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# STUDIES ON BIOCONVERSION

## *Part IV.* On the Efficiency of "Bitumen–Drum" Made Portable Unit for Biogas Generation

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Efficiency of a unit fabricated from used bitumen drums for biogas generation was investigated with bufallo dung as feed material. It was observed that 8-10 % solid content and loading rate of 12 kg. bufallo dung feed per day yielded 0.037-0.0.39 $m^3$ gas/kg. bufallo dung in summer and 0.027-0.029 $m^3$ gas/kg. bufallo dung in winter with 33 % $CO_2$. This biogas unit has an advantage that it is portable, can be moved from place to place, low in cost, easy to construct, operate and clean and quite durable.

*Key words:* Portable unit, Biogas, Bufallo dung.

## INTRODUCTION

During R and D studies on biogas generation, different construction materials including a portable galvanized bitumen drums unit were tried. Efficiency of this portable unit for economical production of biogas was determined alongwith advantages and disadvantages of this design and construction material under local environmental condition.

## MATERIALS AND METHODS

*Biogas plant design.* Prototype of a portable used bitumen drums biogas plant of 23 cft. capacity with 20 cft. working capacity was fabricated in PCSIR laboratories, Karachi workshop. This is made by end to end welding together three or four used bitumen drums of 45 gallon capacity. A long barrel so obtined is closed at both ends, the length of this barrel may be adjusted according to requirement. This barrel is placed on stands to obtain a 15° slope. A funnel shaped feeding inlet is placed near the top, and the connecting pipe of the inlet is carried to nearly half the diameter of the drum. An out-let pipe 6" in diameter is fixed on the other end in a manner that its inside end is 2/3rd the depth of the slurry and outer end is nearly 5" to 6" below the highest point. An air space is thus created at the top of the barrel and collection of gas is possible at the outlet. Gas when produce from this chamber passes through the horizontal pipe fixed on the raised side of the digester into four metal gas holders, also made from used bitumen drums. Gas holders are connected in series and are so arranged that smaller size empty drums are inverted over the upright drums filled with water and, touching the surface of water. A battery of such holders may be made according to the production capacity of fermentation chamber and are interconnected to act as one holder. The upward movement of these inverted drums is restricted by welding 2 pipes to the side of lower drum and adjustable stoppers are attached to these pipes. These gas holders have total 28 cft. gas holding capacity (Fig. 1).

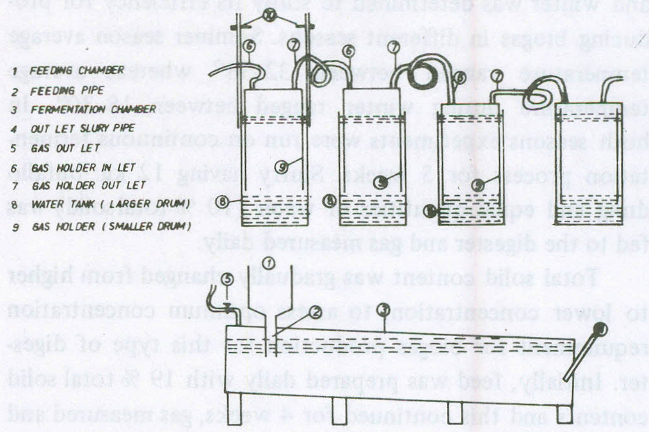


Fig. 1. Portable biogas unit fabricated from bitumen drums.

Bufallo dung from a nearby farm was collected and analyzed for pH, moisture, volatile solids, carbon and nitrogen values (Table 1) according to the standard methods [1]. Two hundred and fifty kg bufallo dung mixed

Table 1. Average analysis of cowdung and feed prepared for biogas generation.

| | Bufallo dung | Feed |
|---|---|---|
| pH | 7.3 | 7.5 |
| Moisture | 77% | 90.8 |
| Total solids | 23% | 9–10% |
| Volatile solids | 77% | 77% |
| Carbon | 43% | 44 |
| Nitrogen | 1.6 | 1.56 |
| C/N Value | 28 | 27.5 |
| Density | – | 1.08 |

with equal weight of water to form slurry was fed through funnel shaped inlet into the digester. Lime was added in sufficient quantity to adjust pH of the slurry to 7.5. The valves and opening of the digesters were checked to ensure complete anaerobic-conditions. Daily temperature and gas measurements were taken throughout the fermentation process. Gas produced was estimated by measuring the difference in level of drums and yield of gas calculated. Carbon dioxide was estimated by Orsat method [2] and methane by substracting the loss in volume of gas. Presence of methane was further confirmed by flammability test [3]. Negligible amount of $H_2S$ is generated when cowdung is used as feed hence it was not measured. Digester was initially run on batch type fermentation process and retention time of material and yields of gas/kg material was established. Biogas generation rate is expressed in terms of wet dung containing 77 % moisture.

Effect of temperature on biogas generation in summer and winter was determined to study its efficiency for producing biogas in different seasons. Summer season average temperature ranged between 32-38° whereas average temperature during winter ranged between 18-30°. In both seasons experiments were run on continuous fermentation process for 5 weeks. Slurry having 12 kg. bufallo dung and equal quantities of water (10 % totalsolid) was fed to the digester and gas measured daily.

Total solid content was gradually changed from higher to lower concentration, to assess optimum concentration requirement for biogas production for this type of digester. Initially, feed was prepared daily with 19 % total solid contents and this continued for 4 weeks, gas measured and analyzed daily. After the 4th week total solid concentration in feed was reduced to 14%, and later to 10 % in succeeding weeks.

Loading rate of feed was changed to optimize efficiency of the digester. Initially, 24 kg bufallo dung/day mixed with appropriate amount of water to give 10 % total solid content, was used. Later, keeping total solid content constant, quantity of bufallo dung was reduced to 20 kg, 16 kg, 12 kg, and 10 kg per day in succeeding weeks. All parameters were kept constant for four weeks before effecting any change.

## RESULTS AND DISCUSSIONS

Biogas generation was evaluated on portable digester, fabricated using empty bitumen drums, druing two summers and winters, each process lasting five weeks. During summer (Table 2) when average temperature ranged 32-38°, first sign of evolution of burnable gas was noted in 4-5 days after initial charging of the digester; retention time was observed as 21 days, and 0.037-0.039 $m^3$ total gas/kg wet dung, (77 % moisture), on an average 32.5 % carbon dioxide and 67.5 % methane was produced (i.e. about 0.025 $m^3$ methane kg/wet dung). Yield of total gas and methane, based on volatile solids added, was 0.20 $m^3$ and 0.14 $m^3$ respectively per kg material used. Volatile solid conversion rate was 46-48 %.

During winter, when average minimum – maximum temperature fluctuated between 18-30°, evolution of burnable gas was delayed till the 10th day, retention time increased to 28 days and yield of gas decreased to 0.027-0.028 $m^3$ total gas/kg wet dung (77 % moisture) with an average of 33 % carbon dioxide and 67 % methane (i.e. about 0.018 $m^3$ methane/kg wet dung). Based on volatile solids 0.16 $m^3$ total gas with 0.10 $m^3$ methane per kg material was calculated. Volatile solids conversion rate of 25 % was noted in winter.

In summer, compared to cement digesters [4] which produced 0.032 $m^3$ total gas per kg bufallo dung (77 % moisture) with 34-35 % carbon dioxide, yield from bitumen drum made digesters, was higher with less ratio of carbon dioxide. Construction material of digesters being metallic absorbed more heat and that too at a faster rate, thus rapidly heating the slurry inside the digester which attains a higher temperature; ideal to microbial activity and gas production. However, in winter, due to persistent low ambient temperatures for long hours (days are short), heat inside the digester remains low, this coupled with marked fluctuations in day and night temperature (difference of 10-12°) has an adverse effect on microbial activity thus

Table 2. Effect of temperature on biogas generation.

| | Summer | Winter |
|---|---|---|
| Average temperature | 32–38° | 18-30° |
| Burnable gas obtained in days | 4–5 | 9 10 |
| Retention time in days | 19–21 | 28-30 |
| Average yield of gas/kg wet bufaloo dung ($m^3$) | 0.037–.039 | 0.027–.029 |
| Average yield of methane/ kg wet bufallo dung ($m^3$) | 0.025 | 0.018 |
| Average yield of methane/kg dry volatile solids ($m^3$) | 0.14 | 0.13 |
| Volatile solid conversion % | 46–48 | 25.0 |

reducing gas yield. It is suggested that measures may be taken for preventing loss of heat and improving the conductivity of digester by insulating with mud or straws, or burrying the digester inside the ground. The yield will improve and will not fall drastically in winter.

*Effect of moisture content on biogas generation using portable digester.* Effect of total solid content on bitumen drum digester showed that 16-18 % and 12-14 % total solid content resulted in lower yield of biogas (Table 3), i.e.

Table 3. Effect of total solids concentration on biogas generation.

| | 1 | 2 | 3 |
|---|---|---|---|
| Bufallo dung per day (kg) | 12 | 12 | 12 |
| Total solid content of feed (%) | 16–18 | 12–14 | 8–10 |
| Total gas/kg wet bufallo dung ($m^3$) | 0.022–0.027 | 0.030–0.034 | 0.035–0.0338 |
| Methane/kg wet bufallo dung ($m^3$) | 0.014–.017 | 0.02–.023 | .024–.025 |
| Methane gas/kg dry volatile solid ($m^3$) | 0.079–0.096 | 0.113–0.130 | 0.135–0.14 |

0.022–027 and 0.030-0.034 $m^3$ total gas/kg wet bufallo dung respectively, whereas when digester was charged with 8-10 % total solids it yielded 0.035-0.037 $m^3$ total gas/kg. wet bufallo dung. Production of methane was also low, 0.014-0.017 and 0.02-0.023 $m^3$ gas/kg wet dung with high total solid content of 16-18 and 12-14 % respectively, as compared to 8-10 % total solid content which resulted in 0.024-0.025 methane/kg. wet dung. Yield based on volatile solids added showed methane gas production, 0.135-0.14 $m^3$/kg. dry material on experiments run with 8-10 % total solids. Subsequently it reduced to 0.113-0.136 and 0.079-096 as total solids content in feed increased. This indicated that as consistency of feed thickened, yield of gas/kg decreased. Concentration of 8-10 % total solid content of feed, therefore, was found to be suitable for fermentation using bitumen digester.

*Effect of loading rate of feed on efficiency of biogas digester and yield of gas.* Loading rate of feed/kg was gradually changed starting from 24, 20, 16, 12 and finally reaching to 10 kg bufallo dung (77 % moisture), maintaining 10 % total solid content. A period of 4 weeks elapsed before feeding the next batch of material. It was observed (Table 4) that as loading rate in terms of bufallo dung and volatile solids decreased, yield of gas/kg wet bufallo dung as well as per kg volatile solids increased upto 12 kg.

Table 4. Effect of loading rate of feed on biogas generation.

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Bufallo dung per day (kg) | 24 | 20 | 16 | 12 | 10 |
| Volatile solids added (kg) | 4.25 | 3.5 | 2.8 | 2.1 | 1.8 |
| Total solid centent of feed (%) | 10 | 10 | 10 | 10 | 10 |
| Total gas produced per day ($m^3$) | 0.31 | 0.38 | 0.44 | 0.42 | 0.034 |
| Yield of total gas/ day/ kg wet bufallo dung ($m^3$) | 0.013 | 0.019 | 0.028 | 0.035 | 0.034 |
| Yield of total gas per day/kg dry volatile solids added ($m^3$) | 0.073 | 0.107 | 0.158 | 0.197 | 0.192 |
| Carbon dioxide % | 40 | 38.5 | 36 | 33 | 32.5-33 |
| Yield of methane/ kg dry volatile solid added ($m^3$) | 0.0438 | 0.065 | 0.10 | 0.13 | 0.13 |

bufallo dung (2.1 kg volatile solids)/day feed. Ten kg bufallo dung (1.8 kg volatile solids) feed yielded 0.034 $m^3$/kg total gas based on bufallo dung (77 % moisture) or 0.192 $m^3$/kg. volatile solids added. This yield was slightly less to that obtained from feed with 12 kg. bufallo dung. Since difference in operational efficiency of digester charged with 10 kg or 12 kg bufallo dung was about the same, optimum feed requirement of the bitumen digester was, therefore, established as 12 kg bufallo dung per day. Though 16 kg bufallo dung feed per day gave higher biogas yield (0.044 $m^3$ total gas/day), but ratio of carbon dioxide generated was also high (36 %), reducing methane content to 0.10 $m^3$/kg dry volatile solids. Carbon dioxide content increased at higher loading rate probably due to limited capacity of the digester, and 21 days retention time. Charging of higher feed resulted in incomplete conversion, and displacement of partially digested material from the outlet as fresh material was charged.

It may be concluded that bitumen drum digester of given capacity could operate efficiently at 8-10 % total solid content, with 12 kg bufallo dung (2.1 kg volatile solids content) per day at 21 days retention time in summer (32-38°) and at 28 days retentions time in winter (18°-30°) with 66-67 % yield of methane. This digester is simple in design, and easy to operate. It is portable and can be moved from place to place to the site of operation as desired. This has been a preliminary study on feasibility on the use of bitumen drum made portable digester for biogas generation. Cost of portable digester as described in this paper comes to be approximately Rs. 5000/-. Whereas a cement digester of equal capacity will cost Rs. 15,000/- Reduction in yield of gas in winter can be controlled by insulating the digester or providing heat from compost pile build around the digester.

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