A biogas plant for the digestion of fresh undiluted cattle dung

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This article describes how the popular fixed dome type family size biogas plant has been successfully modified to allow use of fresh undiluted cattle dung as substrate. A large number of family size biogas plants installed in the countryside in India use cattle dung diluted with an equal quantity of water as substrate. The biogas plant described below requires very little or no water for mixing with the cattle dung, and generates about 50% more biogas.

Un biodigesteur utilisant la bouse de vache
Le dôme fixe du biodigesteur familial a été modifié avec succès afin d'absorber de la bouse de vache fraîche et non diluée comme substrat. Une période de séchage d'environ 45 jours est requise afin que le produit de la digestion puisse être utilisé comme fertilisant. Le design modifié ne nécessite que de faibles quantités d'eau lors du mixage avec la bouse de vache, permet de produire une quantité supplémentaire de biogas pouvant atteindre jusqu 'à 50 % par rapport aux autres procédés. Par ailleurs son exploitation est plus facile alors que les coûts ne sont guère plus élevés.

Introduction

More than three million family-size biogas plants have so far been installed in the countryside in India under the National Programme on Biogas Development. These biogas plants use fresh cattle dung as substrate. The total solids content (TSC) of the fresh cattle dung normally varies between 15–19%. The dung is thoroughly mixed with an equal quantity of water producing a slurry with TSC of 8–10%, which is fed into the biogas plant.

The digested slurry discharged from these biogas units is watery. It contains 94–96% water (TSC 4–6%). The slurry is spread on to the ground or collected into open pits for drying, over a period of up to 45 days, to facilitate its transportation to the fields for use as manure.

Solid-state anaerobic fermentation of biomass

This process occurs at high TSC i.e. the substrate fed into the plant does not flow by itself. This method requires a much smaller quantity of water, makes handling of the digested slurry easier, utilizes a variety of agro-residues as substrate, and conserves nutrients in the digested slurry to provide an excellent manure for crop cultivation. The appearance of the biogas unit may be much cleaner than the common biogas plant and thus may help overcome the farmers' reluctance to locate the plants near their houses (Shyam, 2000).

For the past few years, the All India Co-ordinated Research Project on Renewable Sources of Energy (AICRP on RES) has been working for development of technically sound design(s) of family size biogas plant for solid- state anaerobic digestion of cattle dung and / or mixture of cattle dung and other agro-residues. The Haryana Agricultural University center of the AICRP on RES located at Hisar (around 150 km north-west of New Delhi) has successfully modified the popular fixed dome type biogas plant of 2 m3 capacity for digestion of cattle dung in its solid state. The fresh cattle dung, free from foreign matter, is fed straight into the modified plant.

Development sequence

Early work

A field scale digester for anaerobic digestion of undiluted cattle dung was developed by the Hisar Centre of the AICRP on RES during the late 1990s. The digester, which was charged daily, consisted of a metallic cylindrical drum of about 500 litre capacity, placed vertically on a tripod. The lower end of the drum was tapered to facilitate discharge of the digested dung, and was provided with a leak-proof lid of about 20 cm diameter. A feed inlet of about 30 cm diameter and a gas outlet port were affixed to the upper end of the drum. The digester was initially charged with approximately 340 kg of cattle dung mixed with 50 litres of fresh digested slurry, collected from a running biogas plant. Eight days after initial charging, 8–10 kg of the digested slurry was removed from the outlet and about 10 kg of fresh dung was charged into the inlet of the digester each day. An average gas yield of 35 litre / kg of fresh dung and 0.86 m3 / m3 of the digester volume were reported (Singh & Anand, 1994).

Later on, the digester was evaluated at Bhopal, and an average gas yield during the summer months was found to be much lower. It varied between 14.7–24.4 litre / kg of fresh dung and 0.4–0.5 m^3 / m^3 digester volume. Besides, difficulty was faced in removing the digested slurry from the outlet and charging the fresh cattle dung into the inlet. It was primarily because of the very slow movement of the cattle dung through the digester.

Unexpected findings

However, during the eighth week, after initial charging of the plant, the whole of the substrate in the digester rushed through the outlet as soon as the discharge lid was opened for routine effluent

Non-Theme

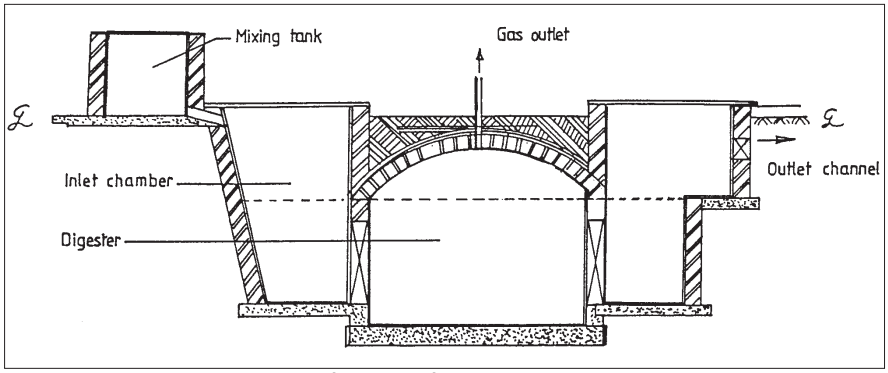

Figure 1 :Schematic of popular fixed dome type Janta biogas plant

Figure 2: Brick masonry hopper for feeding fresh cattle dung into the plant

Table 1:

Operational difficulties	*Remedial measures*
Very slow movement of the substrate (undiluted cattle dung) through the inlet pipe.	A brick masonry hopper was erected around the upper end of the feed pipe (Figure 2)
Digested slurry coming out from the outlet chamber did not flow through the narrow outlet channel. This is shown in the lower part of Figure 3	Outlet channel widened in the subsequent model, as shown in the upper part of Figure 3

Figure 3: Discharge pits of the modified plants: the top pit has an unaltered outlet channel – the lower pit has a channel which has been made wider

removal. This phenomenon was repeated during a second trial.

Further investigation under laboratory conditions was conducted on: the volumetric expansion of the substrate; the way the gas travels through the slurry; and the flow behaviour of cattle dung in solid-state fermentation.

It was found that during digestion, the soluble organic matter was converted to a gas, and the insoluble fibrous matter began dissolving, thereby reducing the viscosity of the fluid fraction. The flowability of the digested cattle dung was found to be slightly higher than that of fresh dung at similar solids concentration.

Thereafter, a 2m^3 capacity popular fixed dome type biogas plant (Figure 1) was modified for feeding undiluted cattle dung into the digester. The main modification was the replacement of the inlet feed chamber by a 20 cm diameter PVC pipe. The upper end of the pipe extends above the ground by about 1.2 m. The modified plant was evaluated using fresh undiluted cattle dung (TSC 16–18%). The operational difficulties encountered and remedial measures taken during the evaluation of the first modified plant are shown in Table 1.

To overcome these problems, a few more modifications were carried out in another 2m^3 capacity Janta biogas plant. The second modified plant has working satisfactorily for more than two years.

Plant description and operation

Modifications

The main modifications incorporated into the second 2 m^3 capacity Janta biogas plant design for solid-state digestion of cattle dung include:

The inlet feed chamber of the Janta plant has been replaced with a commercially available 30 cm diameter RCC pipe as against 20 cm pipe in the first unit.

The outlet slurry chamber has been enlarged to accommodate the total volume of slurry displaced from the digester. The step type construction of the outlet chamber of the Janta plant has been changed to an inclined smooth surface for streamlined flow of the digested slurry.

The outlet channel has been widened from 20 cm to 45 cm for self discharge of the digested slurry on to the ground.

The interior side of the gas dome has been provided with an additional layer of 1:1 cement-sand mortar plaster of about 8 mm thickness to withstand higher gas pressure.

The schematic diagrams of the common Janta biogas plant for

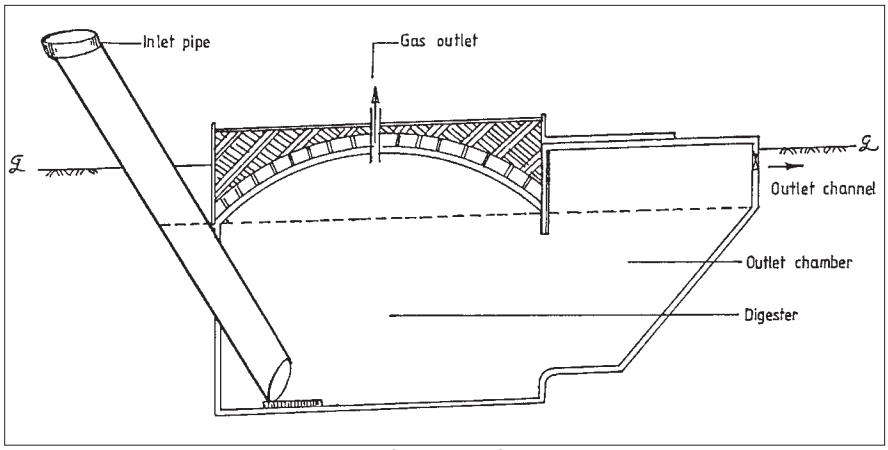

Figure 4: Schematic of the modified Janta biogas plant

Table 2 : Average performance of the popular and modified Janta biogas plants at Hisar*

Parameters	*Popular Janta plant*	*Modified plant for solid-state digestion*
Gas yield, 1/kg dry mass	134	205
Total solids degradation (%)	25	37
Volatile solids degradation (%)	35	49

* Weekly mean ambient temperature over the year normally varies between 9 – 35°C

digestion of diluted cattle dung and the modified Janta biogas plant for digestion of non-diluted cattle dung are shown in Figures 1 & 4.

Plant operation

The modified plant is initially charged as usual with a 1:1 mixture of cattle dung and water (TSC of the mixture 8–10%) along with the innoculum. This is the material that is used to start the digestion process, and fresh digested slurry collected from a working biogas plant is used as innoculum.

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Figure 5: Pouring fresh cattle dung straight into the feed pipe of the plant

Thereafter, the plant is fed every day with a mixture of 50 kg of cattle dung and 50 litres of water for a period of about two months. The operation of the plant gets stabilized during this period. The stabilised operation is indicated by a relatively uniform gas yield of 1500 to 2000 litre/day and a normal flow of well digested slurry through the plant and the outlet chamber / channel.

After the plant operation becomes stabilized, the substrate is changed to fresh undiluted cattle dung.

Every day, 50 kg of fresh cattle dung is poured into the inlet pipe of the modified Janta biogas plant (Figure 5). The dung should be free from foreign matter such as straw, grass, dust, etc and have TSC of less than 18%. (To determine whether the TSC is less than 18%, make a round ball of fresh cattle dung (diameter around 12.5 cm) and put it on a flat surface. If the ball does not retain its spherical shape, the dung is fit for feeding into the plant.)

If the TSC of the cattle dung available is more than 18%, it is brought down to around 16% by mixing with a measured quantity of water.

The cattle dung slowly slides into the digester under gravity and the digested slurry flows out through the outlet chamber into the outlet channel. Widening of the outlet channel from 20 cm to 45 cm facilitated flow of the digested slurry through the outlet channel under gravity (Figure 3).

The digested slurry, which has a TSC of 10–12%, can be transported to the fields every 2–6 days interval as required.

Cost of the plant

The cost of the modified plant has been estimated to be approximately the same as that of the common Janta biogas plant of 2 m^3 capacity.

Performance

The modified second plant has been working satisfactorily at the Hisar centre for the last two years. The average retention period for the modified Janta biogas plant works out to be100 days compared to 50 days for the common Janta biogas plant. The modified plant has performed far better than the Janta plant for diluted cow dung. Important parameters for the common and the modified plants are given in Table 2. The average gas yield for a period of more than a year has been found to be 50% greater for the modified plant than produced by the common Janta plant. Degradation of total solids and volatile solids in the dung have been found to be 40–48% higher in the modified plant. The quality of gas and manure is not affected.

Conclusion

Simple modifications have been carried out on the common fixed-dome type family-size Janta biogas plant for digestion of fresh undiluted cattle dung. No (or very little) water is required for mixing with the dung. The modified plant generates approximately 50% more biogas and makes the handling of both input slurry as well as the digested slurry far easier than the common biogas plant. The cost of the plant is almost the same as that of the common Janta plant. The technology holds great promise for anaerobic digestion of cattle dung, particularly in areas where water is scarce.

References

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Non-Theme