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Biogas plant for power generation in high water table condition

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ABSTRACT

A biogas plant of 30 m3 capacity reinforced cement concrete (R.C.C.) fixed dome type was designed and constructed for power generation at Shree Gopal Krishna Goshala, Cuttack (Odisha). This biogas plant saved 25% water as compared to indigenous design biogas plant. The maximum gas production was recorded as 28650 litres per day for the daily loading of 750 kg of cattle dung. The methane content varied between 47.2 to 55.0%. Biogas generator consumed biogas @ 4.90 m3/h. The total cost of the system was Rs. 5.55 lakhs. The total cost of operation was worked out to be Rs. 437/day. The saving in diesel for the generator was found to be 1.5 lit/h. By considering the cost of diesel and income received from the manure obtained from biogas plant, net saving obtained from the system was Rs. 515/day. The payback period for the biogas based power generation system was found 3 years.

1. Introduction

At present, energy is a fast depleting costly input and there is crisis of energy. Out of six lakh villages in India, 17850 villages are not yet electrified due to inaccessible locations. In alternate sources of energy, biogas is a clean environment friendly fuel which can be used for generating of power where sufficient numbers of cattle are available. India has second largest biogas program in the world at rural and as well as urban levels. India has potential of generating 6.38 x 1010 m3 of biogas from 980 million tons of cattle dung produced annually. The use of biogas in stationary engines is already going on and now its utilization is also feasible in automobiles, used for transportation purposes by enriching and compressing it in cylinders. Biogas can be converted into bio Compressed Natural Gas after its enrichment of methane content and its compression it into cylinders (Dadhich, 2009). Biogas technology has a very significant role to play in integrated agricultural operations, rural sanitation, large scale dairy farms & sewage disposal *etc.* It is estimated that cattle dung, when passed through a biogas unit, yields about 35-45% more nitrogen in manure as compared with heat obtained by burning dung cakes and ordinarily prepared compost, respectively. Besides, from a biogas plant both the products are obtained (Singh *et al.,*1993). Kalia and Singh (2004) designed Himshakti biogas plant which is more structurally stable due to the higher wall thickness and construction of dome at the angle close to 520 to the centre of the dome. It can be easily installed in the soils of stony strata. Its installation cost is nearly the same as the cost of the installation of Deenbandhu biogas plant of same capacity. The developed design of the plants is more efficient in biogas production during different months of the year as compared to the Deenbandhu biogas plant. Solanki, J.N. (2009) concluded that novel biogas plant removed the deficiencies of existing plant and thus it proved an efficient as well as economic plant for the rural development. This Biogas plant not only provided efficient fuel for cooking, lighting and helped to generate motive power, but also gave good organic manure, which was rich in nitrogen, humus and other micronutrients. Ravikrishna (2014) tested biogas-fuelled genset prototypes for low power applications (less than 1 kW) driven by small engines.

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The overall efficiency (chemical-to-electrical) of the genset of 600 watt was around 19%. Ajaga *et al.,* 2016 studied the impact of various factors affecting the use of biogas in a modified gasoline generator of 1.5 kW capacity. The biogas fuel consumption was 3.6 m3/h. The maximum power output was 0.91 kW giving a power drop of 39%. The maximum overall efficiency of biogas fuelled generator set was 15%. NOx and Co emissions were 742 and 30 ppm, respectively. Kaur *et al.,* 2017 developed fixed dome biogas plant for thermophilic conditions to enhance the biogas yield. For fixed dome biogas plant of 10 m3 capacity active, slurry volume was 38.36 m3. The dome height and dome radius were 0.72 and 4.03 m, respectively. Siddhu (2012) evaluated fixed dome biogas plant for biogas production and reported that maximum volume of biogas production was 15.042 m3 on daily basis whereas minimum volume of biogas produced on daily basis was 2.16 m3. The maximum pressure inside the biogas plant was 193 milli-bar and minimum pressure inside the biogas plant was 30 mmilli-bar. Namasivayam and Yamuna (1992) removed impurities like Congo red from the aqueous solutions in biogas waste slurry. After purification biogas could be utilized to run electric pumps, lighting up street lights and operating of chaff cutter *etc.*

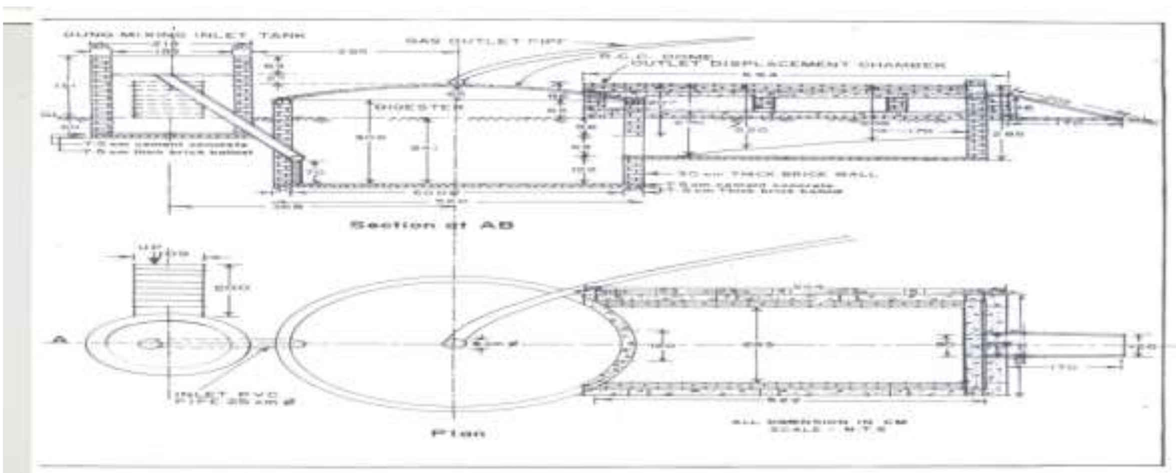
The study on solid state bio-methanization of organic waste, showed that this technology reduced digester volume, higher gas production, utilization of waste in their produce form, high organic loading rates, nutrient conservation in digested slurry, reduced water requirement and better digested slurry management (Kuchania *et al.,* 2000).Typical biogas contains 50-65% methane (CH4), 30-45% carbon dioxide (CO2), moisture and traces of hydrogen sulphide (H2S) and can be used for power generation through internal combustion engine. Reducing CO2 and H2S content will significantly improve engine performance. Different techniques such as water scrubbing system, pressure swing adsorption, chemical absorption method; cryogenic separation & membrane separation available for up gradation of the biogas are compared (Farooq *et al.,* 2012). Keeping in view, a biogas plant of 30 m3 (fixed dome) was planned for Shree Krishna Goshala Cuttack, Orissa to utilize the dung in biogas and generation of power from biogas for operating the irrigation pump, processing of feed, lighting *etc.* as Shree Krishna Goshala Cuttack, Orissa was paying huge amount of money for electric bill for operating the irrigation pump and chaff cutter and was getting energy shortage. Besides, handling of storage and disposal of huge quantity of dung of 1200 cattle in Goshala was also a major problem.

2. Materials and Methods

A fixed dome biogas plant of 30 m3 capacity was designed and constructed at Shree Gopal Krishna Goshala, Cuttack, Odisha under All India Co-ordinated Research Project on Energy in Agriculture and Agro-based Industries Centre at Indian Council of Agriculture Research-National Rice Research Institute, Cuttak in Public-Private-Partnership mode for power generation. The design details of biogas plant are described as under:

Design details of Biogas plant

The values of different design parameters and dimensions for 30 m3 (fixed dome type) biogas plant were calculated and depicted in Figure 1. The digging of pit and construction of digester for a big biogas plant needed a special technique in high water table regions to avoid soil slipping, particularly in sandy soil. The low ground water table (1.22 to 1.83 m) at constriction site created problem during construction of biogas plant. Therefore, sinking well procedure by making a RCC ring and then raising 25 cm thick brick wall on it in stages was followed. The design calculations are given below.



Determination of Diameter of digester

Gas yield per kg of fresh cow dung = 0.04 m^3
Gas production rate, G = 30 m^3/day
Hydraulic Retention time, HRT = 40 days
V = $V_{gs} + V_f$
V_{gs} = V_H
V_{gs} = 50% of daily gas yield

Gas holding capacity (gas storage chamber) of fixed dome of Janta biogas plant is 33% of their daily gas production capacity

Density of (fresh dung + water), p = 1100 kg/m^3 at 10% TSC
The weight of cow dung, W_1 = 750 kg/day
The weight of equal quantity of water, W_2 = 750 kg/day
Working volume of digester = $V_{gs} + V_f$

$$V_{gs} + V_f = \frac{(W1+W2) X\ HRT}{Density}$$

= (W_1 + W_2) kg/day x 40 days

= (750 + 750) kg/day x 40 days

= 60000/1100

= 54.54 m^3

Total volume of digester, V = $V_{gs} + V_f$ + 10% volume of working volume of digester

= 54.54 + 5.45

= 59.99 ~ 60.00 m^3

Height of digester, H

= 3.06 m (Adopted)

V

= $\pi r^2 H$ = 60.00

r

= 2.50 m

Diameter of the digester D = 5.00 m
Slurry displacement (V_{sd})
No. of hrs of gas utilization = 6 h/day

$$Vsd = 0.5G \frac{G}{24}\ x\ 6 +$$

V_{sd} = (0.5 x 30) - $\frac{6}{24}\ x\ 30$ = 7.50 m^3

Depth of slurry displacement inside the digester, (d)

$\frac{\pi}{4}D^2$ x d = Vsd

d = $\frac{7.50\ X\ 4}{\pi\ X\ D^2} = \frac{7.50\ X\ 4}{3.14 X 5.0 X 5.0}$

d = 0.38 m

Design of outlet tank

Volume of outlet tank is holding the slurry = 0.5G = V_{gs} = 50% of the daily gas yield

= $0.5\ X\ TS\ X\ gas\ production\ rate\ per\ kg\ TS$

= 0.5 x (750 x 0.16) x 0.28 m^3/kg TS = 16.8 m^3

Dummy volume above the overflowing level = 2.05 m^3
Total outlet volume = 18.85 m^3

Construction details of Biogas plant

The construction of the plant was done in following parts:

Digging of pit:

For 30 m^3 biogas plant, diameter and depth of digester was worked out 5.0 m and 3.06 m, respectively. The digging of pit and construction of digester for a big biogas plant was found difficult task for depth of plant of more than 152 cm and diameter of the pit of more than 2 m. The design was refined to avoid soil slipping particularly in sandy soil for larger diameter and depth. The low ground water table (10.16-15.24 cm) at constriction site created problem during construction of bio gas plant. Therefore, sinking well procedure by making a RCC ring and then raising 25 cm thick brick wall on it in stages was followed.

Construction of digester

After digging a pit of 122 cm depth, firstly an R C.C ring at the base of foundation was made. After this a brick wall of 25 cm thickness was constructed up to height of 90.44 cm, then construction work was stopped for 4 days, then digging of soil and removing of soil for 90.44 cm was done. After the cylindrical wall of the digester has been built up to height of 122 cm, an outlet gate opening of the size of 63 cm x 120 cm was provided for displacement of slurry from digester. The inlet of dung slurry was provided through 25 cm diameter plastic pipe. The bottom of this pipe is kept 70 cm above the foundation of digester. Water proof cement was used for panting of gas space. The digester form inside was plastered in 1:4 cement mortar. A 7.5 cm thick layer of cement concrete was laid at the floor of digester to check the water entering from bottom of the digester.

Construction of dome

The dome of the plant was constructed with Reinforced Cement Concrete. Shuttering Materials like wooden plank and bamboo was used for making platform. M.S. rod of 8 mm and 10 mm were used for making the net. Cement, sand and stone chips were mixed in the ratio of 1:2:4 and mortar were used for construction of dome. The thickness of dome was laid 10 cm. The entire dome was plastered from both sides. A galvanized iron pipe of 50 mm was provided at the top of dome for biogas outlet and gate valve was provided to control the flow of gas for use

Construction of dung mixing inlet tank

The dung mixing chamber was provided at the top of the inlet pipe. The PVC inlet pipe of 250 mm was laid at angle of 70° with the horizontal. The lower end of the pipe was kept at a height of 70 cm. The diameter and height of dung mixing chamber was kept 155 cm and 64 cm respectively. A 7.5 cm thick layer of concrete mix in the ratio of 1:3:6 were laid at the floor of mixing chamber.

Construction of outlet displacement chamber

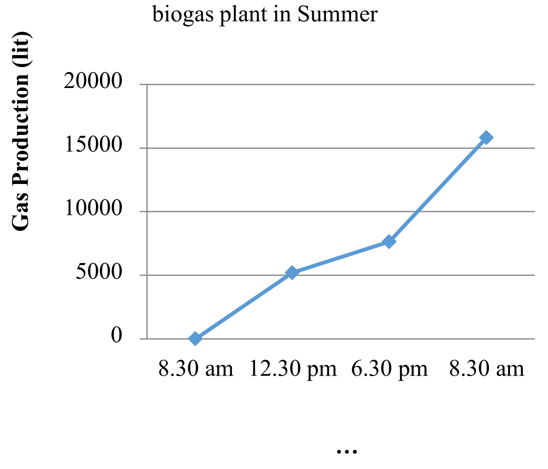
Outlet chamber having dimension of 482 x 283 x 272 cm was constructed for slurry disposal. The thickness of wall was kept 25 cm in brick masonry. The slurry outlet for final disposal to the slurry was constructed. The opening for slurry disposable was kept 80 x 25 cm in size. A free board of 15 cm was provided for displacement chamber. Plastering of outlet chamber was done from both sides.

3. Results & Discussions

Gas production was measured for 24 hours and presented in Figure 2. It is clear from figure that gas production rate was found more between 8.30 am to 6.30 pm whereas it was slightly less between 6.30 pm to 8.30 am. It might be due to bright sun shine hour during day time. Variation in biogas production is depicted in Table 1. The average daily gas production was 27,919 litres whereas maximum gas production was 28650 litres and minimum gas production was 26,671 litres. The minimum and maximum methane content ranged from 47.2 % to 55.0%, respectively. The maximum pressure generated was 80.0 milli-bar at full capacity of slurry formation. During testing voltage varied from 220 to 450 V and current varied between 5-8 amps. Power generated from biogas based engine was utilized to operate a chaff cutter (with electric motor 3.68 kW), submersible pump (with electric motor 1.47 kW) for irrigating the crops. Generated power was also used to illuminate 40 tube lights each of 40 W for 3.0 hrs. Biogas generator (7.5 kVA) consumed biogas @ 4.90 m^3/h. The total solids of the fresh cow dung and digested slurry were 21.82% and 11.30%, respectively indicating reduction of total solids of fresh cow dung by 48.21%.

The volatile solids content of the feed and digested slurry were 72% and 17.75%, respectively. The digested slurry gave TSC of 11.30%. It gets dried within six days. Therefore, digested slurry could be removed from the pits every 5 to 7 days interval. It is evident from Table-2 that the nitrogen, phosphorus and potassium content of slurry is more than fresh cow dung whereas organic content of slurry was found lesser as compared to fresh dung.

Figure 2. Average gas production in 30 cum biogas plant in Summer



Economics Analysis:

Economics of biogas based generation system was worked out. The saving in diesel for the generator was found to be 1.5 lit/h. By considering the cost of diesel and income received from the manure obtained from biogas plant, net saving obtained from the system is Rs. 437/day. It shows that the capital investment of Rs.5, 55,173/- retrieved in about 3 years. There were also incidental advantages of hygienic improvement, the absence of smoke in gas burning, convenience in burning and the increased richness of manure. Besides, biogas plant succeeded in reducing Green House Gases (GHGs) emission in the atmosphere.

Conclusions

The maximum gas production was recorded as 26671-28650 lit/day. liters per day whereas the minimum gas production was 26,671 litres per day for the daily loading of 750 kg of cattle dung. The minimum and maximum methane content was 47.2% and 55.0%, respectively and the average methane content was 49.7 This biogas plant saved 25% water as compared to indigenous design biogas plant. The payback period for the biogas based generation system installed was 3 years.

Table 1. Variation in biogas production

S. No.	Month	Average daily Biogas production (L)	Methane content (%)	Ambient Temperature (℃)	
				Maximum	Minimum
1.	February	26,671	47.2	36.4	23.3
2.	March	28,004	47.8	38.3	24.5
3.	April	28,351	48.9	39.0	25.7
4.	May	28,650	55.0	41.0	24.0

Table 2. Analysis of fresh cattle dung and digested slurry

S. No.	Component	Fresh Cattle dung (Input)	Digested slurry (Output)
1	pH	8.0	7.9
2.	Total solids conc. (%)	21.82	11.30
3.	Total volatile solids (%)	72.00	59.22
4.	Organic Carbon (%)	41.04	39.87
5.	Total nitrogen (%)	1.75	1.85
6.	Total phosphorus **(%)**	0.75	1.12
7.	Total potassium (%)	0.62	1.05

References

Abatzoglou, N., and Boivin, S., (2009). A review of biogas purification process. Biofuels Bioprod. Biorefining 3, 42–71. doi: 10.1002/bbb.117.

Ajaga, N., Ketuma, CT., Tangka, J.K., Vijoi, CT. 2016. Modeling of the operation of a small generator set powered by scrubbed biogas from cow dung. *British Journal of Applied Science & Technology*. 14(1), pp. 1-8.

Anmol Kumar, T.S.A. and Kumari, Surya. Production and Upgradation of Biogas. *Journal of Chemical and Pharmaceutical Sciences Special Issue* 5: October 2016 pp. 129-132.

Dadhich, H., "Application of Small Scale Decentralized Sources of Bio-energy for Rural Energy Security. Renewable Energy and Environment for Sustainable Development. Narosa Publishing House, New Delhi. pp 856-860.

De Hullu, J., Maassen, J.I.W., van Meel, P.A., Shazad, S., Vaessen, J.M.P., (2008). Comparing different biogas upgrading techniques. Eindhoven University of Technology, The Netherlands.

Farooq, M, Chaudhry, I.A., Hussain, S., Ramzan, N. and Ahmad, M., (2012). Biogas up gradation for power generation applications in Pakistan. Journal of Quality and Technology Management Volume VIII, Issue II, December 2012, Page 107–118.

Kalia, A. K., and Singh, S.P. (2004). Development of a Biogas Plant. Energy sources. 26(1) pp. 707-714.

Kaur, Harmanjot, Kumar, Sachin, and Sohpal Vipan Kumar, (2017). Designing of small scale fixed dome biogas digester for paddy straw. *International Journal of Renewable Energy Research.* 7(1): 423-431.

Kuchania, A.K., D.K. Vani and N. Ali (2008). Solid State Biomethanation of Organic Waste.
"Renewable Energy and Environment for sustainable development". (Editors: V.K. Vijay and H.P. Garg, IIT, Delhi), Narosa Publishing House New Delhi. pp 797-802.

Kumar, Anmol and Kumari, Surya T.S.A., (2016). Production and upgradation of Biogas. *Journal of Chemical and Pharmaceutical Sciences*. Special Issue. Pp 129-132.

Namasivayam, C. and Yamuna R.T., (1992) Removal of congo red from aqueous solutions by biogas waste slurry, *Journal of Chemical Technology and Bio-technology,* 53(2) pp. 153-157.

Ravikrishna, R.V. (2014). Development of Biogas genset Prototypes for very low power applications. *Journal of scientific and industrial research* 73(12): 781-785.

Siddhu, MAH,. (2012). Performance evaluation of a fixed dome bio-digester for biogas production. PIASA 130p.

Solanki, J.N. (2009). Novel Biogas Plant Design for the Rural Development. Renewable Energy and Environment for Sustainable Development. Narosa Publishing House, New Delhi. pp 803-809.

Singh, J.B., Myles. Raymond and Dhussa, Anil. Manual on Deenbandhu Biogas plant. Tata McGraw Hill Publishing Company Limited, New Delhi (1993).

Zhao, Q., Leonhardt, E., MacConnell, C., Frear, C. and S. Chen., (2010). Purification Technologies for Biogas Generated by Anaerobic Digestion. CSANR Research Report 2010 – 001.