alkalinity and pH to 7. For this reactor, an Inoculum should be installed in batch reactors, to which inoculum of previous cow dung slurry along with the kitchen waste will be added to develop new Inoculum. A combination of these mixed inoculum will be used for biogas production at 37°C in laboratory (small scale) reactor (30L capacity). Biogas can be used as energy source and also for numerous purposes. In this project, the production of biogas and methane can be done from the starch rich and sugary material.**

In this project RCC tank is designed for capacity of 36.18m^3 costing up to 2 lakh INR. In rural areas RCC tank may be expensive therefore plastic moulded tank is designed costing up to 16000 INR having 12-15 years lifespan.

Key words: Vimeet, biogas, kitchen waste, methane, digester, design

1.INTRODUCTION :

Scarcity of petroleum and coal threatens the supply of fuel throughout the world also problem of their combustion leads to research in different corners to get access the new sources of energy, like renewable energy resources. Solar energy, wind energy, different thermal and hydro sources of energy, biogas are all renewable energy resources. But, biogas is distinct from other renewable energies because of its characteristics of using, controlling and collecting organic wastes and at the same time producing fertilizer and water for use in agricultural irrigation. Biogas does not have any geographical limitations nor does it require advanced technology for producing energy, also it is very simple to use and apply.

Deforestation is a very big problem in developing countries like India, most of the part depends on charcoal and fuel wood for fuel supply which requires cutting of forest. Also deforestation leads to decrease the fertility of land by soil erosion. Use of dung, firewood as energy is also harmful for the health of the masses due to the smoke arising from them causing air pollution. We need an eco-friendly substitute for energy.

Kitchen waste is organic material having the high calorific value and nutritive value to microbes, that's why efficiency of methane production can be increased by several orders of magnitude. It means higher efficiency and size of reactor and cost of biogas production is reduced. Also in most of cities and places, kitchen waste is disposed in landfill or discarded which causes the public health hazards and diseases like malaria, cholera, typhoid. Inadequate management of wastes like uncontrolled dumping bears several adverse consequences. It not only leads to polluting surface and groundwater through leachate and further promotes the breeding of flies, mosquitoes, rats and other disease bearing vectors. Also, it emits unpleasant odour and methane which is a major greenhouse gas contributing to global warming.

Mankind can tackle this problem successfully with the help of methane; however till now we have not been benefited, because of ignorance of basic sciences like output of work is dependent on energy available for doing that work. This fact can be seen in current practices using low calorific inputs like cattle dung, distillery effluent, municipal solid waste (MSW) or sewage, in biogas plants, making methane generation highly inefficient. We can make this system extremely efficient by using kitchen waste or food wastes.

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1. Biogas :

BIOGAS is produced by bacteria through the biodegradation of organic material under anaerobic conditions. Natural generation of biogas is an important part of bio-geochemical carbon cycle. It can be used both in rural and urban areas

1.1 Composition of Biogas:

Table:1-Composition of biogas

Component	Concentration (by volume)
Methane (CH_4)	55-60%
Carbon dioxide (CO_2)	35-40%
Water (H_2O)	2-7%
Hydrogen Sulphide (H_2S)	20-20.000 ppm (2%)
Ammonia (NH_3)	0-0.05%
Nitrogen (N)	0-2%
Oxygen (O_2)	0-2%
Hydrogen (H)	0-1%

1.2 characteristics of biogas:

Composition of biogas depends upon feed material also. Biogas is about 20% lighter than air has an ignition temperature in range of 650 to 750oC.An odourless and colourless gas that burns with blue flame similar to LPG gas. Its caloric value is 20 Mega Joules (MJ) /m3 and it usually burns with 60 % efficiency in a conventional biogas stove. This gas is useful as fuel to substitute firewood, cow-dung, petrol, LPG, diesel and electricity depending on the nature of the task and local supply conditions and constraints. Biogas digester systems provides a residue organic waste, after its anaerobic digestion(AD) that has superior nutrient qualities over normal organic fertilizer, as it is in the form of ammonia and can be used as manure. Anaerobic biogas digesters also function as waste disposal systems, particularly for human wastes and can prevent potential sources of environmental contamination and the spread of pathogens and disease causing bacteria. Biogas technology is particularly valuable in agricultural residual treatment of animal excreta and kitchen refuse (residuals).

1.3 Benefits Of Biogas:

1. Production of energy.
2. Transformation of organic wastes to very high quality fertilizer.
3. Improvement of hygienic conditions through reduction of pathogens.
4. Environmental advantages through protection of soil, water, air etc.
5. Micro economical benefits by energy and fertilizer substitutes.
6. Macro economical benefits through decentralizes energy generation and environmental.

3. LITERATURE REVIEW:

Appropriate rural technology of India, Pune has developed a compact biogas plant which uses waste food rather than any cow dung as feedstock, to supply biogas for cooking. The plant is sufficiently compact to be used by urban households, and about 2000 are currently in use – both in urban and rural households in Maharashtra. The design and development of this simple, yet powerful technology for the people, has won ARTI the *Ashden* Award for sustainable Energy 2006 in the Food Security category. *Dr. Anand Karve* (ARTI) developed a compact biogas system that uses starchy or sugary feedstock (waste grain flour, spoilt grain, overripe or misshapen fruit, nonedible seeds, fruits and rhizomes, green leaves, kitchen waste, leftover food, etc). Just 2 kg of such feedstock produces about 500 g of methane, and the reaction is completed with 24 hours. The conventional biogas systems, using cattle dung, sewerage, etc. use about 40 kg feedstock to produce the same quantity of methane, and require about 40 days to complete the reaction. Thus, from the point of view of conversion of feedstock into methane, the system developed by Dr. Anand Karve is 20 times as efficient as the conventional system, and from the point of view of reaction time, it is 40 times as efficient. Thus, overall, the new system is 800 times as efficient as the conventional biogas system.

The waste materials were collected fresh from various locations around Kano and Kano metropolis, were sun dried for twenty days then oven dried at 110^0C for 10hrs before use. The fruits waste were collected from Naibawa market along Kaduna-Zaria Express way, while the vegetables waste were collected from Yankaba market along Hadejia road and the cow dung was collected from Wudil cattle market. The dried samples were grounded using wooden pestle and mortar. By using sieving machine in order to obtain powdered samples which were then stored in a separate black polyethylene bags. From the dried samples, different slurries were prepared and used for the investigations. 200g of each substrate was taken and mixed with 1.5 litre of water and each transferred into a separate digester. The biogas produced, from the digester was connected to a separate inverted 1000cm3 measuring cylinder. The volume of biogas produced from each digester was recorded separately. The biogas production process was investigated for each of the substrate under investigation and was observed that the highest individual production rate is recorded for the cow dung slurry (control) with average production of 1554 cm3, followed by pineapple waste which had 965 cm3 of biogas, then by orange waste which had 612cm3, pumpkin and spinach wastes had 373 cm3 and 269 cm3 respectively. Therefore, the difference in the production of biogas to a large extent depends on the nature of the substrate. (Studies on biogas production from fruits and vegetable waste. *sagagi, b. S., b. Garba and n. S. Usman*)

Biogas systems are those that take organic material (feedstock) into an air-tight tank, where bacteria break down the material and release biogas, a mixture of mainly methane with some carbon dioxide. The biogas can be burned as a fuel, for cooking or other purposes, and the solid residue can be used as organic compost. Through this compact system, it has been demonstrated that by using feedstock having high calorific and nutritive value to microbes, the efficiency of methane generation can be increased by several orders of magnitude. It is an extremely user friendly system. (Production and Analysis of Biogas

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from Kitchen Waste *Ziana Ziauddin, Rajesh P.*)

Enhancement of Biogas Production From Bakery Waste By The Addition Of Pseudomonas Aeruginosa. The byproduct, Glycerol is very much suitable for the growth anaerobic microorganisms. The initial addition of Pseudomonas aeruginosa increased the biogas production in form of methane and carbon dioxide. (*S. Potivichayanon*)

Biogas is produced by a chemical reaction of the organic materials put in a sealed container by the help of biological process in the absence of oxygen. Biogas plants was fed with organic waste like dead plants, animal material, sewage sludge, kitchen waste and cattle which are converted into a gaseous fuel called biomass. They used cattle dung, pig dung, poultry dropping, kitchen waste and made slurry as per conventional biogas plant and left it for digestion process and they concluded that biogas can be used as a better alternative fuel in the day of energy challenges and municipal sanitation. More research in the field of biogas production is required and its sustainability must be considered in the global renewable scenario. The operation conditions and parametric stabilization imparts a vital role for its vast productivity. (*Amar Kumar Das, Shovan Nandi, Subrat Kumar Patra*)

A survey of the amount of food waste produced in canteen and amount gas cylinders consumed was conducted. A prototype digester was developed and gas collected was quantified and checked for flammability. The calorific value of the obtained gas was calculated. Based on the results obtained from the prototype digester a large scale digester for Sahyadri college canteen was designed and the feasibility and cost benefits were analyzed. It was determined that for that college waste of 50 kg/ day canteen food waste, a 50 m^3 reactor may be required costing around 14 Lakh rupees. The amount of biogas produced daily is equivalent to 0.83 cylinders per day which would replace nearly 60% of the LPG used. The savings achieved is around 3.6 Lakhs rupees per month, with a payback period of 3.9 years(*Abhith G,Renitha D,Shrikalpa P*.)

Volatile Fatty Acids and Ammonia, resulting in higher methane yield and system stability. Co-digestion of food waste with other substances such as waste water could enhance the biodegradation of long chain fatty acids.(*Cunsheng Zhang*)

4. PROJECT DESCRIPTION:

4.1project objectives:

- Effective disposal of kitchen waste.
- Treat wastes that would otherwise produce harmful methane emissions, recycling them into valuable green energy & bio fertilizer.
- Reduce the pollution of ground water resources.
- Promote a social activity.
- Reduce global climate change emissions by 20%.
- Deliver home grown, clean, safe and storable green energy.
- Create job opportunities in rural areas.

5. METHODOLOGY:

1) Selection of project.
2) Comparison of conventional biogas plant and biogas plant using food waste.
3) Ensure Production of gas from food waste (experiment).
4) Campus survey.
5) Visits.
6) Calculation of gas generation and waste required to fulfill the needs.
7) Create a social awareness in near by villages for effective disposal of waste & importance of biogas plant to reduce the stress on environment.
8) Design of plant ensuring good quality at low cost.
9) Promoting this idea of social awareness and concern about environment to different sectors

6. EXPERIMENTS:

6.1 Experiment 1

2 litter bottle
1kg Kitchen waste – cooked and uncooked
Water (1lit)
Result : Gas production was found but not measured.

6.2 Experiment 2

30 liter of container

Water content = 10 L

Kitchen waste (wet) = 3 Kg

Kitchen waste (dry) = 1 Kg

Cow dung = 1 Kg

Table:2-.C/N ratio of materials

Sr no.	Material	Carbon content of material (%)	Nitrogen content of material (%)	C/N ratio
1.	Wheat Flour	46	0.53	87:1
2.	Rice	42	0.53	67:1
3.	Fallen leaves	41	0.75	53:1
4.	Soybean	41	1.30	32:1
5.	Wild grass	14	0.54	27:1
6.	Fruit waste	42	1.2	35:1
7.	Vegetable craps	36	1.44	25:1
8.	Cabbage	43.2	3.6	12:1
9.	Onion	39.75	2.65	15:1
10.	Potato	37.5	1.5	25:1
11.	Tomato	39	3	13:1

6.3 Experiment 3

2 sets of 1 litre bottles.

2 different sets with different composition are installed as below.

1. 200gm cow dung was mixed with kitchen waste and water to make 1lit slurry which is poured in 1lit bottle.

2. 50gm grinded kitchen was mixed with 150gm cow dung and water is added to make 1lit solution which is poured in 1lit bottle.

7. DESIGN OF BIOGAS DIGESTER

Biogas plant must be designed in such a way that it must be affordable for all class people. It must have enough life span and capacity for large waste management and gas generation as well as easy to handle for people in rural areas with low cost. For reaching this goal two types of design are made using two different materials.

7.1 Design of plastic moulded tank and its estimation:

Table:3 – Estimation of plastic tank

Sr no	Particulars	Quantity	Cost per (rs)	Amount
1	Black colour plastic moulded tank (1000L)	2	5400	10800/-
2	Tee shaped pipe(90mm)	1	104	104/-
3	Female adaptor (90mm)	1	76	76/-
4	Male adaptor (90mm)	2	50	100/-
5	Yield cap (threaded) (90mm)	1	32	32/-
6	Rigid PVC pipe (90mm dia. 2m long)	1	390	390/-
7	Elbow (63mm)	1	41	41/-
8	Male adaptor (63mm)	2	25	50/-
9	Rigid PVC pipe (63mm dia. 0.97m long)	1	235	235/-
10	Burn valve (50mm dia)	1	950	950/-
11	Epoxy and hardner	1 lit	400	400/-
12	PVC adhesive solution	100ml	45	45/-
13	Filer , hammer, hacksaw blade		300	300/-
	Total			13523/-
	Miscellaneous 5%			676.15/-
	Contingencies 10%			1352.3/-
	Grand total			15551.45/-

7.2 Design and estimation of R.C.C tank

Capacity

Kitchen waste = (cooked + uncooked) food = 50kg per day

(… As per the survey and analyzing the future increase in population and waste)

Cow dung = 50kg

Water = 20 lit

Capacity of tank = 50+50+20,000

= 20100 lit

= 20.1m^3

Factor of safety = 20.1×1.8

= 36.18 m^3

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Overall capacity of tank = **36.18** $\boldsymbol{m^3}$

Therefore, the biogas plant should be designed for the capacity of 36.18m^3

Design:

Capacity = 20.1× FOS

= 20.1× 1.8

= 36.181- sin∅

Assume depth = 4m, free board = 0.8m

∴ Depth of water (sludge) = 3.2m

Capacity = $\frac{\pi}{4} \times D^2 \times$depth

36.18 = $\frac{\pi}{4} \times D^2 \times 3.2$

∴ D = 3.79m ≅ 3.8m (internal)

Diameter of tank = 3.8m

Height of tank = 4m

For external diameter assume thickness of wall = 400mm

∴ External diameter = 3.8+ (0.4 × 2) = 4.6m

<u>Condition 1- tank is empty and saturated soil pressure outside (max. compression)</u>

Ka = $\frac{1-\sin\emptyset}{1+\sin\emptyset} = \frac{1}{3}$ = 0.33

γ'= 18-10 = 8KN/m^3

Pa = Ka. γ'.H + γ_w.H

Pa = 0.33 × 8 × 4 +10 × 4

Pa = 50.67KN/m^2

C = Pa×$\frac{D}{2}$ = 50.67×$\frac{4.6}{2}$ = 116.53 KN/m

Max. compressive stress (IS 3370, part 2, table 2)

= $\frac{116.53 \times 10^3}{1000 \times 400}$

= 0.29 N/mm^2 <8N/mm^2

…..<u>Hence, safe.</u>

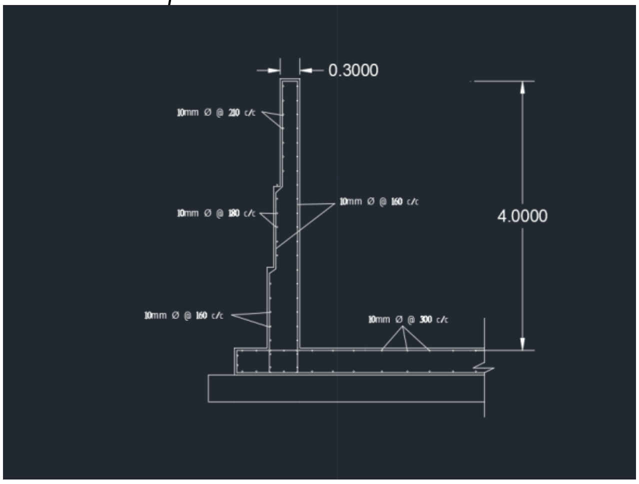
∴No need to provide compressive steel concrete can take all compressive forces.

Condition 2- Tank is full and no soil outside.

Table:4- Design Summary

Sr No	Height from top	A_{st} (main) mm^2	A_{st} (dist.) mm^2	Dia. of bar *Mm*	spacing Main *mm*	Spacing Dist *mm*
1	4m	480	420	10	160	180
2	2.8m	480	420	10	160	180
3	1.6m	480	420	10	160	210
4	Base slab	180	180	10	300	300

Cross section of RCC tank



RATE ANALYSIS

Table:5-Cost of materials

Materials	**Quantity**	**Rate**	**Per**	**Amount**
Cement	210	350	Bag	73500/-
Sand	24.263	900	M^3	21836.7/-
Aggregate	10.245	750	M^3	7683.75/-
Steel	1044.62	80	Kg	83569.6/-
Binding Wire	10.45	65	Kg	679.25/-
Total material cost	-	-	-	187269.3/-

Table:6-Labour cost

Labour	**No.s**	**Rate**	**Amount**
Head mason	1	600	600/-
Mason	2	500	1000/-
Bhisti	2	400	800/-
Male mazdoor	3	450	4050/-
Female mazdoor	2	400	800/-
Carpenter	2	600	1200/-
Bar-bender	2	400	800/-
Blacksmith	2	400	800/-
Sundries	Lump sum	200	200/-
Total amount	-	-	10250/-

Total cost of tank = 91144.45/-

Add 1.5% water charges= 1367.17/-

Add 10% contractors profit=9114.45 /-

∴ Total cost = 101626.065/-

Estimation of Shredder machine:

For the crushing of large quantity of kitchen waste into small pieces there is requirement of shredder machine.

Table:7- Estimation of shredder machine

Srno	Description	Material	Quantity	Price
1	Stand/frame	MS steel	4	35 Rs/kg
2	Cutting blade	EN steel	30	70 Rs/kg
3	Shaft	EN31 steel	2	75 Rs/kg
4	Key	MS steel	2	50 Rs/piece
5	Spur gear	EN31 steel	1	5,000 Rs/piece
6	Gear box	MS steel	1	55,000 Rs/piece
7	Pulley	MS steel	2	250 Rs/piece
8	Belt	Rubber	1	350 Rs/piece
9	Motor	Type-3 phase Induction motor	1	5,500 Rs/piece
10	Bearing	MS steel	1	150 Rs/piece
11	Jaw type coupling	MS steel	1	1,500 Rs/piece

Total price = Rs 70,490

Miscellaneous 5% = Rs 3,524

Installation charges 6% = Rs 4,229

Overall cost = Rs 78,243

7.3 Comparisons between Plastic tank and rcc tank

Plastic Tank is of low cost and is useful for rural areas as well as for the people in urban areas with less capacity of waste generation and less requirement of gas. The waste so generated is to be collected cut into small pieces and then feed into the digester. This is possible only when the waste generated is up to 4-5kg . Its life span is 10-12 years and it can be extended with proper maintenance.

The RCC tank is costly than the plastic mould tank and it is useful for large scale waste generation areas such as hotels, hospitals, institutes, factories, etc. The waste generated can extend more than 20kg so it is not possible to manually cut shred the waste and put into digester so shredder machine is attached to the R.C.C tank. Its life span is more than 20 years.

8.ANALYSIS:

Comparison of conventional biogas system with kitchen waste biogas system

Table:8- Comparison of conventional biogas system with kitchen waste biogas system

Comparison with conventional bio-gas plants	***Conventional biogas systems***	***Biogas systems using kitchen waste***
Amount of required feedstock	40kg+40lit water	1-1.5kg+15lit water
Nature of required feedstock	Dung	Any starchy material
Amount and nature if slurry to be disposed off	80lit sludge	15 lit watery
Reaction time for full utilization of feedstock	40days	48-72 hours
Standard size for household	4000 lit	1000-1500 lit
Capital investment per unit including stove	INR 20,000	INR15,000
Running expenses per meal	INR 25	0 to INR 5

9. Future Scope:

Fertilizer

The digested left over from the digester is rich in nitrogen, phosphorus, and potassium, and can be used as a fertilizer. Digested increased the potato cultivation by 27.5% and forage by 1.5% compared to no added fertilizer. Due to the anaerobic digestion of organic matter, these nutrient concentrations were easily taken up by plants. The effluent can be directly used as a fertilizer in farming. Digested has a high commercial value when exported. The dried effluent could also be used as an adsorbent to remove lead from industrial wastewater. Biogas slurry could be helpful in growing algae, water hyacinth, duck weed, and fish poly-aquaculture.

Lighting and Power Generation

The other major application of household biogas is for lighting and power generation. In many developed countries, biogas from the digesters is sent to a combustion engine to convert it into electrical and mechanical energy. Biogas requires a liquid fuel to start ignition. Diesel fuel can also be combined with biogas for power generation. For instance, in Pura (India), a well-studied community biogas digester can fuel a modified diesel engine and run an electric generator. Bari reported that carbon dioxide up to 40% will not decrease the engine performance using biogas as a fuel. Biogas can also be used to power engines when mixed with petrol or diesel, and it can also help in pumping water for irrigation. Cottage/small scale industries use biogas for pumping, milling, andfor some other production activities.

10. CONCLUSION:

From the study and research it is well concluded that from the point of view of conversion of feedstock into methane, this system is 20times as efficient as the conventional system, and from the point of view of reaction time, it is 40 times as efficient. It is extremely eco-friendly and also user friendly system, because it requires daily only a couple of kg feedstock, and the disposal of daily just 5 liters of effluent slurry.

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