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ORIGINAL ARTICLE

PROSPECTS OF DRY ANAEROBIC DIGESTION OF ORGANIC SOLID WASTES FOR BIOGAS PRODUCTION IN NEPAL

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ABSTRACT: As wet methane fermentation process has only been utilized till now for the treatment of cattle manure to produce biogas in Nepal, the further dissemination of biogas can be fueled by providing solutions to the technical problems including unavailability of water source, scarcity of the space near to house, flow of liquid digestate and handling of slurry to the farm. Dry methane fermentation process is a prosperous and future technology for efficient biogas production with remarkable benefits including stabilization of the organic solid wastes in its produced form, no requirement of liquid source, high organic loading rate, smaller fermenter, no liquid effluent, and no requirement of purification of the effluent. Although it has not been used so far in Nepal, it would be a promising excellent alternative to the conventional wet methane fermentation process to treat cattle manure and other biodegradable materials. The existing technology (Fixed dome type biogas fermenter) can also be used for the dry methane fermentation process in Nepal with minor modifications by increasing the diameter of inlet feeding pipe and enlarging outlet chamber.

KEYWORDS: Dry Fermentation Process, Methane, Organic Solid Waste, Modified Fixed Dome Biogas Digester

INTRODUCTION

The manures and other organic solid wastes require to be managed in an economical and sustainable way in Nepal to avoid depletion of natural resources, minimize risk to human health, reduce environmental burdens and maintain an overall balance in the ecosystem (Jha and Jha, 2010). The increasing demand for renewable energy renders methane fermentation process to one of the most promising technology for green energy production. Anaerobic fermentation treatment is a cost effective, efficient and feasible process to decompose organic materials into two categories of valuable products by a various groups of microorganisms under oxygen-free conditions and solve multifaceted waste problems (Jingura and Rutendo, 2009; Li *et al.*, 2011; Lema and Omil, 2001). One of them is the biogas with rich in methane content and can further be used to produce green electricity, heat or as engine fuel whereas the other one is the digested substrate, nutrient-rich organic fertilizer (Jha *et al.*, 2013). Based on solid contents, fermentation processes are classified into wet and dry fermentation processes. Though wet methane fermentation process of manure and other organic wastes has been extensively used and well known technology (Jingura and Rutendo, 2009), there are some notable bottlenecks with the process including larger digester size, low organic loading rate, requirement of liquid source, and slurry handling problem (Jha *et al.*, 2011).

Dry methane fermentation process is used as a feasible and effective waste-stabilization method to convert a variety of solid bio-waste into renewable energy with production of nutrient rich organic fertilizer without dilution or using limited amount of water. However, dry methane fermentation process has attracted increasing attention all around the world recently; this technology has not been applied in Nepal. The technical challenges for further dissemination of biogas and prospects of dry methane fermentation in Nepal have been presented in this paper. The modification in the existing fixed dome type model for dry anaerobic digestion has been discussed as well.

TECHNICAL BARRIERS FOR DISSEMINATION OF BIOGAS PLANTS IN NEPAL

Energy potential of urban solid waste, agricultural residues, animal wastes and other

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biomass materials in Nepal is quite large (Jha and Jha, 2010). Treating these biogas resources for energy recovery and sustainable waste management can help to solve energy crises, reduce consumption of fossil fuels, save currencies going to foreign countries, and reduce greenhouse gases emission, and decrease health and environmental impacts. Manure and other organic solid waste disposal has become a critical issue from the pollution control point of view. However, 268339 family sized biogas plants have been installed up to December, 2012 throughout the country (BSP-Nepal, 2013), there are several barriers in the development of biogas technologies in Nepal. The overall objective of the Biogas Support Program (BSP-Nepal) is to further develop and disseminate biogas plants as a mainstream renewable energy solution in rural Nepal, while better addressing poverty, social inclusion and regional balance issues and at the same time ensuring enhanced commercialization and sustainability of the sector. Besides socio-economic and policy constraints, some of technical barriers for dissemination of biogas plants in Nepal are listed as follows:

2.1. Lack of water source

As pointed earlier, wet fermentation process has only been utilized till now for the treatment of cattle manure to produce biogas in Nepal. As all the biogas plants in Nepal are wet anaerobic fermenters, water is needed to dilute cattle manure before feeding into the bioreactors (Jha and Jha, 2010; BSP-Nepal, 2012). Due to lack of water source, it is hard to get subsidy from Biogas Support Program (BSP-Nepal) in one side while farmers are not also interested to install the biogas plants because of leachate formation and slurry handling problem (NTES, 2008). This affects the biogas plants dissemination negatively.

2.2. Lack of land nearby house

As almost all the biogas plants in Nepal are house-hold type, farmers install near the kitchen such that the produced biogas is easily flown to the cooking stove. The houses, mainly in Terai-Madhesh (southern Nepal), are concentrated in limited area. The Terai-Madhesh is the most populous region in Nepal and has adequate atmospheric temperature for biogas production from organic wastes. Due to lack of the space, people are unable to install the biogas plants.

2.3. Formation of leachate

As the liquid slurry (TS: 4%-5%) from the digestate flow under and above ground, it pollutes the water source and consequently restricts the promotion of biogas plants in Nepal. It is observed that many insects are present near to biogas plants if the flow of effluents is not controlled properly.

2.4. Handling of slurry

It is hard to transport the digestate or composted slurry from wet anaerobic fermenter to the farm. The dewatering process will increase the cost and requirement of space.

2.5. Cold climate

Minimum fermenter temperatures must be maintained throughout the year for stable performance of a biogas plant. In winter, temperatures drop and affect biogas production in southern Nepal. In northern Nepal, the average temperature is below 20^{o}C. The biogas systems are not operating well.

2.6. Use of only cattle manure as feedstocks

Though many feasible feedstocks for biogas production are available in Nepal (Jha and Jha, 2010), almost all the biogas plants installed are based on cattle dung (BSP-Nepal, 2013) and/or night soil to provide gas for cooking and lighting for a single household. To further promote biogas in Nepal, it is necessary to use other biodegradable wastes as substrate or co-substrate for the biogas plants.

2.7. Lack of use of optimization techniques

Though the installation and operation of biogas plants in Nepal are satisfactory (BSP-Nepal, 2013), almost all the biogas plants are inefficient. The biogas production can be enhanced using optimization techniques like co-fermentation, use of proper inoculum, control of fermentation parameters, suitable reactor configuration, mixing and pretreatment etc. (Jha *et al.*, 2011).

BENEFITS OF DRY ANAEROBIC DIGESTION

Conventional wet anaerobic digestion system requires feed materials with total solids content below 10% while dry methane fermentation process can deal with above 10% total solids content in the feedstocks (Jha *et al.*, 2011). Both types of fermentation process rely on the same principles and processes to biodegrade organic matters. But the advantages of dry fermentation process when compared to liquid fermentation process are utilization of wastes in its produced form, compact fermenter with higher volumetric organic loading rate, lower energy requirements, reduced nutrient run off, lower production of leachate and easy handling of digested residues, limited environmental consequences and its energetically effective performance (Jha et al., 2011; Pavan et al., 2000). Moreover, dry methane fermentation process is considered as capable of producing higher methane production per m3 volume of the bioreactor (Jha et al., 2013). It would be more feasible for semiarid climates and places where no easy access of water (Köttner, 2002). As the comparable methane yields and organic materials removal are obtained in dry fermentation process of cow dung with the wet fermentation process at both mesophilic and thermophilic temperatures, it might be a promising substitute to the conventional process (Jha et al., 2013). In addition, no significant change in the quality of the biogas was detected increasing initial total solid of cow dung from 7.68% to 15.18%. The higher total solid of the dry-digestate (10.87%) makes not only the handing of the digestate easier but also lowers the requirement of space for composting. In contrast, wet fermentation process required larger reactor volume and higher energy to maintain the temperature of the reactor for the same loading rate. To sum up, several technical bottlenecks for dissemination of biogas plants in Nepal can be solved using dry anaerobic digestion process.

MODIFICATION IN DESIGN FOR DRY ANAEROBIC FERMENTER

The fixed dome type (Modified Chinese Model) family sized biogas plant is being used in Nepal (BSP-Nepal, 2013). As per its design, the concentration of feeding material should be around 8% in term of total solids. It can be modified to allow use of fresh undiluted cattle dung as substrate. Dry methane fermentation process occurs at high TS (>10%) 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 manure and other organic solid wastes as substrate, and conserves nutrients in the digested slurry to provide excellent manure for crop cultivation.

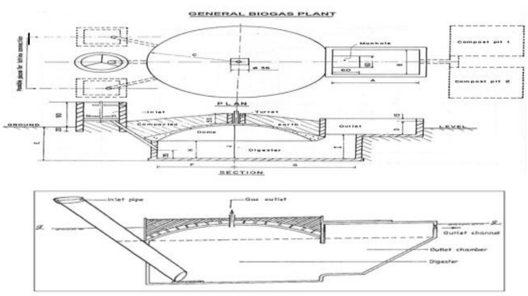

Figure 1: Existing and modified fixed dome type biogas plant.

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). But, difficulty is in removing the digested slurry from the outlet and charging the fresh cattle dung into the inlet because of the very slow movement of the cattle dung through the fermenter. These problems can be reduced using the inlet feed pipe with higher diameter. Moreover, the outlet slurry chamber is needed to enlarge for accommodating the total volume of slurry displaced from the fermenter. The step type construction of the outlet chamber of the plant will be changed to an inclined smooth surface for streamlined flow of the digested slurry. The substrates such as cattle dung and other organic solid wastes slowly slides into the fermenter under gravity and the digested slurry flows out through the outlet chamber into the outlet channel. Widening of the outlet channel facilitated flow of the digested slurry through the outlet channel under gravity (Figure 1). The digested slurry from dry fermenter using manures as substrate has generally total solid of 10%-12% (Jha et al., 2013), which can be transported to the fields directly or composted for further treatment. The cost of the modified plant has been estimated to be approximately the same as that of the conventional type wet anaerobic plant of the same capacity. The technology holds great promise for methane fermentation process of cattle dung and other wastes particularly in areas where water is scarce. As the researches on dry methane fermentation process of organic solid wastes and their mixtures in full scale plants will have great importance, the construction and operation of the full scale model plants in Nepal using above modification have practical significance to solve the technical problems for accelerating the further dissemination of biogas plants in the developing world.

CONCLUSIONS

Limited land near the house, scarcity of water source, cattle manure shortage, excess leachate formation and digested slurry handling are noted the major constraints in the southern Nepal, while low temperature, mainly in winter, and scarcity of water source in the middle and northern Nepal. It will be helpful in accelerating further dissemination of the biogas plants by providing solutions to the above problems using dry anaerobic digestion of organic solid waste. This technology has tremendous application in the future for sustainability of both environment and agriculture because recovering energy by dry methane fermentation process can help to solving energy crisis, diminish consumption of fossil fuels, mitigate health and environmental impacts. The existing technology (Fixed dome type biogas fermenter) can be used for the dry fermentation process as well with minor modifications by increasing the diameter of inlet feeding pipe and enlarging outlet chamber.

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