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BUILDING A LABORATORY-SCALE BIOGAS PLANT AND VERIFYING ITS FUNCTIONALITY

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Abstract

The paper deals with the process of building a laboratory-scale biogas plant and verifying its functionality. The laboratory-scale prototype was constructed in the Department of Safety and Environmental Engineering at the Faculty of Materials Science and Technology in Trnava, of the Slovak University of Technology. The Department has already built a solar laboratory to promote and utilise solar energy, and designed SETUR hydro engine. The laboratory is the next step in the Department's activities in the field of renewable energy sources and biomass. The Department is also involved in the European Union project, where the goal is to upgrade all existed renewable energy sources used in the Department.

Key words

biogas, laboratory-scale biogas plant

Introduction

Anaerobic digestion (AD) is the conversion of organic material directly to gas, termed biogas, a mixture of mainly methane (CH_4) and carbon dioxide (CO_2) with small quantities of other gases such as hydrogen sulphide (H_2S) (1), ammonia (NH_4), water vapour, hydrogen (H_2), nitrogen (N_2) etc.

AD is the process of decomposition of organic matter by a microbial consortium in an oxygen-free environment. It is a process found in many naturally occurring anoxic environments including watercourses, sediments, waterlogged soils and the mammalian gut (2).

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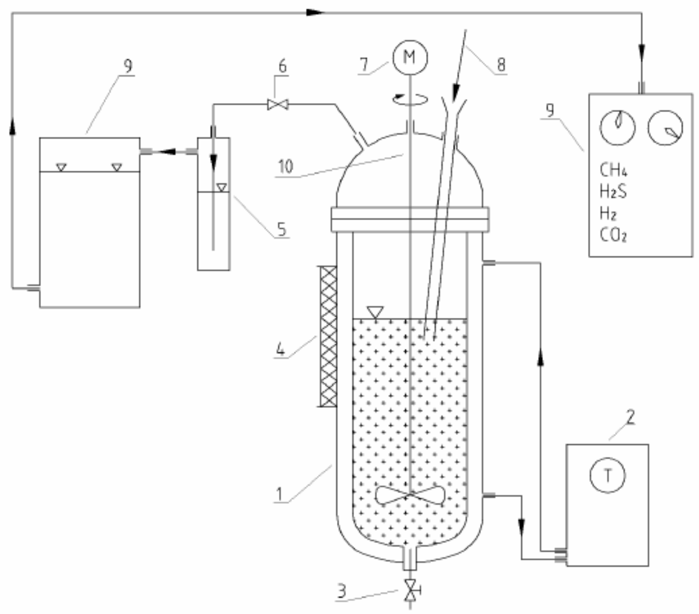
AD can also be applied to a wide range of feedstock including industrial and municipal waste waters, agricultural, municipal, food industry wastes, and plant residues. The production of biogas through anaerobic digestion offers significant advantages over other forms of waste treatment, including (2):

Materials and methodology

The Department of Safety and Environmental Engineering constructed a laboratory-scale biogas plant the scheme which can be seen in the following figures.



1-Bioreactor, 2-Thermostat, 3-Feedstock outlet, 4-Isolation, 5-Washer, 6- Permeable valve, 7-Engine, 8-Feeding, 9-Biogas analyzer, 10-Stirrer

Fig. 1 *Scheme of a biogas plant*

Fig. 2 *Picture of a real biogas plant*

Sewage sludge and kitchen wastes were used as feedstock. Sewage sludge did not have to be modified. Kitchen wastes were mixed.

Feeding and removing the material

The feeding of material to a bioreactor was performed by dosing syringe with the volume of 150 ml. Attached to the syringe was the hose with internal diameter of 7.75 mm. Feedstock was pumped to the hose and then dispensed through a plastic tube of internal diameter 18 mm and 450 mm length into the bioreactor. Plastic hose was installed through the rubber stopper which was inserted in one of the holes of glass cover (Fig. 3). The plastic tube was installed under the feedstock surface in the bioreactor to avoid bioreactor aeration.

***Fig. 3** Installed feeding tube*

***Fig. 4** Bioreactor outlet*

Removing the feedstock from the bioreactor was carried through the bioreactor outlet. The outlet was sealed with a rubber stopper into which a hole was drilled. A short glass tube with an attached short hose with tourniquet was inserted into the hole. (Fig. 4).

Bioreactor

The process of biogas production runs in bioreactor. The container had a volume of 3000 ml, with S40 as double outlet cover. The water circulated from the thermostat in double outlet cover. Constant temperature was maintained in the bioreactor. The volume of circulating water was 1.6 liters. Biogas process took place in the mesophilic phase at 37 ^{o}C. Bioreactor is shown in Fig. 5.

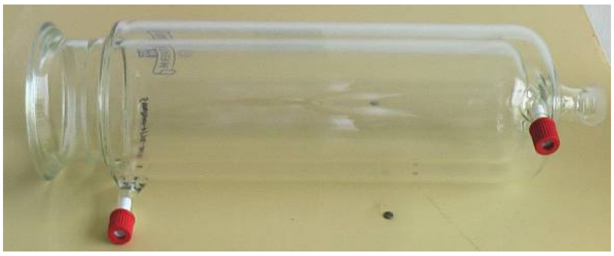


***Fig. 5** Bioreactor, volume 3000 ml*

A part of the bioreactor is the lid with two larger holes with a diameter of 29 mm and a height of 32 mm and two smaller holes with a diameter of 14 mm and a height of 23 mm. The holes are used for stirring, feeding and as a biogas outlet. The lid during the operation is shown in Figures 6 and 7.

***Fig.** 6 Lid*

***Fig. 7** Cover during the operation*

The perfect contact of the bioreactor with cover was fulfilled by lock, which is shown in Fig. 8.

***Fig. 8** Lock*

Thermostat

Another part of the biogas plant is a thermostat maintaining constant temperature in the bioreactor, which is one of the conditions for the optimal biogas production process. The principle of maintaining the temperature is based on a double-jacketed bioreactor, in which heated water circulates to maintain desired temperature of 37 °C. Circulatory thermostat HAAKE C10 was used (Fig. 10). There were no fluctuations in temperature in the operation of the bioreactor.

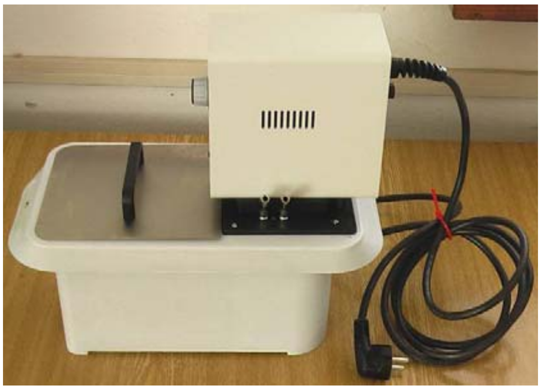


***Fig. 9** Thermostat HAAKE C10*

Stirring

To ensure optimal production of biogas during the process, it is necessary to mix the substrate. The stirrer is installed in the bioreactor through the rubber stopper which was inserted into the hole in the middle hole of the lid. Glass tube with a diameter of 4 mm and length 700 mm was inserted into the rubber stopper, where the hole was drilled. The stirrer was inserted into the tube (Fig. 11), which consists of a welding wire with a diameter of 3 mm and length 450 mm and the blades were welded to the wire and dual-layer coated to resist rust blade. Glass tube was installed under the surface of fermented substrate to prevent bioreactor aeration. The stirrer was powered by engine (Fig. 10). At the beginning, mixing was triggered manually, later on, a timer was purchased, which provide automatic mixing of the substrate by switching circuit according to the settings. The shortest interval of mixing can be adjusted for a period of 15 minutes.

Fig. 10 *Engine of stirring*

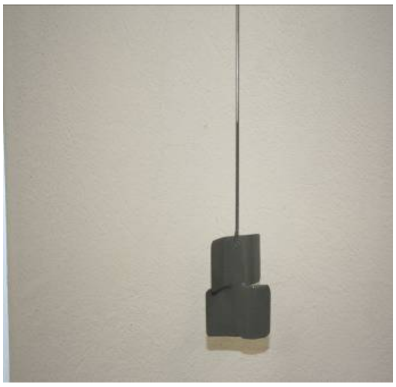


Fig. 11 *Stirrer*

Isolation

Bioreactor isolation was solved simply by using foam, which was wrapped with aluminum foil. The purpose of insulation is to create an environment free from light and heat insulated bioreactor due to heating and easier to maintain a constant temperature.

Biogas outlet

Biogas outlet is done to the washer, which indicates the production of gas with bubbling water. Biogas is then discharged into the room freely. When biogas is analyzed, it must be captured to a plastic bag with a patent.

Biogas analyzer MaMoS 400

Analysis of the biogas is only possible in sufficiently large quantities of biogas, and therefore it is necessary to capture the biogas and subsequently analyzed. The analyzer (Fig. 12) monitors the following four components:

- methane;
- carbon dioxide;
- hydrogen sulfide and
- oxygen.

Fig. 12 *Biogas analyzer MaMoS 400*

Results and discussion

The first operation of the biogas plant was conceived as a stress test. Observed was whether the thermostat can operate continuously and maintain the desired temperature in a reactor. The following chart shows the course of temperature in the bioreactor with temperature sensors that are installed in one of the lid holes.

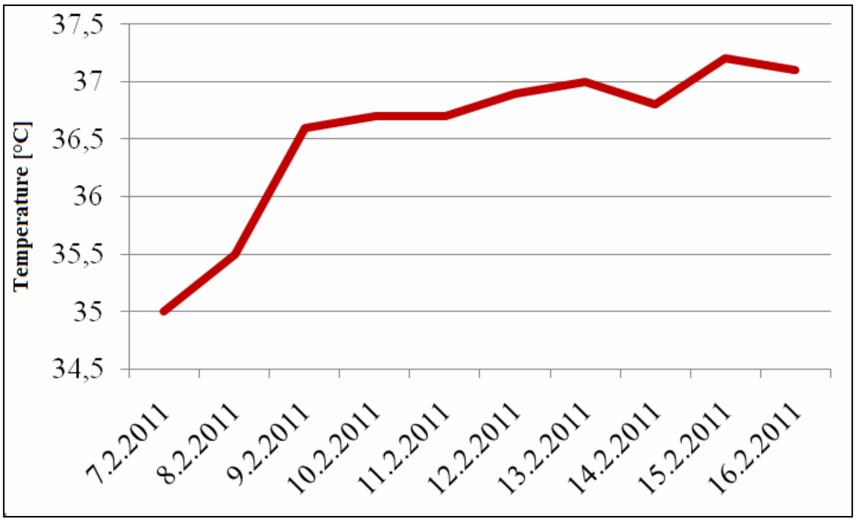


Fig. 13 *Course of temperature in the bioreactor*

Only the initial two days of operation, the temperature in the bioreactor was not adequate, which was resolved by simply raising the thermostat from 37 °C to 39 °C. Working temperature was set according to the literature and experiences from real biogas plants, where the temperature of 37 °C was the most common.

Mixing the substrate during the measurement was run manually, which was insufficient. A simple timer that could switch circuit at least every 15 minutes was purchased and set up to stir every 30 minutes, while mixing lasted 15 minutes. During the first operation, production of biogas was not indicated, which could also be due to the input material with low solids and imperfect mixing.

Sewage sludge with higher solids was used as a feedstock for the second operation, and thus the production of biogas was expected. In the second operation, temperature was monitored and the thermostat during the operation maintained a satisfactory temperature range. During this operation, feeding and removing the feedstock from the bioreactor was planned, since it was considered a longer operation. The process of feeding and removing began after 14 days. The process of feeding and removing was carried out without problems, so there was nothing to be corrected or optimized. After 14 days, biogas bubbling in the washer was indicated. Since a biogas analyzer was not yet available at that time, biogas was collected, withdrawn into the syringe and sprayed into the flame; the increased flame indicated methane content. During this measurement, there was an attempt to measure the volume of biogas produced by calibrated washer. This installation brought about bioreactor air pockets and stopped the production of biogas. The operation was canceled, when the substrate from the reactor through a hole, where is installed stirrer, spilled. This fact can be explained by incomplete mixing of material, and thus a shell was formed on the surface. The produced biogas under the shell pushed out the substrate. The first operation had not problems with mixing due dense substrate. The second operation was denser and the stirrer could not completely mix the substrate.

Before the third operation, it was necessary to resolve the imperfect mixing by installing a more powerful engine with speed control option. Kitchen waste was used as a feedstock. During the measurement, a biogas analyzer was installed, which needed a greater amount of biogas (several liters) for analysis. Hence, there was an effort to capture the biogas produced, because it is impossible to connect the analyzer to the reactor directly owing to the lower production of biogas. In this operation, no biogas was produced due to the low pH in the reactor.

In the fourth operation, sewage sludge from the Piestany wastewater treatment plant was used. Biogas production was recorded and the biogas was stored in a provisional storage of biogas. The provisional storage is a glass which is immersed underwater. The captured biogas displaces water from the cup. Since the glass is calibrated, it is possible to monitor the production of biogas. During operation, there was a problem with motor stirrer, which had to be replaced. The operation continues.

Conclusion

This contribution provides detailed information on the procedure for establishing a biogas plant. Provided is a detailed description of individual components as well as the problems encountered during the operation the purpose of which was to verify the operation of the device. Four operations were launched, during which, there were problems with the mixing and dispensing. In the future, it is certainly necessary to deal with the issue of trapping biogas produced in the subsequent analysis. There was an attempt to capture biogas into a plastic bag with a patent, but it was not successful due to the cessation of biogas production.

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