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SOLAR POND FOR HEATING ANAEROBIC DIGESTERS

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INTRODUCTION

Using biogas is an important way of solving the lack of energy resources in the wide countryside of China. It is well known that the production rate of biogas is strongly affected by the digestion temperature, and the most suitable digestion temperature is 30°C–35°C. But in the wide countryside of China, especially in the northern area, the temperature of most anaerobic digesters, which are built underground, is much lower than 35°C, even lower than 20°C during more than half a year, and there is nearly no gas which can be produced in severe winter.

Using solar pond for heating anaerobic digesters will raise the digestion temperature appreciably and make the digesters operate pretty well even in winter.

We present a theoretical analysis and the numerical results of a calculation for solar pond heating anaerobic digesters in the Beijing area in China, which has been discussed earlier (1), (2), (3). We shall limit the presentation to the experimental results of using a small solar pond for heating underground anaerobic digesters, during the period from September 1984 to August 1986.

EXPERIMENTAL SET-UP AND RESULTS

In 1984, we built a small experimental solar pond which is about 11m^2 in area and 1.2m in depth for heating two undergound anaerobic digesters, the volume of each being 0.8m^3.

A polypropylene heat exchanger was set in the pond at 24cm above the bottom. It was connected with pumps, valves, flow meters, pressure meters and the heat exchangers set in the digesters to make a closed system, in which fresh water flows as working medium.

Two anaerobic digesters were insulated with 0.05m polyethylene and heated by the solar pond, with another two of the same size and physical conditions for comparison.

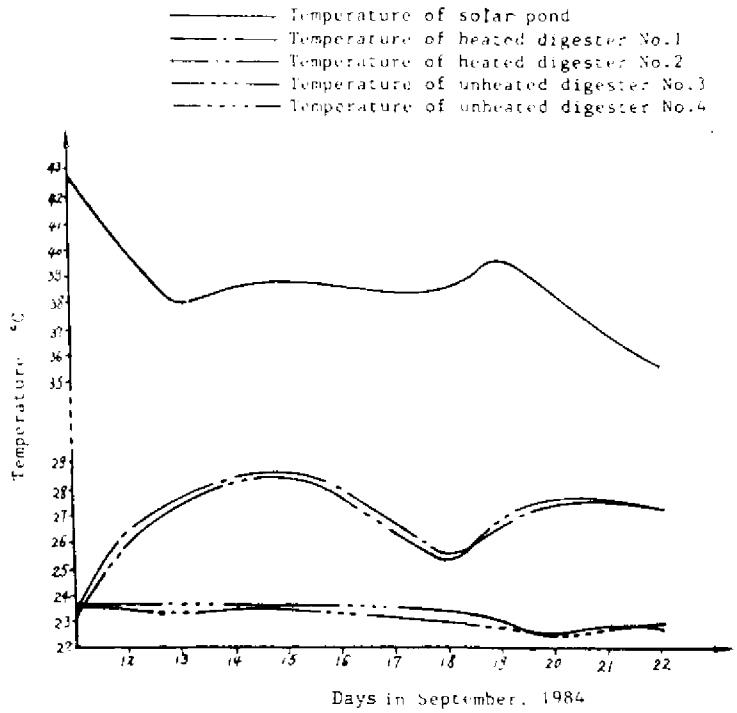
The pond was filled on June 8, and reached its maximum temperature of 48°C on August 8. Since August 28, heat was extracted for heating the digesters.

The experimental results during the following four periods are reported:

(a) September 11–23, 1984:

During this period, heat was extracted for about 10 hours each day except September 16–18, and a total amount of 141 MJ was extracted from the solar pond, the average thermal utilization efficiency η of the solar pond, viz. the ratio of the amount of heat extracted from the pond Q to the amount of solar irradiation upon the surface of the pond Q_0, was about 10%. The digestion temperatures were raised to 27–28°C from 23°C, i.e., 4-5°C higher than that of the unheated digesters, and the biogas production rate increased to about 240%.

The figure below shows the temperatures of the solar pond, two heated digesters and two unheated digesters.



For September 16–18, we had not extracted heat from the pond, the temperature of which almost unchanged, while the temperature of the two heated digesters dropped significantly. On September 22, it was overcast and rainy the whole day, but we had extracted an amount of heat about 12 MJ and maintained the digestion temperatures still over 27°C. It was evident, in spite of the bad weather, that heating by solar pond can still raise the digestion temperature and maintain it rather steady without large fluctuations in a short period. This character would be of great importance and advantage as compared with other ways of utilizing solar thermal utilizations.

(b) November 26–December 4, 1984:

During this period, both the solar insolation and ambient temperature decreased significantly. On the other hand, the surface of the solar pond was shadowed by 1/3 due to the restriction of experimental place. Hence we provided heat to only one digester and with another one for comparison. The average efficiency of the pond was also about 10%.

(c) April 5–May 9, 1985:

During this period, the heat was extracted from the pond and provided to two digesters all the day. The digestion temperatures was again raised by 4–5°C, and the biogas production rates increased to about 240%. From April 30 to May 3, we had stopped the heat extraction, the temperatures of the two heated digesters dropped significantly, while the temperature of the pond raised continuously. The average efficiency of the pond was still as high as 10%.

(d) July 10–August 2, 1986:

During this period, we had just provided heat to one digester, and with another one for comparison. The rise of temperature reached 5–7°C. In spite of the rainy weather during this period, the temperatures of the solar pond and the heated digesters were both rather steady, only slightly affected by the weather. The fluctuation of the pond temperature were generally 2–3°C, and the variations of temperature in near days were only about 1°C. Evidently, these aspects were very profitable for anaerobic digestion. During this period, the increase of biogas production rate was 160%, because the temperatures of both heated and unheated digesters were all in the neighbourhood of 30°C. The thermal utilization efficiency of the pond was still about 10%.

The experimental results of the above four periods are summarized in the following table:

Duration	$Q_0(MJ)$	$Q(MJ)$	$\eta(\%)$	$\Delta T(C)$	$\delta R/R$
84, 9, 12–22	1467	141.0	9.68	4–5	1.4
84, 11, 26–12, 4	434.5	42.3	9.73	2–3	-
85, 4, 9–5, 9	3375	373.6	9.95	4–5	1.4
86, 7, 10–8, 2	4526	436.8	9.65	5–7	0.6

where R is the biogas production rate of the unheated digester and ΔR is the difference of biogas production rates of the heated and the unheated digesters.

CONCLUSION

It is shown by the experimental results that the heating of anaerobic digesters by solar pond is definitely technically available. Not only the effect of temperature raise is evident, but also it is rather steady. Therefore, it is not only possible to increase the biogas production rate in spring, summer and autumn appreciably, but also there is the possibility of making the anaerobic digesters operate pretty well even in winter. Because the effective area of the solar pond we used

is too small, and the physical condition is not good, so the experimental results are not satisfactory. But we do expect, that if we can enlarge the effective area of the solar pond appreciably, then both the temperatures of the pond and the temperature difference with the ambient surroundings would be raised evidently, so the digestion temperature and the biogas production rate can also increase effectively. Hence there exists the possibility to solve the problem that the digesters cannot produce biogas during winter time in most areas of China, which is an encouraging possibility to release the shortage of conventional energy resources in the vast rural areas in China. We are also confident that the above results would be of importance and interest to many developing countries and districts where the insolation and salt resources are rich but lack of conventional energy resources, and this approach would be a valuable choice for these countries and districts.

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