

Operation of a Domestic Biogas Plant in an Urban Setting in a Developing Country-A Field Experience

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Editorial

The main source of fuel for cooking and other domestic applications in most developing countries (especially in sub-Saharan Africa) is fuel wood. This source of fuel is not only non-renewable but leads to deforestation and its attendant contribution to global warming. Coal and charcoal, which are also used where available, equally contributes to environmental problems. In countries like Nigeria where there is abundance of fossil fuel, cooking gas and kerosene are unfortunately hardly available and/or affordable to majority of the low income families that should rely on this source of fuel. Electricity supply is erratic and unreliable. Biogas therefore appears to be a credible alternative fuel for cooking and other purposes in such countries.

Biogas is a major product of anaerobic fermentation of biodegradable organic waste. It has a calorific value of about 22.4 MJ/m³ and contains about 50-60% methane. 30-45% carbon dioxide and a small percentage of hydrogen sulfide, hydrogen, carbon monoxide, ammonia, water vapour and mercaptans. The gas is useful as a fuel substitute for firewood, dung and agricultural residues as well as for petrol and diesel for electricity generation.

Biogas has been used extensively in the rural areas of such countries as India, China, etc. The gas is usually generated from family or community biogas plants using human and other domestic wastes as well as wastes from domestic animals as substrates. In an urban setting in a developing country like Nigeria, the story may not be the same.

One of the characteristics of an urban setting is that the household size is relatively small compared to the rural areas where extended families usually form part of the household. In the case of developing countries, another characteristic is that utility supplies are hardly adequate. Water supply, in particular, is usually a problem implying that having enough water to flush toilets properly as soon as they are used is often a challenge. Often toilets are flushed by pouring a bucket of water into it. This inefficient way of flushing toilets often results in build-up of plaques which necessitates that the toilets be cleaned frequently with detergents and other such chemical to avoid health hazards. Despite these seeming challenges, a domestic biogas plant was set up in Abakaliki, South East Nigeria for the purpose of producing gas for cooking.

The residential building to which the plant was attached (Figure 1) already had an existing septic tank and soak-away system. It is a two storey building (2 floors) and has a total of nine toilets. Due to limited space, however, three of the toilets could not be connected to the biogas plant. The household size is six persons including some four children, 5-14 years of age. There was also some three domestic staff who were not residing in the building but use the guest toilets as the need arose during the day. The existing plumbing facilities had to be modified to accommodate the biogas facility.

The biogas reactor is of the Chinese type with a volume of about 6.28 m³. The reactor was made of 150 mm thick concrete reinforced with 12 mm diameter steel bars. The inside of the reactor was painted with three layers of cement slurry to ensure that the reactor remained

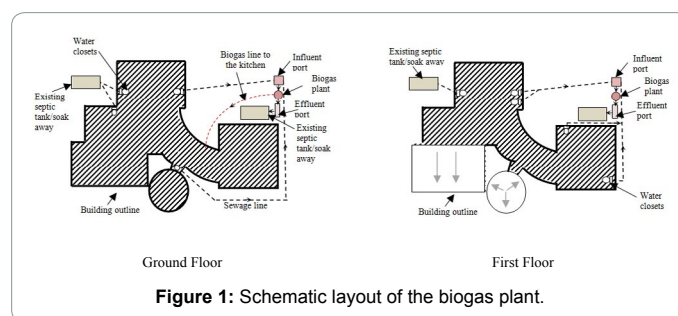


Figure 1: Schematic layout of the biogas plant.

gas tight. The sewage from the toilets was piped to the influent port of the biogas plant while wastewater from the baths/shower (where a lot of soaps and detergents are used) was piped directly into the septic tank without passing through the biogas reactor. The effluent from the reactor was discharged into the already existing septic tank/soak away.

The gas pipeline from the top of the reactor was made to pass through a small manhole in which a bleeding point was provided to remove any condensed water vapour from the biogas whenever necessary. The gas was first passed through a scrubber to remove some of the hydrogen sulphide and CO₂ before connection to the gas cooker. The nozzles of the gas cooker are slightly modified taking into consideration the fact that biogas is not as efficient as pure methane. A pressure gauge connected on the gas pipeline was used to monitor the gas pressure in the digester. A part of the gas was piped to provide two gas light points—one in front of the kitchen and the other in sit-out upstairs.

In starting up the biogas plant, the reactor was loaded with seed materials consisting of some quantity of poultry manure mixed with water. The reactor was filled until both the inlet and effluent ports were submerged in the liquid substrate. The digester was then sealed by covering it with a concrete slab shaped in the form of a male cone frustum which fitted into an identical female conical hole at the top of the reactor. A paste of fine clay soil was placed in between the mating surfaces to provide a gas tight seal. A pan-shaped top of the reactor above the conical cover was kept constantly filled with water to keep the clay wet and prevent it from caking. This ensured that the seal remained gas tight.

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Received July 17, 2017; Accepted July 18, 2017; Published July 25, 2017

Citation: Echiegu EA (2017) Operation of a Domestic Biogas Plant in an Urban Setting in a Developing Country-A Field Experience. J Fundam Renewable Energy Appl 7: e117. doi:10.4172/20904541.1000e117

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Within a day after the start-up of the digester, biogas production was noticed as evidenced by the reading on the gas meter. Before the end of the second day gas production was at its peak with a pressure of 10 kPa recorded. The gas produced was enough to meet the cooking and other domestic needs of the household especially during the early days of operation of the biogas reactor. However some challenges were encountered later.

First, after the initial period, it soon became apparent that the household was not producing enough waste to feed the reactor for efficient performance as the gas pressure rose and fell in response to the availability of substrate, i.e., the quantity of waste produced. This necessitated the need to import some wastes, notably poultry manure, from a neighbouring farm. Even though this appeared to solve the problem, the cost of buying and transporting the poultry manure to the biogas plant seemed to outweigh the benefits. Besides it became apparent that if this is to continue, the need for evacuating the septic tank at relatively short intervals would soon arise as the waste disposal system would have been filling up very frequently. This is an additional cost.

Secondly water supply was a challenge in the household as it relied on an inefficient borehole sunk within the compound. The implication was that flushing of the toilets was not efficiently done necessitating the need for regular washing of the toilets with detergents and other cleaning agent. Unfortunately this was rightly noticed to inhibit the anaerobic bacteria responsible for the production of the biogas, with the result that gas production ceased instantly as soon the toilets were washed with detergents. These two challenges were enough to discontinue the operation of the plant for now until solutions to them can be found.

With these experiences, it would appear that biogas production may not be a viable option for energy production in low density residential urban areas in developing countries unless the inhibition of anaerobes by detergents can be effectively controlled. In the rural areas where ventilated pit (VIP) toilets are very common and where the size of households is relatively large, it is a very good option. Perhaps this explains why it is so viable and very common in the rural areas of India and China. Biogas production is also a very viable option in such settings as schools, hotels, markets, etc. where copious amount of human wastes are produced. This will, of course, be if the problem of chemical inhabitation of the anaerobes can be adequately solved. In such setting, the gas produced can be used for cooking for the students/occupants, as fuel for internal combustion engines for the generation of electricity or for powering absorption refrigerators for storage of perishables in rural markets [1-3].

Biogas production and utilization is also very ideal in livestock farms especially piggery and poultry farms. The quantity of waste produced in such farm is copious and so the problem of insufficient substrate availability does not arise. Although some chemical disinfectants and additives may be used in such farms, the quantity is usually not enough to pose the kind of problem discussed earlier. In such plant set up in a pig farm at Abakaliki, Nigeria, the gas generated is used for lighting the farm and as fuel for food preparation by the farm household.

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