Sustainable Management of Animal Waste in a Rural Setting in India

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Abstract - ***For centuries rural people in India have used animal waste as a source of biogas to be used for cooking purposes. The animal waste is usually shaped into cakes and dried in the open before use. However, this practice has both aesthetic and environmental issues. The open handling and drying of the cakes do not present an aesthetic view of the otherwise green land. Children are often exposed to these wastes that can expose them to diseases. In the rainy season, the water washes away the animal waste and guides it to the river or other water bodies and contaminates the water. This water is often the primary source of potable water. Even the energy obtained from the cakes is not sufficient enough for one family's cooking needs. This leads to additional requirement of expensive gas cylinders. However, families under the poverty line cannot afford gas cylinders and often fall short of gas. This study looks into the suitability, in terms of environmental, social and economic point of view, of a twelve-year old biogas plant in Akhbarpur, a village of Punjab, India, which has continuously provided cooking gas to a family of thirteen members. In addition to studying the technical requirements and present conditions, the owners of the biogas plant were interviewed to determine the effectiveness of the process from a social point of view. A cost analysis of the project determined a payback period of less than three years. This low-tech technology was found to be effective in providing sustainable source of energy in a small community. It was found that the main factor hindering the growth of such a project in a village community was mainly the lack of knowledge and personnel to handle the collection of animal waste and operation of the process. Lack of incentives from the government in the form of environmental credits was also determined to reduce the acceptability of the project.***

Key Words: *Animal waste, Sustainability, Biogas, Rural waste management*

1. INTRODUCTION

A common practice in rural areas of India is the use of animal waste as a source of biogas to be used primarily for cooking purposes. The animal waste is usually collected at the end of the day, shaped into cakes and then left under the sun for drying for at least 15 days in the summer and 30 days in winter on the walls of the houses. This act does not appeal to the eyes, is unhygienic and may the spread of diseases in addition to the practice being environmentally unfriendly at the same time. According to World Health Organization, about 1.6 million people, mostly women and children, die each year due to cooking and heating with wood, dung, coal or crop waste [1]. When it rains these cakes are usually destroyed which means there may not be a cooking gas source to prepare the food. Apart from loss of the heat source, the washed away cakes move towards the nearby lake or river and contaminate the water body. This contamination has major impacts on human health as the water bodies are normally used directly without any treatment. In addition to the cakes, twigs were also used to ignite the fire and then spread it to the cakes to maintain the temperature required for cooking. Besides supplying energy and manure, biogas technology provides an excellent opportunity for mitigation of greenhouse gas (GHG) emission and reducing global warming through substituting firewood for cooking, kerosene for lighting and cooking and chemical fertilizers [2]. A study produced by AGAMA energy in 2008 concluded that at least 9.5% of South Africa's rural houses are viable to produce biogas and take part in a rural biogas program. In other words, 310,000 houses in South Africa produce enough plant or animal waste to feed and run a bio digester [3]. In addition, UAE can also create biogas using animal waste. UAE has a great number of camel and sheep on its land.

Production of biogas requires anaerobic condition where methanogenic bacteria can act on plant waste or animal dung. Biogas is a mixture of gases and primarily consists of 50-70% methane (CH_4), 30-40% carbon dioxide (CO_2), 5-10% hydrogen (H_2) with low concentrations of nitrogen (N_2), traces of water vapor and hydrogen sulfide (H_2S). The methane production usually involves three stages, as follows: (1) Hydrolysis – breaking down of large molecules to sugars, amino acids and fatty acids by hydrolytic and fermentative aerobic bacteria, (2) Acetogenesis – conversion of sugars into short-chain acids, namely acetic acid, and (3) Methanogenesis – conversion of acids to methane by anaerobic bacteria [4]. Using the biogas technology can result in a smoke-free as well as ash-free kitchen. This eliminates the suffering of women and children from the pollution in the developing countries [2]. Biogas can replace the costly firewood and also provide a clean and easily controlled source of renewable energy produced from organic waste materials [5]. Biogas, being flammable, can produce approximately 600 BTU per cubic foot of heat which is relatively low when compared to pure methane (995 BTU per cubic foot). In addition to animal and plant waste, bio digesters can also be fed with municipal waste. This capability of biogas systems can substantially reduce the potential environmental pollution as municipal is a major source of pollution. The key reason for a biogas plant to be a successful project in a rural setting is because the major raw materials – animal and plant waste – are abundant. It saves the people from price and supply fluctuations of convention fuels and fertilizers [4]. Table 1 summarizes some of the potential uses of the biogas and examples of biogas use around the world.

Table -1: Potential uses of biogas

Location	Uses
Pakistan	Pakistan is a house to 168 million animals producing 652 million kg of manure daily, which can generate 16.3 million ton m^3 per day and 21 million ton of bio fertilizer per year. This production can compensate for 20% of nitrogen and 66% of phosphorus used in the fields. According to a report in *The Financial Daily*, a reasonable sized biogas programme, say 100,000 plants per year can generate a direct employment of 50,000 workers. Almost $905 per year can be saved by a biogas plant of $10m^3$ size instead of spending for the fuel [5].
Zalaegerszeg, Hungary	The first eco-friendly bus of the public transport company entered on 27 June, 2012. The bus was driven on biomethane from the sewage treatment plant. This is a step towards turning Zalaegerszeg into a sustainable town [5].
Turku, Finland	The country has been using biogas in public transport vehicles. The goal is to make the bus transport as environmentally friendly as possible [5].
Delhi, India	The city plants to run the buses on biogas collected from sewage treatment plant. With the help of the Swedish government, the Union Ministry of New and Renewable Energy plans to set up a biogas plant within Kesopur Sewage Treatment Plant (STP) in West Delhi [5].
Kerala, India	In 2002, unwanted food waste and other organic waste were used to produce gas for cooking and, in some cases, to produce electricity. This biogas programme was initiated by BIOTECH, for domestic use as well as for schools and hostels and larger municipal sites. BIOTECH built and installed 12,000 domestic plants, 220 institutional plants and 17 municipal plants that use waste from municipal fish markets to produce biogas which is then used in a 3kw engine to generate electricity for lighting the market [6].

2. OBJECTIVES

The objective of the study was to determine the effectiveness and social acceptance of a small septic tank biogas plant in rural India that has been in operation using animal waste to produce biogas for domestic use and fertilizer.

3. METHODOLOGY

3.1 BIOGAS PLANT

In this study a home-based biogas plant was investigated. The plant is situated in the village of Akhbarpur, Punjab, India. For initiating the plant, cow manure from nearby barn was transported in trucks and dumped into the tanks after mixing with water. The septic tank is illustrated in Fig -1 and Fig -2. The tank was designed with two chambers with the intention of having one of the chambers act as an overflow chamber if needed. Each chamber is buried 8ft into the ground and has a diameter of 8ft. In the ten years of operation the tank has not been cleaned of the residue sludge as there has not been a need for it. The biogas produced in the tank is transferred directly to gas burners that operate non-stop until the biogas is exhausted.

3.2 ANIMAL WASTE

Domestic cow manure is added to the tank on a daily basis. Since the initiation animal waste from four cows has been enough to run the plant effectively. The tank has been in operation non-stop for eight years. The manure is collected as soon as possible to reduce contamination with leaves and sand. This quick collection also allows keeping the cattle hoofs clean. The manure is first mixed with water in a tank. The amount of water added is based on the ability to easily mix the manure to produce workable slurry. Although not accurately measured, the rough estimate is to have a water to sludge ratio of 1:2 in terms of volume. The manure holding tank also serves as a vessel to separate grass and other solid wastes from the diluted manure slurry. The manure slurry is then added to the septic tank.

Fig -1: Septic tank investigated in the study

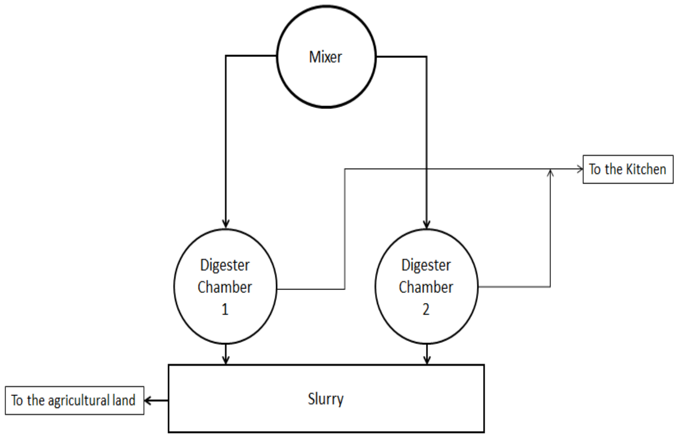

Fig -2: Sketch of the biogas plant

3.3 PRODUCTION OF BIOGAS

At the study site methane is generally produced after four days and is directly transported to the kitchen via pipes made of steel or polypropylene pipes (PPR). The produced biogas is primarily used for cooking. After the anaerobic digestion of the waste the sludge/slurry moves into a cement tank. The slurry, which is a byproduct of biogas plant, serves as manure for the surrounding fields due to its high fertilizer value Fig -3. Anaerobic digestion of the sludge releases greater amount of phosphate into the slurry. Currently, the slurry is used in conjunction to and act as a substitute to chemical fertilizers for supplying nitrogen, phosphate and potassium [2]. During the digestion process, nitrogen in the organic matter is converted to ammonium. Ammonium is readily accepted by the soil and is absorbed by plants slowly. This form is more stable when plowed into the soil, unlike nitrogen that oxidizes into nitrates and nitrites which do not get absorbed by the plants and are readily washed away.

Fig -3: Production of manure slurry

4. RESULTS AND DISCUSSIONS

The anaerobic treatment of animal waste in a simple setup as shown in this study not only provides an environmentally friendly method of waste disposal, but also minimizes the household cost of cooking gas. It avoids the accumulation of animal waste in the surrounding areas. If the area around the plant is kept clean then it protects from the disease causing germs and helps maintain the hygiene. The status quo of preparing cow dung cakes as a source of cooking gas is unhygienic and can lead to spreading of diseases. In addition, the production and use of the cakes is limited during the rainy season and need more time to dry in winters. On the other hand, a biogas set up works effectively throughout the year.

The biogas plant studied in this report provides medium intensity heat for cooking and requires minimal maintenance after every 15 years. Although sufficient gas may not be produced from the biogas plant at all times, it is possible to reduce the need for gas cylinder source of cooking gas. Although the act of collecting and mixing of the waste for the biogas plant may be nauseating and involves manual work, it is more environmentally friendly that the current method of making cow dung cakes. Moreover, with minimal knowledge, acceptance and guidance it is not difficult to operate the plant.

5. COST ANALYSIS

The initial cost of constructing the plant in Akhbarpur was about $550 (INR 35,000). Although the initial cost of constructing the biogas plant and laying the pipes is high, it is possible to have a low pay back period. On an average the cost of 1 gas cylinder is $8 (INR 460) and an average household with 10 members uses approximately 3 cylinders per month (pers. comm. Mr. Bhupinder Singh). On a conservative side it is possible to get a return on investment within 3 years of actual operation of the plant. However, this 3-year count excludes the money saved on chemical fertilizers by using the phosphate-rich sludge from the In addition to the direct cost savings, it is important to remember that this method of reusing and recycling a waste provides environmental benefits that cannot always be measured monetarily.

6. SOCIAL ACCEPTANCE OF A BIOGAS PLANT

Residents of the village surrounding the biogas plant were interviewed on their views about setting up a biogas plant in/near their village. It was found that the villagers had little or no knowledge about a biogas plant. Upon enlightening them of the process, the main issue to the surveyed people was the initial capital investment. One of the roadblocks to implementing a biogas plant in their opinion was the need to receive an immediate profit. In addition, environmental sustainability and unhygienic practices did not pose an important driver due to the lack of education and knowledge. Another issue that people surveyed faced was the lack of land and space to construct a septic tank. However, a suggestion was made to construct a semi-centralized plant that would collect the waste from nearby houses and provide them with gas. This may work as it could arrange for employment and also could act as an incentive for the villagers. This suggestion was more acceptable to the local people.

7. ADVANTAGES OF BIOGAS TECHNOLOGY

Biogas production can serve as an important source of heat for various purposes [7]. Apart from serving as a source of heat, biogas systems offer to manage waste, be it animal waste or municipal. These systems have the ability to destroy bacteria and parasitic eggs in human and animal waste materials so as to be applied to the crops safely. The resulting slurry from the anaerobic process is rich in nitrogen, phosphorus, calcium and potassium. These chemicals have high nutrient value and most can be recovered through precipitation processes. One such precipitate is struvite (magnesium ammonium phosphate, $MgNH_4PO_4$). Struvite can be used to recover nitrogen and phosphorus through crystallization process by adding magnesium to it. Struvite is known to be a good slow-release fertilizer that is free from bacteria and contains lower heavy metals than typical chemical fertilizers [8]. The slower nutrient leaching loss and its fertilizer quality make struvite an eco-friendly fertilizer [9].

To make it safer for the plant growth and quality, biogas technology is capable of destroying the bacteria and parasitic eggs available in animal and human waste. Biogas systems can almost completely eradicate hookworm eggs and blood flukes and can kill as much as 30-90% of roundworms and pinworms [7].

8. CONCLUSIONS

The study found that the biogas plant has been operating efficiently without any problems for a long time. Due to the age of the plant and the continuous operations is possible that minimum maintenance of the pipes is required in the next few years. An economic analysis of the plant suggests that a payback period of 3 years or less is usually practical depending on the size of the operation. Among the various responses from the interviewees, the one fact that stood out was the lack of knowledge about the outcomes of treating and reusing of animal waste. Without the knowledge of the benefits of treating animal waste, there was a lack of enthusiasm to look forward for a change in the status quo with respect to handling of animal waste.

This method is environmental friendly, pocket friendly and keeps the society satisfied. This method provides cooking gas and fertilizers and saves the waste from being dumped into the landfill where it may cause harm to human health.

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