SOLAR BIOGAS DIGESTER

Kh S Karimov[a,b], Muhammad Abid[a]

ABSTRACT

Solar energy is utilized for heating of biogas digester in order to achieve the desired temperature and decrease the retention period. Both the passive and active methods are used. In the active method with forced convection, digester contains the separate solar collector connected by pipes with heat exchanger and pump. In this paper, design and investigation of biogas digester consisting of methane tank with built-in solar collector to utilize solar energy for the heating of the slurry prepared from the dung and heat exchanger are discussed in detail. The digester was laboratory type and consists of cylindrical metallic tank of size of 0.5 m in diameter; 1 m in height and 200 liters in volume. It s concluded that in the winter period, retention time of this digester is shorter and produced biogas volume is larger with respect of ordinary biogas digester. Based on the results achieved from this indigenous development locally, it may be used for the construction of large volume digesters for use in the farms, especially located in the remote and mountain areas where the climate in the winter period is cold.

INTRODUCTION

Energy is one of the most important factors for the development of the society. It is known that consuming energy is proportional to quality or standard of life. There is a close relationship between energy consumption and the Gross National Product (GNP). It is obvious that for further development of the country additional sources of energy is required, which are cheap, safe and environmentally compatible with respect to the action on possible wastes. Utilization of renewable energy is one route to help in solving the above mentioned problems. In particular, biogas as a source of renewable energy is produced by biotechnology and used wide on residential scale [1]. The biogas was produced for the very first time in 1814 by Deivi from organic wastes. In 1900 production of biogas was started in Bombay (India) [2, 3]. Biogas consists of 55-70% methane (CH_4) and around of 27-44% carbon dioxide (CO_2) and less than 1% H_2 and H_2S. At present biogas is used widely in some countries for lighting, machines, and vehicles, generators, cooking and heating. Biogas generation is suitable for small to large scale operation and at present is realized in a number of developed and developing countries as USA, Hungary, China, India etc. Since 1990s biogas projects construction in China has developed steadily by the end of 1998, there were altogether 6.88 million household biogas digesters [4]. In Russia biogas digesters are used for processing of hard dung into biogas [5]. Over the last few years the very first biogas digesters were constructed in Tajikistan as well [6,7] and it was found that the digesters can work with sufficiently high efficiency in mountain areas as well.

[a]GIK Institute of Engineering Sciences and Technology, Topi, Swabi

[b]Physical Technical Institute of Academy of Sciences, Tajikistan

Organic waste processing to biogas is favored by wet, warm and dark conditions. To maintain constant conditions of temperature, a suitable input material is a golden rule for successful digester operation. The anaerobic process reactions are slightly exothermic (a calorific value is about of 20 Mjouls/m^3). But producing heat is not sufficient to significantly affect the temperature of the bulk material. For heating of biomaterial solar energy is used in some digesters of laboratory (a bottle–type where a bioreactor has small volume) [8] or industrial type [9]. There are two methods of the heating of digester by solar energy i.e. passive and active [9]. In the case of passive heating, for example, the digester's body can absorb the solar energy as a receiver through a lid or dome. If an active method is used the digesters consist of two basic parts: solar collector and bioreactor (methane tank) connected through pipes, heat exchanger and pump. In the whole this system is more complicated and expensive. In this paper we report design of solar biogas digester (SBD) where the collector is built-in the digester, that makes the system cheaper, more compact and reliable in the work.

EXPERIMENTAL SETUP

Designed SBD is a laboratory or bottle-type digester and its schematic is shown in Fig.1. The SBD consists of cylindrical metallic tank of size of 0.5 m in diameter, 1 m in height and 200 liters in volume. The surface of the digester from outside was covered by thermo insulative material a glass wool, except of south side: this side played the role of built-in collector and was blackened to increase absorption of solar irradiation and covered under 45° by glass. In the blackened side of the digester on the different heights in the distance of 0.5 m metallic pipes of diameter 3mm were installed, duly connected with heat exchanger installed inside of the digester. The heat exchanger was fixed in the level above of the inlet pipe. For the production of the biogas, slurry was prepared with 50% of dung and 50% of water. The slurry was put into the digester up to the level of 70% of the height of digester. The heat exchanger was immersed in the slurry. The lid of the digester was fixed tightly. Usually after retention period digester starts production of biogas. As a reference it was used the same size ordinary biogas digester, i.e. without "built-in collector" and heat exchanger, and where body was covered from all sides by a glass wool. Experimentally the ambient temperature and temperature inside of the methane tank along with the volume of produced biogas at fixed pressure was measured. The volume of biogas was estimated by use of gas-holder that had two sections: with constant volume and elastic variable volume (total volume was 100-150 liters).

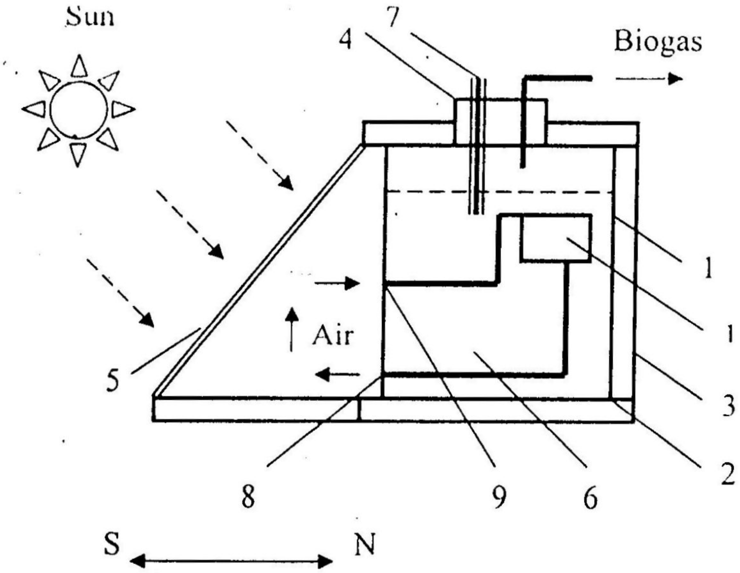

Figure 1: Solar Biogas Digester

Figure captions: 1- metallic methane tank, 2- glass wool . 3- aluminum foil, 4 –metallic lid with rubber tight, 5 – glass, 6 – slurry , 7 – thermometer, 8 - cold air outlet , 9 - warm air inlet, 10 – heat exchanger.

OPERATION

Solar beams are absorbed by blackened side surface of the digester. As a result, partly heat conduction occurs through southern wall of the digester and partly heating of surrounding air between glass and digester's wall. Due to convection, the warm air moves up to inlet, through pipes to heat exchanger and heats slurry. Cooled air moves down and through the pipes to outlet located near of the bottom and goes out to collector and again is heated. Here the natural convection takes place and no need to the pump as in active methods of heating [8, 9]. But unlike to simple passive methods of digester heating here the heat exchanger is used. At night, glass surface is covered by quilt to prevent losses of the heat. At hot days, where no need to heat by solar energy the glass covered by light color curtain to increase reflection of the light beams from the surface of the digester.

RESULTS AND DISCUSSIONS

The optimal temperature range for psicrophilic, mesophilic and thermophilic bacterias' growth and activity and biogas production is about 20°C, 35°C and 55°C respectively [1, 9]. In the winter period usually the average temperature in biogas digester is lowered that decreases rate of biogas production but increases the retention period. In the conditions of Dushanbe (Tajikistan) the average day-night ambient temperature is about of 0°C. The SBD worked continuously in winter period where there is need to use solar energy for heating of methane tank, but data were taken in day time from 10 a.m. to 2 p.m. (Table-1). Variations of ambient temperature in winter were in the interval of 5-15°C.

From the Table-1, it is seen that in the case of SBG the retention time is shorter and produced biogas volume is larger with respect to the biogas digester. It is probably due to the higher average temperature inside the methane tank in the case of SBG. The designed digester is cheaper as described in [8] bottle-type digester because in later case pump and separate collector of solar energy are used, though there temperature variation is less i.e. 40±1°C, due to the use of water-jackets around of bioreactor and precise control system. In construction of the solar biogas digester the scheme like Tromble-Michel wall is used [1, 9]; in which body of biogas digester plays the role of that wall. Heated by solar energy air by natural convection (without of pumping) through heat exchanger heats the biomaterial inside of the methane tank.

Table 1 – Experimental Data on Investigation of Solar Biogas Digester

	Temperature Range (°C)	Biogas Pressure (Bar)	Retention Period (day)	Produced Biogas (liter/day)
Solar Biogas Digester	25-35	0.1-0.2	25-30	100-150
Biogas Digester	20-30	0.1-0.2	30-35	90-120

CONCLUSIONS

The designed laboratory type solar biogas digester with built-in solar collector and heat exchanger, where natural convection is realized, has some advantages as compared to the conventional digester due to the shorter retention time (on 15%) and larger amount of produced biogas (in 20%). The digesters where solar energy is used for heating of the slurry by forced convection the designed one is cheaper and can work without of electric power supply for pumping. This digester may be used for demonstrative purposes and as a teaching aid. As digester's methane tank volume is small (200 liters), the obtained results may be used for the design of large volume digesters for use in the farms, especially located in the remote and mountain areas where the average temperature in the winter period is around of 0°C.

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