A Study on the Influence Arsenic in Methane Fermentation Biogas Plant

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Abstract

In past research, it has been suggested that NH4-N derived from animal excreta is related to arsenic contamination in groundwater. The authors pondered methane fermentation biogas plant can treat animal excreta before ground infiltration. At the same time energy and organic fertilizer production is vital outcome of it. But influence of arsenic in the plant is necessary to disclose. The research purpose is to investigate behavioral changes of arsenic in methane fermentation process. The authors constructed biogas plant at arsenic contaminated area and measured arsenic besides concerned data. As a result, behavior of arsenic and validity of biogas plant were clarified.

Keywords: Arsenic, Methane Fermentation, Biogas, Waste Management

1. INTRODUCTION

Biogas simply can be defined, a flammable gas generated from residue of animal or plant through microbiological breakdown which is a great source of alternative energy. Biogas is about 20% lighter than air. It is colourless and odourless burn with clear blue flame similar to LPG [2]. Research on Biogas is being started in India since long and stretching the technology from 20^{th} Century to till date [3]. The newly constructed Model Biogas Plant (MBP) at Newada village of Bahraich district in Uttar Pradesh, India is a consequence of Bahraich Arsenic Mitigation Project (BAMP). Bahraich is highly arsenic contaminated district in Uttar Pradesh according to Uttar Pradesh Jal Nigam (UPJN). 11.77 % tube wells are above permissible limit as per the Indian guide line 50 ppb. Bahraich is situated at 27.58°N and 81.6°E. Fig.1 shows the location of project area in Bahraich district, India.

Decomposition of organic matter in the ground more or less causes arsenic release in ground water has been revealed [1]. It is also known that mostly arsenic sufferers are living in below poverty level. A major part of organic matter from animal excreta is being decomposing in south Asia especially in India. BAMP household survey, 2011 explored that Newada village itself has average more than 2 cattle at each individual house. Most of the animal excreta decomposed unhygienic in the research area. Despite of not identifying the main source of ground water arsenic contamination in the research area the authors took chance to know the behaviour change of arsenic in the biogas plant. The MBP can treat a huge amount of animal excreta to generate energy. Similarly the methane fermentation system provides good quality of bio-fertilizer essential for crop production and pisciculture. A standard daily life is expected as another outcome. The research aims to reduce arsenic contamination in ground water through proper animal excreta decomposition. To know the behavioural change of arsenic, routinely produced gas and fermented slurry was checked.

The purpose of the research is to establish a sustainable biogas plant in rural area and investigation of arsenic behavior in methane fermentation.

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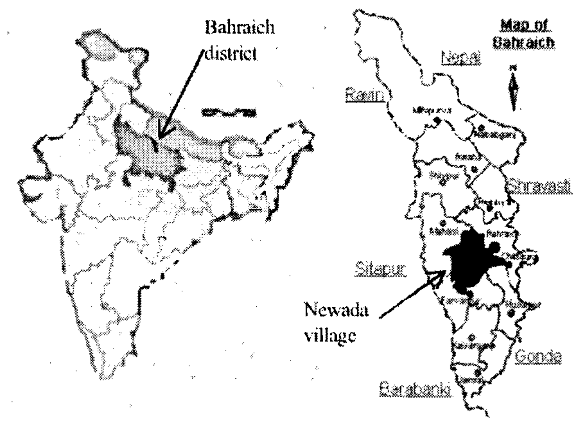

Fig.1 Location of Project Area

2. MATERIAL AND METHOD

2.1 Place Selection

A household survey was done in May, 2011. Before MBP construction following criteria was observed; i. Number of cows, ii. Family member, iii. Sunny free space, iv. Arsenic contaminated water source and v. Owner interest. Table-1 shows the household survey findings.

It is important to ensure the availability of feed material before constructing a biogas plant. Similarly sunny place to receive favorable temperature for methane bacteria is required for well decomposition of feed material. Arsenic water source was needed to know its behavior change in the biogas plant. The authors conducted a household survey establishing a survey format and interview. Finally the household which have sunny land and enough livestock was selected.

Table.1 Household Survey Findings

Village	Habitation	Household	Population	Livestock	
				Cow	Buffalo
Newada	23	653	3441	625	480
Chetra	4	90	557	121	50

2.2 Model Biogas Plant (MBP)

The plant is called MBP was first constructed as a UOM model in the field after small scale research at the University of Miyazaki, Japan in 2009. The MBP size was considered based on amount of raw material and required gas production. In addition electricity production was considered besides cooking. The plant was designed above the ground to maintain it while necessary. Fig.2 shows the schematic diagram of MBP. 2 layers nonporous plastic water tank was used to make the MBP. Methane fermentation tank (MFT) was the major tank to decompose fresh dung. Fermented slurry was deposited into Slurry tank (ST) for further use of separated liquid from the slurry. Produced biogas was treated by iron oxide contained Desulfurizer (DS) to remove toxic Hydrogen Sulfide (H_2S) gas before storing into Gasholder (GH). A drainage system was made to remove produced water in DS. The capacity of fermentation tank was calculated 2400 L. Required gas pressure for cooking was made putting weight on gasholder. A manometer 300 mmH_2O was installed to maintain the produced gas pressure. It combine pressure gauge with safety valve.

In order to control slurry temperature, this MBP equipped a solar water heater (SWH) system. It is very useful for increase in gas production and decrease in energy consumption of MBP.

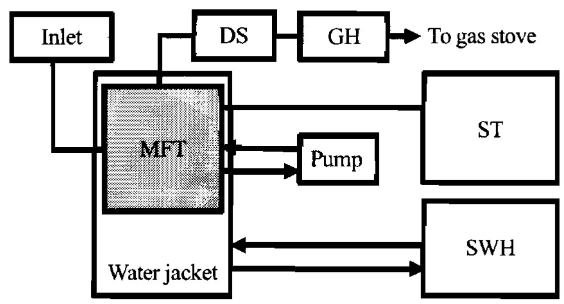

Fig.2 Schematic Diagram of Model Biogas Plant

Anaerobic fermentation base biogas plant need airtight fermentation tank. Capacity of the fermentation tank is 2500 L. In this MBP, fermentation tank was covered by another tank called water jacket. The jacket is used to hold solar heated water especially during low temperature season. The MFT has two pair of inlet and outlet port. A pair of inlet and outlet is connected with pump for slurry stirring. Another inlet is for pouring fresh dung and outlet for removing fermented slurry which is connected with Slurry tank. Each inlet and outlet has PVC ball valve to stop slurry flow. Daily feeding anaerobic fermentation tank need to certain remove of old slurry. Therefore 1 m of PVC pipe was installed with inlet and outlet in different height inside the MFT. Fig.3 shows the MFT structure. Each connection of MFT was made of PVC.

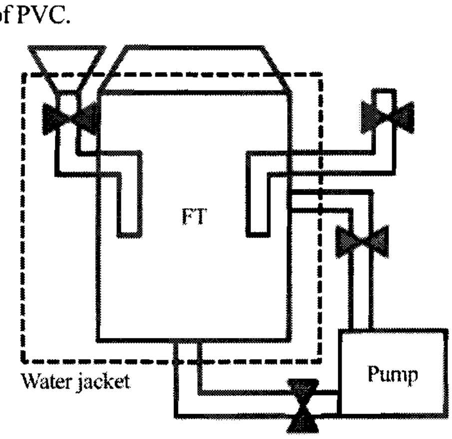

Fig.3 Structure of Methane Fermentation Tank

Lid of fermentation tank was made of 2.5 mm thick iron sheet which was installed by bolt nut with the tank. Iron flat bar was used to reinforce. In order to keep airtight, silicone packing was used between tank manhole and lid. Produced biogas was easily deposited into gasholder from the gas outlet point installed on the FT lid. To measure slurry temperature of FT thermocouple was installed.

2.3 MBP Operation Method

Daily fresh dung was collected into 50 L poly drum from the caretaker's own buffalo. Collected dung was mixed with tube well water in same ratio. In order to avoid any clog into circulation pump, mixed dung was filtrated by handy aluminium mesh before pouring into inlet of fermentation tank. Daily feeding was 120 L considering 20 days retention time whereas methane fermentation tank was filled by 2400 L of slurry.

Slurry was stirred into methane fermentation tank twice a day for 5 minutes by engine pump at morning and evening. Amount of gas production was measured by gas meter which was recorded daily at 11:00 am before putting fresh dung. Produced biogas is using daily for cooking 19 members family 2 times a day. Condensed water from desulfurizer was removed once a week from the drainage valve. Gas sampling and slurry sampling was done once a week. pH of slurry in FT was measured by portable pH meter. Pack test was used to measure $NH4^+$ and concentration CO_2 and H_2S were measured by gas detector tube. Arsenic in tube well water was tested once a month by Wagtech field kit. Slurry sample was tested at University of Miyazaki, Japan for investigating arsenic.

In order to investigate fermentation condition, 2 data logger were used. One is temperature data logger for fermentation tank slurry and the other is multi data logger for atmospheric temperature and humidity. These recorded at each 10 minutes. Temperature data was collected once a week to control the suitable temperature. 37 ~ 38 deg. C was the suitable temperature for the anaerobic mesospheric bacteria for their best activity in the past research [4].

To control the temperature, solar heating water circulation system was established. But solar water heater was not used in experiment period. SWH cannot get enough solar energy because of rainy season from July to September.

3. RESULT AND DISCUSSION

3.1 Temperature Measurement

Temperature is a vital factor in the anaerobic methane fermentation system. Temperature fluctuation decreased a huge amount gas production. Target temperature of this research was 37 °C. Temperature fluctuation in FT during experiment period is shown in Fig. 4. Temperature was fluctuated by weather and atmospheric temperature.

Fig.5 shows example of temperature fluctuation in a day. In a sunny and warm day maximum temperature was above 40 °C and minimum was about 37 °C. In rainy or cloudy day maximum temperature was below 30 °C and minimum was about 28 °C.

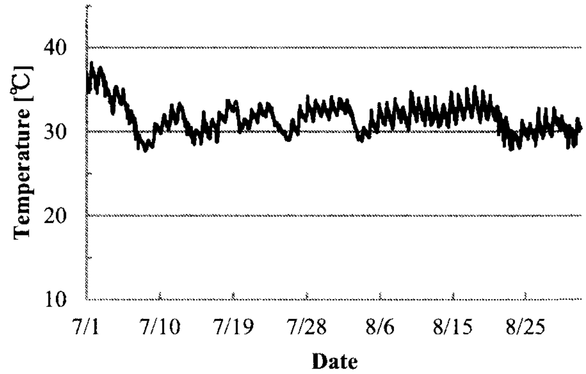

Fig. 4 Temperature Fluctuation

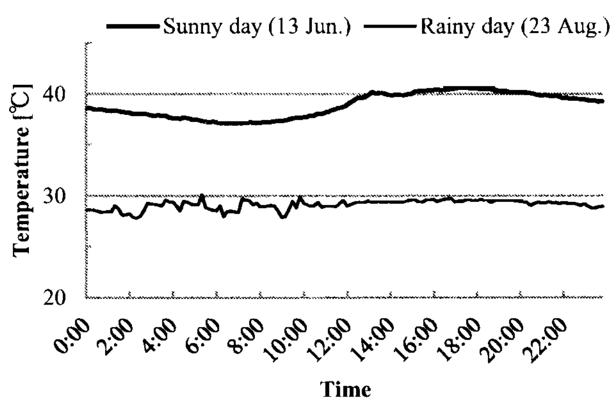

Fig. 5 Temperature Fluctuation in a Day

3.2 Gas Production:

Quantity of produced biogas was measured by gas meter once a day at 11:00 am. Fig.6 shows the quantity of gas production from July to August. In this graph left axis shows daily gas production and right axis total gas production.

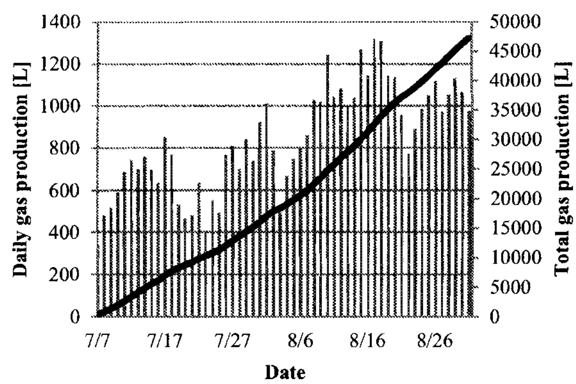

Fig. 6 Daily and Total Gas Production

In this research maximum daily gas production was observed when the temperature was almost 32℃ in a whole day. Gas production was low when temperature was below 31 ℃. Gas production was low when temperature decreased in rainy day similarly gas production improved when temperature increased in warm day. However, gas production is affected by not only temperature but also other factor.

3.3 Effect of pH

Biogas generation is highly influenced by pH. Suitable pH in the anaerobic fermentation is 6.8 to 7.5. When pH was higher than 7.5 production of gas was reduced. Fig.7 shows control of pH. In this research when pH was 7.00 then biogas production was higher. To control the pH, lime water was used during July. The pH was changed by amount of fresh dung input. Accordingly, pH has been controlled by amount of fresh dung.

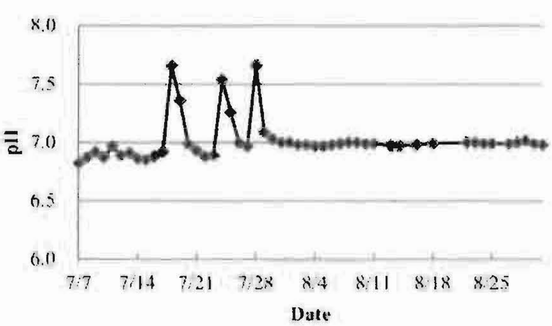

Fig.7 Change of pH

3.4 Gas Concentration

Generated biogas density was measured by gas detector tube. Carbon dioxide (CO_2) and Hydrogen Sulphide (H_2S) were measured once a week. AsH_3 was measured often. In the present research H_2S was removed by iron oxide desulfurizer devise.

Not so remarkable differences of CO_2 between Fermentation tank (FT) and Gasholder (GH) was found which is shown in Fig.8

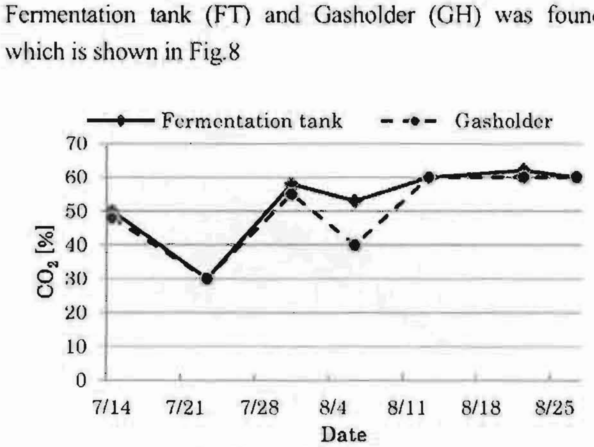

Fig.8 CO_2 Concentration.

3.5 Slurry Observation

Generally, methane fermentation biogas plant produces organic fertilizer which is same amount of inputted material in every day. But liquid fertilizer doesn't have portability. In order to reduce amount of fertilizer, the authors considered trying to reuse fermented slurry.

Slurry from fermentation tank was collected to observe the separation duration of liquid from slurry. To investigate the separation of fermented liquid, the slurry observation was done.

After stirring 500 ml fermented slurry was collected into two measuring cylinder respectively. Slurry was observed twice a day from 9:00 am to 21:00. Every changes of slurry were recorded through images and note down. Fig.9 and 10 shows the changes of slurry. Maximum separation was observed within a day 200 ml and rest 50 ml took 5 days to separate. This result suggests the possibility which liquid part of slurry can be used again as diluent for fresh dung.

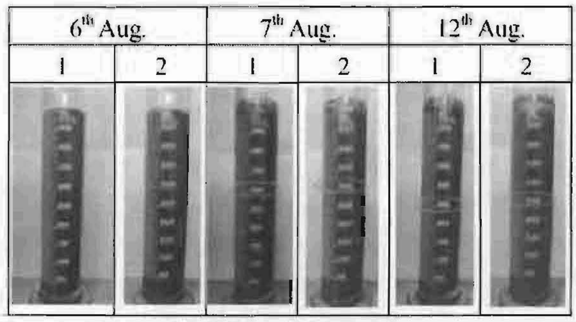

Fig.9 Slurry Observation

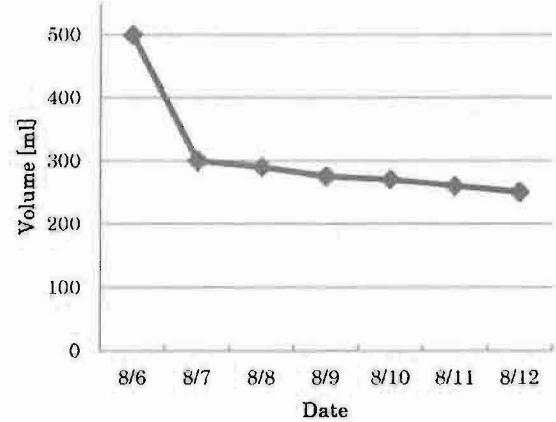

Fig.10 Slurry Separation Curve

3.6 Arsenic Measurement

In order to investigate the influence of arsenic in biogas plant, arsenic analyses was done. At first, arsenic concentration of cow dung as biogas feed material was measured by radioactivation analysis. This method can identify the chemical elements. As a result, arsenic was not detected from cow dung.

Table 2 Result of Arsenic Measurement by EDX

Sampling point, Type of detector	Cr	Fe	Cu	Zn	As	Se	Cd	Ba	Pb	Hg
Gas holder, AsH_3	0.04	0.97	4.41	32.27	**4.16**	1.31	1.3	10.04	2.24	50.13
Fermentation tank AsH_3	0.24	1.21	3.73	37.93	**3.39**	1.92	1.5	13.06	1.44	48.89
Gas holder, H_2S	0.2	1.32	4.29	27.87	**0.64**	0.71	1.17	13.77	0.62	1.81
Gas holder, H_2S	1.01	1.82	5.21	27.83	**1.32**	0.5	1.38	14.85	1.6	1.82
Fermentation tank, H_2S	0.11	2.75	1137.7	61.96	**1.56**	0.67	1.04	10.23	0.98	-0.26
Fermentation tank, H_2S	0.43	2.06	1181.91	60.59	**1.68**	0.92	1.83	12.63	1.78	-0.4
Gas holder, CO_2	0.15	1.23	7.59	25.38	**1.55**	0.71	1.52	10.38	0.34	-0.32
Fermentation tank, CO_2	0.46	0.72	6.56	26.5	**1.56**	0.75	1.68	15.95	0.77	-0.49

Next, arsenic concentration of tube well water was measured by arsenater. This water is used as diluent for biogas feed material. Arsenic contamination was found and its concentration is about 50 ppb. This result shows that arsenic compound is put into methane fermentation tank.

Arsine (AsH_3) which is gaseous form of arsenic compound was measured by gas detector tube. But H_2S may interfered to detect AsH_3 by detector tube was assumed. To confirm the presence of AsH_3, Energy Dispersive X-ray spectroscopy (EDX) was used. Reacted substance was collected from detector tube measure by EDX. Collected substance was crushed into powder and measured. In this method arsenic concentration was not detected as ppm order but intensity of arsenic shown in Table-2 was detected by power spectrum. This result shows that some arsenic compound was contained as gaseous form in biogas.

4. CONCLUSION

Initially energy production was achieved treating animal excreta. Similarly excreta infiltration into ground was reduced by this technology. Temperature and pH relation to produce biogas was discussed.

Major findings are as follows;

i) Increase of gas production was achieved controlling of pH.

ii) Possibility which liquid part of fermented slurry can be used again as diluent for fresh dung was suggested.

iii) Arsenic compound was contained as gaseous form in biogas.

Eventually the research data can make sense of MBP validity in arsenic polluted area. Furthermore, the exact confirmation of relationship between biogas and arsenic should be done.

5. ACKNOWLEDGMENTS

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