BIOGAS FROM HUMAN WASTE

Workshop held in Delhi. August 22-23. 1986.

CORT CONSORTIUM ON RURAL TECHNOLOGY

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INTRODUCTION

Y.K. Sharma/ Secretary
Consortium on Rural Technology

INTRODUCTION

Biogas plants have been accepted by now in the country as a device for improving the quality of the life of the people. They help in recycling of the cattle wastes and produce both fuel and manure from the same quantity of dung. At present it is understood that over 3 million families own biogas plants plants in the country.

The majority of these biogas plants use cattle dung as the feedstock. At the same time there are efforts to also use alternative feedstocks like human excreta, and also other agricultural wastes, water hyacinth etc.

The safe disposal of night-soil/human excreta is of major consideration for any sanitary programmes and one of them can be through feeding it into the biogas digesters.

It is agreed that the use of the gas from the nightsoil will be considered taboo by the majority of our people. But at the same time there are many who have accepted it more at individual level than at the community level.

Some of the community biogas plants directly fed on human excreta are at Masoodpur village near Delhi; Sewagram, Wardha; Midnapur (West Bengal) and Puri in Orissa.

The gas produced from the plants established in Orissa and Midnapur is utilised for cooking purposes by the scheduled caste of community. Its use also produced the worst kind of reaction from the beneficiaries because the worst kind of reaction from the beneficiaries because the ground-work that was needed to be done for educating the people does not seems to have been done before installation of such plants. This means if awareness and education programme is carried out before supplying this gas for cooking, it may not only be used by the scheduled caste but also by others increasingly. At the same time night-soil can be a very good alternative feedstock especially where cattle dung is not available, as in our urban areas. Such areas can be where large number of people reside at one place like school/college hostels, hospitals, police lines, Army units, Jhuggi-Jhopri colonies etc. etc.

Some of the problems that come to mind are :

1. In night soil fed biogas plant, what would be suitable mix of feeds and in what proportion.

2. How much of water should be added to the different kinds of feeds (so far as dung is concerned it is at 1 : 1 ratio)

3. On what basis would the digester be planned-on the basis of summer or the winter temperature ? If the summer temperature is taken as a basis for the design, will not the gas production suffer in winter ? If it is based on winter temperature will not the digester volume have to be very large - and hence demanding a higher

surface area and higher costs.

4. What are the practical measures to prevent heat loss from the digester during the night in winter ?

5. What models would be preferable, floating dome of the KVIC model or a fixed dome of the Janta type ?

6. What kind of repairs, how often and involving what kind of service will be required ? Will the service be available locally ?

7. What should be the arrangement for the post-digestion of the slurry ? Should the effluent slurry be dried on sand feds or stored in lagoon pits or aerobically composted with other organic materials ?

8. Since the biogas plant fed with human excreta is required to be near the latrine and also near the kitchen and yet at least 50 feet away from the water sources, there was a problem of reconciling these requirements.

9. How far should the slurry be stored so that it does not have the other problems.

Considering the various problems associated with biogas plants fed fully or partially with human excreta. The Consortium in collaboration with Action for Food Production (AFPRO) invited a workshop on biogas from human waste. A small working group to decide on the various issues associated with the subject was constituted. The folowing five aspects of the nightsoil biogas plant were identified and institutions and individuals working on them were invited to the workshop. These aspects are:-

1. Social aspects
2. Health aspects
3. Design and R&D aspects
4. Treatment of Slurry and its use
5. Strategy for Promotion and Integration with other Development Programmes

The workshop was held on August 22nd and 23rd, 1986. The keynote address was delivered by Prof. Maheshwar Dayal, Secretary, Department of Non-conventional Energy Sources, Government of India and the background paper was presented by the scientists from NEERI - National Environmental Engineering Research Institute, Nagpur. Such a workshop was very much welcomed and it generated a lot of interest and interaction between scientists and the social action groups. It was participated by about 75 participants drawn from Government Departments, Research Institutions and Voluntary Organisations. Based on the presentations, the papers, discussions and the recommendations made on the different issues referred above,

The proceeding and the papers of the workshop have been edited by Sri Shailendra Nath Ghosh. We are also grateful to him for writing the prologue and the epilogue.

We hope that the publication of proceedings of Conference would be found useful and generate further interest in the subject.

PROLOGUE

Shailendra Nath Ghosh

In order that the benefits of the discussions do not remain confined to the enclaves of specialists, it is necessary to explain a few fundamentals of the biogas-cum-manure plant operation.

Biogas is obtained from decomposition of biological source material or biomass (i.e. organic waste) in a biological process. Since we are interested in methane gas which can serve as cooking fuel, produce light, and drive stationary engines, the biological agents have to be the methane producing bacteria which function only in an atmosphere from which oxygen has been excluded (anaerobic bacteria). In the presence of oxygen, the decomposing organic matter produces only carbon dioxide. Airtightness is crucial to biogas plant functioning. This makes exacting demands on masonry skill.

Voltaile solids content of the input is important. It is the portion of a sample which can be burnt off and which represents the amount of organic matter really available to the bacteria for their own nourishment and conversion into gases and single-cell protein biomas. Although a small part of the volatile solids (such as lignin, hair, feathers) is usually non-digestible or very slowly digestible, volatile solid is the digestible or very slowly digestible, volatile solid is the basis for calculating the gas potential and determining the loading rate and retention time. The non-volatile part of the input represents that portion of a sample which is left as ash when burnt. It is also called fixed solids.

For anaerobic biogasification, the necessary nutrients are carbon, nitrogen and phosphorous. Of these, the ratio between carbon and nitrogen is important because it is the carbonaceous matter which is converted to gas and humus-building materials, and any nitrogen other than what is required by the bacteria will end up as ammonia which, when excessive, will be toxic to the bacteria. Organic material with a C:N ratio higher than 30:1 will produce a raw gas with less methane*(1) and more carbon-dioxide, while a C:N ratio substantially lower than 30:1 will produce excessive ammonia and supress methanogenic bacteria. In international literature, there seems to be a difference of opinion. Some western sources say that the C/N ratio of 30:1 is the best for methane production. The Chinese sources say that this should be between 20:1 and 25:1. Indian scene has no opinion on this matter.

Nightsoil being low in C/N ratio-between 5:1 and 7:1 needs to be supplemented by other materials which are high in callulosic content and low in nitrogen, such as excrement of herbivorous animals, fallen leaves, fresh grass, vegetable stalks, garbage etc. In rural areas, where such materials are abundant, it should not be difficult to bring the mixed feed to the optimal C/N ratio. But this requires a fair knowledge of the C/N ratio as different kinds of materials available in the locale. China's scientific bodies have made available to Chinese farmers the carbon/nitrogen ratios of the common materials usable in biogas digesters. It should be the responsibility of our scientific bodies and our Universities and colleges to contribute such knowledge regarding materials specific to each locale.

The process of producing methane-rich gas involves a series of reactions in which three types of bacteria take part. These three types are : (i) the hydrolysing bacteria which transform the compounds into solubles and the heavy particles into simpler one so that these can be attacked by others; (ii) the acidogenic bacteria which convert the broken-down organic matter into organic acids, principally acetic acid; and (iii) the methaneogenic bacteria which take up the acetic and convert it into methane, *carbon dioxide etc.*

Since a balance has to be maintained between these three stages, the rate of loading has to be duly observed. If the organic matter is added too rapidly, the hardy and quickly multiplying acidogenic bacteria will grow even faster and produce a surfeit of volatile acids, lowering the pH of the slurry to the detriment of the methanogenic bacteria.

The pH level of the digester slurry is a crucial factor. It is a measure of the acidic or basic (i.e. alkaline) nature of the slurry. What is the optimum pH level -- on this question, there seems to be some difference.

According to some researchers, "the methogenic bacteria generally funcion in in the pH range of 6.4 to 7.5. with 7.0 or neutral pH being the optimum point". According to a Chinese source, "the environment must be kept either at the neutral pH level or at slightly alkaline". According to still another Chinese source, "ideally, the pH in a pit should be a little on the alkaline or neutral, with a pH of 7.0 to 8.5". Possibly a pH of 8.5. is tolerable with cattledung as input, whose potential for ammonia production is low. With nightsoil as an input, this level is risky. We can exclude the extremes of pH 6.4 and pH 8.5 from our consideration and seem to maintain pH between 7 and 8. Significant deviations from this will mean digester failure. Low pH will mean acid toxicity and high pH will mean ammonia toxicity to methane producing bacterial. This is the reason why it is necessary to frequently check and adjust the pH of the liquid.

The question is : how can a lay person check and adjust the pH. "A Chinese Biogas Manual says:

"The method of checking is simple. (1) Dip a piece of litmus into some of the fermentation liquid, immediately observe the change in colour, and compare this with a chart of colour to tell the pH of the liquid. (2) The people of Sichuan have observed that a red or yellow flame in the gas generally corresponds to slight overacidity in the fermentation liquid".*

When this is observed, "one should remove some of the old material and replace it with a compensating amount of new material, or add some lime or ash, to adjust the acidity and restore normal gas production".

Temparature is a key factor in biogas plant operation. It is universally accepted (i) that the level of temperature decides not only the killing rate of pathogens but also which group of methaneogenic bacteria will function in the digester. Although it is true that thermophilic range of temparature (48-60°c) kills the pathogens quicker, improves gas yields and completely digests the slurry in a shorter detention period, it loses its justification on the ground that production of this order of temperature requires input of external energy. Moreover, the thermophilic methanogenic bacteria are more sensitive to variations in the environment. Mesophilic methanogenic group of bacteria, which functions at 30-40°c range, is more suitable for household or community biogas plants. A constant range of temparature is important. A sudden rise or fall by even 2-3°C affects the methane forming bacteria.

Although generally the above two temparature ranges are mentioned in literature on biogas, the Chinese sources say that in Sichuan Province, they depend for fermentation on the ordinary temparature of 10-30°c. An IRDC publication, too, reporting on the experience from the same province, says: "After operating for more than a year, it was found that normal production can be achieved by keeping the temperature at 20°c. During the summer and autumn the tank's temperature averages about 23°c and plenty of biogas is produced; in winter when temperatures range from 0 to 7°c, the tank's temperature stays at about 10°c and biogas is still produced.

This should raise the question: why, then, do we find it so difficult to run biogas plants even at temperatures ranging between 13°c and 23°c ? Does this necessitate any pre-treatment of the "feedstocks" in India's northernmost regions, particularly in winter - as is done in the temperate regions in China ? The discussions that follow are intended to answer these questions plus those that have been raised in the Introduction.

(1)* Biogas produced by anerobic, decomposition, generally, consists of 60-10% methane. The remaining 30-40% is combination of carbon dioxide, hydrogen sulfide and other gases.

(2)* Human excreta is rich in nitrogen. Its nitrogen content is 5-7% as compared with 1.7% in cattle dung. Human urine contains about 18% nitrogen.

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*Those who prefer testing by a Chemical may draw a small quantity of slurry and put 2-3 drops of phenol phthalene.

KEYNOTE ADDRESS

KEYNOTE ADDRESS

Maheshwar Dayal
Secretary/Dept. of Non-Conventional
Energy Sources, Ministry of Energy, Govt of India

At the outset, I would like to congratulate the Consortium on Rural Technology (CORT) for taking the initiative in organising this workshop on Biogas from Human Wastes. Not only the prospects of biogas generation from human waste will be discussed but also the problem areas. This is all the more important at this juncture when Government of India is embarking in a major way on implementing an integrated action plan for rural sanitation and when a major thrust has been given for energy generation from renewable sources.

The severity of the problems relating to inadequate sanitary facilitates in rural and urban areas hardly needs any emphasis. The latest statistics available reveal that only 0.72% of the rural population have access to sanitary facilities. The situation in urban areas is not much better as 33% or more of the urban population have no toilet facilities worth the name. The obvious result is that people have perforce to use open fields, farm land, ponds, flowing streams, streets, railway tracks etc. Consequent to increase in population, industries, urban centres, and transport facilities the abovementioned traditional options have more than reached the limits. Apart from the direct and obnoxious effects such as foul smell, pollution and filth, the untreated human waste causes disease, mosquito infestation, high infant mortality rate etc. It is said that the pathogens emanating from human waste are responsible for nearly 80% of diseases in India and the cost in terms of medical treatment and lost production on this account is around Rs. 450 crores per annum.. For women, particularly in the rural areas, the problem of sanitation facilities is particularly severe, as privacy is declining with declining forest cover and increase of population.

Realising these difficulties, Government has taken up an integrated programme of setting up rural latrines during the 7th Plan. It is expected that 80% of the urban areas and 25% of the rural areas would have sanitary facilities by the year 1990. Effective management and proper disposal of the human waste will be required at all times.

As you are all aware, worldwide effect is continuing for development and use of alternate and renewable energy sources. The production of biogas, in this context, is gaining greater attention. The success of generating biogas from cowdung and other animal wastes had led to exploration of alternate material as sources of biogas production, including human waste, sewage sludge, agricultural wastes and industrial wastes which contain organic matter etc. A number of agencies including non-governmental organisations have taken up the establishment of biogas plants based on nightsoil either as a supplementary feed or exclusively as feed material. Utilisation of nightsoil for biogas generation is advantageous and some form of its treatment is obligatory from social and health points of view. Biogas plant enables production of energy as a useful and badly needed commodity while performing this treatment. Further, anaerobic digestion of human waste also yields manure rich in nitrogen which is safer to handle and reduces harmful pathogens, thus diminishing the chances of faeces-borne and related communicable diseases.

The National Project on Biogas Deve-

BACKGROUND PAPER

cases, environmental pollution and spread of diseases. Dry conservancy system, though not desirable considering the aesthetic aspects, is likely to continue in majority of villages and towns in India for the coming two or three decades, as the water carriage system is very expensive. In this paper an attempt has been made to provide information about nightsoil digestion in laboratory scale units along with the data obtained on pilot plants. Some information has also been documented regarding removal of parasites during nightsoil digestion.

Treatment Methods

i) The most common method in vogue in India is burial in the ground either by itself or with town refuse. It often create fly and odour nuisance along with contamination of ground water by percolation and leaching and may cause enteric diseases such as cholera, typhoid, dysentry, infectious hepatitis, helminthic diseases and ameobic dysentry.

ii) Chemical treatment requires treatment using lime and ferrous sulphate in a clarifloculator. The sludge is thickened, vacuum filtered and sludge cake is burnt in a rotary kiln. The separated liquid is neutralised, diluted and treated in thickling filter or in an activated sludge process. The final effluents in the plants existing in Japan are reported to have neutral pH 60 mg/l BOD, 150 mg/l suspended solids, coliforms less than 300 MPN (most probable number) and viable ascarisova less than 5 per 100 ml. This method has limited application under Indian context due to costs of collection and chemical treatment.

iii) Extensive work has been done in the anaerobic digestion of cowdung and other organic materials. The anaerobic digestion of organic waste materials, such as farm manure, litter, garbage and nightsoil, accompanied by the recovery of methane for fuel, has been an important development in rural sanitation. Some of the more important aspects of recent advances are control of temperature and introduction of mixing of digester contents. Efficiency of some of the digestion units decreased in the following order:

Thermophilic (seeded and agiated); Thermophilic (agitated only); Thermophilic (seeded only); Thermophilic (without agitation/seeding) Mesophilic (seeded and agitated); Mesophilic (seeded only).

iv) Pillai and his associates at Bangalore have indicated that good activated sludge can be developed from night soil. Activated sludge treatment system will be an expensive proposition under Indian situation. This method of treatment is extensively being used in Japan.

Gas composition was essentially the same under thermophilic and mesophilic conditions. Heat required for thermophilic is about 2.5 times that for mesophilic one. Moreover, the digestion time and reactor size are about one half for the mesophilic one. However the cost of construction of both types of reactors for a certain volume of nighsoil is nearly the same because there is higher cost of construction of digester in one type and the higher cost of heating element in the other. Thermophilic digestion is recommended only when cheap surplus source of heat is available. Prolonged use of thermophilic digestion process may result in lysis of the micro-organisms[3] and also results in the destruction of pathogenic bacteria as well as parasitic ova contained in the nightsoil. Ram Mohan Rao[3] reported that thermophilic digestion of nightsoil alone and of nightsoil and cowdung mixture in the ratio of 2:1 resulted in a volatile solids reduction of 45% and above, provided loading rates were kept under 2.4 kg VS/m^3 per day in both cases with gas production of 0.45 and 0.35 m^3/kg of VS respectively. The specific resistances of the sludges were found to be 1.63 x 10^{10} and 0.6 x 10^{10} s^2/g for nightsoil alone and nightsoil with cowdung respectively. The specific resistance of sludge using nightsoil at a loading rate 2.8 Kg VS/m^3 per day nearly doubled.

Composting of nightsoil along with town refuse has been and is still being practised in many parts of the world. But in many parts of India this kind of treatment is pursued in a very haphazard manner. This results in fly breeding, odour nuisance and high incidence of helminthic infections. All the details regarding decomposition has been documented in a monograph by World Health Organisation.[5]

Characteristics of Night Soil

The quality and composition of human faeces and urine are presented in Table 1. Table 2 describes the composition of the nightsoil which was used in laboratory and pilot plant studies at NEERI, Nagpur.

Faeces is rich in organic materials containing appreciable quantity of nitrogen and phosphorus. Data reported in Table 2 indicate that on an average, nightsoil contained 13.3% total solids of which 8% were volatile solids.

TABLE-1: Quality and Composition of Human Faeces and Urine

Approximate Quantity	Faeces	Urine
Water content in the nightsoil per capita	135-270 gram	1.0-1.3 litre
Dry wt, per capita	35-70 gram	50-70 gram
Approximate Composition (Dry Basis)		
Moisture, %	66-80	93-96
Solids	20-34	4-7
Composition of Solids		
*Organic matter, %	88-97	65-85
*Nitrogen (N), %	5-7	15-19
*Potassium (K),%	0.83-2.1	2.6-3.6
*Carbon, %	40-55	11-17
*Calcium (Ca), %	2.9-3.6	3.3-4.3
*C/N ratio	5-10	0.6-1.1

TABLE-2: Characteristics of Nightsoil used in Laboratory/Pilot Plant Studies at NEERI, Nagpur.

Parameters (Dry basis)	Average Values
pH	5.2-5.6
Moisture %	86.7
Total Solids, %	13.3
Volatile Solids, %	11.6
* Total Nitrogen (N) %	4.0
* Total Phosphorus (o), %	1.53
* Potassium (K), %	1.08
BOD TESTED OVER 5 DAYS AT 20°C	
- in gram per gram of total solids	0.4467
- in gram per gram of volatile solids	0.5155
COD in g/g of total solids	1.0698
in g/g of volatile solids	1.2344
BOD/COD/ratio	2.4
BOD:N:P	100:9:3.4

★ BOD/COD ratio gives the proportion of biodegradable organic matter to the total organics It enables us to decide on whether all the wastes are attractive for biogas generation The higher the ratio the more the expected biogas Ed

About 44.7% of total solids of 51.6% volatile Solids in nightsoil are easily this loading, it is possible to decompose more than 50% of volatile matter with gas production greater than 0.5 m^3 per kg of volatile solids fed (i.e. 0.92 to 1.12 m^3 per kg of volatile solid decomposed). This gas would have a methane content of 60-65%.

During the studies, it was observed that the slurry in the digester separated out into two distinct layers - sludge at the bottom and supernatant at the top. Up to 6.22 per cent solid concentration in the feed, the digested sludge dried quickly on a sandbad. The dewaterability of the sludge deteriorated with increasing solid concentration in the feed. Dried cake was black in colour and had no smell. Digested nightsoil slurry had an average 2.8 to 4.8% of N, 2.2 to 4.0% of Phosphorus (P_2O_5) and 0.5-1.6% of Potash (K_2O) on dry basis. Thus the manurial value of night soil is retained in the digested slurry.

Shanta[11] carried out laboratory studies at 37°C using various propositions of nightsoil and cowdung and the results are presented in Table 4.

Addition of nightsoil to cowdung can stimulate biogas production. When cowdung and nightsoil were added in equal proportion in volume, the gas production was 0.35 m^3/kg of volatile solid added. The corresponding gas production per kg VS of nightsoil and per kg VS added. The corresponding gas production per kg VS of nightsoil and per kg VS cowdung - each digested separately - were 0.49 m^3 and 0.13 m^3 respectively. The authors also observed that cow dung has a potential to suppress ammonia toxicity since the quantity of ammoniacal nitrogen released into the slurry was low in the feed mixtures as compared to night soil alone.

Removal of Pathogens

Shanta[12] carried out laboratory studies to determine the extent of removal of helminth parasites removals during nightsoil digestion at 37°C and results are presented in Table 5.

Ascaris eggs survive for longer periods than hookworms.It is also observed that the sludge and supernatant from digester still contain viable eggs.

Table -4 : Effect of Addition of Cow Dung in Night Soil

Nightsoil %	Cow Dung %	Gas Production / Volatile matter Added (VSa)	m^3/Kg/VS / Volatile matter Destroyed (VSr)
0	100	0.158	0.740
25	75	0.210	0.860
50	50	0.350	0.920
75	25	0.400	0.920
100	0	0.500	1.090

Table - 5 : Percent Reduction of Helminth Ova in Laboratory Night Soil Digester

Loading rate Kg./VS.d	Detention time d	PH	Influent No.Ova/Litre		Effluent No.Ova/Litre		% Reduction	
			Ascaris	Hookworm	Ascaris	Hookworm	Ascaris	Hookworm
2.21	20	7.50	4000	58200	2080	21360	48.0	63.2
1.78	25	7.60	114000	18200	38324	1639	66.5	90.6
1.45	30	7.65	94110	21820	28248	1528	70.0	93.0

NEERI also conducted extensive studies on pilot nightsoil digesters at Central prison, Nagpur to demonstrate the techniques of total recycle of human wastes. The digesters were similar to KVIC gas plants in all respects except for the addition of a manually operated homogeniser to bring nightsoil into a suspension before it is fed to the digester. Nightsoil was homogenised into a slurry of 6 to 8% total solids. Once or twice in a week, the digested sludge from the nightsoil digester was withdrawn into a sludge drying bed. The results for a 18 m^3 and 29 m^3 capacity nightsoil digesters are reported in Table 6 and 7. Removal of helminthic parasites from 18 m^3 pilot plant is presented in Table 8. Details about the gas production, composition of gas, calorific value, manurial value etc. obtained from the pilot plants are reported in Table 9.

The study was carried out at an average digester temperature of 28°C while the ambient temperature varied between 13°C and 33°C.

Table -6 : Experimental Results obtained on 18 m^3 Capacity Pilot Plant.

Parameters	SETS I	II	III	IV
Average loading Kg of volatile solid added/m^3/day	2.02	1.55	1.73	3.08
pH	7.2-7.8	7.1-7.5	7.4-7.9	7.0-7.6
Alkalinity, mg/litre	10,294	9,000	12,000	10,000
Total solids, %	6.50	6.10	6.10	6.45
Total valitile Soil %	5.31	4.92	4.86	5.89
Volatile acids, mg/litre	125.1	175.7	130	4246

Total ammonia-N, mg/litre	2100	1875.8	1912	1302
CST	1155.3	646.3	493	1302
VS reduction, %	52.7	48.8	50.5	57.4
Gas production, m^3/kg VSa (volatile solid added)	0.367	0.245	0.437	0.430

It was observed that there was no clearcut separation of sludge and supernatant and only slurry could be discharged.* About 0.076 kg cake/capita/day with 50% mixture was produced. It was also noticed that the performance of digester remained by and large the same with increased loading rates upto 3.56 kg/VS/m^3/day but the dewaterability of the slurry decreased appreciably.* This is an important point because the area for sludge drying will increase with increased loading rates.

Table - 7: Experimental Results obtained on 29 m^3 Capacity Pilot Plant.

Parameters	SETS I	SETS II
Average loading, Kg VS/m^3/day	2.00	1.16
pH	7.1-7.6	7.2-7.8
Alkalinity, mg/litre	8500	11000
Total Solids, %	4.5	5.9
Total Volatile Solids, %	3.5	4.6
Volatile acids, mg/litre	184	743
Total ammonia as N, mg/litre	1701	2162
CST	2761	1268
Volatile solid reduction, %	52	54
Gas production, m^3/Kg of VSa (Volatile solid added)	0.289	0.655

★ These contradicted Trivedi's observations given earlier Ed

Table - 8: Removal of Helminthic Ova in 18 m^3 Capacity Digester

Parameters Loading Kg/m^3a	Per Cent Removal	
	Hook Worm	Ascaris
1.99	66.0 ± 23.10	37.0 ± 22.61
1.60	70.0 ± 12.11	52.1 ± 16.51
1.79	65.3 ± 23.64	35.3 ± 22.7

Table - 9 : Other Results Concerning Gas Production Manurial Value, etc.

Parameters	Value
Gas production/capacity/day	0.025 m^3
Methane, %	60.65
Carbon-di-oxide, %	30-35
Hydrogen Sulphide, %	0.05-0.10
Fuel Value, K cal/m^3	5600-6500
Quantity of sludge produced	0.71 Litres wet/capita per day with 5% total solids.
Manurial value of sludge	
- . Nitrogen, %	3.25
- Phosphorous, %	1.00
- Potassium, %	0.83

Practical Application

Based on the laboratory and plant studies, it is possible to design nightsoil digesters for different population groups up to 2000 persons. For higher population, data can be adopted for designing but instead of one digester for the entire community, several small units will have to be built at different locations, if mechanical units have to be kept low. This may also facilitate easy handling and transportation of nightsoil from respective localities to the treatment site. Community nightsoil digesters have been designed and oplerated successfully by

Sulabh International.[13] Badrinath, et al[14] have given elsewhere the specific design details of nightsoils diesters, which would be very useful in this connection.

Nightsoil collection and disposl will continue for several more decades in our country and it is necessary to consider total recycling of nightsoil. It consists of digestion of nightsoil and recovery of the biogas generated. The digested slurry will be filtered on sludge drying beds and the dried sludge can be used as manure. The filtrate from drying beds will be treated in an oxidation pond followed by polishing pond* to reduce BOD and other pollutants and also for removal of bacterial and helminthic pathogens. It is possible to harvest fish from these ponds provided the effluent is diluted with fresh water.

CONCLUSIONS:

1. Various methods that are being adopted for treatment and disposal of nightsoil have been listed.

2. Laboratory studies carried out at NEERI on nightsoil digestion revealed the following:

   a) per capital contribution of total solids and volatile solids is 64.7 g and 56.3 g per day.

   b) For design purposes, total solids concentration in the feed, detention time and loading rates and important.

   c) Digesters become non-operative if the free ammonia concentration exceeds 275 mg/litre.

   d) Ascaris and helminthic parasites are removed to the extent of 67% and 91% respectively at a detention period of 25 days.

3. Nightsoil addition can enhance the production of biogas in cowdung digestion.

4. Data concerning the performance of 18 m^3 and 29 m^3 nightsoil digesters have been reported including the manurial value of the digested sludge.

5. Total recyclying scheme for nightsoil has also been indicated for future use for large population areas.

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★ "Polishing Pond" is meant for "polishing up" the filtrate from the sludge-drying beds, i e for improving its quality further Ed

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SOCIAL ASPECTS

NIGHTSOIL BASED BIOGAS PLANT

Its roll in social equality and community benefits and the problem of its social acceptance

Smt. Savitri Madan *

Abstract

Thirty four years back, nightsoil based biogas plants were constructed essentially as a "Bhangi Mukti" measure (upliftment of scavengers). But its importance for public health, women's welfare, achieving success in afforestation, improvement of soil fertility, production of better quality of crops and an aesthetically satisfying environment is immense.

The sources of inhibitions that impede the spread of biogas plants are discussed. The primacy of political will and the importance of highly motivated voluntary agencies are emphasised.

Introduction

In our country, Late Appasaheb Patwardhan pioneered the construction of nightsoil based biogas plants more than thirty years back (since 1953), mainly as a social benefit programme for emancipation and uplift of scavengers (Bhangi Mukti). Later, in his capacity as chairman of 'Bhangi Mukti Samiti' (which was constituted in 1957) of Gandhi Smarak Nidhi, he advocated and arranged financial help (subsidy) from Nidhi's funds for the construction of biogas plants. Consequently, Maharashtra Gandhi Smarak Nidhi continued the work of construction of nightsoil based biogas plants as a part of its 'Bhangi Mukti Yojana'.

Ideology of 'Bhangi Mukti Yojana'

Late Appasaheb Patwardhan passionately felt (i) that to force some one else to do our own dirty work is a sin committed towards humanity. The scavenger who does this job is treated as undignified, lowly and untouchable in social structure. This can be changed if each person does his own dirty work himself; and (ii) that in order to reduce repulsive feeling in doing this dirty work, the methods and implements for the disposal of nightsoil have to be improved.

Role of nightsoil based biogas plants in "Bhangi Mukti"

Appasaheb Pathwardhan had fully realized the significant role that nightsoil based biogas plant can play as a source of fertilizer, better health and energy. However, his stress was on the social benefitts (Bhangi Mukti) likely to be derived from the plants. The biogas plant design developed by him was a water jacketed floating dome type plant modified from 'Gramlaxmi' design developed by Sri Jasbhai Patel. Further, he insisted that it should be onsite disposal plant to which latrines were directly connected, so that not even mechanical carriage of nightsoil was not involved. This plant could be very easily maintained by any family without some one else's help. The scavenger then thus freed from dirty work, could be rehabilitated by learning other skills. With stigma of dirt gone, he could be rehabilitated socially as well. In the night of this thinking, the view that nightsoil based biogas plants

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should be based primarily in scavenger's colonies, to be maintained and used by them is a very distorted view of the issue. In fact it would be a new device to perpetuate the social injustice meted out to the scavenger community. In Maharashtra several such 'onsite' disposal nightsoil based biogas plants are functioning in individual households and institutions. They are maintained by the families or institutions themselves.

Thus, by adopting a suitable design and methodology for implementation, the nightsoil based biogas plant can plan a very significant role in 'Antyodaya' and social equality programmes.

Women's Welfare

In rural setup women face a considerable problem as regards attending to nature's call. Nightsoil based biogas plant placed in one's own family or amongst a group of houses will ease this problem. It would be feasible even if the household does not possess any cattle. The latrine could serve the purpose. However, if at a little extra cost nightsoil biogas plant could be constructed, it would augment their fuel supply and would reduce their work of collecting firewood. Time saved from this work could be used for recreation, care of children or for earning some extra income for family by stitching etc. Further, it will partially improve their lot in the kitchen.

Benefit to family:

There would be multiple benefits for the family. The time, which the family members spend in going to far away fields for defecation, will be saved. The home surroundings will be clean, pleasant and aesthetically satisfying. In addition, the generated biogas will reduce the expenditure on fuel. Further, manure of a very good quality will be available, which the family can use either in their own farm or sell it.

Benefits for the Community

Latrine-connected biogas plants will yield other benefits:

i) Cutting the trees for firewood will be reduced in proportion to the available biogas;

ii) Incidence of communicable diseases will be reduced due to lesser pollution of water sources and lesser faecal contamination of food through flies and insects.

iii) Ailments in the cattle populatior would be reduced.

iv) Crops would be healthier if open defecation in the fieids is reduced.

v) Availability of organic manure of high quality would be beneficial for the crops.

Problems in Social Acceptance

It can be said without any hesitation that the nightsoil based biogas plants offer benefits in terms of social, economic, health and environmental improvements. Yet, the programme of constructing nightsoil biogas plants may not be very easy to implement. Suitable technology is not much of a problem. Necessary financial input will also not be very difficult. The major hurdle will be a social acceptance of these plants. Inhibition to use biogas and slurry from nightsoil based biogas plants is noticed on several grounds. Efforts to deal with this inhibition effectively will have to be made very vigorously. Some important factors responsible forthis inhibition could be identified.

1. Ignorance about the nature of biogas leads to a misconceived feeling that these end-products are dirty

and unhygienic.

2. A wrong notion prevails that the nightsoil based biogas plant will make their surroundings unclean and foul smelling.

3. A feeling exists that the grains and vegetables grown in the farm where slurry is used as a fertilizer, will not be clean and wholesome.

4. A doubt about religious sanctity creeps in one's mind. One feels that it is not right to use gas and food obtained from dirt, for religious purposes.

5. Possibility of ridicule from neighbours and relatives weighs heavily on the mind of the user.

6. A fear of possible non-acceptance of eatables from the user's home by the villagers become a formidable deterrent.

Many more reasons could be enumerated. To counter these deterrents, educational efforts will be required for tackling these problems.

Improving Social Acceptance

It is not proposed to deal with detailed measures for promotion in this paper. It would be adequate to put forth a general perspective.

i) **Role of Voluntary Agencies**

Highly motivated voluntary agencies possessing missionary zeal will be an asset in promoting this work. However, it will yield better results if the Government identifies such institutions, encourages them and helps them financially for this task. It would be worth remembering that the initial construction and promotion of nightsoil based biogas plant was a totally voluntary and inspired effort of Late Appasaheb Patwardhan. Later it was continued by Maharashtra Gandhi Smarak Nidhi, which unfortunately got very limited back-up from elsewhere.

ii) The Government already has an infrastructure for rural development. This machinery could be motivated for promotion of nightsoil based biogas plant. Voluntary agencies can act as resource agencies for the orientation of these personnel.

iii) **Political will:** This is probably the most important factor. The decision for promoting nightsoil based plants through out the country will have to be a decision of the representatives of the people. With this support, it will be easy to promote nightsoil based biogas plant as one of the tools for social uplift.

Conclusion:

It is felt that the social uplift aspect of nightsoil based biogas plant are very significant. With the political will and efforts of voluntary agencies and governmental infrastructure, nightsoil gas plant will positively enrich rural social and cultural fabric.

SOCIAL ASPECTS OF NIGHTSOIL BIOGAS PLANTS

Ishwarbhai Patel *

Abstract

The paper gives inspiring instances of nightsoil based biogas-cum-manure production in Gujarat that shine through the mist of ignorant prejudice. These experiences should help overcome the pessimism that it will be long before nightsoil based biogas-cum-fertiliser plant becomes socially acceptable. Defects in biogas construction and planning, which came to the author's notice during a survey of 120 samples, are listed. Constructive suggestions for improving the efficiency of bio-degradation, increasing the temperature regimen of biogas plants and for amendment of governmental procedures are given.

- Ed.

Introduction

There are 46087 biogas plants, in Gujarat; 6467 latrines are connected to biogas plants.The first biogas plant in Gujarat with public latrines connected to it was constructed at Safai Vidyalaya, Vyara, Gujarat in 1958 on private property. The biogas thus produced was used to cook food for 15 employees and also for illumination. The digested sludge was carried away by the municipal authorities. This success story was repeated in the post-basic schools and hostels in Surat District. Biogas Plant Technician Training courses of 3 months' duration were conducted. Yet, our people are yet to accept the use of biogas plants with latrines connected. As per Manu-smriti, it is stated that latrine should be located 400 steps away as defecation is considered dirty. In the conventional communities orthodox people visit latrines by putting on separate clothing. The Mohenjodaro excavations have revealed the provisions of bathroom and drainage but not of latrines, implying thereby the prevalence of open defecation which corroborates belief in Manusmruti statements.

The rural as well as urban communities' connections of latrines to biogas plants are rather recent. In village Khoraj, Gandhinagar District (Gujarat), some 10 latrines have been connected to the biogas plants, but the use become effective after 15-18 months of construction. This was made possible by mass education by a 10day workshop which incorporated religious, scientific and educational basis of biogas plants. At Nadiad, Gujarat, 16 latrines 'used by 400 girl students had been connected to biogas plants. They did not accept the tea and snacks cooked with biogas; this indicated the deep-rooted prejudice. Some progressive farmers with scientific approach connected latrines to their biogas plants in 1958. But even today a stigma is attached to it so that food cooked with biogas cannot be an offering to God.

In Vahelal, Ahmedabad District, a farmer has constructed a flat-roofed biogas plant in his floor area with the latrine connected to it. The cattle dung, too, is fed to it. The digested slurry is collected by the women in the house and dumped in the compost pit. Such illustrations are useful in shaking social inertia and countering prejudices. It has been observed that the Advisi agricultural daily wage earners do not handle

* Principal, Safai Vidyalaya, Harijan Ashram, Ahmedabad

the digested slurry; in them the feeling is well entrenched that only the scavanging community can do such jobs. Such trends are based on "religious beliefs".

A progressive farmer of Ranip (Ahmedabad) constructed two latrines in his premises, one for own family and other for the public who may not be having such facility. He invites people to use the public latrine. Some 40 users avail themselves of it. The owner runs his family kitchen from the biogas produce therefrom. In the Chetanawadi area of Mehsana (Gujarat), a biogas plant, fed from 6 latrines serving 12 tenants is in operation. The tenants get cooking gas at Rs. 35/- per month. The outgoing slurry is used as organic manure to grow vegetables. It is an excellent example of low-cost sanitation with recycling of wastes. Another biogas plant is in operation at the Pathey Hotel at Krishna Nagar on the National Highway which provides easing facilities for passengers, drivers and conductors. The biogas is utilised in the hotel. In a decent large hotel Ahmedabad in a rural environment, livestock wastes and garbage are fed to the digester and the biogas from it is used in the kitchen. The digested, drained, dried and parcelled out sludge cakes are packed in 2 kg polythene bags and sold at Rs. 5/- each for the city's individual kitchen gardens. Such experiences should help demolish the social stigma attached to connection of nightsoil to biogas plants.

Financial Subsidy for Latrine connected Biogas Plants

The Government of Gujarat pays a subsidy of Rs. 300/- to any biogas plant which admit wastes from latrine. This scheme initiated by the Rural Development Department had a positive impact and gathered momentum, thanks to the co-operation of educational and other institutions. It saved rural women from smoke nuisance which affected their eyes. It has proved to be a blessing to them as the womenfolk can now have privacy during the daytime without having to cover long distances. It leads to better health because poor sanitation and unprotected water are responsible for 80% of prevalent diseases which cause a loss of 73 million mandays. It saves an equivalent of Rs.500/- in terms of production of gas and fertilizers.

Sulabh International has started community biogas plants with latrines connected to these. It is necessary to propagate the concept that waste is wealth when it is recycled. The implementation becomes successful when the maintenance and cleaning is done by the owner. It is observed that generally, the prosperous farmers avail themselves of this scheme. It has not yet percolated to the strata of landless labourers.

Ideally, the theory and practice go hand in hand but in reality, there is always a gap. It is necessary to bridge this gap. The following observations are based on a survey of some 120 samples.

1. The field results hardly approach 50% of the figures claimed by scientific bodies.

2. The organising agency does not, in general, posses adequate knowledge about biogas plants. The available information does not reach the users.

3. The proportion of excreta and water is 1:2 litres per use. This slows down biochemical reactions and reduces the liberation of biogas.

4. Normally one large sludge drying bed is provided but it is necessary to have 4-5 small ones.

5. Distances of biogas carrying pipes were found to be very long. It

should not exceed 20 m.

6. Biogas plant should not be under any shade or shadow at any time in the day. Only 70% plants were found to be free from the shadow walls and only 10% plants were found to be away from trees.

7. The priority of users was found to be in the following order: cooking, mechanical gadgets, and manure. About 98% of biogas plants were seen to be used for cooking purposes only.

8. For maintenance of gas pressure for flow, the slurry must be fed twice a day. In 95% of the biogas plants, feeding of slurry was done only once a day.

9. The proliferation of biogas plants is of national importance. It has been observed that procedures for obtaining Sanchai and Subsidy are arduous and timeconsuming as was felt by 75% of people under study.

10. The organisers were found to be running after target of numbers, forgetting the users and the necessary oprational guidance is difficult to get.

Suggestions and Recommendations:

Nightsoil has been looked upon with repugnance. Because of maladies associated with nightsoil, the operational and maintenance personal have been looked upon with disdain. Nightsoil, if misused or mismanaged, is hazardous. If managed scientifically and carefully, it yields several benefits. Some emperical suggestions from scientific and social standpoints are made below.

1. The size of gas dome may be reduced to get more pressure and effective anerobic biogradation.

2. Non-corrosive HDPE (high density polyethylene) or fibre-reinforced plastic containers are available as gas holders. These may be painted black for absorption of solar rays.

3. Attempts are needed to use local and inexpensive materials for construction of biogas plants.

4. Intensive and effective training programme coupled with simplified procedures for quick processing of applications along with their relevant publicity would go a long way in mass propagation of plants for decentralised harnessing of renewable resources of great national importance.

मानव मलूमत्र पर आधारित गैस संयन्त्र

–बनवारी लाल चौधरी

भारत में और विशेषत ग्राम क्षेत्र में सामान्य भावना पवित्रता और कालुष्य की है न कि स्वच्छता और स्वास्थ्यता की, इसने जन्म दिया अस्पर्शयता को अत कोई भी; गदी निरूपित वस्तु या स्थिति को सामान्य जन निपटाता नही है उसे छूता तक नहीं है– और यह कार्य फिर एक समाज विशेष को सौंप दिया जाता है। गाय पवित्र है अत गाय का गोबर न केवल स्वय शुद्ध है। वरन् गोबर और गौमूत्र का उपयोग शुद्धीकरण हेतु किया जाता है। मानव मल व मूत्र अस्पर्शय है इसलिये उसे देखते ही घृणा की भावना, थू थू करने की भावना, जागृत होती है फिर भले ही हम आम रास्तों पर कुआ के पास यहा तक कि मदिरो के आसपास ही क्यो न निपट ले।

गैस संयत्र मे किस द्रव्यमान का उपयोग करें यह बहुत महत्त्व धारण कर लेता है, गोबर और कृषि जन्म–कचरा का ग्राम समाज हमेशा व्यवहार करता रहता है अत इनसे चलित गैस सयत्र को समाज सहज ही स्वीकार कर लेता है। मानव मल मूत्र सचालित गैस सयत्र का प्रचार उसके प्रति प्रचलित भावना के कारण बहुत मद गति का है। केवल कुछेक सस्थाओं मे ये सफलता पूर्वक चल रहे हैं। भारत के शहरो और गावों में मलमूत्र का निपटान एक समस्या है एक वर्ग विशेष के लोग आज भी मैला सिर पर ढो रहे हैं, इसका उपयोगी और लाभकारी हल इसे गैस और खाद बना देने में हैं। मानव मल के खाद को सॉन खाद मानते हैं और मूत्रखाद को हीरा खाद। पर लोगो के मन में ऐसी गलत धारणाये हैं कि इसे बनाना और उपयोग करने मे झिझकते हैं। मानव मलमूत्र का सदुपयोग न करके हम राष्ट्र की कम से कम 500 करोड की राष्ट्रीय सपदा नष्ट कर रहे हैं और अरबो रूपया मल मूत्र से फैली गदगी के कारण हुई बीमारियों के उपचार और रोकथाम पर खर्च कर रहे हैं, इसके निराकरण का एक उत्तम और उपयोगी उपाय गैस सयत्र मे मलमूत्र का उपयोग है।

मलमूत्र मिश्रित गैस सयत्र के प्रचार और उपयोग हेतू तीन स्तरो पर पहल करनी होगी –

1 शैक्षणिक
2 आर्थिक
3 तकनिकी

शैक्षणिक : लोगो को मलमूत्र के सही निपटान के प्रति जागृत करना होगा प्राथमिक शाला, प्रौढशिक्षा शाला और महिला मडल में इस पर पाठ और चर्चा हो इसमें श्रव्य दृश्य साधनो का खूब उपयोग हो, स्लाइड लघु फिल्म हर सिनेमा घरों में शालाओं में दिखाई जावें, गदगी से निपटने का सही ज्ञान हो, लोगों को ऐसे सयत्र के आर्थिक और स्वास्थ्य की दृष्टि से होने वाले लाभ बताये जावें।

आर्थिक : ऐसे सडास के निर्माण पर जिसका मलमूत्र बिना कहीं अटके सीधा मलमूत्र गैस सयत्र में चला जाय कम से कम 15 रुपये का खर्च आवेगा। आरभिक वर्षों में प्रोत्साहन देने के निमित्त गैस सयत्र से जुडी सडास पर शत प्रतिशत अनुदान दिया जाय साथ ही लोगों को समझाया जाय कि इस पद्धति से उन्हें अधिक गैस मिलेगी जिससे उनका ईंधन और प्रकाश पर होने वाले खर्च में बहुत बचत होगी।

जो गोबर गैस सयत्र पहले से बने है, उनमें सडास जोडने की ठीक और कम खर्चीली पद्धति विकसित हो तथा जो लोग ऐसा करना चाहें उन्हें इसके लिये शत प्रतिशत अनुदान दिया जाय।

अनुदान प्राप्ति में होने वाला विलब और भ्रष्टाचार को समाप्त करने के लिये व्यवहारी युक्ति खोजी जाय।

तकनीकी सयत्र का वर्तमान डिजाईन ऐसा है कि उसमें एवं उसकी छीजन स्लरी में मल तैरता दिखता है इसके कारण लोग उससे घृणा करने लगते है यह खामी बहुत अश तक पानी के जैकेट बाले डिजाइन से मिट जाती है इसका एक और बडा फायदा यह है कि वाटर जैकेट में थोड़ा सा एजिन का जला तेल डालते रहने से ड्रम में जग भी नहीं लगती।

छीन स्लरी का उपयोग . स्लरी का उपयोग सामान्यत दो तरीके से किया जाता है पहला तरीका इसे सीधा फसल, सागभाजी, उद्यान आदि में डालना यह तरीका अधिक प्रचलित और अपव्ययी है। पर यह श्रेयकर और लाभकारी नहीं है। दूसरा तरीका स्लरी का जामन के रूप में उपयोग कर इससे कूडा करकट का कम्पोस्ट बनाना है, इस उपयोग से कम्पोस्ट की गुणवता बहुत बढ जाती है।

गैस सयत्र के पास ही यदि कम्पोस्ट के गड्ढे हो तो स्लरी को एक नाली द्वारा इनसे जोड देना चाहिये। कस्तूरबा ग्राम कृषि क्षेत्र ने ऐसा ही किया है। जहा गड्ढे दूर हों वहा सयत्र से जुडी हुई ही एक पक्की टंकी बना ली जाय जिसमें छीजन स्लरी एकत्र होती रहे। यहा से बाल्टियों में भर भर कर कम्पोस्ट बनाने में उपयोग किया जाय।

मानव मूत्र व मल सलग्न गैस सयत्र समाजिक, आर्थिक और स्वास्थ्य की दृष्टि से लाभकारी है अत इसके प्रचार प्रसार और उपयोग का कार्य समन्वित, एकीकृत और सम्पूर्ण दृष्टि से उठाया जाना चाहिये।

SOCIAL ASPECTS OF THE NIGHTSOIL BIOGAS PLANT PROGRAMME THROUGH CASE STUDIES

Krishna Mahapatra *

This paper presents the fruits of certain case studies where community biogas plants were constructed without the community's participation in the formulation of schemes.

The social aspects are the most significant aspects of a technology-intensive programme and may decide the latter's fate in terms of success and failure.

In the nightsoil-based biogas programme, these aspects have been of greater significance due to the sensitivity of the issue in the Indian socio-cultural context.

Very broadly speaking, such technology-intensive programmes seem to have three main aspects:

1. The technical-including the skill involved, the resources etc.

2. The social-including the beneficiary group attitude, the use concept etc.

3. The organisational aspects - including the maintenance, the running of the programme etc.

This paper through case studies of nightsoil based community biogas plants at Puri, Varanasi, Masudpur and Midnapur tries to illustrate the significant role of social aspects in the positive implementation and working of the programme and seeks to give some suggestions.

The Puri, Varanasi and Midnapur plants are entirely for Harijan communities.The Masudpur plant is a part of a demonstration project of Khadi Gramodyog, and the beneficiary group which has to pay for the gas supply for cooking purposes, is a mixed group in the neighbouring village complex comprising of different caste and class and awareness backgrounds.

While the Midnapur plant was closed down after a few months of functioning and was thus a total failure, the other three plants are in various stages of functioning under a wide range of constraints which range from purely social to the technical.

The Puri and Midnapur plants were fed by nightsoil carried from dry latrines to the plants through the municipality collection system.

The Beriban (Varanasi), Masudpur (Haryana) plants were attached to latrines which were specially constructed to be used by men, women and children of the villages.

In all these cases the gas was chiefly for cooking purpose except at Beriban where the use was to be for lighting which was a greater need for the people.

From the study of the 4 community biogas plants significant aspects which come to light are:

1. The Puri programme was started

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without the people's participation, but still was a relative success as the economic benefits overruled the constraints of ethos and values and the feeling of discrimination as they were Harijans.

2. The Beriban programme at Varanasi was an impractical idea under the given conditions and therefore non-functional. The most important constraint was the shortage of water. Next was the ethos of women who must not be seen going for natures' call, with cans in hand - as it was something to be shy of, in view of the man-woman relationship.

3. Masudpur programme was different as the villagers using the gas for cooking did not have the feeling of abhorrence seen in the other areas but the use of latrines was not a practice here. The poor maintenance of latrines due to shortage of water added to the propensity to avoid of the latrines. With several construction works going on for multi-storeyed buildings around the village the villagers were gradually finding a shortage of open grounds, but the laying down of sewage system in the village had given them hope of having their own latrines in their homes and till such time they preferred to "somehow manage" rather than go to the "closed cooped-up filthy latrine."

The study of the four cases quite clearly establish the need to ensure people's participation at all levels of planning, implementation and management.

BIOGAS PLANTS BASED ON NIGHTSOIL

Amulya Chakraborty *

Abstract

The thirty latrine-connected AFPRO-design-based family-size biogas plants constructed in Contai sub-division (Midnapore district, West Bengal) have been operating without much trouble so far as gas generation is concerned. In rural areas, the movement for low-cost latrine and smokeless chullah has caught on. Progress in the programme for nightsoil-plus-other animal-waste based biogas plants depends on innovations in (i) low-cost design; (ii) the technology of using water hyacinth and varieties of foliage as inputs along with nightsoil and cattledung; and (iii) the finding of uses for the slurry as fish meal and the like. The paper posits a few other questions requiring research based scientific advice.

The disappearance of bushes and jungles has greatly reduced the scope for open-air defecation. The resulting threat to women's privacy has created a strong impulse for domestic latrines. The grave shortage of fuelwood and the need for keeping the ponds clean as a source of water for cooking purposes have created a new awareness for nightsoil-based biogas plants. People have come to feel that the alternative is helpless dependence on tubewells that often go out of repair and the pollution of tanks by nightsoil washed over from the roadside by rainwater.

-Ed.

Introduction

The Lok Shiksha Parishad, Narendrapur evolved a system of latrine based on a pan attached with a U-pipe and without any septic tank. The nightsoil is discharged into the digester of the biogas plant (1.3 or 5 cum as may be the case), by a pipe, In every case the latrine-connected fixed-dome plant is fitted with an inlet chamber for feeding cowdung and outlet chamber for discharge of the slurry according to the AFPRO design. In this way nearly 30 biogas plants of family size (2 or 3 cum), constructed during 1985 in five villages in Contai Sub-division are found to be operating without much trouble so far as gas generation is concerned.

In some cases where mixed feeding system was introduced, the DIC staff of the district suggested the use of scrapings of carcass of dead animals as inputs for quick generation of energy. The plant owners are reluctant to use such material. We, too, have not found any literature which suggests that such material can be fed into biogas plants.

Progress/innovation is necessary in the following respects:

i) Low-cost design for domestic latrine-connected biogas plant digester.

ii) The utility of fresh slurry as fish meal. It has to be well established.

iii) The proportion of materials like water hyacinth and similar varieties of foliage in relation to cow dung or nightsoil for ensuring gas and light at the rated capacity.

Besides, scientific advice is needed on:

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i) the pros and cons of substitution of the inlet chamber steps by a pipe as in the KVIC model. (This is generally advocated by DIC).

ii) the advisability of otherwise of putting animal carcass of dead animals.

Integration with Development Programme

It is observed that the move for introducing smokeless chullah and low-cost latrine has made some headway in the rural areas.The programme for low-cost nightsoil biogas plants should now be emphasised. In fact, the response of the villagers wherever we went and propagated the utility of the biogas plants has been beyond our expectation.

Here again, the problem is that a large number of enthuiasts for biogas plants in the villages are without any cattle or poultry or piggery. Now, domestic biogas plant (even 1 cum size) cannot generate gas only by nightsoil from the small-size and single-family systems, because it appears that the regular use of connected latrine by 35 to 40 persons will produce gas from the plant considered sufficient for only 5 to 6 members. In such cases our advice has been to collect cowdung from outside or set up poultry farms or have goat farm or piggery so that the additional feeding material may come from their own household. These are, however, good as advice but cannot be practised by villagers in general. The matter, however, requires some analytical study by the experts so that some concrete suggestions might be offered to the villagers who are willing to have biogas plant fitted to latrines but have no cattle of their own.

From the Viewpoint of Domestic and Social Sanitation

The ordinary families in the villages in different districts of our State (West Bengal) are now responding very enthusiastically to our education-cum-motivation camps for propagating biogas plants with a stress on nightsoil. We have tried to examine the factors behind such enthusiasm. I may cite here a very important factor behind such motivation. It is the crisis in the traditional open-air toilet system. In one education camp held in a village in North 24-Parganas district in July 1986 the heads of the Muslim as well as scheduled caste families argued that low-cost latrines are now essentially required for womenfolk. The gradual disappearance of the village forestry, bushes and jungles makes it extremely difficult for the women in particular to go out to the traditional open-air latrine. Increasing population and extension of housing are also creating problems in this matter.

In a similar education camp conducted by us in the South 24-Parganas (near the Sundarbans) very recently people showed eagerness for protecting the village tanks from roadside by heavy rain water. These tanks are the main source of water for cooking and washing. Tubewells are too few in number and once a tubewell goes out of order, repair becomes a problem for the Panchayat Samity. Therefore, a latrine is now-a-days a common demand in these areas. When they were told that a digester can produce cooking fuel and some light in the evening, they were all for it. A public sector Bank has assured that proposals sponsored by our institution will be financed by them.

These instances show that nightsoil based biogas plants have now caught the imagination of the people. Our contention is that the experts in the AFPRO, CORT, CART and the Non-conventional Energy Department of the Government have now to find out how gas generation from nightsoil based digesters can be augmented in an easy process practicable for the villagers. The programme for energy and sanitation is intimately connected with the movement for pollution-free environment.

Let us also consider the issue of community gas plants. Proposals from about half-a-doze areas have been made to us for nightsoil-based community plants in village areas where a particular vocational group of families reside in a cluster.In one such area, there are 30 potters families, their total population being about 220 (adults and minors taken together). Even if all of them use the community latrines, the optimum gas generated from the plant can serve only about 30 of them, that is one member per family. So, we cannot proceed with any such project unless additional feeding is available. That can be arranged from outside but a cost will be involved both for the material and management.We propose to utilise water hyacinth that is abundant in the marshy land near by. But it may not be a permanent solution. What is needed is a break-through by R & D.

HEALTH ASPECTS

NIGHTSOIL BIOGAS PLANTS

Health Aspects

S.R. Kshirsagar *

Abstract

This paper gives the warning that nightsoil-based biogas plants which are being propagated as a health protection and energy conservation measure many themselves turn out to be the source of dissemination of diseases unless utmost care is taken at all stages. If the nightsoil is to be manually collected from elsewhere for feeding into the digester, the scavengers come into direct contact with pathogens. It is possible for the pathogens to survive in large numbers in the digester and pass over to the effluent. Anaerobic digestion over merely 30-35 days' detention time is unhelpful for pathogen destruction. Even the drying of effluents removed after this insufficient detention time does not help in making the manure innocuous. There are great hazards if the crops grown with such manure are eaten raw. The use of sludge on croplands or in fish farms contaminate food articles widely. In the same manner as labourers are sewage-fed farms suffer from higher incidence of infections of helminthic and intestinal pathogens, the workers on sludge-fed farms, too, are likely to be victims.

The conclusion that flow from the above observations is that a longer retention time in the digester (HRT) is necessary since the optimal conditions in terms of temperature, pH and moisture content are unavailable in field conditions. Sun drying on open sandbeds for 10-20 days has been recommended. Aerobic composting of the slurry with agricultural wastes, which at its peak period raises the temperature to over 60°C, has been recommended.

Ed.

INTRODUCTION

Biogas generation through anaerobic decomposition of organic matter is not new to our country. It has however presently assumed greater importance and significance in the context of energy crisis and the need for development of renewable sources of energy.

Health Aspects

Although a variety of organic materials such as cattle dung, water hyacinth, agricultural wastes, can be used as a feedstock for production of biogas, the use of human excreta is advantageous because of (i) its availability at all human settlements and at low/no cost and the dire need for its treatment. While advocating and recommending large scale use of human excremental matter for biogas production, attention must be paid to the health aspects involved in its procurement and use in biogas units and also in the disposal/use of the effluent because of the possible presence of pathogenic organisms. Table No.1 gives common types of pathogenic organisms present in human excremental matter and urine.

Handling of raw human excreta, even as feedstock for production of biogas, obviously results in a great occupational hazard. The system of collection and conveyance of human excreta by hand in tins or baskets and then feeding into the gas plants manually is therefore highly objectionable from the viewpoint of the health of scavengers involved

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in the system. They come into direct contact with the pathogens potentially present in the excreta to be fed to biogas units. These risks can be reduced but not eliminated altogether by resorting to mechanization of the different operations. This will, of course, add to the cost and intricacy; and villages and smaller towns in developing countries like ours may not be able to afford such facilities. It is for these reasons and also from the sociological point of view that the low-cost sanitation system of 'on-site treatment and disposal' of human excreta using covered leaching pits is being advocated by sanitary engineers and it is now being widely adopted both in rural areas and small towns where conventional sewerage system is not feasible. In this method, although biogas is not available[1], human health is protected.[2]

When nightsoil is collected and is to be fed to biogas units, it is first homogenized in a mixing tank fitted with paddles and water added 'if necessary' to make the moisture content in the feedstock to about 90-95%. This helps in feeding it into the biogas units easily by gravity and mixing it well with the decomposing mass already present in the digester-reactor units.

The Process of Anaerobic Decomposition

In this process, facultative aerobic and anaerobic type of saprophytic micro-organisms first break the complex organic material fed to the digesters into simpler compounds forming organic acids and carbon-dioxide. The digester containes a variety of bacteria which act successively upon the feed material and in the end of the methanogenic group of bacteria stabilise and mineralise the matter producing methane gas. In order to achieve more complete destruction of organic matter in the process and to obtain maximum amount of gas containing higher proportion of methane in the shortest possible time, the conditions of decomposition in the digesters must be maintained at their optimum levels by controlling parameters such as temperature, pH, moisture contents, etc. at 35-37°C, 7-7.5, and 90-95% respectively. Under such conditions, the organic matter (excreta) fed to the digesters can get practically fully stabilized within a period of 20-25 days. The detention period, however, is increased from 20-25 days to 30-35 days to compensate for field conditions which may not be ideal.

It will be, however, observed that conditions in biogas units are much the same as are prevalent in the biogas of living human beings. These conditions are taken advantage of by the pathogenic organisms discharged by sick persons or by the Vectors which are thus potentially present in the extreta fed to digesters. Obviously, these pathogens will survive in the digestion processes in large numbers. Some reduction would, of course, occur due to the competition for food material from other microbes and also due to attack from predators. Thus, the process of anaerobic decomposition, even if carried out in a controlled manner is not helpful in destroying the pathogenic organisms within the detention period of 30-35 days normally deployed. Hence the effluent slurries coming out of nightsoil-fed biogas units will be equally hazardous to handle, dispose of or utilise in the fields as manure.

Again, some of the pathogenic organisms (e.g. those of amoebic dysentery) which can form cysts or the eggs of some of the helminths (e.g. ascaris) will remain totally unaffected while passing through the anaerobic decomposition, in the digesters and the effluent slurries would contain these. Some of these may sink into the portion of the digested sludge in a dormant form and can become

1) Manure, however can be recovered from this method, Ed.

2) This method, however, is not entirely free from hazards Groundwater contamination has been reported from many areas Ed

active and infectious on entering human systems.

Disposal/Utilisation of Effluents & Digested Sludge:

The digested sludge and the effluents from nightsoil-fed biogas plants contain good amount of fertilizing elements such as nitrogen, phosphorus and potash (2-3, 1.2-2.6, and 1.5-1.8 percent respectively). Besides, the humus is a very good soil builder and fertilizer. Since both of these contain large amount of moisture these are first dried on open sand beds overlying open jointed pipe drains. The moisture gets reduced due to both percolation and evaporation to about 50-60% when the solid cake produced on the surface of beds can be removed and utilised as farm manure. This cake manure would, however, contain many of the pathogenic organisms still surviving and hence the workers removing it from the drying beds, transporting it or using it on the farms should be given protecting garments (i.e. gumboots and rubber hand gloves) and be asked to observe personal hygiene so as to reduce/eliminate the health hazard involved in these operations. The crops to be grown over the farms fertilized with biogas plant effluents dried or otherwise should also be such which are not to be eaten raw. This will prevent any danger of contamination of the food articles and the spread of epidemics amongst the consumers of the farm produce.

Risk of Infection and Methods of Disinfection of Effluent Slurries/Sludges

Table No.2 indicates the likelihood of infiltration of pathogens into humans through sludge disposal and associated pathways. From this table it will be observed that the pathway of distribution/marketing which is commonly used for utilisation of sludges on land or fish farms is more dangerous due to the handlers' direct contact with these pathogens. These are also likely to contaminate the food articles which are being produced. Sea disposal can also cause contamination of fish and other foods obtained from it. Likely danger to human health depends upon the number of organisms potentially present in each of the pathway and the infective dose. Table No.3 gives some indication on these aspects.

NEERI has observed in its studies on sewage farms that labourers working on such farms are having higher incidence of infections due to helminthic and intestinal pathogens. Although in our country reports are not available about epidemics which can be attributed specifically to the use of sewage or sludges for fertilizing the farms, any lack of data in this respect cannot be constructed as a positive indicator of safety of handling and using this material (i.e. sewage and nightsoil sludges) for fertilizing land and fish farms.

Bhabha Atomic Research Centre, Bombay has, of course, carried out field experiments to demonstrate sterilization of sewage sludges using radioactive isotopes. But these techniques are costly and require specialised knowledge and skills and additional safety precautions in handling and administering the required doses of radioactive substances to sewage sludges for disinfection. These may not therefore be technically and economically feasible for application to common biodigester sludges in our country.

The simple and economical method which is practicable for use in our country would be sun drying on open beds of sand only. Sufficient space should be available for the purpose near biogas plant sites because such natural drying may take from 10-20 days depending upon the climate in the geographical location of the plant, and the season at the place. During rainy seasons, again, this open drying method may not work at some places. Erection of simple roof sheds over drying beds and prevention of entry ot storm water run-off to the drying bed sites would help in regions of high rainfall intensities. Of course, this would involve additional initial investments for the construction of roof sheds over the drying beds but there is no recurring expenditure and the method is simple to operate.

Mixing of compostable type of refuse/agricultural residue and composting of the digested nightsoil/effluent slurry aerobically can also help quicker drying. The compost so obtained will also be richer in quality because the other ingredients will imbibe nitrogen from nightsoil. This method will also have the advantage of simultaneous treatment and disposal of refuse and biogas plant effluent. The aerobic composting is expected to build higher temperatures (over 60°C) in the decomposing biomass for over 5-6 days so as to destroy the pathogens potentially present in the effluent slurries of biogas plants and the resulting compost is safer to handle and use on the farms. Sufficient space must, however, be available at the biogas (nightsoil) plants sites for the purpose.

Conclusion

In an attempt to tap all possible sources of non-conventional energy systems, the use of human excreta as a feedstock of biogas plants is being advocated. However, this feedstock (i.e. nightsoil) may contain a variety of organisms pathogenic to human beings. The process of anaerobic decomposition does not eliminate all pathogens. Hence proper care should be taken in not only handling and feeding the raw material to the biogas plants and in handling the slurry but also in its use as manure.

Table - I : Bacteria, Viruses and Parasites in Wastewater and Sludges

Group (1)	Pathogens (2)	Diseases (3)
BACTERIA	Salmonella (1700 types)	Typhoid, paratyphoid & salmonellosis
	Shigella (4 species)	Bacillary dysentry
	Enteropathogenic:	
	Escherichia coli	Gastroenteritis
	Yersinia enterocolitica	-do-
	Compylobacter jejuni	-do-
	Vibrro cholerae	Cholera
	Leptospira spp.	Weil's disease
VIRUSES	Enteroviruses:	
	Poliovirus (3 types)	Paralysis, meningitis,

(1)	(2)	(3)
		fever
	Echovirus (32 types)	Meningitis, respiratory disease, rach, diarrhoea, fever
	Coxsackie virus A (23 types)	Horpasgina, respiratory disease, meningitis fever
	Coxsakie virus B (6 types)	Myofarditis, congenital heart anomalies, rash, fever, meningitis, respiratory disease, pleurodynia.
	New Enteroviruses (5 types) acute haemorrhagic	Meningitis, encephalitis, respiratory disease, acute haemorrhagic conjuuctivities, fever
	Hepatitis Type A (Entrovirus 72)	Infectious hepatitis
	Gastroenteritis virus (Norwalk type agents)	Epidemic vomitting and diarrhoea, fever
	Rotavirus (4 types) (Reoviridae family)	Epidemic vomitting and diarrhoea, chiefly of children.
	Reovirus (3 types)	Not clearly established.
	Adenovirus (41 types)	Associated with respiratory disease in children but aetiology not clearly established
PROTOZOA	Entamoeba histolytica	Amoebic dysentry, liver abscessl, colonic ulceration
	Giardia lambia Ballantidium coli	Diarrhoea, malabsorption Mild diarrhoea, colonic ulceration.
HELMINTHS	Ascaris lumbricoides (Roundworm)	Ascariasis

Ancyclostoma duodenale (Hookworm)	Anaemia Anaemia
Necator americanus (Hookworm)	Anaemia
Taenia saginate	Taeniais

Ref: "Feasibility for performing a risk assessment on pathogens" by Larry Fradkin, Steven Lutkenholf, Jery Strate, elliot Lomnitz, Barney Cornaby, Journal Water Pollution Control Federation, December, 1985, page 1185.

TABLE - II Likelihood of Exposure of Pathogens to Humans as Related to Sludge Disposal and Associated Pathways (a)

Disposal Method	Pathway					
	Surface Water	Ground Water	Direct Contact	Food	Aerosol/ particulates	Sediments
Landfill	**b	****	*	*	**	NA c
Landspread	**	***	**	**	***	NA c
Distributing/ Marketing	**	**	***	****	**	NA c
Ocean Disposal	**	NA c	**	****	**	***

a = Estimates likelihood of exposure along pathways. Comparisons of sludge disposal options may not be valid.

b = **** Most Likely

*** Likely

** Possible

* Unlikely

c = A Not Applicable

Ref: "Feasibility for performing a risk assessment on Pathogens" by Larry Fradkin, et al. Journal of Water Pollution Control Federation, Dec. 1985, page 1186.

TABLE - III : Likelihood of Exposure from Pathogens to Humans as Related to the Number of Organisms Potentially Present in Each Pathway and the Infectious Dose a.b

Number of organisms/ infectious dose	PATHWAYS					
	Surface Water	Ground Water	Direct Contact	Food	Aerosol/ particulates	Sediments
Bacteria	*** ***	***	***	***	*	***
Viruses	****	****	****	****	**	****
Helminths	--	--	****	****[c]	--	**
Protozoa	*	--	**	**	--	**

a = **** Many organisms/low infectious dose

= *** Many organisms/high infectious dose

= ** Few organisms/low infectious dose

= * Few organisms/high infectious dose

= -- Presence unlikely/high or low infectious dose

b = This table is a qualitative estimate of likelihood. A more quantitative version of this table would be produced from the output of a risk assessment. These risk assessment results possible could make the table homogenous such that comparisons can be made along rows and columns.

c = The **** score for land based disposal sites; for ocean disposal the score would be**.

Ref: "Feasibility for performing a risk assessment on pathogens" by Larry Fradkin, et. al., Journal of Water Pollution Control Federation, Dec. 1985, page 1186.

NIGHTSOIL BIOGAS PLANTS

Health aspects and design

*H.K. Chanakaya**

Abstract

The paper explains why the cattle-dung-based biogas plant's design cannot straightaway be adopted as suitable for nightsoil-fed plants, why in nightsoil based biogas plants it is so very difficult to maintain the optimum solid concentration, why the residence time in nightsoil digester has to be longer and post-digestion secondary treatment is an indispensable requirement. It also explains the design objectives of nightsoil-based biogas plants and the advantage of multiple types of feedstocks as in China and pinpoints a few areas for in-depth research.

In the author's opinion, the Hydraulic retention time of 35-52 days is insufficient for a nightsoil digester. (In this it differs from the background paper presented by NEERI). The author makes the point that since the occurrence of ova is the least in the middle portion of the digester column, the outlet should begin from there. It is necessary to desist from feeding nightsoil into the plant for two months preceding the periodical cleansing of the sludge from the digester bottom, which means, alternative arrangements for toiletry has to be provided for, from the very beginning.

The paper suggests that there must be post-digestion terminal treatment by either biological or chemical means or by storage of at least one year's duration in a soaking pit. Although its emphasis is on biological means - composting or algeal culture - it leaves open the debate over chemical means.

Ed.

Introduction

The utilisation of human excreta (nightsoil) for the production of biogas has been often mentioned but has rarely received adequate attention or put to practice effectively. This is in spite of the fact that the very first biogas plant in the country (1897 in Matunga) utilised human excreta as feed. There are both sociological and technological issues (especially health) which have to be considered before widespread application is thought of. Nightsoil biogas would provide: (i) a source of energy; (ii) a source of fertiliser; and (iii) a method for the improvement of rural health and sanitation.

Simple calculations can be made to show that when the human excreta of a small village (adult population about 250) is put to biogas production, the resultant biogas can be used to produce approximately 10 KWh of electricity. This can be used for street lighting/domestic lighting/lifting drinking water/running a light industry etc. This shows that a large potential exists for the use of biogas energy towards meeting a part of the rural energy needs with concommittant improvements in the village sanitation

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and health.

While cattle and other animal dung are relatively free of human pathogens and consequently safe, the human excreta have to be handled with considerable care to guard against the reinfection process of faecesborne pathogens. In case this aspect is neglected (in nightsoil biogas plants), the primary objective of improvement in village health and sanitation may not be realised at all. Dung-based biogas production has some superior advantages, which are absent in nightsoil-based biogas production. In the former,

1. the optimal solids concentration is 9%.

2. the feed (dung) and water is mixed by hand to bring down the concentration of dung to 9%.

3. the optimum residence time (HRT) is based on economic considerations of the rate of gas production.

4. The effluent slurry is left in the open for drying and handled without fear of pathogen infection.

From the above considerations it can be seen that the present designs of biogas plants (in India) cannot be straightaway extended for use of human excreta and need modification.

The optimal solids concentration of 9% TS (total solids) cannot normally be maintained in excreta discharged from the conventional toilets (except in the case of dry toilets) owing to the fact that for every normal use, about 30-80 g of dry solids[1] discharged along with 3-10 litres of water used for flushing etc. (Table 1 gives the daily production of nightsoil in some areas of India and for developing countries). The solids concentration in the above mentioned case is too low for economical running of biogas plants. It is thus necessary to change the toilet design in such a way that a maximum of 1 litre of water of discharged (along with solids) per call. The resultant solids concentration then would be around 3-5%.

Manual mixing of feed as followed for cowdung based biogas plants cannot be adopted for nightsoil plants (where nightsoil is collected from dry toilets) for obvious reasons and hence the discharge from the toilets should preferably be sent directly into biogas plants with some degree of mechanical agitation to ensure rapid decomposition and facilitate the settling of ova trapped within the solids. Contact with pathogenic material (injection) can occur during several of the folowing operations normally carried out in connection with a biogas plant.

a. Collection, transportation and mixing into slurry.

b. Formation of areosols during the above operations and their inhalation.

c. handling, transport and treatment of effluent slurry.

d. contamination and infection through tools and implements used, washing water etc.

Hence it is necessary to avoid these infection routes as much as possible, with minimal cost and sophistication.

The optimum residence times of 35-52 days used in the conventional dung based biogas plants has been arrived at by optimising cost versus gas yields. This however, will not hold good for digesters designed to be run on nightsoil because during this retention period many pathogens present in nightsoil are still viable and it would be dangerous to discharge such effluents into the open, permitting human handling and exposure to vectors of disease transmission. The viability of the normally occurring pathogenic specials in human excreta, their numbers, and responses to environmental conditions is presented in Table 2[1,2]. It can be seen from the table that in most parts of our country (w.r.t. temperature inside the digester), a substantial load of pathogens is likely to be discharged in the effluent. It is then necessary to so modify the design that the pathogens are retained (or inactivated) within the digester while only the excess water and spent solids are discharged for secondary treatment.

The above concept has been tested and studied in detail in China[2]. Research findings show that ova of the major pathogenic species present in nightsoil plants have the following characteristics (Table 3). Under the existing conditions of specific gravity (1.005-1.010) and viscosity of slurry within the digester, majority of the pathogenic ova settle down under their own weight. The bacterial and viral pathogens however, were found to be distributed throughout the digester liquid and their numbers decreased with increased residence times. As a result it was proposed that the outlet for these plants should be from the middle portion of the digester (where the occurrence of ova was the least). However, as this layer still contains bacterial and viral pathogens, further treatment is recommended.

It is a continuously run biogas plant with outlet as recommended above, plenty of liquid effluents is released, while most of the solids and pathogenic ova are retained within the digester. Over a period of time the solids will accumulate and fill up the digester necessitating the manual removal of the sludge inside. There being many pathogenic species in it, it has been recommended that the plant be not fed for about two months prior to emptying (for manure removal). Concomitantly, the digester and the attached toilet will be out of use for the above period and alternatives have to be devised.

In order to overcome the above two problems, i.e. handling of an effluent with bacterial and viral pathogens and occasional emptying of the digester of solids containing pathogens of helminthic, protozoal, bacterial and viral origin, some degree of treatment has to be carried out to render this effluent harmless. It should be noted here that the above considerations of discharging liquid effluent (and no solids) with bacterial and Viral pathogens (but no hookworms) will occur only when the digester is operated in the same way as in China i.e. all forms of wastes are charged into the biogas such as straw, human excreta, piggery waste and lots of water. The digester in effect operates well below the optimum concentration and the residence times there are very large (about 6 months or so). Thus, some form of terminal treatment namely, composting, use of chemicals etc. will have to be employed. The above mode of operation creates the need to find an alternative for the excreta disposal during the two months of inoperation preceding the sludge removal for manurial purposes.

Recommendations

From the above discussions it is obvious that the existing dung-based biogas plants need some modifications before these are operated with nightsoil as feed. The design objectives for this system will be as follows:

1. Operation of the plant at optimal or near-optimal solids concentration;
2. Optimisation of the retention times (HRT/SRT) based on gas yield, health and economic considerations;
3. elimination or near-elimination of human handling of pathogenic material;
4. generation of a simple and low cost

pathogen elimination system and its optimisation.

5. reductions in the risk of re-infection.

The above criteria provide choice between two modes of operation for the biogas plant

1. Construction of biogas plants with toilets attached and connected directly to the biogas plants, with provision for (i) the accumulation of sludge and pathogenic ova and (ii) release of only the liquid effluents which may be discharged into soak pits (with care taken to ensure prevention of ground and subsoil water) or for employing other chemical and biological methods. (This option necessitates removal of solid sludge from the digester occasionally and operation under dilute conditions with an alternate arrangement for two months for stopping feed to the digester.

2. Construction of biogas plants connected directly to toilets of low water discharge without provision for any settling of solid and pathogenic ova. The effluents bearing all types of pathogenic material is led to be a terminal treatment system for rendering it free of pathogens. Two simple options are available, They are:

   (i) leading the effluent into soak pits which are used in sequence so that when one is full the other is put into operation with a minimum residence time of 1 year in the pits;

   (ii) leading the effluent to a compost pit and raising the temperature of the material by composting other organic wastes and consequent killing of pathogens.

Both the above mentioned options have some limitations. The use of soak pits cannot be recommended on soils of high water table and in cases of proximity to domestic wells. Composting require adequate knowledge of the process with respect to effluent storage, handling and composting techniques. This latter technique is likely to be difficult in areas of high rainfall. When the above-mentioned terminal treatment procedures are unsuitable due to many locale-specific reasons, there are other options to choose from, such as algal ponds, lagoon irrigation, etc. which are less effective.

For biogas production from nightsoil, several aspects need in-depth research. Data in the following areas would go a long way towards making nightsoil biogas plants more effective.

(i) Pattern of diffusion, disintegration of solids, its physical behaviour during decomposition etc.

(ii) optimum residence times with respect to gas yields, pathogen kill or inactivation and costs.

(iii) methods for organic solids-liquid separation and concentration of solids (exclusion of excess water from digester feed).

Another important issue to be considered during the planning of such biogas plants is the method of use. It is obvious from table 1 that even under ideal conditions the highest per capita gas availability is unlikely to exceed 40 litres/day (about 220 KCal (t)/day). Since the per capita gas requirement is higher, it, then, becomes necessary to run, larger systems rather than operating family-scale nightsoil based plants. Of course, the shortfall can be met by supplementing the feed by other organic inputs. However, when rural health and sanitation is also combined with the objective of energy, the energy output as biogas can be utilised to lift water for domestic use, provide for street lighting, or other facilities as incentive to used the system. This biogas and sanitation providing system has to be structured and planned according to localespecific and sociological needs.

Acknowledgments

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Table - I: Characteristics of Human Waste

	Average	Range	Average TS%	Urine	Total Average BOD (g)5	Average BOD_5 of Faeces d^{-1} (g)
Indian: rural	385	255-520				
Urban	170	110-240				
New Delhi	311	19-1505				
Dev. Country (Average)						
- Urban	250	-	20	1.2	30-55	21.7
- Rural	350	-	15	1.2	-	21.7

Source Ref. 1.

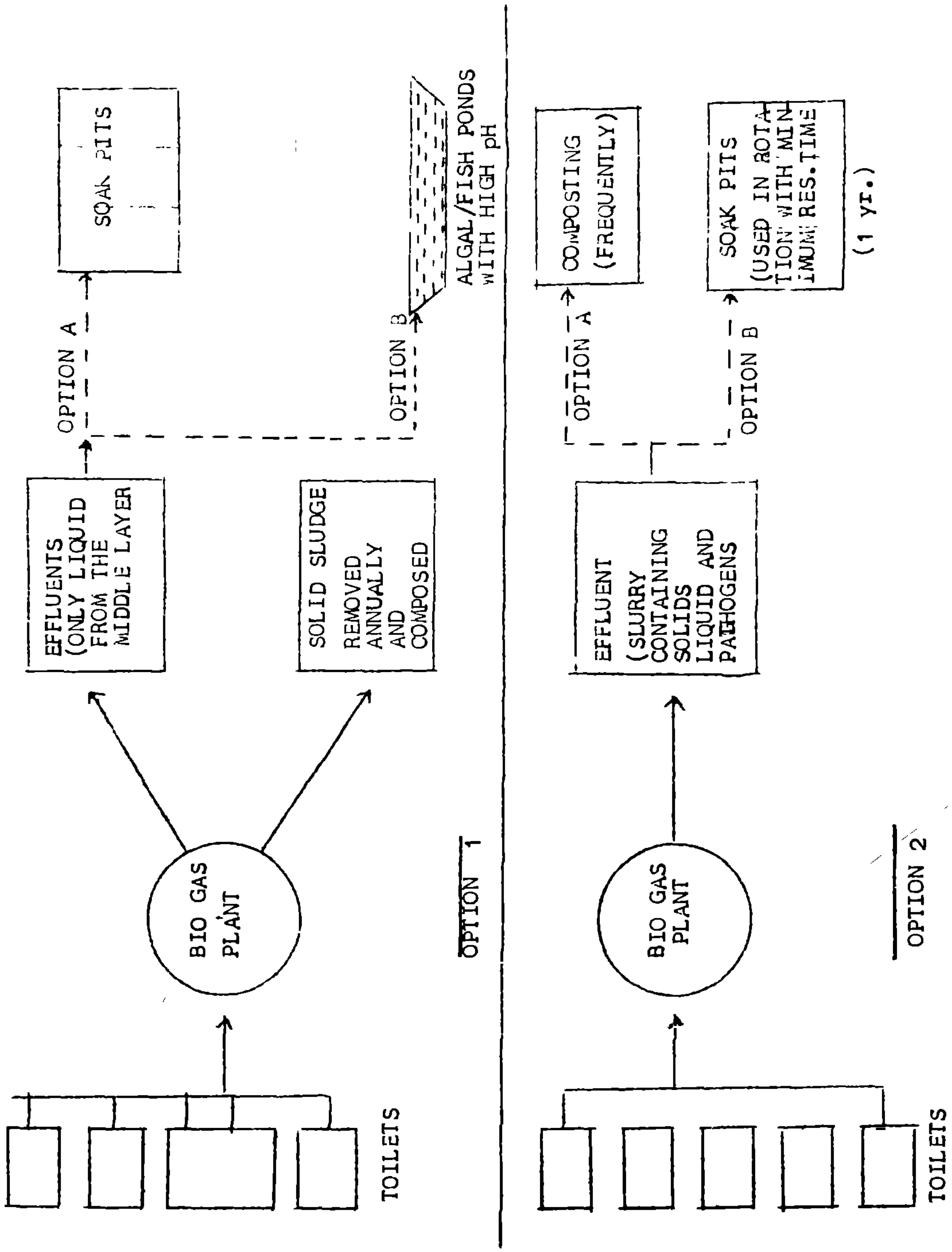
Table - 2 : Occurrence and persistence of a few faeces borne pathogens

Organisms	Com.name	Typical persons infected	no. org/g-feces	Persistence 20-30C (d)	Digester 20-30C (d)	Digester 35-38C (d)	Digester 55C (min) (min)	Digester Effluents
Ascaris	Roundworm	60	10^4	90	yrs	18	-	
Enterobiue	Pinworm	-	-	-	7	-	-	
Ano/costoma	Hookworm	40	10^3	76-87	-	23	-	0
Schistosoma	Bilharzia	25	40	8-14	2-3	13	-	752
Tichuris		60	$2x10^3$	-	1-1.5y	-	-	
Enteric virus		5	10^6	-	180	-	-	
Hepatitis A	hepatitis	-	-	-	210	-	-	
Rota virus	-	-	-	-	-	360	-	
Shigellea		-	10^6	-	40	-	20	
Salmonellae		-	10^6	-	60-360	-	20	
Path E.Coil	-	-	10^8	-	-	-	20	31
Vibrio Cholera	Cholera	-	10^6	-	-	-	-	9000
Entamaeba	Amoebiasis	30	10^{4-5}	-	-	-	-	-
Leptospira		-	-	-	-	7	-	-

Table -3: Characteristics of some Pathogens

	Sp.gr.	Settling rate 50% (h)	(1m fall) 95% (h)
Digester contents	1.005 to 1.01	-	-
Hookworm ova	1.060	4.0	20.0
Ascaris ova	1.14	-	8.0
Schistosoma ova	1.200	-	2.0

Source Ref.2


TOILETS
BIO GAS PLANT
EFFLUENTS (ONLY LIQUID FROM THE MIDDLE LAYER
SOLID SLUDGE REMOVED ANNUALLY AND COMPOSED
OPTION A
SOAK PITS
OPTION B
ALGAL/FISH PONDS WITH HIGH pH
OPTION 1
TOILETS
BIO GAS PLANT
EFFLUENT (SLURRY CONTAINING SOLIDS LIQUID AND PATHOGENS
OPTION A
COMPOSTING (FREQUENTLY)
OPTION B
SOAK PITS (USED IN ROTATION WITH MINIMUM RES. TIME (1 yr.)
OPTION 2

BIOGAS FROM NIGHTSOIL

The health aspects and design

S M Navrekar

Abstract

The paper gives the criteria for an appropriate excreta disposal system and shows that none of the pre-existing systems of disposals - namely, single-pit/twin-pit latrines, aqua privies, septic tanks and sewage treatment - is appropriate. Recyclying apart, each fails on the sanitation criteria. For a proper appraisal of the issues involved in sanitation, the paper gives the classifications of viruses, bacteria, protozoa and helminths, the diseases they cause and the distances they can travel. Thus, pit latrines often contaminate ground water. Where the actual retention time is not very long, the effluents from aqua privies and septic tanks are nearly as hazardous as fresh nightsoil; and although the conventional sewage plant is regarded as sophisticated, the effluents from it contain a high percentage of viable pathogens on account of its provision for a short retention time. Only the biogas plant has the potential of an ideal system.

Here, again, the system that requires carriage of nightsoil from elsewhere is hazardous. Onsite floating dome gas plant without water jacket causes odour and fly and mosquito nuisance and spread diseases through them. Only the fixeddome system with a composting complement is the ideal.

The Navrekar model has attempted to resolve the controversy over retention time by providing for pre-treatment of nightsoil before feeding it to the digester. A liquefying tank below the w.c. basin induces physical disintegration of the nightsoil and separates the helminths from the rest. The nightsoil so prepared would not require more than 40 days retention time in the digester.

The paper gives a chart of temperature time relationship for the elimination of pathogens, organism-typewise, to show how anaerobic digestion, coupled with the anaerobic process of composting can remove all health hazards and produce the much needed manure and energy.

Ed.

Introduction

If we peep into the history of human civilisation, we find that in ancient times there existed no specialised system of waste disposal. Though the act of excretion is as old as Man himself, the systems for disposing these wastes came into existence only a century or two ago. As the knowledge of various sciences-especially microbiology and health sciences-developed, many problems in the traditional waste disposal systems were identified and to overcome these problems, the scientists and technocrafts the world over devised several excreta disposal systems to suit various conditions.

An Ideal Excreta Disposal System

It is very important to note that no specific design of such a system can be generalised for the whole world. However, an excreta disposal system is said to be appropriate when (i) it is technically feasible; (ii) is affordable; (iii) can be maintained by users and fulfils their expectations; (iv) does not require carriage of excreta or offsite deposition of the same by scavengers; (v) provides for

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recycling the excrements by way of beneficial products; (iv) creates no health hazards. The prominent waste disposal systems in practice today are, (1) pit latrines (2) aqua privies and septic tanks (3) twin pit latrines (4) conventional sewage treatment etc.

If we judge these systems in the light of the abovementioned criteria we find that each of these has some merits and demerits and none is able to fulfil all of the essential criteria.

The Health Aspect

Keeping aside other factors it will be worthwhile to elaborate the health aspect of these systems which is of utmost importance.

Human excreta is a potent agent which carries and transmits various deadly diseases. The main pathogenic organism found in nightsoil are.

1. **Viruses:** Many viruses which infect the intestinal tract are found in faeces, the main groups being Polioviruses, Echoviruses, Rotaviruses, Hepatitis 'A' virus.

Poliviruses cause symptoms like influenza or meningtis. In some cases paralytic symptoms are also observed. Many people in developing countries harbour these viruses but very few of them (one in one thousand) get actual illness.

Echoviruses are responsible for simple fevers, diarrhoea and respiratory illness.

Hepatitis 'A' Virus is the casual agent of infectious hepatitis. It sometimes leads to jaundice but does not show external symptoms. This is common in children. Recent research has revealed that this virus is related to infant diarrhoea.

2. **Bacteria**

Human faeces contain many other bacteria which do not cause diseases. These bacteria are useful as faecal indicator while studying pollution of a given area. Escherichia coil is the common faecal indicator.

3. **Protozoa** - Protozoa or amoeba mainly infect large intestine and cause dysentery, diarrhoea, ulcer etc.

4. **Heleminths (worms)** Helminths are another group of organisms which are transmitted through faeces. These are parasitic organisms. Heleminths cannot multiply in human body as they require secondary host like pig, cattle or snail for completing their life cycle. Hence their population in human body can increase only by repeated infections. The helminths can be broadly classified in two groups

	Bacteria	Disease	Whether excreted through urine too
1.	Salmonella typhi	Typhiod	Yes
2.	Salmonella	Paratyphoid	Yes
3.	Shigella spp	Bacillary dysentery	No
4.	Vibrio Cholerae	Cholera	No
5.	Pathogenic E coil	Diarrhoea or Gastroenteritis	No
6.	Campylobacter	Diarrhoea	No

viz. round worms and flat worms. The most dangerous kind of flat

Diseases caused by Protozoa

	Protozoa	Diseases
1.	Entamoeba hystolytica	Ulcer of colon, amoebic dysentery, liver abscess
2.	Giardia lamblia	Diarrhoea and Mal-absorption.
3.	Balantidium coil	Mild diarrhoea, colonic ulcer

worm is the tapeworm which is also difficult to eradicate.

Helminths excreted through faeces and the diseases caused by them:

	Cammon name	Scientific Name	Disease
1.	Round worm	Ascaris lumbricoides	Ascariasis
2.	Pin	Enterobius vermicularis	Enterobiasis
3.		Gastordicoides hominis	Gastrodiscoidiasis
4.	Hookworm	Necator americanus	Hookworm
5.	Threadworm	Strongyloides stercoralis	Strongyloidasis
6.	Tapeworm	Taenia saginate	Teeniasis
7.	Whipworm	Trichuris trichiura	Trichuriasis

Pathogen elimination in various systems

Pit latrines - In single-pit latrines and twopit latrines, the main hazard is caused by groundwater contamination.The contaminated water from the pit seeps in the surrounding soil and finally reaches the water sources, if any nearby, through which the pathogens can find their way to human ingestion.

The movement of protozoan cysts and helminth ova can be expected to be very limited because of their size.

Studies show that bacteria can travel a distance of up to 30 metres in sand and fine soils and upto several hundred meters in gravel and fractured rock. Viruses can normally travel upto 60m, the maximum recorded distance being 1.6 km. In an area where there are many pit latrines there will always be a risk of pathogenic viruses and bacteria reaching the groundwater.

During rainy season, these latrines are often filled with water causing the spread of filth all over the ground. A study in Ethiopia shows that 800 out of 836 wells from an area were contaminated by pathogens from pit latrines.

Aqua privies and septic tanks -

In aqua privies and septic tanks the pathogen removal is only by settling of the sludge. Where the retention times are very short, the effluent may be as hazardous as the fresh nightsoil. It is very common that septic tanks and aqua privies are not desludged at regular intervals. This results in building up of a sludge layer resulting in decreasing the retention time capacity.

Conventional Sewage Treatment -

A common sewage treatment process combines pre-treatment, primary sedimentation, activated sludge/trickling filter, secondary sedimentation etc. Though this is considered to be the most sophisticated and technically sound systems, the effluent from this system contains high percentage of viable pathogens. This also is mainly because of the very low retention times (5 to 12 hours).

From the above discussion it can be concluded that none of the existing waste disposal systems is totally free from health hazards.

The Biogas system

On this background it can be stated that a biogas system, which exploits the principle of anaerobic digestion, is the only ideal option for disposing of (recycling) the human waste provided it (i) involves onsite treatment in a fixed-dome digester and (ii) is coupled with a well-managed composting unit.

Many attempts have been made for long to dispose of nightsoil in biogas digesters especially in China and India. The various design needs for this can be summarised in a flow chart as under.

It will be seen that all the types listed under onsite treatment can be found under offsite treatment.

Among the various designs only the onsite fixed dome with adjoining compost unit is the ideal one as all others carry some health risk or cause some nuisance which are as follows:

Offsite treatment: - This involves collection of nightsoil and its carriage to the site of the plant. This causes health hazards to the workers and odour nuisance at the time of feeding. Similarly mosquito and fly nuisance cannot be avoided. At the same time this practice degrades man.

Onsite floating dome. The dome gets corroded very rapidly and requires high initial expenses. The one without water jacket floats directly into nightsoil which causes the spread of pathogens through flies. Odour, fly and mosquito nuisance is a common feature. Introduction of water jacket avoids these kinds of nuisance althogh the cost remains nearly the same.

Biogas digesters using nightsoil

Onsite Treatment		**Offsite Treatment**	
Floating Dome	Fixed dome	Floating dome	Fixed dome
With Water jacket	Without water jacket	With water jacket	Without water jacket
With adjoining compost unit	Without compost unit	With adjoining compost unit	Without adjoining compost unit

Onsite fixed-dome without composting: - The effluent coming out of this type may contain some viable pathogens and it may, therefore, be unfit for agricultural re-use.

Onsite fixed-dome with composting: This surprisingly eliminates all the harmful pathogens from human nightsoil.

A modified efficient design

It is often recommended that the retention time of a biogas digester be increased to vaoid viable helminth ova in the effluent. Increasing the retention time naturally increases the cost of the unit. Similarly, it is only the Ascaris ova which survive longer. If there is proper separation of these ova prior to the discharge of the effluent, there is not much harm.

A nightsoil-based biogas digester developed by Late Shri M.V. Navrekar has some special features which avoid these hazards.

It is an onsite fixed-dome type digester. The nightsoil is received by a liquefyling tank below the w.c. basins. The liquefication of nightsoil takes place in this tank. The liquefied nightsoil passes into the intermediate siphon tank which allows only the liquefied excreta to flow into the inlet of the biogas plant. The liquefying tank provides two benefits (i) Primary physical disintegration of excreta takes place in this tank which separates the helminth ova from the rest of the effluent and retains them there. (ii) As the liquefaction phase is completed outside the digester, the retention period of it can be shorter (40 days in this case).

The effluent coming out is diverted to compost pit where the garbage is collected. Composting has a special ability to kill pathogens which is described in the succeeding paragraphs.

A unit of this kind is working satisfactorily in a Municipal College Hospital at Sangmaner (Maharashtra). The second one is proposed at Chopada (Maharashtra).

Pathogens Elimination in a Biogas Digester

The Helminths: The ova of helminths are denser than the nightsoil slurry and during the liquefaction phase, settle down at the bottom. Within 20 hrs, 95% ova get settled. The hookworm ova survive only for 9 days under anaerobic conditions and those of schistosoms and ascaris can survive up to 10 days. In a biogas digester the outlet pipe is generally located at some specific height from the bottom leaving a certain space for sedimentation. If the ova get separated perfectly, they can be retained in this space for more than 100 days causing their inactivation.

2. The Bacteria: The common pathogenic bacteria which spread through faeces are: (i) Salmonella sp (typhoid fever); (ii) Shigella sp (dysentry); (iii) Vibrio Cholerae (cholera); (iv) Mycobacterium tuberculosis (T.B.). These bacteria cannot survive when subjected to anaerobic condition at 22°-37° for about 20 days (range 6 to 20 days).

Composting

Biogas digester, coupled with composting unit, eliminates all the chances of pathogen survival. The temperatures in a properly managed compost can reach

Organism	In-unheated anaerobic digestion	In Composing
1. Enteric	May survive for over three months	Killed rapidly at 60°C.

Organism	In-unheated anaerobic digestion	In composting
2. Salmonellae	May survive for several weeks	Killed in 20 hrs at 60°C
3. Shigellae	Unlikely to survive for more than a few days	Killed in hr. at 55°c or in 10 days at 40°C
4. E-Coil	May survive for several weeks	Rapidly killed above 60°C
5. Cholera	May survive for one or two weeks	Killed rapidly 55°C
6. Lepotospire	Survive for not more than two days	Killed in 10 mts. at 50°C
7. Entamoabacysts	May survive for three weeks	Killed in 5 mts at 50°C and 1 day at 40°C.
8. Hookworm ova	Ova will survive	Killed in 5 mts at 50°C and in 1 hour at 45°C.
9. Ascaris ova	Ova will survive for many months	Killed in 2 hrs. at 55°C in 20 hrs. at 50°C and 200 hrs 45°C
10. Schistosome	Ova may survive for many months	Killed in 1 hr 50°C
11. Taenia Ova	Ova will survive for a few months.	Killed in 10 mts. at 58°C and in over 4 hrs at 45°C.

as high as 50° - 60°C. This kills the pathogenic flora within a short period. The following table shows the ability of anaerobic digestion and composting to kill pathogens.

Epilogue

From the above discussion it can be concluded that Biogas technique can very well be adopted to treat nightsoil. It implies no health hazards to the public. The system is so efficient in converting the wastes into energy and manure that every effort should be made to secure the benefits from this system everywhere in the country.

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NIGHTSOIL BASED BIOGAS PLANTS

A useful device for rural health and development

S V. Mapuskar

Abstract

Both open defecation and cartage/manual carriage of nighsoil are health hazards. Only pit latrines for composting, aqua privy and nightsoil based biogas plants are safe. Biogas plants are costlier than aqua privies but the returne these plants pay in terms of public health, bio-energy and manure are incomparably higher. Anaerobic digestion with an assured retention period of 40-45 days at 32°C-35°C eliminate the viral, bacterial and protozoal pathogen. The retention period will also see the worrisome helminth ova settle at the bottom of the digester and get enmeshed in the heavy sludge. However, if the retention period is sought to be reduced to 25-30 days, the effluent will need to be retained in the adjacent pit for a few months to rid it of its pathogens.

Observance of the guidelines for running biogas plants will improve rural health.

Ed.

Introduction

Nightsoil based biogas plants have been functioning efficiently and satisfactorily since Late Appasaheb Patwardhan pioneered these plants more than thirty years ago. However apprehensions about these plants persist even now. A fear persists that such plants and the use of slurry from these plants are likely to pose health hazards. Is this fear real or misconceived? A closer look is very essential.

Common Pathogens in Faeces

the fear is not without reason. Human excreta is a principal vehicle for the transmission and spread of a number of communicable diseases. The disease-causing organism from human wastes spread to a new host via a number of routes. Therefore, proper treatment of human waste is very important so that these organisms do not get an access to new host. We must see whether a particular system for the treatment of human waste is able to intercept the pathogen in such a way that the spread of these diseases is prevented.

The common disease producing organisms are from four groups (i) Viruses; (ii) bacteria; (iii) Protozoa; (iv) Parasites. These are enumerated in Table No.1.

The comparative study of the behaviour of these organisms in various systems of treatment of human waste will give us definite indication about the suitability of the particular treatment system. The treatment of human waste in biogas plant will have to be viewed in the same light.

Options for Nightsoil Disposal

As a preliminary, it would be desirable to review the present day common options available for nightsoil disposal in rural areas. Broadly, two modes need to be considered:

a) 'Dry System' disposal by various

means;

b) 'Wet System' disposal by various types of latrines including biogas plants.

There is, of course, the open defecation practice which precludes any disposal. In this country, this has become the rule rather than the exception. 70% of the population (nearly 48 crore people) of this country resort to open defecation everyday anywhere, any time without any hesitation. This ghastly situation will have to be consistantly kept in view while discussing near-ideal methodologies. Open defecation means an abundant dose of pathogens to the environment and people.

1. 'Dry System' disposal comprises two important groups:

i) Offsite disposal. Manual carriage or cartage system which is prevalent in most of the small and moderately big townships. Nearly 10% population is covered by this system. This system is worse than open defecation because this system keeps on sprinkling pathogens in areas which are densely populated.

ii) Pit latrines of various designs are gradually getting popular in rural and urban fringe areas. Nearly 10% of the population is covered by this system. In this system nightsoil is digested 'on site' in the covered pits, so that pathogens do not get access very easily to the surroundings. This appears to be one of the promising systems for developing countries.

2. 'Wet System' disposal systems comprise two important groups.

i) 'Onsite' systems where water and anaerobes are essential part of the process. These systems are, mainly, septic tanks, aqua privy latrines and our present topic of discussion, the biogas plants. These are essentially anaerobic digestion systems with varying retention periods. Nearly 10% of the population is covered by this system. In this system, pathogens do not find access to the surroundings without being appreciably impacted. This system is another promising system for the developing countries.

ii) 'Offsite' disposal: water carriage system of sewage disposal is available in bigger townships and cities. The lucky 10% in the country are covered by this luxury. This system is supposed to deal with pathogens adequately if the treatment plants function properly. Unfortunately, in many cases, due to improper management or "paucity of funds", raw sewage is let out in the rivers, thus causing health hazard for downstream settlement.

Suffice it to say that 'dry onsite' and 'wet onsite' systems are going to be of some significance to this country in near future.

Faecal Pathogen Survival after Treatment of Faeces on Different Systems

The possibility of spread of pathogens through the above mentioned modes of treatment of human waste has to be reviewed and compared. Also, the survival of pathogens in the end products in each system have to be seen.

'Open defecation' has to be done away with. We are all aware that it is our biggest health hazard. The 'dry system' of offsite disposal by manual carriage or cartage, too, need not be considered because the spread of pathogens through that system is self-evident. Thus, out of the dry systems, only 'onsite' pit and composting latrines need to be considered. Under the 'wet system', the option 'offsite' water carriage sewage system is very capital-intensive, water use-intensive and requires elaborate management. If not managed properly, it create health hazard through water or soil pollution. Thus, from this group, only 'on site wet' system essentially comprising anaerobic digestion process deserves consideration.

Thus, our studies will have to remain restricted to only two systems, namely:

1. 'dry onsite' system of pit and compost latrine; and

2. 'Wet onsite' system incorporating anaerobic digestion.

The presence or absence of pathogens in the end products in each system is safe from the health point of view. It will help in deciding the operational requirements for making it a safe system. It has been observed that the survival time for the pathogens depends on two important factors.

i) Temperature; and

ii) Retention time. The higher the temperature, the lower the retention time required.

In the case of pit latrines, where the pits are usually opened after more than three months, all or most of the viral, bacterial and protozonal infections are eliminated. Helminth ova, however, persist for several months (See Table No.2).

As far as 'wet on-site' systems are concerned, limited data about aqua privy and biogas systems are available. However, we can reach some conclusions by putting together the available data about aqua privy and anaerobic digestion in biogas plant simulating conditions in laboratory. Table No.2 shows these results. From this it will be clear that in anaerobic digestion at 32°C - 35°C, viral, bacterial and protozoal pathogens are eliminated within a period of 44 days. Thus, if a retention period of 40 to 45 days is allowed for digestion, these pathogens will not be present in the effluent slurry from the biogas plant. Further, in biogas plant it has been noted that the helminthic ova settle down at the bottom of the plant and remain enmeshed in settled sludge. Hence, the effluent is nearly free from ova. Thus, the effluent is likely to be free from most infections. If it is proposed to reduce the retention period to about 25 to 30 days, the effluent can be made pathogen free by allowing it to settle and remain exposed to sunlight, in the manure pits adjacent to outlet from biogas plant, for a few months. Table No.2 shows the approximate time required for eliminating pathogens from the sludge.

Place of Biogas Plant in Safe Treatment of Human Waste

The review about the available options for nightsoil and survival characteristics of pathogens indicate that on-site disposal of nightsoil in biogas plant is safest from health point of view. Safety is ensured by the following factors:

i) retention and the digestion of nightsoil for a specific period in anaerobic conditions;

ii) retention of digested slurry (effluent) in manure pits;

iii) digested slurry does not attract flies and other insects;

iv) raw nightsoil is not allowed any exposure to surroundings, for which choice of suitable design is essential;

v) manual handling of nightsoil is absent.

Costwise, construction of biogas

plant will be costlier than pit privies and only marginally costlier than aqua privy. However, unlike pit privy or aqua privy, in biogas plant there is an advantageous re-use of nightsoil in the sense that biogas plant gives returns in terms of biogas for energy and fertilizer for agricultural use. Thus, although biogas plant is initially capital-intensive, in the long run, it gives much more returns on the additional investment, making it a beneficial proposition.

Conclusion:

It is therefore felt that nightsoil based biogas plants is yet to get the pride of place it deserves. Some people tend to deprecate it overzealously on the grounds of possible danger of health. The truth is just the opposite. It is the direct application of nightsoil in the form and the open defecation and manual collection and dumping of nightsoil in compost pits that leads to dangerous dissemination of pathogens through various modes of transfer. The mode of channelling excreta in the 'onsite' disposal biogas plants and from there on to the field is a direct health gain. Nightsoil based biogas plants will actually help in improving rural health. In addition, these plants will play an important role as a source of bio-energy and a safe, desirable organic manure of very high quality. These direct economic benefits added to the benefits to public health may provide a stronger motivation for better sanitation.

Table -1 : Important Pathogens Excreted in Faeces

	Organism	Disease
I	**Enteroviruses**	
	Polio Viruses	Poliomyelitis
	Echoviruses	
	Coxsackie viruses	
	Reoviruses	
	Advenoviruses	
	Hepatitis virus	Infective Hepatitis
	Rotaviruses	Gastroenteritis
II	**Bacteria**	
	Salmonella typhii	Typhoid fever
	Salomonella poaratyphii	Paratyphoid fever
	Shigella	Bacillary Dysentery
	Vibrio cholerae	Cholera
	Pathogenic E. Coli	Diarrhoea
	Campylobacter	Diarrhoea

	Organism	Disease
III	Protozoa	
	Entamoeba Histolytica	Amoebic Dysentery
	Giardia lamblia	Diarrhoea
	Balantidium Coli	Diarrhoea
IV	**Helminths**	
	Ascaris lumbricoides	Ascariasia
	Enterobius vermicularis	Enterobiasis
	Ankylostoma duo-denale	Hookworm infestation
	Strongyloides stercoralis	Threadworm
	Taenia saginata	Tapeworm
	Taenia solium	Tapeworm
	Trichuris trichiura	Whipworm

Table - 2 :Survival Time of Pathogens in some Excreta Disposal Systems

Organism	Pit & Composting latrines with 3 months retention	Anaerobic digestion at 32°C-35°C	Survival time in sludge
Enteroviruses	Less than 3 months	28 days	3 months
Bacteria			
Salmonella typhii	-do-	4-5 weeks	1 month
Salmonella paratyphii	-do-	4-6 weeks	1 month
Shigella	-do-	9-10 days	1 month
Vibrio Cholerae	-do-	7-14 days	5 days
Pathogenic E. Coli	-do-	4-8 days	5 days
Protozoa			
Entamoeba histolytica	-do-	3 weeks	2 weeks
Giardia lamblia	-do-	-do-	-do-
Balantidium coli	-do-	-do-	-do-

Organism	Pit & Composting latrines with 3 months retention	Anaerobic digestion at 32°C-35°C	Survival time in sludge
Helminths			
Ascaris Lumbricoides	Ova survive	Ova survive	Ova survive
Enterobious vermicularis	-do-	-do-	-do-
Ankylostoma dudenale	-do-	-do-	-do-
Strongyloides sterooralis	-do-	-do-	-do-
Taenia saginata	-do-	-do-	-do-
Tadnia solium	-do-	-do-	-do-
Trichuris trichiura	-do-	-do-	-do-

HEALTH ASPECTS OF ANAEROBIC DIGESTION

Yashwant Singh

The human excreta contains disease-causing organisms of hepatitis (infectious), gastroenteritis, respiratory illness, poliomeylitis (viral diseases); typhoid fever, salmonelloses bacillary dysentery, cholera, tuberculosis (bacterial); amaebiasis (protozoans); and various helminthic diseases.

Anaerobic digestion of human excreta provides biogas and effluent slurry as fertiliser. The questions raised very pertinently are: whether (i) the anaerobic digestion significantly affects the pathogens and (ii) the effluent is within the mark of safe disposal.

The reported data on the survival of the pathogenic micro-organisms in the anaerobic digestion process have a wider range of values. Temperature plays a very important role in the minimisation of these micro-organisms. Poliovirus at temperature 35°C is reduced by 98.5% within two days. Within the temparature range of 22-37°C Salmonella typhosa is reduced by 99% in 6 days while Salmonella spp. (causing salmonellosis) by 82-86% in 6-20 days. Mycobacterium tuberculosis at temparature 30°C is killed 100% but the detention days was not reported. All encysted helminths are destroyed except ascaris cysts which are able to survive even after 14 days at temparature 35°C. Other studies revealed efficacy of thermophilic digestion (48-60°C] which destroyed ascaris cysts completely. When mesophilic operation (below 40°C) is followed by storage of digested slurry and its drying for about six months, even the ascaris are destroyed.

In one study Entamoeba histolytica cysts were reported not to survive anaerobic digestion. In other studies, species similar ro E.histolytica, but having different cultural requirements was found in sludge digestion and Imhoff tanks.

Pathogens get killed inside the digester because of the change in environmental conditions and lack of nutrients, apart from temparature. This die-off continues when the digested slurry is stored and even when it has bee applied to the soil. During storage, the reamining undigested part of human excreta gets decomposed and stabilised providing unfavourable conditions for growth of most of the micro-organisms. The surviving pathogens, if any, would get killed when the dried sludge or composted material is applied to the soil; the soil microbes and soil environmental conditions can take care of these severly weakened pathogens.

Even then, in the first season of application of this dried sludge, the cultivation of carrot, radish and like plants is not advisable because a few viable pathogens (cysts and eggs) may adhere to the surface of the edible part of the plant and infect the consumers. The cultivation of cereals is suggested in the first year. Afterwards any crop may be grown.

Use of chemical disinfectants and moist heat treatment (i.e. steam sterlization), too, can effectively destroy the pathogens on human excreta but their costs are prohibitive. Moreover, these are merely destructive of pathogens without any potential for converting wastes into assets.

Anaerobic micro-organisms gasify 80-90 per cent of the carbon substrate and yield only 10-20% of microbial cell sludge. The solid matter to be disposed of is, therefore, much reduced. There is not much risk of odour or insect breeding when the digested sludge is spread in the open.

To sum up, anaerobic digestion of human excreta removes most pathogens and this controls the pollution of soil, water and air. The effluent's subsequent storage and use in soild system as manure, with certain precautions, will reduce health hazards very considerably. This is better than any other treatment.

Resource

"methane Generation from Human, Animal and Agricultural Wastes". National Academy of Sciences, USA, Washington D.C. 1977.

HEALTH AND HYGIENE ISSUES

*Rajammal P Devdas**
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Abstract

India's basic problem of safe water supply and sanitary disposal of human excreta are interrelated. Improper disposal of nightsoil brings soil pollution, water pollution, and diseases such as typhoid, para-typhoid, cholera, hookworm. About 45 million people in India are infested with hookworms. The incidence of other excreta-related diseases too, is very high. In obeisance to nature's principle of recyclying and for increasing the social acceptance of nightsoil-based biogas, the women's college at Coimbatore started a biogas plant based on the waste products of 66 girls plus 10 kg of cowdung per day. The biogas proved better than LPG as a cooking fuel.

Cleanliness next to godlines is a prime requirement closely related to good health. On the solid foundation of health, man's happiness rests. Health depends on sanitation which is a way of life. It is the quality of living that is expressed in the clean home, clean farm, the clean business, the clean neighbourhood and the clean community. A clean home and community are possible when pollution is arrested effectively by treating, utilizing or disposing of waste in and around the house.

Health and Environment

The health status - whether of an individual or of a community or a nation - is determined by the interplay of two ecological universes i.e. the internal environment of man himself and the external environment which surrounds him.

Today the environment is being polluted as never before by the accumulation of solid wastes. Everywhere the amounts of solid waste generated by every person each day are increasing as a result of social, economic and technological changes. At the same time, the the land available for depositing waste is getting correspondingly reduced due

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to increasing urbanization, and consequent increase in area occupied by buildings and industries.

Public health largely depends on the efficiency with which all refuse is collected and removed in the context of the shrinking space. A number of disposal methods including composting, and conversion of waste into energy and manures becomes extremely important as measures for recycling. India's basic problems of safe water supply and sanitary disposal of human excreta are interrelated.

Public Health Importance

Human excreta consist of the solid and semi-solid residue (faeces) from the large intestine and the liquid (urine) excreted by the kidneys. Human excreta is a source of infection. The health hazards of improper excreta disposal are (i) soil pollution; (ii) water pollution; (iii) contamination of foods; (iv) propagation of flies.

The resulting diseases are typhoid and para-typhoid fever, dysentery, diarrhoea, cholera, hookworm disease, ascariasis, viral hepatitis and similar other intestinal infections and parasitic infestations. These diseases are not only a burden on the community in terms of mortality and a low expectation of life but a basic deterrent to social and economic progress.

Statistics indicate that the intestinal group of diseases claim about 5 million lives every year while another 50 million people suffer from these infections. Surveys carried out in the community development block areas shows that the enteric group of fevers is very common in rural areas - the annual incidence varying from 102 to 2119 per 100000 of population. Hookworm disease is also known to be highly prevalent: about 45 million people are estimated to be infested with hookworm. A number of diseases and epidemics like cholera, typhoid, dysentery and hookworm that occur in rural areas very frequently are caused by the absence of sanitary method of disposal of excreta. The disease agents in the excreta spread through the channels water, fingers, flies, soil and food.

Recycling of Nightsoil

Various researches have led to the discovery of biogas scheme based on cowdung, nightsoil and finely chopped left-over fodder and vegetables. The gobar gas plant system has gained acceptability among the public. The nightsoil gas plant has not yet gained momentum among the home-makers and the population.

The College Biogas Plant

A 2 cu.m. nightsoil biogas plant (Rs.3000/-) was, therefore, constructed at Sri Avinashlingam House Science College for Women, Coimbatore. The nightsoil for the plant was collected from six latrines used by 66 adolescent girls. For enhancing the fermentation of nightsoil, 10 Kg of cowdung was added daily. The nitrogen content of the slurry was estimated to be 1.7 per cent. Laboratory experiments proved that nightsoil gas is a substitute for petroleum gas. It was being used in lighting a gas lamp also.

Conclusion

Nightsoil may be effectively utilized for gas production. The clearance of nightsoil in this manner may lead to the health and happiness of the population ensuring the nation's prosperity. There is a wide scope for transferring the national waste to a national wealth.

BIOGAS FROM HUMAN WASTE

Public health and Social Aspects

D.R. Gupta

Abstract

Countering the view expressed by some that the slurry from biogas plants might lead to wider dissemination of pathogens, the paper claims that the die-off rate (in the digester) of the disease-producing organisms of public health significance ranges from 83 to 100 per cent at 22-37°" if the digestion time is not significantly lower than 14 days". The die-off process continues during the storage and drying up of the slurry and after application to the soil due to pathogens' nutrient starvation and hostile environment.

The paper further analyses the psychological factors that inhibit the spread of latrine based biogas plant. Breaking the barrier of age-old taboo, therefore, becames more important.

- Ed.

Introduction

Nightsoil is the accumulation of human faeces and urine collection without dilution by large volumes of water. Nightsoil is generally carted or carried by scavengers on the shoulders or the head. Some public health aspects of the production of biogas by anaerobic digestion of nightsoil with or without animal waste are discussed first.

Public Health Aspects

Potential hazards inherent in the biogas plants using nightsoil partially or wholly, are the results of two practices:

a) The handling involved in the use of nightsoil as a part of the waste fed to the digesters;

b) The use in crop production, of the digested slurry produced in biogas plants (digester).

As regards handling,

i) Although the use of dung from diseased animals may entail some danger, it would be less than that involved in the use of human faeces if it was to be handled physically, and

ii) In India, most of the night-soil based biogas plants are directly linked with Latrines; as such no physical handling of nightsoil is involved in charging them.

Anaerobic Digestion

The following table gives the die-off rate of enteric micro-organisms of public health significance in terms of temperature and residence time during anaerobic digestion. The table demonstrates the importance of the anaerobic digestion process in the treatment of human wastes: with few exceptions, pathogenic enteric micro-organisms are effectively killed off if the digestion time is not significantly shorter than 14 days at a temperature

Organisms	Category	Temperature °C	Residence Time (Days)	Die-off (%)
Poliovirus	Viral	35.2	2	98.5

Salmonella ssp	Bacterial	22-37	6.20	82.96
Salmonella typhosa	-do-	22-376	6	99
Mycobacterium tuberculosis	-do-	30	Not reported	100
Ascaris	Helminthic	29	15	90
Parasite cysts	-do-	30	10	100

not significantly lower than 30°C.

In view of the above, anaerobic digestion produces sufficiently high rate of die-off of pathogenic micro-organisms. Anaerobic digestion of organic material for biogas production, therefore, provides a public health benefit beyond that of any other treatment likely to be used in rural areas.

The risk of indiscriminate dissemination of eggs of parasitic organisms is also minimized when nightsoil is processed in biogas plants.

It appears that there is no other practical method of testing human excreta- whether for disposal or for return of nutrients to the land as fertilizer- that will reduce the burden of pathogenic organisms as much as anaerobic digestion.

Use of Digested Slurry as Manure

i) The public health hazards associated with the use as manure of the plant effluent slurry/sludge will depend upon:

a) The incidence of viable pathogenic organisms found in the nightsoil;

b) The survival rate of these organisms in the digester's effluent slurry.

c) Storage time of the sludge prior to the application of the land.

Storage and drying after the digestion period will further minimize and perhaps eliminate the risk of parasite eggs spreading in the rural environment.

Effective destruction of pathogenic enteric micro-organisms does not preclude the survival of at least some micro-organisms of public health significance despite destruction of as much as 90% of such organisms.

Once the digested slurry has been removed from the night soil based plant, micro-organisms that have survived the process continue to die-off because of the lack of nutrients and the hostile environment. This die-off process continues both during storage, drying of, and after the dried slurry has been applied to the soil.

The possibility of contaminating crops with these surviving pathogens could be eliminated by pasteurization which is the practice in some European countries. This process is so costly, however, that its economic feasibility is marginal for India.

Inhabitants of most villages are probably already exposed to the enteric diseases endemic to their area. The introduction of biogas Plants for night soil alone or with animal wastes, therefore, should not create any new or additional health hazards. On the contrary, it should reduce the present health hazards of disposing of night soil significantly.

CONCLUSION

In the final analysis, it will be desirable that the Government institute schemes which encourage installation of latrine linked or nightsoil based biogas plants. This can also very well serve as a catalyst to the construction of nightsoil plants as the economic value of the biogas and manure obtained from it becomes clear. In this way, the public health hazard of the common practice in rural areas of defecating in the fields would be minimized. Furthermore, connecting the latrines directly to household or community biogas plants would eliminate any health hazard connected with direct handling of human waste.

Social Aspects

Various points discussed under/Public/Health/Aspects represent the positive considerations for popularisation of partially or wholly nightsoil based biogas plants.

The barrier to the acceptance in such plants comes from social aspects. Following observations are made based upon our involvement in the biogas programme, which includes latrine wherever we instal biogas plants.

We have succeeded in providing latrine connections to 20% of the plants (40 plants). About 10% plant users have working latrines but there may still be 2 to 3% plants owners who may not be using these latrines. This highlights a social resistance to the use of biogas produced from nightsoil linked biogas plants.

In Punjab, from a case study of 3 community biogas plants, which have been provided with a set of latrines for male and female members separately, it is found that latrines are not being used.

The following social barriers are identified to the acceptance of nightsoil based linked biogas plants:

i) Users or agriculture labourers hesitate to lift the digested slurry for use as manure.

ii) Due to ageold custom, nightsoil is expected to be handled/lifted by scavengers only and no body else will touch it.

iii) Isolated users feel shy of using gas coming out of the nightsoil linked plant due to social stigma attached to it. Though they themselves may be quite liberal and convinced about its fertiliser value and harmless effect as cooking fuel, they may simply not do so for fear of what other people will say. In a few cases of households having nightsoil-linked digester, it was discovered that the guests visiting the family have been found objecting to eating food cooked with gas coming out of such digesters.

CONCLUSION

It is felt that anaerobic digestion process provide immense fuel and fertilizer value and better sanitary alternative for disposal of human waste. A strong awareness needs to be created about the values of disposing of nightsoil through biogas plants with or without animal waste. Desirable change in the attitude of the potential biogas users or otherwise will come only through mass awareness and education of the immense value of processing of human waste through anaerobic digestion. Age-old taboo of not handling nightsoil will have to be broken.

Sources

(i) Methane Generation from Human, Animal and Agriculture as Wastes- National Academy of Sciences, Washington, D.C. 1977.

(ii) Our own case studies.

DESIGN AND R&D ASPECTS

DESIGN ASPECTS OF BIOGAS PLANTS FED BY HUMAN EXCRETA WITH OR WITHOUT SUPPLEMENTARY FEEDSTOCKS

*L K Sinha** — *Dr M.B Mazumdar***

ABSTRACT

The biogas plant is essentially an anaerobic fermentor in which organic wastes are subjected to microbial digestion in the absence of free oxygen. Theoretically, there could be many design possibiliites but, in practice there are limitations due to cost considerations, scale of operation and management difficulties.

Since the process of anaerobic digestion may serve the purpose of waste treatment (for sanitation) and fertilizer production in addition to energy generation, careful consideration of the objectives is the most important step. The primary aim of municipal sewage-sludge digestion, for example, has been to stabilize the sludge for sanitation. Production of energy is secondary in this case and the treatment process is optimised even at the expense of energy input (in the form of heat/mechanical energy).

Digester process may be classified according to the operating temperature and also according to the feeding schedule. There temerature ranges have been observed for bio-mentanation - psychrophilic, mesophilic and thermophilic (increasing order of temperature). The first one is yet to be applied in a biogas digester. The relatively slow mesophilic range of operation is favoured when the objective is to get energy with lower inputs of capital and management in small scales of operation. On the other hand, the energy-and-capital intensive thermophilic range is preferred when destruction/reduction of pathogens is important and handling of large amounts of wastes is involved, e.g. municipal sewage treatment. Depending in the situation, the feeding could be in batches, continuous, or semi-continuous. The batch system is applied in digestion of municipal sewage sludge and in multi-tank batch plants for seasonal agricul/-tural waste.

The desirability of stirring a biogas plant is still a matter of controversy. Normally, high-rate sophisticated sewage digesters and the KVIC (Khadi and Village Industries Commission) cowdung plants (Gobar Gas) have stirring arrangements although the speed and extent of stirring is quite different. Another important consideration is the material of construction which ranges from masonry and mild steel to plastics and fibre glass-reincorced plastics. Understandably, in the digestion and disposal of human excreta, the design should ensure destruction (or reduction to the minimum possible level) of pathogens. In small scales of operations involved in a biogas plant, thermophilic digestion may not be feasible. Under such circumstances, the design should provide for adequate retention time and if need be, secondary treatment of the effluent depending upon the body receiving the final effluent discharge.

In this country, not much evidence is available about the use of human excreta as the sold feedstock of the biogas plant. In most of the cases, toilets have been connected to the floating-dome cow-dung fed biogas plant (gobar-gas) in both family as well

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as large community/institutional biogas plants. The only examples of large biogas plants fed by human excreta can be cound at the Sulabh Public Toilets. These are fixed-dome underground digesters of masonry construction.

So far, the tendency has been to use empirical considerations for designing a biogas plant. Engineering aspects of the plant have been the main design considerations and the microbiological aspects have generally been ignored.

DESIGN OF BIOGAS PLANT ON NIGHTSOIL

*Rahul Parikh**

Abstract

Selection of a design for a biogas plant from night soil is governed by criteria - digester efficiency, cost of construction and public health aspects. Community latrines at public utility places, institutions or dormitories are ideal places for introducing the night soil biogas plants. The degree of hazard would be significantly less than that to which people are currently exposed in the traditional disposal or use of night soil. In addition to this energy and fertilizer can be generated. Design of a digester, inlet mechanism and outlet mechanism of a night soil biogas plant are discussed.

General Design Criteria

This paper deals with design aspects of a biogas plant using night soil from a community or from centralised latrines such as public utility places, institutions and dormitories. Anaerobic treatment of sewage is beyond the scope of this paper.

To justify the construction of a gas plant two prerequisites must be met: (1) optimum gas should be extracted from the available amount of nightsoil in the smallest possible size of a gas plant; and (2) least possible water should be fed to the digester along with nightsoil. This leads to the question of design of a latrine pan, flushing arrangement, slope of the pipes carrying nightsoil to the gas plant. To justify the public health aspect, maximum killing of the pathogens and parasitic eggs should be achieved through anaerobic digestion and subsequent treatment to the effluent slurry.

Subsidiary considerations involve onsite requirements such as: (i) adequate space for Biogas plant must be available close to the latrines and the place where the gas will be used; (ii) space must be provided adjacent to the digester for storing or composting the digested sludge from the gas plant; and (iii) the bio-gas plant must not be constructed within 15 meter (50 ft) of a drinking water well.

Digester Design

There can be a digester fed exclu-

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sively by nightsoil or a digester with mixed feed materials. In general, with nightsoil, daily fed (semi-continuous) digester should be selected, mainly for the public health aspect.

Connecting individual latrine to the "gobar" (cattle dung) gas plant is an accepted mechanism at many places in India. Hygienic disposal of the nightsoil rather than increase in gas production, is a major achievement of these plants In the plants with nightsoil as a primary feed material it is desirable to add other suitable organic wastes to increase efficiency of the digester. Nightsoil is a very low C/N (between 6:1 and 10:1) matter. Therefore, mixing of higher C/N materials i.e. materials having more cellulose, will promote gas production.

Parameters to be considered for designing a wholly nightsoil-fed digester are mainly (i) organic loading rate; (ii) retention period and (iii) dilution by water.

Optimum loading rates for nightsoil digesters in India are reported as 1.04 to 2.23 kg of volatile solids on a dry weight basis, per day per m^3 of digester volume*. As volatile solids are 80 to 90 per cent of the total solids in nightsoil, the total solids fed per m^3 of digester volume would be 1.8-2 kg, dry weight. Assuming 90% moisture in fresh nightsoil, it would mean that 18-20 kg of wet nightsoil can be loaded everyday per m^3 of digester capacity. Further, if we assume that per capita contribution of wet nightsoil is only 500 gms on an average, it would then mean that one m^3 of digester capacity should be provided for 36-40 persons.Variation in any of the above figures, as occurs in different situations, will change this porportion. An average daily gas production of 23-34 litres per capita was recorded from the plants with the above loading rate.

According to the above calculations about 20 Kg wet nightsoil should be loaded per day per one m^3 digester volume. If no further dilution by urine or water is assumed, the digester will function at a retention period of about 50 days. In practice dilution, moderately in excess to extreme, will unavoidably occur. This will reduce the retention period. To maintain the desired retention period in such circumstances, the loading rate of solids has to be decreased from the optimum value. This leads to increase in cost of construction.

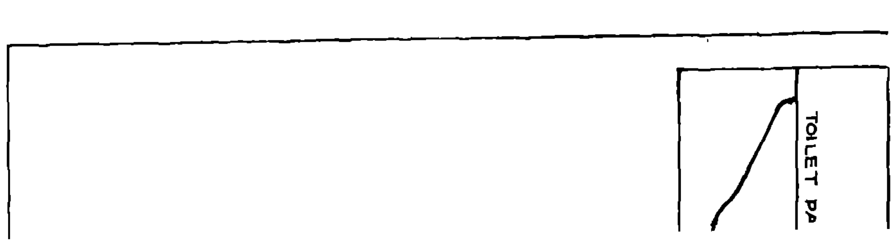
Public health aspect is another criterion for selecting the retention period. There are varieties of enteric pathogens, viruses and parasitic eggs in the nightsoil and urine that can infect human beings through various media such as water, food and direct contact. It has been reported that Ascaris egg mortality should be above 95% which is the epidemotological ly safe level. They neither grow nor die at 27°C for 40 days. Parasitic eggs can survive for 15-40 days at 20°C to 30°C temperature.

Looking from a different angle, any anaerobic treatment to nightsoil will mean significantly less hazard than that to which the people are currently exposed by the traditional methods of nightsoil disposal. Therefore, a compromise has to be made between average gas production per day and survival of pathogens in the effluent slurry for deciding the retention period in the digester. In general it can be said that the choice of the digester design is guided by the criteria - digestion efficiency from microbiological point of view, cost of construction and public health aspect.

Inlet Mechanism

For a small-scale nightsoil plant

* For temperate climates, a loading rate of 1 6 kg of volatile solides per m³ of digester volume is recommended Ed



where control on use of water is possible, filtration and separation of liquid can be avoided. For a large-scale plant one has to compare the cost of filtration process with the cost of increased digester volume, considering the exigencies of each situation.

A cement pipe of suitable size is good enough as inlet pipe to the digester in a floating gas holder plant or a fixed-dome plant. In a nightsoil digester pathogens and parasitic eggs settle at bottom of the digester. Therefore to avoid stirring of the bottom slurry the inlet pipe should not open at the bottom.

An appropriate feeding mechanism for family or community biogas plants could be pipe (china clay or cast iron) from the latrine pan leading to a small tank open to atmosphere: and the inlet pipe of the digester can start from the bottom of this tank. Bottom of this inlet tank should be above the level of overflow of the effluent slurry, so that it remains empty and a vent pipe connected to the tank carries away the foul smell. The tank remains closed by a lid. The pipes between the latrine pans and the inlet tank remains clean of nightsoil with very little amount of water if the pipes have a proper slope which is about 1 in 6. In this case a pan without water-sealed U-trap can conveniently be used.

Outlet Mechanism

Effluent slurry of a nightsoil plant can be fed to an existing sewage system or can be used for composting organic wastes or can be stored in pits before making any use, depending upon the criteria installing a nightsoil plant.

There will be a slurry displacement tank in a fixed-dome plant and a simple outlet pipe in a floating gas holder plant. In both the cases the outlet should be 30 to 60 cms. above the bottom of the digester for least disturbing the extreme bottom slurry where there is a concentration of live parasitic eggs. Reports on Chinese experience suggest that the nightsoil digester should be desludge once a year to prevent too much sludge building up. Some parasitic eggs do survive in the sludge removed from the digester. Therefore, during such annual cleaning operation, chemical treatment is suggested to disinfect the sludge before it is used.

Relative levels in the construction play very significant role in functioning of a plant; therefore, they have to be decided carefully. Normally, overflow of effluent slurry is a reference level. Top of the inlet pipe to the digester should be at 10-15 cm higher level than that of the overflow. Level of the latrine pans would have to be higher than the top of the inlet pipe. The exact height would depend on the distance between the two.

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NIGHTSOIL-FED BIOGAS PLANTS BASIS FOR DESIGN

*Anil Dhussa**

Abstract

If their elimination is not complete, the effluent may be given a secondary treatment by way of applying chemicals, oxidation and also composting. With the experience of composting habits of people having cowdung based biogas plants, asking for controlled treatment will be too big a demand on plant owners. Therefore, the only alternative is to get rid of most of the micro-organisms before the material comes out of the biogas plant.

2. The available data on the kill rate or stabilizing of parasitic eggs and bacteria is not absolutely conclusive and can at best be used as suggestive data with extra bit of caution. The kill rate depends heavily on temperature as a total removal is reported within a few hours to 4-5 days at 55°C. Whereas some parasite eggs survive for more than 100 days at temperatures between 9 and 18°C, schistosme eggs are reportedly killed within 14 days at 26°C. Notably, it takes only 30 days to kill 90% but 70-100 days to kill 99% of these schistosome eggs in winter (temperature ranging from 9 to 18°C).Thus the first step for designing a nightsoil fed biogas plant is to fix an appropriate hydraulic retention time (HRT) at which it is planned to be operated. As far as possible the HRT should be fixed for worst operating conditions.

3. The above discussions were based on the assumptions that the effluent from biogas plants fed with nightsoil will be dried and used as manure and not be led into a water stream or drainage. For the latter cause, the norm of reduction of chemical oxygen demand (COD) to a permissible limit also becomes as important as the reduction of becteria and parasite eggs.

KVIC Model (Floating Drum) Plants

Digesters of this type of plants have a high depth-to-diameter ratio. The input material enters the digester bottom through a pipe and travels upwards to the outlet pipe fitted at the top or comes down over the partition wall into the outlet pipe placed at the bottom on the other side of the partition wall. It was designed to work as a typically "plug-flow digester" where plugs were expected to move vertically upwards and downwards. Cattle dung slurry which is quite thick can be expected to follow this flow pattern to some extent but there is all the possibility of inter-mixing of various vertically travelling layers i.e. the digested and the less digested material, which ultimately gives rise to short-circuiting. Therefore, the effective HRT will be less than the designed HRT. The extent of intermixing of layers will be much greater when the nightsoil is fed in these digesters because its particle size is smaller than that of cattle dung. The slurry formed by nightsoil is much thinner and also not as homogenous as the cattle dung slurry. Therefore, the effective retention time of this type of digesters for nightsoil will be less than that for cattle dung and much less than the designed HRT.

The extent of export circuiting can be determined by using tracer technique. But as long as it is not done, a safeguard against short-circuiting should be provided in some manner while designing a plant of KVIC type for nightsoil if a plant of this type has to be installed.

Janata Biogas Plant

This one has a much shallower digester and the net movement* is horizontally from the inlet towards the outlet side. The possibility of intermixing between less digested and the more digested material is less because it occurs more if there is a forced vertical movement of mass. However, the diameters of Janata biogas plants of higher capacities are very large: therefore, as the movement of material is only from inlet to outlet there is no force acting on it in the direction perpendicular to the line joining the inlet and outlet tank guiding the direction off low. This results in non-utilization of some parts of digester volume and also in shortcircuiting of inputs. Even otherwise, the effective retention time in this case also will be less than the designed HRT.

Design of Nightsoil Biogas Plant.

Based on the above discussions, the following sequence of operations is formulated for designing a foolproof nightsoil-fed biogas plant:

1. Fixation for HRT for given temperature.

2. Design of digester with an effective HRT of the fixed duration

3. Planning of complete biogas production and distribution systems.

Criterion for fixation of HRT for nightsoil-fed biogas plants has been outlined above in para 2 under "controlling parameters". The selected HRT should match the operating temperature which may vary from region to region under natural conditions or can be controlled by artificial means. While almost all the family size plants are operated at ambient temperature, large-size plants can be designed for operation at controlled higher temperature e.g. 35°C or 55°C etc. Once the HRT has been fixed, a digester is designed with an effective HRT of a given order. Care should be taken to avoid all possible chances at least to minimise chances of short-circuiting. A truly plugflow digester would be an ideal choice whereas a constantly stirred digester is the worst. The effective HRT vis-a-vis the designed HRT for a partially mixed-feed digester with minimal vertical movement and with most of the movement in the direction of flow (this will be the case with a tubular digester) is the closest to the plugflow.

After finalising the digester, other parts of the biogas system are designed. The main considerations for this exercise are that the input material is not exposed to atmosphere and a system for treatment of effluent from the nightsoil biogas plant is planned as an integral part of the biogas system.

A biogas system was designed by AFPRO on the basis of these guidelines for a pilot demonstration project on biogas from nightsoil for a colony in Puri, Orissa.2 The digester employed is not of the tubular design but it is of Janata type with some modifications to make it appropriate for nightsoil. This system is not claimed to be perfect and there is need for more efforts in this direction in order to effectively apply the anaerobic digestion technology for treating nightsoil and producing biogas.

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* The heavier particle may go down, the lighter may go up but the overall flow is horizontal Ed

NIGHTSOIL BASED BIOGAS PLANTS TIME TESTED DESIGN

Floating dome on Water Jacketed Digester

S V. Mapuskar *

Abstract

In Maharashtra, floating-dome water-jacketed digesters have been functioning satisfactorily for more than thirty years. Hence the fear that nightsoil-based plant might be hazardous or unfeasible is totally baseless. Several principles should be followed in case of these digesters. There should be no manual contact with nightsoil. Undigested nightsoil should not be visible or exposed to surroundings. Adequate arrangements for aeration and drying of slurry before its use in farms is essential. Maintenance should be easy.

The author claims that the water-jacketed floating-drum design, which has been adopted by the Maharashtra Unit of Gandhi Smarak Nidhi, meets all requirements. There is, however, scope for further research for improvements in respect of dilution, C/N ratio, bacterial content etc.

- Ed.

Introduction

t seems that there is plenty of apprehension even in the minds of some of the learned technologists and scientists about the feasibility and safety of biogas plant working solely on human wastes (nightsoil). Many tend to take for granted that nightsoil based biogas plant is not feasible or that it is hazarous. Many of these apprehensions are based on hypothetical assumptions not backed by experiences in the field or by laboratory data, which are, unfortunately, scanty. The facts show , that in Maharashtra, these plants have been functioning very satisfactorily for the last more than thirty years. If the facts do not tally with the hypothesis, we must try to find out where the hypothesis has gone wrong and not vice versa.Field experiences in Maharashtra show us that nightsoilfed biogas plants operate very satisfactorily. Therefore, if in some instances, there are any failures or mulfunctioning, the reasons are more likely to be found in the selection of technology or in operational and maintenance routines. Hence, it would be desirable to review the design and technology which has been in use successfully in Maharashtra for the last thirty years. It would also be necessary to decide on the basic parameters and optimization criteria. These will help in arriving at decisions about the suitable technology and design to be used for nightsoil based biogas plants.

Basic Parameters and Operational Criteria

In addition to the criteria for cattle-dung based biogas plant, the following important requirements need to be considered so far as nightsoil based biogas plant is concerned.

i) There should not be any direct handling of excreta. When it is indispensable, it should be by hygienic methods.

ii) Undigested nightsoil should not get exposed to surroundings. Flies, other insects and animals must

* Maharashtra Gandhi Smarak, Nidhi, Kothrud, Poona

not get access to it.

iii) Aesthetically, there should be freedom from odour and unsightly conditions (faeces should not be visible at any stage).

iv) Surface soil should not be contaminated.

v) Arrangements need to be made for aeration and drying or for composting of slurry before its use in farm as a manure.

vi) There should be no contamination of surface or subsoil water.

vii) Maintenance should be easy and should not evoke any repulsive feelings.

viii) Cleansing water per user may be around two litres (there need not be 1:1 dilution as in cattle dung).

ix) Use of disinfectants for cleaning the latrines should not be permitted.

While deciding on a suitable design for nightsoil based plant these requirements will have to be necessarily considered.

Late Appasaheb Patwardhan's Pioneering Efforts since 1953

Late Appasaheb Patwardhan, a Gandhian worker and visionary fired with an obsession for 'Bhangi Mukti' and 'Gram Safai' programme, worked feverishly since 1928 on the problem of nightsoil disposal, devising in the process several innovative designs for latrine as well as biogas plants. In 1953, he pioneered nightsoil based biogas plants in India by constructing the first nightsoil based biogas plant at Kankavali in Ratnagiri district of Maharashtra. He constructed many more such plants subsequently, creating a cadre of trained social workers in the process. The design which he devised had a floating-dome-type gasholder moving on partially water jacketed digester. He had given thought to every important flow that was likely to creep in and provided solutions for the same. As a result, even after thirty years, out ;of all the designs now available, the design developed by him remains the best.

Review of Salient Features of the Design

The water jacket digester design is similar to 'Gramlaxmi' design developed by Sri Jasbhai. Patel (which was later adopted for propagation by KVIC). However, it has some important additional features:

1. The major difference is in the construction of digester. In water jacket design, the lower portion of digester design is similar. However, the design differs in the upper five feet. In water jacket design, the ledge is made wider, and above the ledge in upper three feet of digester, an inner circular wall of 4 inch width is constructed leaving a gap of about 6 inches between the outer and inner walls. This annular gap of 3 feet depth is kept constantly filled with water. The gas holder floats in this water jacket. The digesting slurry is completely covered since it remains inside the inner circular wall and is separated from water jacket by this inner wall. Thus the slurry in digester is completely covered by gas holder, doesn't come in contact with atmosphere and is obviously not visible. What is exposed to environment is only the water from water jacket in which the gas holder floats.

2. About 6" wide belt around the outer side of inner wall should be left unplastered so that the soaked water will prevent the gas from leaking through the brickwork of inner wall.

3. The inlet pipe from the floor of the dinn chamber of the outside latrine should open at a level higher than the floor of the digester, if nightsoil is the only feed being used. Since the nightsoil has a tendency to float, the inlet pipe is likely to get choked frequently if the inlet pipe is too near the floor.

4. The top of the latrine seat is kept at height of 2 feet above the slurry level, i.e. outlet level. If this is not done, the lower end of the of the pan gets chocked frequently. Also, the nightsoil may come out from the cleaning chamber occasionally.

5. The water seal trap which is used for the latrine pan should have a waterseal of only 15 mm to 22 mm*. This will help in minimizing the quantity of water needed for flushing. The water seal traps at present available in market have a water seal of 50 mm to 70 mm. These are unsuitable. Use of 'Sopa' (simple) latrine pan developed by Appasaheb Patwardhan has been found to be very suitable.

6. Water tap should be provided outside the latrine enclosure. If tap is provided inside, excessive water would be used despite intentions for frugal use.

7. Latrine seats should be placed very close to the plant so that latrine to plant drainline is as short as possible. Further, with 'onsite' latrine seats, the problem of carrying nightsoil to the plant will not arise.

8. Effluent slurry may be allowed to dry or may be composted in the manure pits. Two pits are alternately used.

9. Although not strictly within the scope of this paper, it may be mentioned that many times, the latrines connected to cattle dung plants do not have adequate plinth height. This results in a backflow to the waterseal trap leading to choking. In order to avoid this, the latrine plinth height should be atleast 1 1/2 feet above the top of dung feeding chamber.

Design Suitability Test

A review of the design characteristics and functioning of various designs (predominantly KVIC, Janata and water jacket) in relation to the nightsoil feed, is self-revealing.

In KVIC design the gas holder floats in the digesting slurry. As a result undigested slurry is present between the outer surface of gas holder and the wall of the digester. In the case of nightsoil feed, undigested nightsoil finds access to this annular gap through which it is exposed to the surroundings. This gives rise to offensive foul smell. The insects and animals get direct access to nightsoil and spread disease. The nightsoil is visible. Many times nightsoil also sticks to the outside of the gasholder which needs cleaning. With exposed nightsoil, the chances of soil pollution are ever present.

In Janata plant, slurry is constantly moving between the digester and the inlet-outlet chambers. During such movements undigested nightsoil will enter inlet and outlet chambers, from where it will give out foul smell. Also the insects find access to inlet and outlet chambers. In case, inlet and outlet chambers are not covered properly there is a total exposure of nightsoil.

In water jacket design, as has been already discussed, the gas holder floats in water jacket. The slurry is completely covered as it lies inside the inner wall

* The traps manufactured by NEERI or Maharashtra Gandhi Smarak Nidhi etc. have a 15 to 20 mm water seal Ed.

of the jacket.Thus, slurry is not exposed to atmosphere. Hence there is no smell. Flies, insects and animals cannot reach slurry. There is no soil contamination as only digested slurry comes out from outlet pipe.

Thus, it is evident that water jacket design meets all requirements of a suitable design for nightsoil based biogas plant. Small sized 'onsite disposal' construction not involving carriage, manual or otherwise, of nightsoil will be most advisable.

Experience with Some Examples in the Field:

In Maharashtra, since 1953, all nightsoil based biogas plants constructed by the late Annasaheb Patwardhan and his worker volunteers, have water jacket type design. These have been functioning satisfactorily. His work was later continued by Maharashtra Gandhi Smarak Nidhi, using the same design. These plants are also functioning satisfactorily for many years. A brief review of some of these plants may be worthwhile.

1. First nightsoil based biogas plant constructed at Kankavali in Ratnagiri district of Maharashtra State was constructed in 1953. The design used was water jacket type digester. A twelve-seat community latrine block was attached to 300 cu. ft. capacity plant. The unit was maintained by Gopuri Ashram of Appasaheb Patwardhan. The gas was used in Gopuri Ashram farm.

2. The biogas plant at Maharashtra Gandhi Smarak Nidhi staff quarters was constructed in 1967. The plant has water-jacket-type digester. The capacity is 70 cu. ft. It has one latrine attached. The latrine is used by four families: the number of users is around twenty. Gas has been given to one family. Manure is used for plantation.

3. The biogas plant at Dr. Jogalakar's hospital at village Shirval in Distt. Satara, Maharashtra was constructed in 1967. The design has water jacket type digester. The capacity is 150 cu. ft. The input is from a block of 10 latrine seats on site. The owner has allowed villagers to use the latrines. 100 to 150 users use the latrines daily. Gas is used in the hospital and the owner's residence. Manure is used in the owner's farm. The doctor is reported to be saving about 70 litres of kerosene per month.

4. The biogas plant in Dehu village in Pune Dist. owned by Sri Mohansingh Pardeshi was constructed in 1978. It is a 6 cu.m. capacity plant with water jacketed digester.Two latrines are attached to the plant. The owner has allowed about 10 neighbouring families to use the latrines, who pay Rs. 5/- per month per family as maintenance charges to the owner. About 100 persons use the latrine daily.The gas is sufficient for household cooking of the owner's family of about 15 members. Through the sale of manure, the owner recovers about Rs. 600/- annually. Thus the plant has been a profitable business for the family. This is an example which can be a guideline elsewhere.

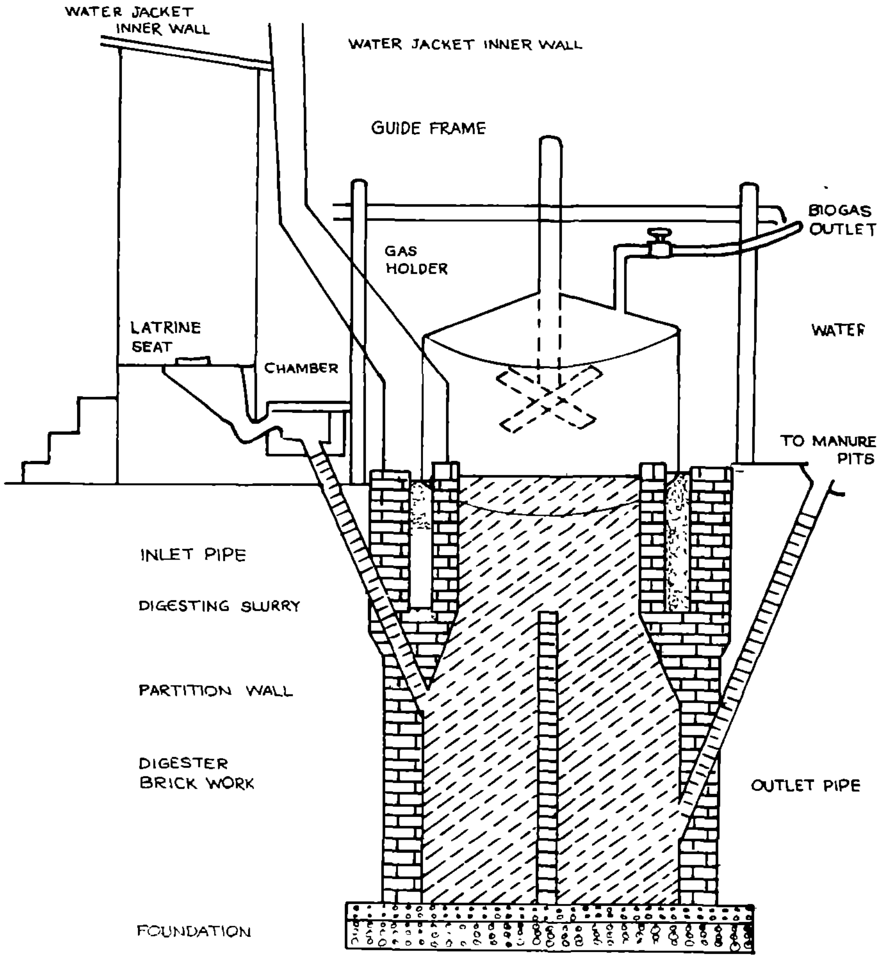
5. At Relegan Shindi Village in Ahmednagar Dist. Maharashtra, a biogas plant for backward class hostel has been constructed.About 10 latrines are attached (on site) to the plant. Hostel students and other villagers use the latrines. The gas is used for the mass cooking and lighting in a temple.

6. I had an occasion to visit one community gas plant in village Karudayya Kaundan Patti in Tamilnadu. This is a rehabilitated village. The plant

has a capacity of 40 cu.m. The plant has a water jacketed digester. It was constructed by Gandhigram Trust. 54 families use the latrines. It is one of the cleanest and efficiently maintained community biogas plants.

These are only a few representative examples.These examples show that nightsoil based biogas plants function very satisfactorily. The design used in all these cases has been of water jacketed digester with floating gas holder. This seems to be the best design for nightsoil based biogas plant. Biogas from human waste is a very sound and workable proposition provided suitable design is used. Biogas from human wastes is being used for the last thirty years. Fear is, therefore, unfounded. Of course, there is scope for research as regards dilution, C/N ratio, microbiology, design etc. From the available data and field experience, it can be concluded that nightsoil based biogas plant will be a valuable asset for rural health, bio-energy, agriculture and rural development.

FLOATING DOME BIOGAS PLANT
WITH WATER JACKET DIGESTER
(Suitable for Human Waste Treatment)



DESIGN AND IMPLEMENTATION OF A PILOT DEMONSTRATION COMMUNITY NIGHTSOIL BIOGAS SCHEME

*Anil K. Dhussa**— *Raymond Myles***

Abstract

In India about two-thirds of the urban population use dry (i.e. flushless) latrines. Night-soil from these latrines is dumped at pre-assigned places outside the city/town or municipal limits. However this causes immense pollution due to direct exposure to the atmosphere; at the same time it leads to wastage of organic material which has great potential for the production of biogas as well as excellent organic manure. AFPRO's notable achievement was to provide technical assistance for design and implementation of a cluster of three biogas plants each of 20 cu.m. capacity - a demonstration community nightsoil Biogas scheme for Acharya Harihar Colony, Puri, Orissa, at the request of Public Health Deptt. (PHD), Government of Orissa, Bhubaneshwar.Constructed in 1984, the entire scheme has been working well. It has the following main components - Biogas production system; Biogas distribution system; Nightsoil feeding system; Effluent treatment system. Their characteristics are presented here. The differences between the K.V.I.C. model and the Janata Model are also discussed.

-Ed.

Introduction

The safe disposal of nightsoil is a major consideration for any sanitary programme. There are three major methods of disposal of nightsoil, being adopted at present in a large-scale sanitary programme in India.The first being the complicated sewage system which involves huge capital investment and time duration for execution of the projects. The maintenance cost of such schemes is quite high and according to National Sample Survey of 1973-74 only 20% of urban households are covered by sewerage. The same survey reveals that only 14% of urban households use the latrines connected with septic tanks, which form the second method of nightsoil disposal.[1] The third method is through dry latrines which have been in use in practically all the towns of India and about 2/3rd of urban population still uses them. The nightsoil from these dry latrines is dumped in pre-assigned places outside the city/town or municipal limits everyday by scavenger community. This causes immense pollution due to direct exposure to the atmosphere and at the same time leads to wastage of organic material which has great potential for the production of biogas as well as excellent organic manure.

Though attempts are being made to convert the dry latrines into more hygienic low-cost latrines, it will take years before all will be converted. Realising this problem, AFPRO (Action for Food Production), a non-profit technical service organisation, had constructed a community nightsoil biogas plant in Midnapur,[2] for Midnapur Municipal Committee (MMC), West Bengal. This pilot study plant was designed and built by AFPRO in the year 1981 for the treatment of human waste and also to get the twin benefits biogas and organic manure. This plant was operated on the nightsoil collected from the dry latrines in the MMC area. Many useful lessons with respect to operational and socio-economic aspects were learnt from this pilot study project.[3]

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Later, the Public Health Engineering Department (PHD), Government of Orissa decided to set up a pilot demonstration project for converting some of the nightsoil available from the city of Puri, into biogas and manure and approached AFPRO through "Gram Vikas" for its design and construction.The project was located at nightsoil dumping site and the generated gas supplied to a nearby sweepers' colony (Acharya Harijar Colony). The project envisaged the generation of biogas from nightsoil for supplying it to 60 houses. The total installed capacity of the community nightsoil plants scheme was proposed to be 60 cu m.

Background of the Plant Design for Biogas Production System.

There are two basic types of biogas in India, namely - (i) floating-drum type (KVIC model) and (ii) fixed-dome type (Janata model). The KVIC model plants have digesters connected with inlet and outlet pipes near the bottom and are separated by a partition wall. The input material (feedstock) in the first half of the digester is expected to travel upwards and over the partition wall into the second half and downwards to the outlet pipe to be discharged after completion of the entire cycle of its hydraulic retention time (HRT). The expected flow pattern can be termed as "quasi-plug flow". However, the nightsoil mixed with water does not form a very homogenous mixture as is the case with cattle dung slurry: hence, it cannot be expected to follow the same flow pattern. There is all the likelihood of some shortcircuiting of raw-materials.

It is reported that 99.6% of hookworms die under anaerobic conditions within 70 days,[4] at a temperature of 16°C. Therefore, the nightsoil must remain in the plant for over 70 days to become free from pathogens and parasitic ova and should not be left exposed to the atmosphere during the fermentation (digestion) period. The KVIC design for nightsoil based biogas plants cannot be said to be fully safe because it does not shut out possibilities of the slurry's escape into outlet pipe even before spending the requisite residence time in the digester.

The other population design, named Janata biogas (fixed-dome) plant, has the advantage of having a large diameter and less depth, thus reducing the vertical movement of raw material (The vertical movement causes mixing of the more and the less digested material and therefore the possibility of shortcircuiting, as in the case of KVIC plant, gets reduced in the Janata model). The Janata plant also has the advantage of having its digester completely covered from the top, thus preventing foul smell and pollution from the digester.

The Janata plant, however, has the disadvantages of a very large inlet and it necessitates the exposure of fresh feedstock to the atmosphere for 2-3 days. This will not be tolerable for a nightsoil biogas plant because of its obnoxious smell.

For large plants (say 15 cu.m capacity and above), large diameter of the digester is also undesirable because the input material (feedstock) would tend to flow straight towards the outlet tank since there is no distinct force acting on it to flow sideways and no arrangements have been made for guiding the flow. This means significant reduction in the effective digester volume for largersize plants.

Design of Nightsoil Plant Scheme for Acharya Harihar Colony, Puri

The community nightsoil biogas plants system at Puri, Orissa was designed on the basis of AFPRO's previous experience of implementing and operation of 15 cu.m. Janata biogas plants fed with nightsoil at Midnapur, West Bengal, and keeping in view the constraints and limitations mentioned in para 2.1 to 2.5 above in the two most popular Indian plant designs.

The design of (i) biogas production system; (ii) gas distribution system; (iii) feeding system and (iv) effluent treatment system, for the community nightsoil biogas plant scheme at Acharya Harihar Colony, Puri are presented below:

Biogas Production System

The entire gas production capacity of 60 cum. gas was proposed to be met by three fixed-dome plants of 20 cu m capacity each.The basic design of the 20 cu.m. fixeddome plant has been adopted from the Janata biogas plants' operational concept. In the modified fixeddome plant design the inlet tank has been removed and the mixing tank is connected with the digester through a pipe of 150 mm diameter. Since the upper portion (above the initial slurry level) of inlet and outlet tanks determine the gas storage capacity of the plant, the displacement chamber design on the outlet tank has been made larger to account for the removal of displacement chamber from the inlet side.

A "baffle wall" has been provided in the middle of the digester to ensure the sideways movement of the slurry closer to the digester wall (instead of letting it follow the shortest path to the outlet) thus ensuring the effective utilisation of most of the digester volume. In order that the turbulence be kept at the minimum, the "baffle wall" is so designed that the feedstock goes around the wall and not over the wall, as is the case in the KVIC plant.

The dimensional sketch of 20 cu m. fixed-dome nightsoil biogas plant designed for 75 days HRT is given in drawing-1.

Biogas Distribution System

In the community nightsoil biogas scheme the gas produced at one spot is required to be distributed to 60 houses for cooking. A distribution system for this type of scheme should be available at all the points of utilisation (all the 60 houses) at equal pressure. This is of utmost importance because the gas in the plant is available at rather low pressure (between 0 and 90 cm of water column) and variation in pressure affects the flow of gas.[5]

The gas distribution system has been designed for a maximum variation of 0.5 cm of water column pressure between any two houses or storeys.The galvanised iron pipe is recommended for use in order to ensure the durability of the system and to minimise the recurring maintenance cost.The piping layout is given in diagram -2.

Nightsoil Feeding System

Nightsoil has to be made in the form of slurry by mixing it with water. The feeding system consists of a mixing tank which is fitted with a churner operated either on a dual-fuel engine of 3 HP or manually. Normally in a cattle-dung operated plant system of this capacity the mixing is done manually but since the fresh nightsoil has bad odour which cannot be tolerated for a long time, mechanical mixer has been designed for this project.

Daily input of 700 litres of fresh slurry containing about 10% dry matter is recommended for each of these plants.

Effluent Treatment System

Since the hydraulic retention time (HRT) of each biogas plant is kept at 75 days, it is expected that the slurry coming out of the plants after undergoing anaerobic fermentation for 75 days will be free from pathogens and parasitic ova. Therefore, the effluent, which will contain about 92-93% water in it, needs to be dried before it can be used as manure.

Drying is planned to be done in pits of 3 feet depth.Total retention time for effluent in the drying pit is kept at 90 days, also allowing for addition of some other bio-wastes for composting.

Conclusion

This innovation in the existing fixed-dome (Janata plant) design has been done by AFPRO with a specific purpose of efficient treatment of nightsoil. However, other raw-materials which can be made into a homogenous slurry form can also be treated efficiently, if these design changes are incorporated in all capacities (1 to 30 cu m.) of existing popular fixed-dome (Janata plant) design.

The successful operational demonstration of this community nightsoil biogas scheme will open up possibilities for acceptance of such projects for efficient treatment of nightsoil from dry latrines for giving the dual benefits of biogas and organic manure, thus making the treatment of nightsoil on economically viable proposition.

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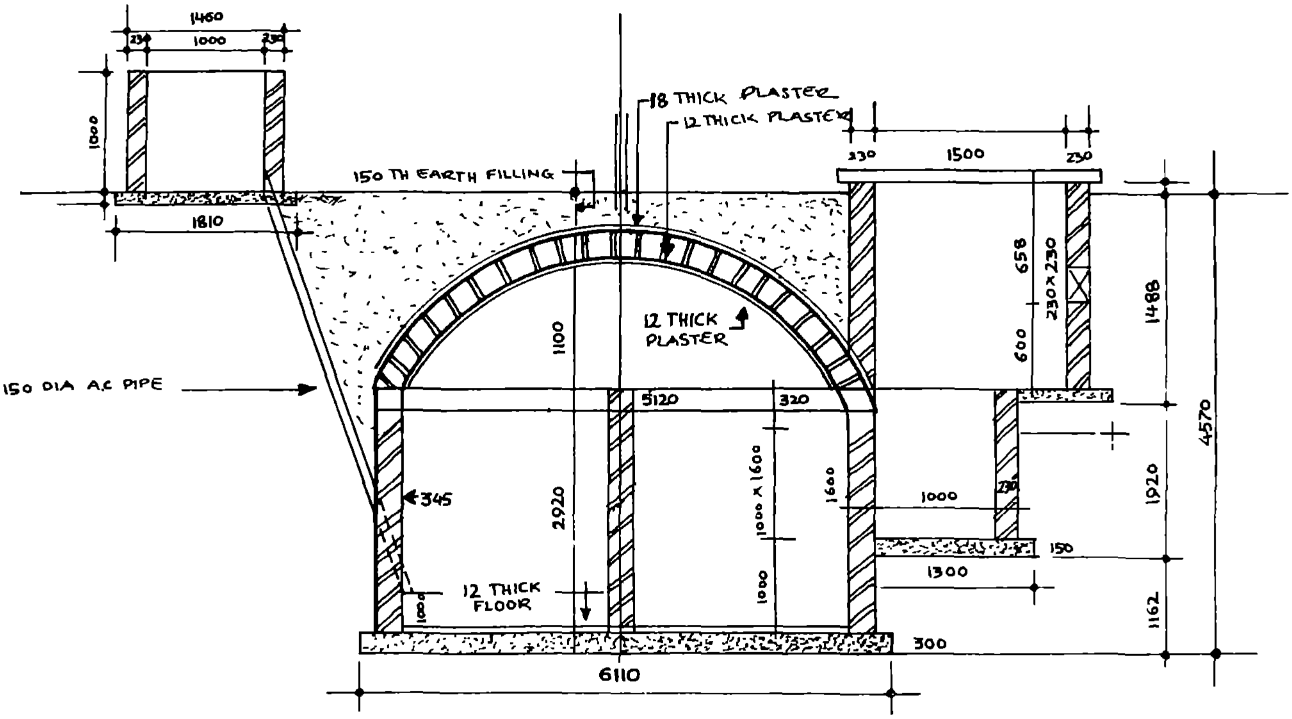
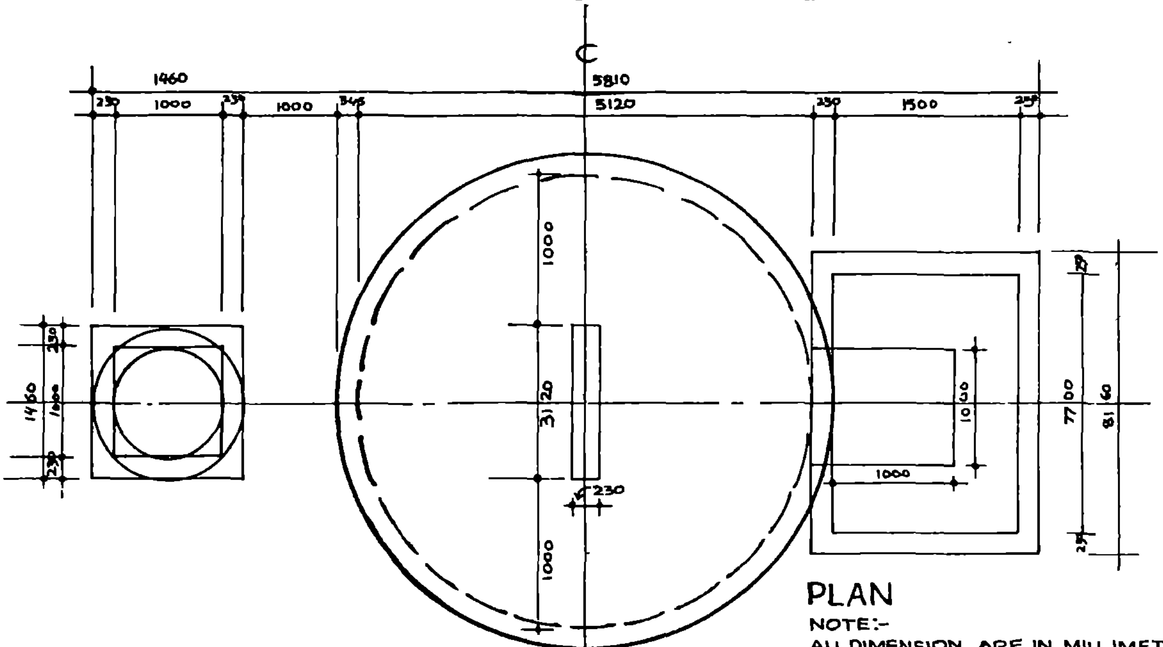
FIXED DOME NIGHTSOIL BIOGAS PLANT.

CAPACITY - 20 Cum (700 cft)



LONGITUDINAL SECTION.



PLAN

NOTE:-
ALL DIMENSION ARE IN MILLIMETERES

DETAILS OF CONSTRUCTION MATERIAL, LABOUR & MASONS		
S.NO	PARTICULARS	QUANTITY
1	BRICKS	14000
2	CEMENT	120 BAGS
3	BRICK BALLAST	350 CFT
4	FINE SAND	400 CFT
5	COARSE SAND	300 CFT
6	ENAMEL PAINT	7 LTS
7	G I PIPE WITH TWO SOCKETS	9"
8	OUTLET COVERS	L x B
9	LABOUR (UN-SKILLED) FOR DIGGING THE PIT (LABOUR DAYS)	50-70
10	MASONS (SKILLED/TRAINED) MASON DAYS	75-95
11	LABOUR (SEMI-SKILLED) FOR CONSTRUCTION WORK LABOUR DAYS	150-190

ACTION FOR FOOD PRODUCTION
25/1A, INDUSTRIAL AREA, NEW DELHI 110058

DATE.	1 JAN 1985	11/2
DESIGNED	AFPRO	
DRAWN	K C NARULA	
CHECKED	ANIL DHUSSA	
APPROVED	R.M MYLES	

SCALE = 1 30 -AFPRO-

SOME ASPECTS ON THE DESIGN OF FAMILY-SIZE FIXED-DOME NIGHTSOIL BIOGAS PLANTS

Anjan K Kalia *

Abstract

Fast extension without proper feedback from the users and requisite research is leading to disappointments in Himachal Pradesh and also posing problems of health hazards from these very digesters. The problem is not merely people's prejudice against nightsoil: inadequacy of technology is a major cause. In fixed-dome plants, there is excess odour from inlet and outlet pipes, the light but undecomposed nightsoil tends to flow to the outlet tank and does not flow back to the fermentation chamber. Not much research has been done to correlate the hydraulic retention time, the varying temperature levels particularly in the 13°C-23°C range and the percentage inactivation of pathogens.

Detailed design of a familysize 3 cu.m gas capacity biogas plant, with a novel type of baffle wall, has been suggested for trial.

- Ed.

Introduction

Fast extension of familysize biogas plants in different parts of the country over the years[1] has proved the utility of biogas plants not only in providing a clean fuel for cooking and light but also in reducing the environmental pollution. Since these plants involve the use of cattle dung, it is essential to have a minimum number of cattle heads for meeting dung requirements. Another bulky organic material that can be made available for biogas production is the human excrement. Not much effort has been made on the use of human excrement alone or in combination with cattle dung although the former is a better material for biogas production.[2] Some efforts have been made by agencies like KVIC and PRAD to attach latrines to cattle-dung-fed biogas plants with attached latrines,[3] but utility of biogas plants remained limited not only because of people's inhibition but also on account of a lack of proper foolproof appropriate technology suitable for different agro-climatic and geographical conditions of the country. The research work conducted on the use of cattledung-fed biogas plants run on nightsoil has mostly remained restricted[4] to the gas plants with floating gas holder which is a technology adopted since 1900[5]. AFPRO designed[6,7] a number of fixeddome Janta Biogas Plants fed on nightsoil. But their work has remained more or less restricted to community biogas plants when fed exclusively by nightsoil. The main limitation in the adoption of biogas production purely on nightsoil is that human excrement from a family of 5-6 members cannot produce sufficient biogas by itself. However, this source can contribute to the overall biogas production from familysize biogas plants, apart from providing a sanitary disposal of the waste with almost negligible additional cost compared to construction of a separate septic tank required for the latrine. But a dilemma remains as

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to whether the design of fixed-dome family-size biogas plant is suitable and safe for the use of human excreta from family latrine as the floating drum gas plant is. It is also not clear if a simple attachment of a latrine pipe to the former can serve the purpose. A number of beneficiaries in Himachal Pradesh - who, spurred by extension agencies, installed pipes connecting latrines with 2-4 m^3 fixed-dome Janta biogas plants - had to discontinue the use of these latrines due to various problems. This paper discusses some practical aspects experienced in this regard.

I. Unsatisfactory Design of Latrine Attached to Biogas Plant

Dilution of human waste for proper anaerobic fermentation is a common problem with all types of bio-gas digesters using this waste. Though nearly 2-3 times dilution of human excrement is the most suitable[8] to reduce solid content to 5-6% for maximum biogas production, sometimes more and at other times less water is used by the users depending upon their habits which affects the rate of decomposition of this waste in all types of biogas plants. In fixed-dome biogas plants with attached latrines the additional difficulties are as follows:

i) There is excess odour from the sewage pipe connected to these biogas plants. As the biogas gets collected in fixed dome of the gas plant, pressure is created which displaces digesting slurry from the digester not only into the inlet and outlet tanks of the gas but also in the sewage pipe which contains fresh human excreta, thus resulting in the pushing of obnoxious smell into the latrine. Even the users who have water seal in their latrine seat face this problem of bubbling out of these dispaced gases from the pipe to the latrine.

ii) As no specific guidelines are provided for construction of latrines above the gas plants, these are often so constructed that the height of latrine seat is just equal to that of the slurry discharge hole of the outlet tank of these biogas plants. The two heights being the same, a problem crops up. As the biogas accumulation reaches the limit of gas holder's capacity, a part of fresh human excreta along with dung slurry is pushed back to the latrine seat, thus making the latrine unusable. The problem is more at places where the biogas plants are constructed with their dome at the ground level or above it and the rest of the house and the latrine is at a lower height.

II. Insanitary Conditions of the Outlet Tank of the Biogas Plant

Human excreta does not form a homogenous slurry in the gas plant as no mechanical stirring is provided. Further physico-chemical parameters of human excreta vary with the type of food taken by the family. Where human excrement is lighter than the slurry in the tank, it floats to the top in the fermenting chamber. It happens mostly when the users consume more fat in their diet. As the slurry from the fermenting chamber is disposed to outlet tank, a part of this light undecomposed nightsoil comes in the outlet tank and being lighter, does not go back to the gas plant with the cattle dung slurry, thus forming a top surface in the outlet tank. This creates insanitary condition in the oultet tank of the gas plant by creating odour-nuisance and attracting flies etc.

III. Incidence of Diseases due to Pathogenic Organisms and Parasite in the Sludge.

The improperly digested human excrement is unsafe for utilization as a manure for crop production as it can result in spread of diseases of viral, bacterial, protozoan and helminthic origin[9,10]. In most of the existing biogas plants, the pipe from latrine is attached to the centre of the digester wall. As the hydraulic retention time (HRT) of feed in these plants is 55 days,[11] the fresh dung slurry added in the inlet is theoretically expected to come to the outlet tank after this period. But since the human excreta enters the gas plant nearly in the centre of digester, it is expected to come out of the gas plant in less than 28 days. Further, since the human excreta is lighter than cattle dung slurry, it comes out of the digester even earlier due to short-circuiting of its path in the digester. This excreta is not decomposed because of its short retention time for anaerobic decomposition. Low bacterial activity in the gas plants when the digester temperature[12] remains between 13°C and 23°C during different months of a year also causes inadequate digestion. The ill-digested slurry contains various types of pathogenic organisms and parasites. As the slurry from the gas plant which contains this undecomposed human excreta is used as manure directly in the fields either alone or along with water or by transporting mechanically, it can cause serious problems of spread of faeces borne diseases like gastyroenteritis, typhoid, cholera, tuberculosis, dysentery hookworms, round worms, pipe worms, tape worms etc. The pathogens responsible for these diseases can be carried by direct contact or by the edible portion of the crop, or by plant root systems whose cell wall barriers these pathogens panetrate.[13] Thus, the anaerobic fermentation, if not complete, while producing biogas and manure, can result in a serious health hazard.

Points for Attention

The following design aspects need standardisation before adoption by masses:

1) There is an urgent need to bring about technology improvements in the family-size fixed dome biogas plant for attaching a household latrine. The latrine attached to the family-size biogas plant may be so constructed that the water seal of the latrine seat is 20-30 cm above the slurry discharge hole of the outlet tank of the biogas plant and preferably, above the top of dome as well.

2) The lower end of the sewage pipe may be close to the inlet tank and preferably 2-5 cm below the upper end of the outlet opening of the gas plant. This portion will be the most suitable for entry of human excreta to the digester under gravity when there is nearly zero gas pressure in the gas plant.

3) To avoid the problem of obnoxious smell in a latrine it is essential that a vent pipe may be provided to a latrine seat. It will not only avoid the entry of foul smell from the sewage pipe under pressure of gas in the gas plant but may also help in the downflow of human excreta in a pipe which will not go smoothly from the water seal trap due to inbuilt pressure of gasses in the pipe.

4) As the amount of water recommended for use in latrine with human excrement is 2-3 times (approximately, one litre), it may be advisable[14] to have a latrine seat with 25 mm water seal trap as compared to 50 mm in a conventional flush latrine. This aspect needs engineering investigation.*

5) Not much data are available correlating the residence time and the percentage inactivation of pathogens

* This water seal traps manufactured by NEERI and by the Maharashtra Unit of Gandhi Smarak Nidhi are 15 cm - 20 cm Ed

and parasites in human excreta under anaerobic conditions at different temperature ranges in 13°C-23°C, which is the temperature prevailing in the digesters of this region. Only limited data are available at 35°C or 16°C[16]; and then there are general recommendations for digestion period of nightsoil when used with other wastes for adequate destruction of pathogens. The period for which human excreta should remain in active anaerobic conditions of the digester to have effective control of pathogens needs to be investigated.

Suggested Design of Biogas Plant

Keeping all these points into consideration, the detail of 3 m^3 fixed-dome latrine-connected biogas plant is shown in Figure 1. It has a nightsoil chamber created by the construction of a wall in its digester. Assuming that this chamber will never be uniformily filled with human excrement, its volume is proposed to be nearly 1.5 times the total volume of 90 days' accumulated excrement[17] from 5-6 persons diluted to 3 times with water. The height of the chamber wall should be such that its corner touches the dome but its central part is about 10 cm lower than the dome. This chamber will not allow the light nightsoil to enter the main digester but will allow gases to go to the dome for use. One semi-circular hole of dia 30 cm in this wall is proposed so that the level of the slurry in this chamber remains in equilibrium with that in the main digester by the slurry's movement through it during variable conditions of gas pressure in the gas plant. To minimize the flow of heavy nightsoil from this chamber to the main digester, this hole is placed nearly diagonally to the sewage pipe hole and nearly 15 cm above the floor so that the movement of the heavy nightsoil which goes to the floor is slightly restricted. The detail front view of the chamber wall is shown in Fig 2a and the layout of latrine seat vent pipe and sewage pipe in Fig. 2b.

Table 1: Item-wise Cost of Construction of Latrine-attached Family-size Cattle-dung-fed Biogas Plant

Chamber Construction			Latrine Fittings		
Item	No.	Approx. Cost.-Rs.	Item	No.	Approx. Cost.-Rs.
Bricks	150	100	IWC (Chips)	1	100
Cement	1 bag	60	AC P Trap	1	15
Sand	0.2 m^3	20	AC door junction	1	20
Labour	-	70	AC Reducer (100/50)	1	15
			AC Cowl 10 cm	1	15
			AC Loose coller	2	25
			1.8m AC pipe 10 cm	1	45

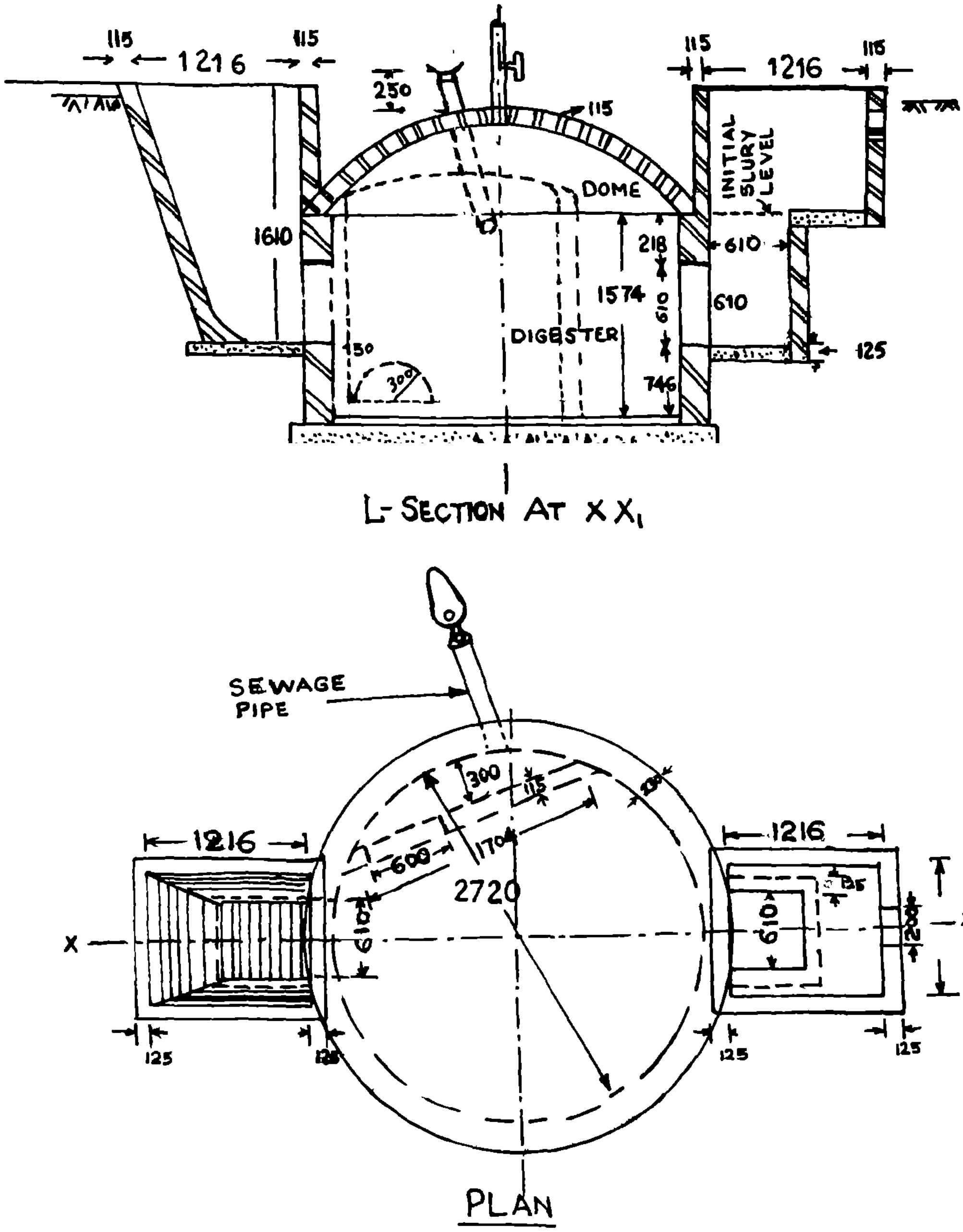

FIG 1. HPKVV 3m^3 FAMILY SIZE CATTLE DUNG FED BIOGAS PLANT WITH ATTACHED LATRINE

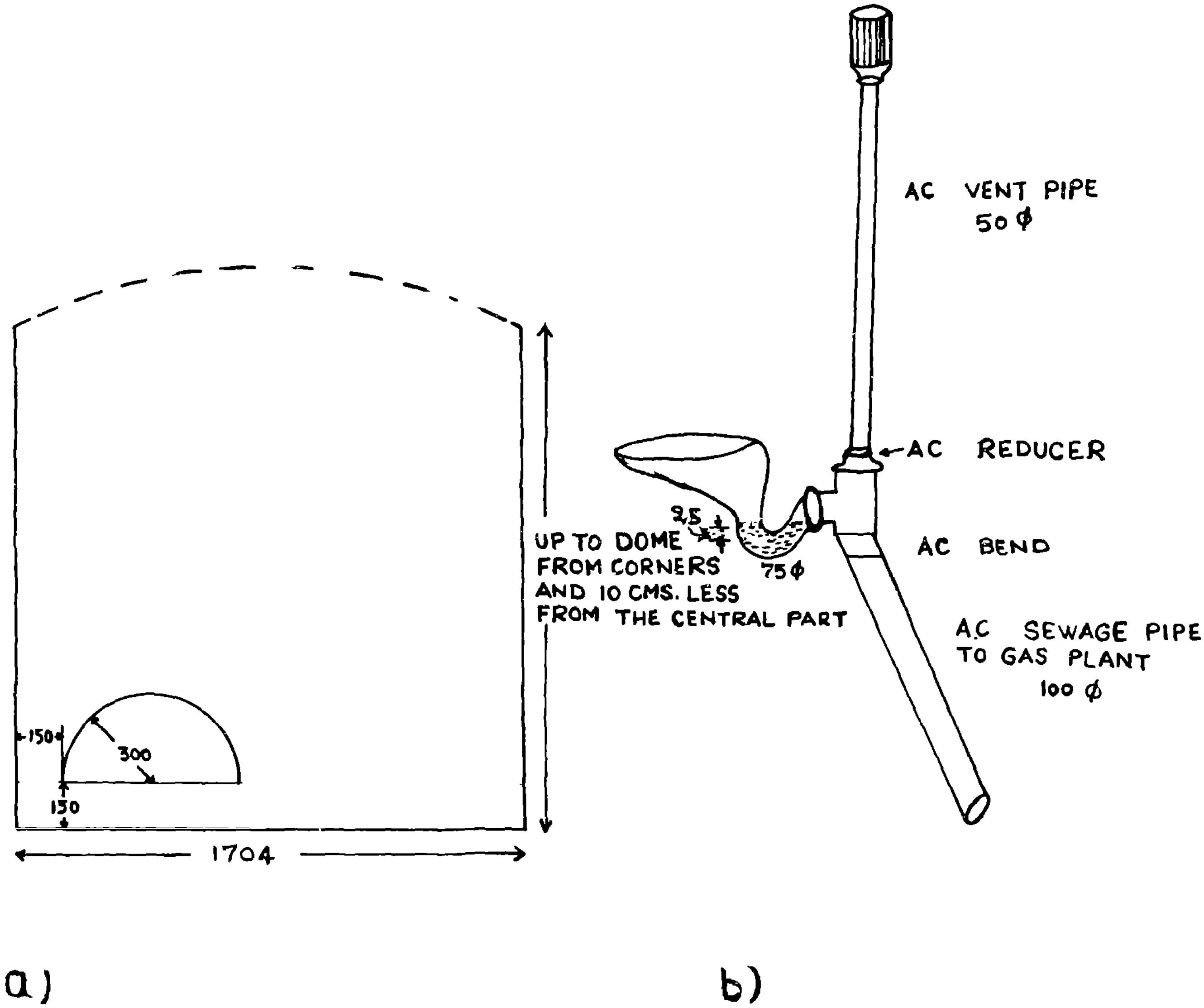

FIG 2. a FRONT VIEW OF THE CHAMBER WALL.
b. LATRINE SEAT, VENT PIPE AND SEWAGE PIPE ARRANGEMENT.

Chamber Construction			Latrine Fittings		
Item	No.	Approx. Cost.-Rs.	Item	No.	Approx. Cost.-Rs.
			AC Vent pipe 5 cm	2	65
		250			300

Grand Total: 250+ 300 = 550/-

Item-wise estimate of cost required for construction of nightsoil chamber suitable for 3 m3 family-size fixed-dome biogas plant and latrine assembly (excluding the construction cost of latrine structure) is given in Table 1, which suggestes that small additional cost of Rs. 550/- only on this plant will not only provide a satisfactory sanitary latrine but also produce 90 litres more biogas per day, apart from adding to the manurial contents to the slurry from this gas plant.

Acknowledgement

The author is grateful to Dr. G. Dev, Director of Research, H.P. Krishi Vishva Vidyalaya, Palampur for his constant encouragement for research in this field and for his valuable suggestions in preparing this manuscript. Financial support provided by the ICAR under its AICRP on Renewable Enbergy Sources is greatly acknowledged.

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IMPROVED LINKAGE OF LATRINE COMPLEX TO COMMUNITY BIOGAS DIGESTER

*S.K. Vyas**

Abstract

Recently the Government of India is laying great emphasis on Community Biogas programme. Along with the sanction of Comunity Biogas complex, funds are also provided for construction of public latrines complex to serve three purposes.

1. *To provide facilities for the poor section of society to avail of such facilities.*

2. *To increase biogas production.*

3. *To improve the hygenic conditions in the rural India.*

The present system of linking latrine complex to the digesters needs a lot of improvement for effective mixing of effluent from latrine complex, to avoid choking and for better fermentation.

* Punjab Agricultural University, Ludhiana

MALAPRABHA LATRINE BIOGAS PLANT

A new innovative design for utlization of biogas from latrine

S V Mapuskar *

Introduction

he author has innovated a system for recovering biogas from "latrine plants" at a cost which is slightly higher than the conventional aqua privy latrines of the same capacity. It is claimed that the plants built on this model have been functioning satisfactorily since 1981. The plant comprises of three rectangular compartments. The physical features of these chambers and their functions are given in the paper.

In both the pit privy and aqua privy types of latrines, the gases generated in the process of digestion of nightsoil are considered a nuisance and arrangements are made to remove these via a vent pipe placed as high as possible. In case of pit privy the gases contain mainly carbon dioxide which is not very useful. In case of aqua privy, this socalled "nuisance gas" is nothing but biogas.

Can this gas be trapped and used as a fuel by planning some innovative design for latrine? Can this gas supplement the fuel requirements of the family? With a view to providing an answer, this author thought of developing an appropriate design which would act as a bio-gas plant. Design of such a biogas plant as would have all the necessary features of a latrine was found feasible in 1981.

New design for recovering biogas from latrine

A biogas plant working on nightsoil feed could be constructed in a very conventional manner. The latrine biogas plants constructed on the basis of this author's design are functioning very satisfactorily in and around Dehu in Pune District of Maharashtra for the last five years. The plant has been aptly termed 'MAIMPRABHA' latrine biogas plant.

The land requirement for 'Malaprabha' latrine plant is the same as for aqua privy latrine. The additional design features incorporated in the construction of 'Malaprabha' plant involve a small additional cost over and above the estimated cost for aqua privy latrine of the same capacity. The additional cost is easily offset by the saving in the cost of conventional fuel.

Salient Features of the Design

The plant comprises three rectangular compartments. Latrine superstructure is superimposed on first compartment.

It consists of the following components:

(i) Latrine seat and superstructure; (ii) inlet drop pipe; (iii) digestion and gas storage chamber; (iv) biogas outlet pipe; (v) displacement window; (vi) displacement chamber; (vi) outlet chamber; (viii) slurry outlet pipe.

Latrine seat and superstructure are superimposed on the first chamber which is a digestion-cum-gas storage chamber. From the latrine pan an inlet drop pipe starts. This pipe is of rigid PVC. Its one end is embedded in the R.C.C. slab of the roof of the digestion

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chamber. Its other end projects for about 600 mm in the chamber. A zigzag PVC pipe fitting is saddled on to the inlet pipe which is projecting in the digestion chamber. This fitting acts as a scumbreaking device. The digestion chamber is the bigger of the three chambers. Its roof consists of R.C.C. slab on top of which the latrine is placed. The plaster of the walls and roof of this chamber is made leakproof against gas and vapour by multiple layers of cement-lime-mortar plaster. The chamber walls and the roof are painted with bituminous emulsion paint.

The wall which separates this chamber from the second and the third chamber, has approx. 2 ft. x 2 ft. opening near the floor. This is a displacement window which connects the digestion chamber with the second chamber termed displacement chamber. Displacement chamber is connected to the third chamber called outlet chamber via a chamber interconnecting pipe. Slurry outlet pipe is placed at the upper edge of the outlet chamber (Refer to drawings).

Working of the Plant

From the latrine pan, the nightsoil enters the digestion chamber from inlet pipe. It starts fermenting in digestion chamber, where anaerobic conditions are present. As the digestion proceeds, the biogas is produced and moves towards the roof. It cannot escape through the inlet because the inlet pipe dips in the digestion chamber slurry to the extent of 600 mm. The biogas thus gets accumulated in the top portion of the digestion chamber. As the gas increases, it starts pushing the slurry downwards. Due to the pressure, the slurry moves to the displacement chamber through the displacement window. As this slurry moves to the displacement chamber, the fluid from displacement chamber moves to the outlet chamber via the chamber interconnection. From the outlet chamber the excess fluid moves out through the outlet as an effluent. During this process the gas in the gas store is under pressure proportionate to the difference between the fluid level in the digestion chamber and that in the displacement and outlet chambers. Outlet level is kept at 100 mm. above the level of the roof of digestion chamber so that the pressure on the gas can be maintained. The gas which is stored in gas storage space is let out through the gas outlet pipe which is fixed in the roof of the digestion chamber. From the gas outlet, the pipe connection is led to the burner where the gas is used as and when required. While the gas is being used up, the slurry level in digestion chamber will start rising till the slurry in all three tanks attain the same level. As the propulsion pressure for the gas is provided by the difference in slurry levels in the three chambers, the sizes of chambers and outlet level are adjusted in such a way that the propulsion pressure for the gas will vary within the range of 10 cm to 50 cm. During the up and down movement of the slurry in the digestion chamber, the scumbreaker will keep on cutting the scum automatically.

If for some reason, the gas remains unused, the slurry level in digestion chamber will be pushed down till it reaches the opening of inlet pipe and the excess gas will pass through inlet pipe and escape through the vent pipe attached to the upper end of the inlet pipe. Gases which will be liberated in displacement and outlet chambers will also escape through a separate vent pipe, thus avoiding the odour completely. As the latrine seat is provided with waterseal, the latrine superstructure will also be free from odour.

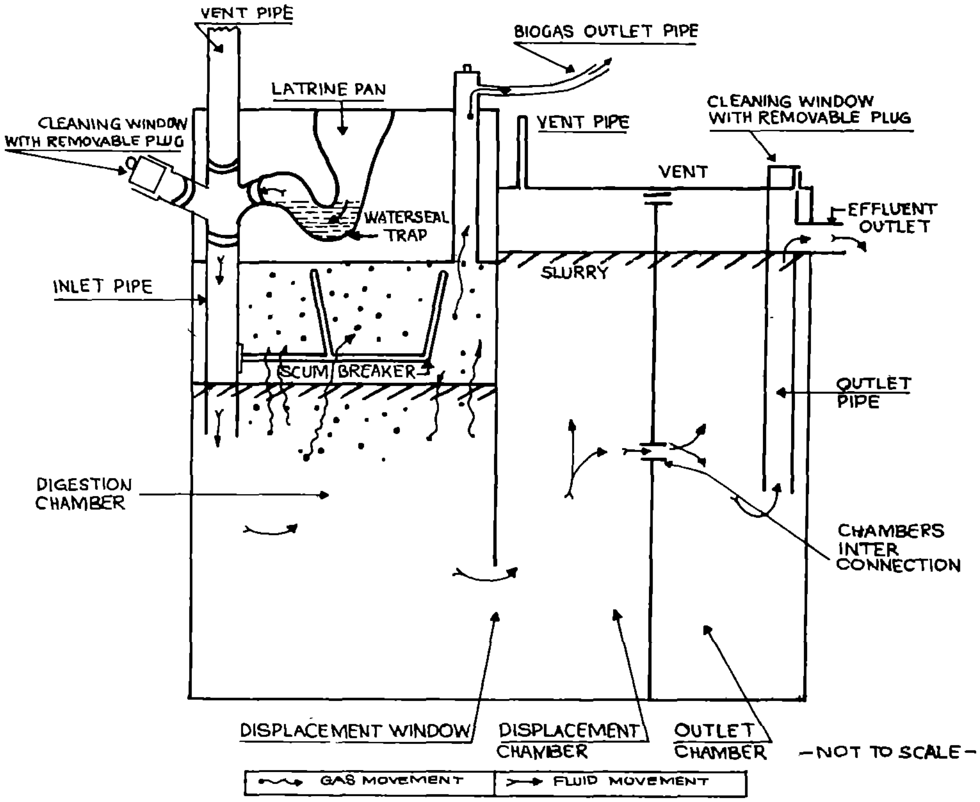
In the whole process, once the nightsoil gets inside the plant via waterseal, it is not at all exposed to the surroundings. Obviously, it will not be visible, nor will it give any faecal pollution or any

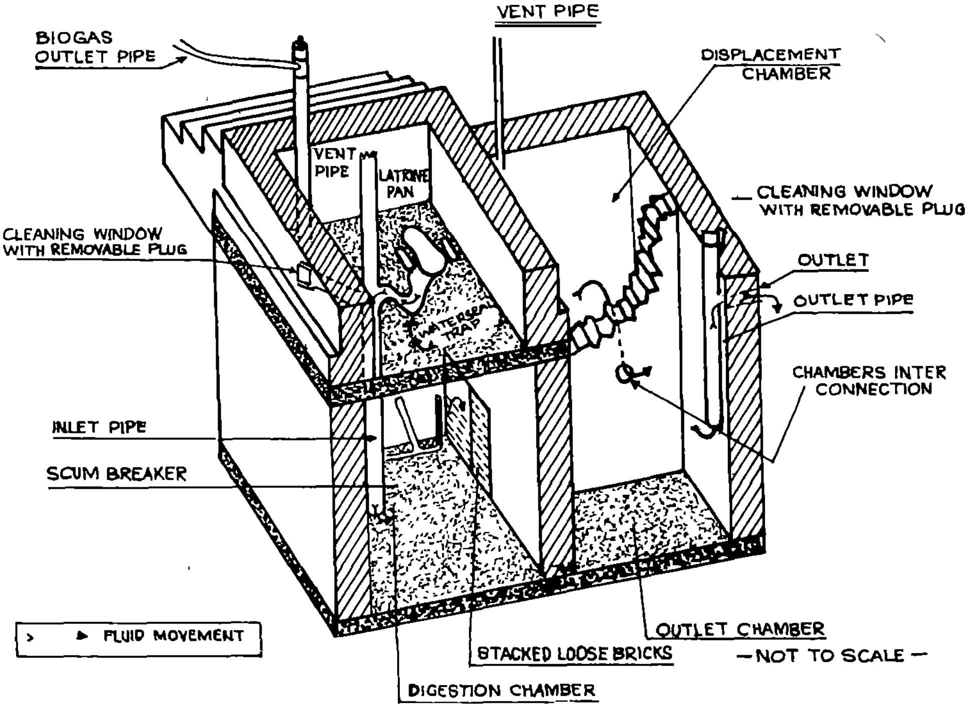
"MALAPRABHA" LATRINE BIOGAS PLANT

Schematic Arrangement of Latrine & Plant Chambers

Explaining the Mode of Functioning

Developed by Dr.S.V. Mapuskar





JYOTSNA AROGYA PRABODHAN, DEHU, DIST. PUNE.

smell. Only the fully digested odourless and harmless slurry will come out from the outlet. It can then be led to manure pits and from there on to the farm.

Retention Period and Capacity of the Plant

While calculating the total volume of the plant and the digester chamber, it is presumed that the amount of water entering the plant will be about 2 litres per user. Further, it is planned that about 25 user will use one latrine seat. The volume of the digester is planned in such a way that faeces of 25 users per day will have a retention period of 40 days in the plant. From 25 users roughly one cu m of biogas would be available. Thus, the standard, which emerges, is to have one latrine seat per 25 users to get 1 cu m biogas per day with plant retention period of 40 days. The dimensions for the chambers are decided on this basis. The dimensions and the volume also tally with the requirements scheduled for aqua privy latrines for the same number of users.

Suitability as regards basic requirements for nightsoil based biogas plants

As has been already discussed, (i) the maintenance of the plant can be easily done by the owner; (ii) nightsoil carriage is not involved; (iii) nightsoil is not exposed to surroundings: therefore, insects and animals cannot have access to faeces; (iv) aesthetically, it is clean and odourless; (v) due to retention period of 40 to 45 days, the effluent is virtually pathogen free.

Additional capital cost and the benefits received

As can be seen from the design, additional expenditure involved over and above the cost for aqua privy latrine is very marginal, Rs. 1,000/- or so, which is necessary for providing inlet pipe, gas outlet, scum breaker and a gas proof plastering for the first chamber. This marginally additional cost is recovered through augmentation in fuel supply for the family.

Conclusion

'Malaprabha' latrine biogas plant is a new innovative design developed for recovering biogas from anaerobically digested nightsoil. Latrine is integrated with biogas plant. Nightsoil is fed directly from the latrine seat to the plant. Its design features and mode of functioning are very convenient. The plant has proved to be very hygienic, harmless and very easy to maintain. Such plants are functioning very satisfactorily for the last five years. The design thus is very promising.

TREATMENT OF SLURRY AND ITS USE

MANURE FROM ANAEROBIC TREATMENT OF HUMAN WASTE

A.C. Gaur— K.C. Khandelal* **

Abstract

The slurry from anaerobic digestion is a valuable organic manure which improves soil fertility and increases agricultural production. The chemical composition of faeces and urine is such as contains almost all nutrients including trace elements needed by the plants. Urine has even higher nitrogen and potassium content than the faeces.

Biogas plant slurry is richer in ammoniacal form of nitrogen than the solid organic manure produced aerobically.Therefore, this slurry could be applied on land and ploughed in immediately or it could be composted with solid crop residues, farm wastes, city organic wastes etc.Mixing of phosphates during composting reduces ammonia losses. About 50% of the phosphorous content in the slurry is in the form which plants can early take up.

Pathogenic enteric bacteria get killed if the actual retention time in the digester is 14 days at 35°C. The die-off rate of even the enteric viruses is 22% at this level of temperature and retention time. There is no cost-effective method which can match anaerobic digestion in the destruction of disease-producing organisms. Composting can kill most of the remaining pathogens.

The paper gives some data from China and the Phillipines on crop responses to organic manures because systematic studies in India on crop responses to organic manure have not been made. The paper points to certain fields where R&D efforts are of prime importance.

- Ed.

Introduction

Human waste has been used traditionally as manure after composting with other organic materials, such as town refuse, cattle waste etc.Nightsoil contains relatively higher amounts of plant nutrients, particularly N, P and K than cattle dung. Chinese and Japanese farmers had maintained the productivity of their soils, mainly by extensive use of human excreta as manure. It is recognized that if it is properly collected and processed, it can be hygenically safe for land application. Human waste is of economic importance as source of plant nutrients.

Sanitary disposal of human waste is achieved cost-effectively by the process of anaerobic digestion. The waste matter is recycled as manure for agricultural fields. The Government of India has taken up recently a programme of linking of biogas plants with sanitary latrines. In the State of Gujarat and Maharashtra, many beneficiaries have already opted for biogas plants based on human waste alone or mixture of human and cattle waste. The spent slurry after some more treatment is recommended for use as manure.

Biogas Slurry as Valuable Manure

The use of spent slurry as manuare helps in its sanitary disposal with simul-

* Head, Division of Microbiology, IARI, New Delhi * * Principal, Scientific Officer, D.N E S , New Delhi

taneously achieving the recycling of materials as shown in Fig.1.

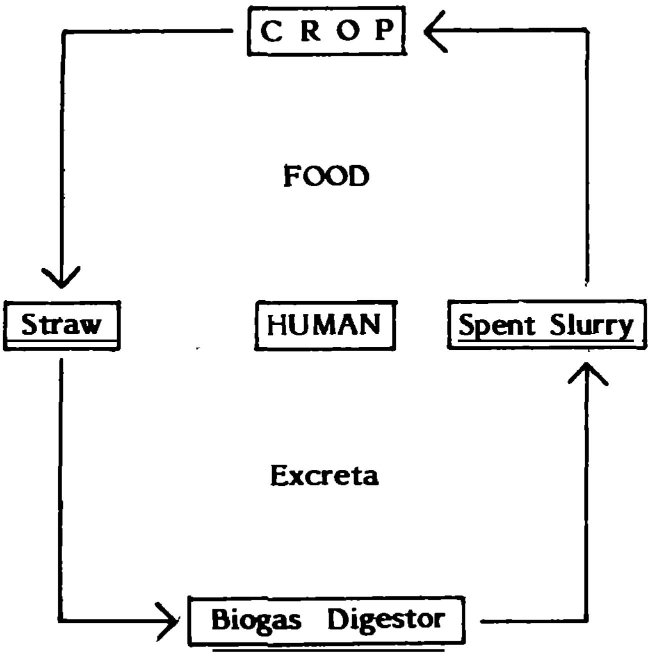


Fig. 1: Cyclic usages of organic materials built around biogas system for agricultural production.

It increases the supply of organic manure for improving soil-fertility and increasing agricultural production.

Quantity:

Human waste contains almost all plant nutrients including trace elements The daily per capita excretion of faecal materials (faeces and urine) is dependent upon many factors, viz., age of the person, diet, state of health, climate etc.

The average faecal weight varies from 100 to 500 gm per capita per day. The quantity of urine varies from 1.0 to 1.3 kg per capita per day. These figures depending on the population can help in selecting an adequate size of biogas plant. It is, however, advisable to study the availability of human waste in a given community before planning a biogas system.

Chemical Composition

Average chemical composition of nightsoil and urine is given in Table 1.

Table 1: Chemical composition of faeces and urine.

Item	Faeces	Urine
Moisture (%)	70-85	93-96
Organic matter (% dry wt.)	88-87	65-85
Nitrogen (%)	5-7	15-19
P_2O_5 (%)	3-5.4	2.5-5
K_2O (%) 1-2.5	3-4.5	
CaO (%)	4.5	4.5-6

An estimation of manurial value of faeces and urine of human beings showed that 2.10 grams N, 1.64 grams of P_2O_5 and 0.73 grams K_2O per person per day was excreted and the corresponding values for urine were 12.1, 1.8 and 2.2 per person per day.

Biogas digestion system avoids the loss of ammonia and hence slurry is richer in nitrogen content than solid organic manures produced aerobically. However, ammoniacal nitrogen is lost if the spent-slurry is sundried. Therefore, either slurry could directly be used for land application without drying which would provide both plant nutrients and water or it could be used for composting with either solid crop residues, farm and city organic wastes or already humified compsot for maturity before transfer to fields. During composting, it could be mixed with phosphatic fertilizers to reduce ammoniacal losses.*

The organic acids present in slurry help in greater availability of phosphate and potash, to crop plants. About 50 per cent of the total phosphorus content in slurry is in available form.

Uses

The composition of spent slurry from nightsoil biogas plants is given in Table 2.

Table 2: Composition of spent slurry from nightsoil biogas plant.

Item	Percent on dry weight basis
Nitron	3.0 - 5.0
P_2O_5	2.5 - 4.4
K_2O	0.7 - 1.9

It can be used either after dilution with water for manuring of fodder and cereal crops or directly applied to land and mixed. It is also used for manuring of fish ponds.

Improvement in Method Needed:

Although the commonly used method of drying of spent-slurry on simple sand beds helps in the elimination of pathogens to some extent, the process leads to loss of ammoniacal and nitrate nitrogen through volatilization, denitrification and leaching. There is a need to improve the method of slurry treatment and to find out the best form for its application to avoid losses of nutrients and harness the maximum benefit of the product.

The spent slurry can be used for hastening the composting of refuse and farm wastes. Thus the composting period and losses are reduced. As soon as the C/N ratio of compost-spent slurry is reached around 20:1, its application to land is recommended because mineralization of plant nutrient starts at this range and heterotrophic activity is supported by chemoauto-trophic activity.

During the process of rapid composting (aerobic in nature), the temperature in the compost pits or heaps rises above 60°C up to 65°C or more which causes death of almost all kinds of pathogens in a short period of a few hours to days. This also helps in increasing the quantity of manure and thus allowing recycling of more quantity of organic materials in soils.

Public Health Aspects

With regard to public health aspects during handling of spent slurry, divergent views have been expressed. Plate counts for micro-organisms of the manures and human excreta samples showed the presence in highest number of bacteria (38×10^7) in nightsoil. Some were pathogenic while some were non-pathogenic and normal commensals of gastro-intestinal tract (Table 3. **Next page**).

It has, however, been demonstrated that pathogenic enteric bacteria are effectively killed if the digestion time is at least 14 days at a temperature of 35°C. It also results in the dieoff of enteric viruses upto 22%. NEERI has reported 66 to 90% removal of ascaris and hookworm but spent slurry still contains viable helminth eggs. Nevertheless, there is hardly any other better and cost-effective method of treating human excreta that can reduce the burden

(See Table 3 on next page.)

* Even if rock phosphate is added, the organic acids in the slurry will solubilise it It may also be noted in this connection that phosphate solubilising culture is available not only from the USSR but also from the Microbiology of IARI, now head by Dr Gaur, the author of this paper Ed.

Table 3 : Organisms isolated from farm manures and pre-digested nightsoil

Sample	Group		
	Bacteria	Fungi	Others
Nightsoil	Escherichia coli Proteus vulgaris Citrobacter Aerobacter aerogenes Pseudomonas aeroginosa Staphylococcus aureus Salmonella Paratyphi	Rhizopus Penicillium Aspergillus	Ascaris lubricoides (eggs)
Farm manures (poultry and cattle dung)	Escherichia coli Citrobacter Aerobacter aerogenes Pseudomonas Bacillus	Rhizopus Penicillium Aspergillus Mucor Pilobolus	Actinomycetes

of pathogen, than anaerobic digestion. However, there is further scope to reduce the pathogens by composting the slurry with solid compostable materials.

Response of Crops

In an experiment conducted at Central Luzon State University, the Philippines, the highest yield of string beans was obtained when the crop was manured with nightsoil and the yield was further increased when the full dose of fertilizer was added. However the difference was not much (Table 4).

Table 4 : Yield of string bean when treated with organic manures and fertilizers

Treatment	Yield of string bean in Kg in 3 x 5 m. area plot		
	Compost	Nightsoil	Pigdung
5 t/ha manure	2.37	3.13	1.93
5 t/ha manure + 60N+80(P_2O_5) + 100 (K_2O)	3.95	4.33	4.09
5 t/ha manure + 30+40+50	3.63	3.77	3.44
10 t/ha manure	2.79	3.39	4.70

Treatment	Yield of string bean in Kg in 3 x 5 m. area plot		
	Compost	Nightsoil	Pigdung
10 t/ha manure + 60+80+100	3.65	3.84	3.53
10 t/ha manure + 30+40+50	2.77	3.86	3.46

Field Experiments conducted in China showed that use of spent slurry from anerobic digestion of human waste, pig waste and rice straw, had increased the yield of maize by 28%, rice by 10%, cotton by 24.7% and winter wheat by 12.4%.

Systematic experimentations on this aspect are yet to be carried out in India.

R & D Programme

For efficient recyclying of human wastes as manure, R &D efforts are needed in the following areas:

a) On survival of pathogens and remedial measures.

b) For linking slurry treatment with composting to obtaining organo-mineral-biofertilizer for efficient recycling of night soil.

c) Mechanical devices for collection of human waste and disposal of spent slurry.

d) Field trials on the use of different forms of spent slurry as manure.

e) Effect of spent slurry on physico-chemical and microbiological properties of soils.

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BIOGAS PLANT EFFLUENT HANDLING AND UTILISATION

Anil Dbussa

Abstract

This paper presents an overview of the methods presently in vogue for the handling of slurry; its diverse uses as a supplement to and replacement for farmyard manure and chemical fertilizer; as an additive to Livestock feed and the economic advantage to be derived from such usage.

-Ed.

Introduction

Research and Development in the field of biogas technology has been largely confined to the areas of biogas generation system. Little attention has been paid to optimising the use of effluent inspite of the fact that a plant is economically non-viable unless the benefits to be derived from effluent use have been computed. It is also recognised that the major part of nitrogen fed into the digester is conserved during the digestion process.

The composition of the slurry obtained from biogas plants depends upon the composition of raw materials fed into the digesters. Normally 30-50% of the organic matter fed in is decomposed in the biogas plants. Therefore, the slurry contains about 50-70% of the organic matter fed to the digester. This organic matter is not further putrefiable. Hence this reduces the problems of smell and insect development.

The constituent that is most important from the point of view of soil nutrient is also conserved by anaerobic fermentation. Practically all the nitrogen present in the raw material in organic or ammoniac nitrogen forms, is retained in the digested slurry. Results of a typical experiment on bench scale biogas plants using cattle dung as the raw material are given in Table I, which show that nearly 99% of the total nitrogen content is retained in the effluent slurry. These results also show that 17% of the total original nitrogen is available in ammonia form after digestion as against only 5.5% in the input material.[2] This however, depends upon the total nitrogen in the material i.e. the more the nitrogen content, the higher is the ammonia fraction after digestion. In case of anaerobic digestion of rice straw the ammonia concentration in the effluent has been reported to be only 8-10%.

Improper treatment of biogas plant effluent, however, may result in 10-30% loss of the total nitrogen content. Therefore, for better nitrogen economy, it implies that the higher the nitrogen content of feed materials the greater is the need of proper storage and treatment of effluent.

Effluent Treatment

The Biogas Plant effluent is mostly used as manure but it can also be used as feed for cattle and fish etc. The effluent however, has to be treated one way or the other before putting it to any use. Following are a few ways of treating the effluent.

1. Sun drying

2. Compost making

3. Filtration

4. Solid separation by centrifuge.

Sun Drying

Sun drying is practised in a large number of cases despite the fact that almost all the nitrogen present in the ammonia form gets volatilized if exposed to sun. Since the slurry coming out of the Biogas Plants has over 90% moisture, and application of liquid manure is not always feasible, it may have to be dried in sun. However, if the purpose of drying is ;only storage of slurry which can rarely be used continuously, then, in order to minimize the loss of ammonia nitrogen, it should be stored in deep lagoons or tanks that present a minimum of surface area for ammonia volatilization.

Compost Making

Compost making is the most widely practiced and recommended way of slurry treatment. It is covered with farm wastes and other household wastes. This protects it from exposure to sun and the presence of slurry aids in quicker composting of other wastes. The net result is conservation of nitrogen, faster drying of slurry and recycling of other organic wastes to land.

Filtration

Problem of storage of slurry is often encountered for large scale operations. As has been stated earlier the Biogas Plant effluents contain over 90% moisture. Nitrogen loss as a result of sun drying can be prevented if the moisture, is reduced by filtration. Since the materials to be handled by a filtering device would be too large and the material usually is fibrous, the filtration surface area required would also be too large. This is one constraint and it makes the system too expensive.

Filtration by employing sand, stones and leaf has been tried at few places but it's practicability is yet to be established.

Centrifugation

If the solid separation for high nitrogen content materials is required to be done, the sun drying and also filtration- which is a slow process-can not be employed, nitrogen rich biogas plant effluent can be used for supplementing cattle feed if the moisture is removed without losing its nutritive value. Centrifuge can be employed for solid separation in such cases.

Utilization of Biogas Plant Effluent

The biogas plant effluent is commonly identified to be of use only as manure which undoubtedly is the major use but it can also be used as feed for livestock fairly effectively.[3] While the mineral fertilizers are effective inputs for increasing immediate crop production, the organic manure plays a very significant role in improving the soil and also for replacing a part of the highly energy-intensive chemical fertilizer.[4] Following are the outcomes of a few experiments conducted on the application of biogas plant effluent for the production of various crops and for rearing livestocks (pigs etc.).

Comparison of effect of Biogas Plant Effluent and Farm Yard Manure

Fixed quantities of effluent and FYM were applied for cultivation of different crops for comparing the effect of these manures. The result are given in Table

II. Though the effluent application gave higher output in case of all the crops the difference in case of wheat and cotton was maximum.

Use of Biogas Plant Effluent for Cucumber Production.

Varying quantities of biogas plant effluent and the recommended quantities of NPK fertilizer were applied on a fixed area for comparing their effect on the yield of cucumber. It is observed that the total yield per plot is more in case of 15 ton/ha slurry application than for the recommended quantity of fertilizers. (refer Table III).

Use of Biogas Effluent with or without Fertilizer for Tomato Production

Varying quantities of effluent with and without fertilizer were applied for tomato cultivation to compare their effect on yield vis-a-vis yield by application of only recommended quantity of fertilizer Yield for all levels of slurry application were much less than the control.

When applied with half the recommended quantity of fertilizer gave better yields but still less than that obtained from application of full dose of fertilizer. Yields are given in table IV.

Effection on Biogas Effluent Utilization on the Yield of Mungbean

The table V gives yields of mungbean obtained from application of various levels of effluent alone and with half the recommended quantity of NPK. The comparison of these yields with that obtained from the application of full dose of NPK shows that the effect of low level of effluent application is insignificant 20 ton/ha slurry with or without NPK has given almost same yield in both cases. It may be concluded that the leguminous crops don't respond well to the application of manures.

Use of Biogas Effluent for Sunflower Cultivation

In case of sunflower, the use of biogas slurry alone or with 60 kg/ha Nitrogen gave yields lower than the control (120 kg/ha applications). However, 5 ton/ha slurry application gave 27% higher yields than the unfertilized plot which indicated the potential of biogas plant effluent as organic manure.

Utilization of Biogas Plant Effluent as a Component for Livestock ration

Biogas Plant effluent is commonly used as manure therefore its use as livestock ration has not been studied in depth. Following are the results of a few experiments on the use of effluent to supplement the ration for pigs, goats and chicken with a view to reduce the cost of livestock ration.

For goats, even upto 30% replacement of standard ration gave slight increase in the average daily weight gain compared to standard ration.

For pigs, the average daily weight gain was a little less than control but the cost of weight gain was lower for upto 20% slurry use.

For broilers, upto 30% sludge use did not affect significantly the weight gain and the feed effect. But for layers even 0.5% replacement of the standard ration by sludge was not tolerable: it resulted in poor growth.

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Table - I : Distribution of Nitrogen in Biogas Generation Process

	Total Kjeldahl Nitrogen (TKN) (GM)	Ammonia Nitrogen (GM)	Organic Nitrogen (GM)
Nitrogen Input			
In 1.5 kg fresh dung	3.805	0.13	3.575
In 500 ml innoculum	0.798	0.126	3.672
	4.603	0.256	4.347
Nitrogen recovered			
In gasses evolved	0.005	0.005	-
In digested slurry	4.536	0.797	3.739
Total recovered	4.541	0.802	3.739
Percent of TKN	(98.7)	(17.4)	(81.2)
Nitrogen recovered after drying	3.731	0.028	3.783
Percent in TKN	(81.1)	(0.006)	(80.4)

Source: As given in Reference 2 above)

Table - II : Comparison of effect of Effluent and FYM

Crops	Yields kg/ plot Digester effluent	FYM	Kg.	Increase %
Rice	636.4	597.5	38.0	6.5

Maize	555.9	510.4	45.5	8.9
Wheat	450	390.5	59.5	15.2
Cotton	154.5	133.5	21.5	15.7

Source: As given in Reference 2 above.

Table - III: Comparative Yields of Cucumber for Varying Quantities of Effluent vis-a-vis Fertilizer

Treatment	Average yield per plot (Kg)
Control A (No manure of fertilizer)	3.70
Control B (recommended quantity of NPK)	6.78
5 t/ha slurry	3.2
10 t/ha slurry	4.57
15 t/ha slurry	7.36
20 t/ha slurry	6.2

(Source: As given in Reference 4 above)

Table - IV : Effect of Slurry Application on Production

Treatment	Yields t/ha	% increase control
Control	26.12	
Fertilizer aa 90-120-60 kg NPK	61.02	133.61
5 t/ha slurry	34.34	31.47
10 t/ha slurry	37.69	44.29
15 t/ha slurry	40.53	55.17
20 t/ha slurry	42.74	63.63
5 t/ha slurry 45-60-30 NPK	47.33	81.20
10 t/ha slurry + 45-60-30 NPK	47.53	81.97
15 t/ha slurry + 45-60-30 NPK	49.12	88.06
20 t/ha slurry + 45-60-30 NPK	54.56	108.88

(Source :As given in Reference 4 above)

Table -V : Effect of Biogas Slurry with and without mineral fertilizer on Mungbean production

Treatment	Computed Yield kg/ha	% increase over control
Control	764.77	--
NPK at 30-60-0	921.50	22.25
5 t/ha slurry	756.75	0.25
10 t/ha slurry	780.38	3.38
15 t/ha slurry	774.38	2.60
20 t/ha slurry	875.25	15.95
5 t/ha slurry NP 15-30	796.12	5.46
10 t/ha slurry NP 15-30	820.50	8.70
15 t/ha slurry NP 15-30	821.25	8.80
20 t/ha slurry NP 15-30	869.25	15.14

(Source: Reference 4 above)

Table -VI : Effect of Biogas Slurry with and without mineral fertilizer.

Upon production of Sunflower

Treatment	Computed yield kg/ha
Control	1773.33
120 kg/ha N	3233.33
5 t/ha slurry	2426.67
10 t/ha slurry	2206.67
15 t/ha slurry	2573.33
5 t/ha 60 N	2706.67
10 t/ha 60 N	2226.57
15 t/ha 60 N	2646.67

(Source: Reference 4 above)

खाद एवं ईंधन का श्रोत गोबर गैस संयन्त्र

-मा ह.राका *

हमारे देश का किसान यह भली प्रकार जानता है कि गोबर की इस अमूल्य खाद की सहायता से भूमि को उपजाऊ बनाकर फसलो की भरपूर एव लगातार पैदावार ली जा सकती है। लेकिन उसके पास ईंधन का अन्य कोई सस्ता एव सुलभ साधन उपलब्ध न होने से अपने पशुओं से प्राप्त गोबर का उपयोग कण्डे बनाकर ईंधन के रूप मे कर रहा है। इस कारण फसलो को भूमि से जो आवश्यक तत्व मिलने चाहिये वह नही मिलने से एव लगातार फसल लेते रहने से भूमि की उपजाऊ शक्ति कम होती जा रही है। ऐसी स्थिति मे भूमि को उत्तम खाद एव जलाने को सस्ता ईंधन मिले इसके लिये वैज्ञानिको ने हमे एक साधारण यत्र दिया है। जिसे गोबर गैस सयत्र कहते हैं। जिसकी सहायता से गोबर द्वारा गैस के रूप मे ईंधन एव उत्तम खाद प्राप्त की जा सकती है। इस सयत्र मे गोबर के साथ साथ मानव के मलमूत्र का भी उपयोग कर सकते हैं। सयत्र मे उपचारित गोबर, मल मूत्र आदि से ईंधन के रूप मे उपयोगी ज्वलनशील गैस प्राप्त करने के बाद भी जो हिस्सा स्लेरी के रूप मे निकलता है, उसमे गोबर मे पाये जाने वाले उत्तम एव पोषक तत्व सुरक्षित ही नही रहते हैं वरन् बहुत ही गुणयुक्त खाद का काम देते हैं। साथ ही गोबर एव मल मूत्र जो इधर-उधर बिखरा पडा रहता है उससे होने वाली गन्दगी मच्छर एव प्रदूषण से भी मुक्ति मिलती है।

एक छोटा-सा किसान जिसके पास कुछ जमीन एव चार-पाच पशु हो वह भी गोबर गैस सयत्र बनवा सकता है। सयत्र 60 घनफीट से लेकर 5000 घनफीट तक की क्षमता के बन सकते हैं। 60 घनफीट वाले सयत्र के लिये प्रतिदिन 40/45 किलो ताजा गोबर चाहिये जिससे प्राप्त गैस 4/5 व्यक्तियों के भोजन को बनाने के लिये पर्याप्त होगी। एक किलो गोबर से 1 3 घनफीट गैस और प्रति व्यक्ति मलमूत्र से 1 0 घनफीट गैस रोजाना प्राप्त होती है। भोजन बनाने मे प्रतिदिन प्रति व्यक्ति 12 घन फीट गैस उपयोग मे आती है। आमतौर पर एक भेंस से 14 किलो, गाय से 10 किलो और एक बछडे से 4 किलो गोबर रोजाना प्राप्त होता है। सयत्र से गोबर के साथ साथ मानव का मलमूत्र भी जोडना चाहिये। क्योकि मानव के मलमूत्र से 3 0 से 5 0 प्रतिशत तक नत्रजन व 2 5 से 4 4 प्रतिशत तक स्फुर होता है। जबकि गोबर मे 1 8 नत्रजन व 1 0 स्फुर रहता है। इसलिये केवल गोबर से प्राप्त सलेरी में नत्रजन व स्फुर की मात्रा मानव के मलमूत्र के साथ जुडी सयत्र से प्राप्त स्लरी के मुकाबे कम रहता है। अत गोबर गैस सयत्र के साथ पाखाना जोडना ज्यादा लाभप्रद होगा।

भारतीय कृषि अनुसधान के भूतपूर्व डायरेक्टर जनरल डा स्वामीनाथन का अनुमान है कि 2000 ईस्वी तक हमें प्रति वर्ष 46 0 लाख टन नत्रजन, 39 40 लाख टन स्फुर की आवश्यकता होगी। लेकिन अभी जितनी क्षमता रासायनिक खाद बनाने की है उस हिसाब से हमे 14 6 लाख टन नत्रजन एव 5 0 लाख टन स्फुर बना सकेगे। अत उन्होने जैविक खाद के उपयोग की सिफारिश की है। यदि समस्त पशुओ के गोबर एव मानव के मलमूत्र का अधिक उपयोग किया जाये तो एक वर्ष में ही आवश्यकता से अधि तत्व प्राप्त हो जायेंगे, क्योकि एक मनुष्य के मलमूत्र से करीब 5 किलो नत्रजन व एक पशु से प्राप्त गोबर से करीब 10 किलो नत्रजन मिलता है। यदि हम 55 करोड मनुष्यो की व 22 करोड पशुओ की आबादी माने तो हमे करीब 47 5 लाख टन नत्रजन प्राप्त हो सकता है। साथ ही उससे ईंधन की मात्रा एव उसका मूल्य निम्नानुसार होगा -

अ	पशुओ से प्राप्त गोबर करीब	करोड टन
ब	"अ" से प्राप्त गैस	करोड घनफीट
स	मनुष्यो की आबादी करीब	55 करोड
द	मनुष्यो से प्राप्त मलमूत्र से गैस	55 करोड घनफीट
क	कुल गैस प्राप्त "अ" "स"	1745 करोड घनफीट
ख	कोयला बराबर	92 करोड टन
ग	पैट्रोल बराबर	7 5 करोड गैलन

गोबर गैस धुयें से रहित होने के कारण बर्तन, कपडे आदि साफ सुथरे रहेंगे— साथ ही महिलाओ के स्वास्थ्य और आखो की रक्षा होगी। समय और श्रम की भी काफी बचत होगी। सयत्र मे गोबर के समीरीकरण की क्रिया पूर्ण हो जाने से प्राप्त खाद दुर्गन्ध रहित होने से मक्खिया, मच्छर आदि पैदा नही होते और वातावरण स्वच्छ रहता है।

इन्दौर-खण्डवा रोड पर स्थित कस्तूरबाग्राम मे 2500 घनफीट की क्षमता वाला एक गोबर गैस सयत्र है। जो मध्यप्रदेश मे सबसे बडा है। इसमे छोटे-बडे 175 पशुओ से प्राप्त गोबर को प्रतिदिन उपयोग मे लिया जा रहा है। यह सयत्र पिछले सात वर्षों से लगातार बिना एक दिन भी बद हुये सफलता पूर्वक कार्य कर रहा है। इससे प्राप्त गैस द्वारा तीस परिवारो के करीब 150 व्यक्तियो का भोजन प्रतिदिन बनाया जाता है। और प्रतिवर्ष खेती के लिये 300 टन याने 600 गाडी कम्पोस्ट खाद भी प्राप्त होता है।

इन्दौर जिले मे 1974-75 मे 62 व 1975-76 मे 102 गोबर गैस सयन्त्र बन चुके हैं।

सयन्त्र के निर्माण के सम्बन्ध मे कुछ बाते ध्यान मे रखना जरूरी होगा। सयन्त्र ऊचे स्थान पर हो। जहा बरसात का पानी इकट्ठा न होने पावे। एव खुले स्थान पर बनाना चाहिये। जिससे पर्याप्त मात्रा मे वर्ष बर धूप मिलती रहे। ताकि समीरीकरण की क्रिया तेजी से हो। ठण्ड की अवस्था में और खासकर शीत ऋतु में समीरीकरण से धीरे-धीरे गैस कम बनती है साथ ही रसोई घर के समीप ही बनावे ताकि गैस का पर्याप्त दबाव चूल्हे को मिलता रहे व पाइप लाइन का खर्च भी कम आवे। इसमे घोल बनाने के लिये पानी की काफी आवश्यकता होती है। अत पानी की समुचित व्यवस्था भी समीप होनी चाहिये। पानी के पीने के कुए सेकम से कम 50 फीट दूरी पर हो। सयन्त्र के पास थोडी जगह की और आवश्यकता होगी। जिसमे गड्ढे खोदकर सयत्र से निकलने वाली सेलरी खाद को एकत्रित कर सके। पशुघर की निकटता का भी ध्यान रखना जरूरी होगा ताकि गोबर आसानी से सयत्र तक लाया जा सके।

सयन्त्र से प्राप्त खाद पूरी तरह से पची हुई होने से सिचाई के पानी के साथ स्प्रिकलर द्वारा सीधे खेत मे पहुचाई जा सकती है। ताजे मिश्रण का उपयोग ज्यादा लाभप्रद होता है। क्योकि उसमे नत्रजन की मात्रा कुछ अधिक मिलती है। व पौधो को नत्रजन रासायनिक खाद के समान शीघ्रता से प्राप्त होती है। साथ ही साथ ताजा होने की स्थिति मे मिट्टी मे आसानी से घुल मिल जाती है। यदि मिश्रण का उपयोग सीधे नही किया जावे तो इस सेलरी की सहायता से फार्म के अन्य पदार्थ घास-फूस-कूडा-कचरा सडाकर कम्पोस्ट बनाया जा सकता है। इन सब बेकार वस्तुओं को एक गड्डे में डालकर एक सतह बना दी जाती है। जिसे ऊपर से निकली सेलरी को फैलने दिया जाता है। इसके ऊपर फिर बेकार घास-फूस-कूडा कचरा और फिर सेलरी। इस प्रकार की प्रक्रिया को जब तक दोहराया जाता है, जब तक गड्ढा भर न जाये। इस प्रकार तैयार किया हुआ कम्पोस्ट तीन माह मे ही तैयार हो जाता है। जबकि गोबर से सीधे कम्पोस्ट बनाने मेदुगने से बी ज्यादा समय लगता है। गैस सयत्र से प्राप्त खाद की मात्रा सीधे तैयार किये गये खाद के बजाय 43 प्रतिशत अधिक होती है। उदाहरण के लिये यदि गोबर से सीधे सात गाडी खाद मिलता है तो सयत्र के माध्यम से 10 गाडी खाद साथ ही 18 7 लाख किलो केलोरीज प्रभावी उक्ष्मा प्राप्त होती है। यदि सेलरी की सहायता से अन्य कूडे-कचडे को सडाकर कम्पोस्ट बनावे तो करीब 15 से 20 गाडी खाद प्राप्त हो सकता है।

गोबर से सीधे ही तैयार किये गये कम्पोस्ट की बजाय गसेबा गैस सयन्त्र के माध्यम से प्राप्त खाद मे चार गुना ज्यादा नत्रजन, 5 गुना ज्यादा स्फुर और दो गुना ज्यादा पोटास की मात्रा रहती है। यौन तयत्र से प्राप्त स्लरी खाद मे 1 8 प्रतिशत नत्रजन, एक प्रतिशत स्फुर और 0 8 प्रतिशत पोटाश है। इसके अतिरिक्त अन्य आवश्यक तत्व जैसे केल्शिम, मेग्नेशियम, गधक, लोहा, जस्ता, ताबा आदि रहता है। इस स्लरी मे नत्रजन, अमोनियम के रूप मे रहता है। जो फसल के लिये तुरन्त लाभकारी होता है। इस तर एक टन याने दो गाडी खाद मे 18 किलो नत्रजन, 10 किलो स्फुर और 8 किलो पोटाश मिलता है। इसका अर्थ यह हुआ कि एक टन खाद मे जितने तत्व हैं वह 40 किलो यूरिया, 63 किलो सुपर

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फास्फेट और 14 किलो पोटाश के तत्व के बराबर हुआ। यदि हम इसका गणित लगावें तो एक टन खाद की कीमत रुपये 40 00 प्रति गाडी के हिसाब से रुपये 800 00। होती है। तो उतने ही तत्व के रासायनिक खाद की कीमत रुपये 130 00% होती है। अर्थात सयत्र से प्राप्त खाद की कीमत रासायनिक खाद की उपेक्षा बहुत ही कम है एव साथ ही साथ अन्य तत्व भी मिलते हैं। जो पौधों को बढने और पनपने के लिये नितान्त आवश्यक है। तथा विपुल मात्रा में हमे प्राप्त होता है। जो मिट्टी के लिये बहुत ही मूल्यवान है। यह सब रासायनिक खाद के उपयोग से प्राप्त नहीं होते है। क्योंकि फैक्ट्रीयों में निर्मित नत्रजन भूमि के ह्यूमन का आक्सीकरण कर देता है।

विश्वभर मे यह अनुभव किया गया है कि ह्यूमन को भारी मात्रा मे दिये बिना फसल मे स्थायी उत्पादन वृद्धि एव हरितक्राति असभव है। भले ही एन पी के रासायनिक खाद भारी मात्रा में दिया जाता रहे यह प्रकृति का नियम है कि जो कुछ भूमि से प्राप्त किया जावे उसे किसी न किसी रूप मे भूमि को वापस किया जाना चाहिये। इस बेकार कूडे, कचरे, घास, फूस, पशुओ एव मनुष्यो से प्राप्त मलमूत्र, गोबर आदि को गोबर गैस सयन्त्र के माध्यम से सेन्द्रिय खाद के रूप मे भूमि को लौटाया जा सकता है। इस नियम पर गांधीजी ने भी काफी जोर दिया था। और गाधीजी के विचारो पर आधारित कुछ सस्थायों इस दिशा में खेती का कार्य सफलतापूर्वक कर रही हैं।

डा स्वामीनाथन ने इस सिद्धान्त को प्रतिपादित करते हुये कहा कि मेरी आस्था बनी है कि गाधी विचार पर आधारित कृषि पद्धति ही ऐसी पद्धति है जिससे हमारी विशाल आबादी को पोषित किया जा सकता है। गाधी खेती मे प्राकृतिक पुर्नपूर्ति का सिद्धान्त निहित है। इसमे भूमि की स्थानीय उर्वरा शक्ति की अभिवृद्धि करने का सिद्धान्त है। उसमे अभिशोषण को कोई स्थान नही है। सतत अभिवृद्धि करना है सरक्षण करना है, निर्माण करना है।"

पशुओं के गोबर से सीधे तैयार की गई खाद की तुलना मे सयत्र से प्राप्त खाद देने से फसलो मे 25 से 37 प्रतिशत तक अधिक पैदावार होते देखी गई है। और आलू की पैदावार मे तो बहुत ही वृद्धि पाई गई है। सयन्त्र की खाद का मिट्टी मे बेक्टीरिया की सख्या काफी बढती है। इस खाद के कण काफी बारीक होने से मिट्टी मे आसानी से घुस जाते हैं। इससे मिट्टी की भौतिक दशा तो सुधरती ही है वरन साल दर साल मिट्टी की बुनियादी उत्पादन शक्ति मे बी वृद्धि होती जाती है। मिट्टी हल्की व भुरभुरी होने से उसकी सरलता से गहरी जुताई की जा सकती है। जिससे समय की बचत होती है। भूमि की सतह बरसात के पानी के भार से कडी होने से बचती हैं। तथा भूमि का कटाव भी कम होता है व भारी यन्त्र का खेत मे उपयोग करने से भी भूमि की उत्पादक शक्ति मे कोई कमी का अहसास नहीं होता। भूमि की जल शक्ति भी बढती है। इससे फसलो को उगने और पनपने मे काफी सहायता मिलती है। जिन फसलों मे सयन्त्र की खाद दी गई है वे फसले उस फसल की तुलना मे जिसमे दूसरी खाद दी गई है अधिक सूखा बर्दास्त करने की क्षमता रहती है। दूसरी भूमि की अपेक्षा सप्रति जल के कारण अधिक उपज दे सकती है, उसी प्रकार तेज वर्षा मे भी पौधों के खाद्य पदार्थों को बह जाने से रोकने मे सहायक होती है, अर्थात् कम वर्षा और अधिक वर्षा दोनो ही स्थितियो मे फसलो को सम्हाल लेती है। मिट्टी मे ह्यूमत की मात्रा भी काफी बढ जाती है। जो मिट्टी को खुला रखती हैं, सिमटने नही देती। उसे हवादार बनाये रखती है। साथ ही मिट्टी को इस योग्य बनाती है कि उतने ज्यादा समय तक नमी बनी रहे और रिस रिस कर पानी निकलने तथा वाष्पीकरण से नुकसान नही हो, इस खाद से तैयार किये गये बीजो में उत्पादन शक्ति अधिक होती है। और यदि ये बीज सामान्य भूमि मे भी बोये जावे तो फसल अच्छी उगती हैं। यह खाद अच्छी तरह पकी हुई होने से इसमें अवाच्छित घास के बीज नष्ट हो जाते हैं। जिससे फसलो मे घासपात कम उगने से निदाई खर्च मे भी बचत होगी तथा डोराई की भी कम जरूरत होगी। इस खाद से अन्य जैसे फसल, सब्जिया, फल आदि उत्तम, स्वादिष्ट एव स्वास्थ्यवर्धक विटामिन और प्रोटीनयुक्त मवेशियों के लिए उपजाया हुआ चारा दाना भी पशुओ को स्वस्थ्य रखता है। व उनसे प्राप्त दूध भी आरोग्य वर्धक होता है। इन पशुओ की खाद का गुणधर्म भी प्रतिवर्ष क्रमश उत्तम होता रहता है।

इस खाद के प्रभाव से फसले एव पौधे स्वस्थ्य होते हैं तथा उनमे बीमारी अवरोधक एव कीट आक्रमणो का सामना करने की शक्ति बढती है। इस कारण इन पर कीटाणुओ का प्रकोप बहुत कम होने से विषैली रासायनिक औषधियो के प्रयोग की आवश्यकता नहीं के बराबर होगी लेकिन आज जैविक खाद का उपयोग बहुत कम होने के कारण पौधो मे बीमारी अवरोधक तत्व घटने से विषैली दवाईयो का उपयोग काफी मात्रा मे बढता ही जा रहा है। और इससे प्रतिकूल प्रभाव से सम्बन्धित चेतावनी देते हुए स्टाकहोम (इगलैंड) विश्वविद्यालय के प्रोफेसर लार्स एहरेनवर्गर ने माह जनवरी 1976 में आध्र प्रदेश के वाल्टर शहर मे सम्पन्न हुये इण्डियन साइन्स कान्फ्रेस के अधिवेशन मे बताया कि अध्ययन से पता चला है कि भारत मे मनुष्यो एव पशुओ की खाद्य सामग्री, सब्जिया, मछलिया, अण्डो मे व यहा तक कि लोगो के खून के नमूनो मे भी फसलो पर उपयोग की गई जहरीली दवाईयो का असर पाया गया है। अत नाशक दवाईयो का उपयोग बहुत ही कम से कम उपयोग हो और यह तभी सभव होगा जबकि सयन्त्रो के माध्यम से प्राप्त खाद का ज्यादा से ज्यादा उपयोग हो। क्योकि जैविक खाद मे ही बीमारी रोकने की क्षमता है।

घरेलू खाद व उत्तम जैविक खाद की समस्या के समाधान तथा फसल मे स्थायी उत्पादन वृद्धि एव हरित क्राति की सफलता मे गोबर गैस सयन्त्र एक बहुत बडा योगदान प्रदान कर सकता है।

STRATEGY FOR PROMOTION AND INTEGRATION WITH OTHER DEVELOPMENT PROGRAMMES

NIGHTSOIL BASED BIOGAS PLANT STRATEGY FOR PROMOTION AND INTEGRATION WITH DEVELOPMENT PROJECTS

H.N Todankar *

Abstract

Community biogas plants should be distributed all over the village, it should not be only one plant for the entire village. Joining latrines to cattledung-based biogas plants is essential. Mass education on the multi-faceted benefits of biogas plants, establishing demonstration plants in every village, proving the relatedness of biogas plant to every kind of welfare and developmental work, coordination with the efforts of voluntary organisations etc. should be the constituents of the promotional strategy. The idea that biogas plants are suitable for only the owners of sufficient number of cattleheads should be given up. At present institutional biogas plants below 40 cu.m. do not get grants or subsidy; this should be revised. Hostels, hospitals, hotels, should be encouraged to run biogas plants. Primary health centres, municipal offices could have demonstration plants attached. Masons constructing dung-based gas plants be given training for nightsoil plants. Voluntary agencies need to be approached for orienting the village and block-level government employees to this work.

-Ed.

Introduction

Our experience for last several years shows that very large capacity nightsoil-based community biogas plants attached to a block of several latrine seats are very difficult to manage. The capacity is under-utilized because only the families in the vicinity of such plant use latrines. Families residing at a distance from the plant often resort to open defecation. In comparison, small plants distributed conveniently all over the village work more efficiently. Maintenance of family owned plants is decidedly better than community-latrine-based plants. It is advantageous to convince the owner that he stands to gain if he allows neighbouring families to use the latrine by realizing nominal maintenance costs from them.

Encouragement for joining latrine to the cowdung based biogas plant is also essential. It should form a part of generali campaign for improving social acceptance of biogas from nightsoil.

Strategy for Improving Social Acceptance

Social non-acceptance or reluctant acceptance of biogas from human waste is a major stumbling block in the promotion of nightsoil based biogas plant. Planned efforts for mass education will be necessary to remove the inhibitions. In educational programme, stress must be given on the facts that (i) biogas from nightsoil is identical with biogas from cattledung; (ii) it is harmless and is not dirty and unhygienic; (iii) nightsoil treatment in biogas plant will avoid pollution in the village and in drinking water, keep the village clean and will be conducive to health; (iv) it will produce very high quality manure; (v) dirty scavenging work will be avoided. Various mass education media and audio-visual aids should be used for the purpose.

Establishing demonstration nightsoil based biogas plants in every village, either individually or institutionally owned,

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will be very useful for convincing the villagers that these plants are harmless, beneficial and convenient. These demonstrations will accelerate the process of acceptance. It is felt that public latrines should not be used for this purpose as their maintenance is likely to be poor and might defeat the purpose.

Planning the Programme for Implementation

A planned coordination between the existing development programmes and the efforts of voluntary agencies active in the field can lead to a significant thrust to the programme for biogas from human wastes.

At present in National Biogas Development Programme (NBDP) while judging the feasibility of biogas plant, cattleheads are considered a must. This needs to be revised. Plant should be considered feasible if adequate number of latrine users are available. NABARD also may be advised accordingly. This will also solve the problem about loans, subsidy and rate of interest for nightsoil-based biogas plant financing.

At present institutional biogas plants below 40 Cu.m. capacity do not get grants or subsidy. In case of nightsoil based biogas plants, this condition of minimum capacity should be waived and financial assistance may be given irrespective of capacity.

A programme for conversion of dry latrines into sanitary latrines is in progress. Wherever feasible nightsoil based biogas plants could be incorporated in this conversion programme. Hostels, hospitals, hotels etc. should be encouraged to construct biogas plants. Primary health centres, municipalities etc. could serve as good sites for demonstration plants. Government could actively consider such sites under its control for the construction of such plants.

In municipal or corporation areas, gas plant construction should be permitted and actively encouraged. Even where sewerage system exists, if biogas plants are interposed near the building, the load on municipal sewerage will be reduced.

New township development authorities approve only aqua privy or septic tank latrines. They do not allow biogas plants. They may be advised to allow construction of nightsoil based biogas plants.

The construction know-how is at present available with many voluntary agencies. Their assistance in implementation activities will be a valuable asset.

Developing Manpower and Organizational Infrastructure

Governmental infrastructure already exists in the form of village-level and block-level staff for community development. What will be required is an orientation of this staff.Voluntary agencies at present working in the field can be useful for this prupose. Their cadre of devoted social workers can be utilized for imparting the required training.

The masons who are already trained under NBDP can be given short training particularly in the designs suitable for nightsoil-based biogas plants. This job could be entrusted to the voluntary agencies.

As already mentioned all the involved manpower must also be specifically oriented towards working for improving social acceptance.

Involvement of Zilla Parishads, municipalities township development authorities also have to be made conscious about the role which they can play in the propagation of nightsoil based gas plants.

PROMOTIONAL STRATEGY ON BIOGAS PROGRAMMES

N.B. Mazumdar — Yashwant Singh***

Abstract

The importance of biogas technology for the developing economies is wides recognized. Due to the decentralised nature of this technology, the extension activities are essential. Without a wide coverage, substantial benefits cannot be derived. Obviously, programme implementation should be aimed at removal of promotional constraints - both technical as well as socio-economic. The following areas would need immediate as well as longterm attention :

1. *Problem-based research and development activities to solve technical problems, such as optimisation of gas production under different environmental conditions, development of cheap and efficient utility systems, innovation in construction materials etc.*

2. *A detailed survery of the potentialities of using biogas technology on micro and macro levels vis-a-vis the existing energy use pattern.*

3. *Cost-benefit analysis of the system, covering the benefits such as sanitation and fertilizer, in addition to biogas.*

4. *Education to generate awareness among the masses.*

5. *Government support inthe form of subsidy and incentives, policy formulation regarding allocation of building materials such as cement, mild steel etc.*

6. *Training of construction personnel for developing skilled manpower.*

7. *Management skills, especially rural management systems which can take care of such facilities on longterm basis. Biogas plants may be constructed with subsidy or grants but they must be maintained properly on day-to-day basis for which a sense of involvement on the part of the beneficiaries is essential.*

8. *Setting up centre at block/district levels to render technical/managerial help as well as procurement of materials of construction and utility systems.*

9. *Integration with other development projects for smooth adoption of the technology.*

10. *International cooperation attempts to identify commonalities of approach, exchange of ideas and expertise deeloped for mutual benefit.*

11. *Assessing the feedback and so on.*

This is a challenged with promises of a prosperous future instead of the doomsday.

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STRATEGY FOR PROMOTION OF BIOGAS PLANTS FROM HUMAN WASTE IN RURAL AREAS

Raymond Myles*

Abstract

Human excreta can be processed in (i) family-size biogas plants either as the exclusive feed or together with animal dung; (ii) in community biogas plants fed wholly by human wastes. (iii) in family-size or community biogas plants together with agricultural wastes, crop wastes etc. The author discusses the social and institutional constraints in the promotion of nightsoil-based digester and suggests a number of measures to motivate the potential beneficiaries and training of construction and maintenance personnel. He also pinpoints the need for guidelines from authoritative bodies in science and technology on certain unresolved controversies, particularly regarding (i) the hydraulic retention time (HRT) in the digester and (ii) the treatment of digested slurry to make it safe for use as manure.

Ed.

Introduction

The need to dispose of human waste safely in rural areas has been accepted. It remains to identify feasible technologies and strategies to carry out the task. Anaerobic digesters are one of several means by which nightsoil can be treated. They offer a further advantage: in the process they provide fuel for cooking or lighting and a relatively safe manure.

Various Options for Using Human Excreta for Biogas

There are various options available for processing human waste in biogas digesters.

a) Family-size biogas plants on cent per cent human excreta

A one cu.m. plant attached to a latrine used by 25-30 persons in a joint family will be able to meet the basic lighting needs of such family.

b) Family-size animal-dung-fed plant attached to latrine

A small family with 1 or 2 heads of cattle or a few small animals e.g. goats, pigs, etc., can attach their latrine to a biogas digester. This mixed feed based digester should be able to provide fuel for cooking and lighting for the entire family and also organic manure.

c) Agricultural waste and crop residue biogas digesters connected to latrines.

These plants will be of the semi-batch type for composting under anaerobic conditions and are feasible only in rural areas. The size of digester will depend upon the average seasonal biomass available with the farmers.

d) Community biogas plants fed entirely with human excreta

Such plants can be used for cooking, lighting, pumping of drinking water, or generating electricity etc. for the community. They fall into two groups:

i) those nightsoil digesters which are connected to community

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latrine; and

ii) those digesters that are loaded with material collected from latrines.

Nightsoil digester connected with community latrines

Such plants should be possible in most villages. The gas can be used for lighting. The village panchayat could manage the latrines and digester.

Nightsoil digester fed with material from dry latrines

At present, human waste is collected from dry latrines and dumped at a pre-assigned spot. It could instead be fed into digesters.

AFPRO has designed and built all but one type of plants. Agricultural waste and crop residue fed biogas digesters connected to latrines remain to be built.

Promotion of Nightsoil Digesters and Constraints in their Widespread Usage

Based on the feedback from a few pilot study-cum-demonstration plants by AFPRO, some of the problems and constraints in promotion and acceptance of nightsoil biogas plants are given below:

i) People have reservations about using gas produced for human waste.

ii) Where rural people do not share these inhibitions, the present limitation is imposed by the very small number of people who actually use enclosed latrines rather than open spaces.

iii) Technical guidance is not available at the grass-root level to enable large-scale implementation. After installation, service for the nightsoil -fed digester is also lacking.

iv) Because of certain habits coupled with lack of proper use, education and cleaning facilities, the community latrines tend to degenerate and become very dirty. This keeps people away. This coupled with the fact that people are used to defecating in open areas tend to reduce the feed material.

v) Under field conditions the pour flush latrines as they exist require 1-3 litres of water to flush away the material. The water can be more or less controlled to the required quantity in family-size latrine attached to biogas plant, if they are properly designed and constructed. However, in community latrine attached biogas plant the quantity of water is very difficult to control which results in too much of dilution of slurry.

vi) The shortage of water is another constraint on the large-scale adoption of community nightsoilfed biogas plants.

Strategy for Promotion of Nightsoil Plant in Rural Areas.

Biogas plants linked with family latrines are becoming increasingly popular in Gujarat and Maharashtra. However, they have yet to gain acceptance in other states of India. AFPRO have constructed a few nightsoilfed biogas digesters and would like to share some thoughts for promotion of such plants in rural areas.

a) There is a wide difference of opinion with regard to HRT (Hyrdaulic Retention Time) for nightsoil plants. R&D institutes must provide definite recommendations to designers and technical service agencies about the optimal size of plant for efficient treatment of human waste.

b) Recommendations are also needed with regard to handling of digested slurry so that it is rendered safe before being used as manure.

c) Publicity and education material is required to promote any programme for popularising nightsoil plants.

d) Appropriate teaching aids are needed for all categories of persons who will promote, manage and use the plants and their effluent.

e) Technical staff needs to be trained. Such staff will include masons, supervisors, construction engineers and extension managers.

f) Potential beneficiaries need to be motivated. A start may be made by urging them to use the gas for lighting.

g) Gas from community biogas plants could be used for street lighting and for dual-fuel engines for operating pumps for drinking water.

h) The management of the digester to ensure its smooth working and the maintenance of public latrines has to be worked out thoroughly. These should be managed by committees rather than left to the whim of an individual.

i) Demonstration plants and latrines should be built in different areas and this pilot scheme carefully monitored. Such a demonstration project may provide insights which will help in the formulation of a national policy.

Conclusion:

There is immense scope for nightsoil-fed biogas plants in the rural areas of this country. One must have patience to implement such schemes and study the various socio-economic and cultural aspects connected with them.

RECOMMENDATIONS OF THE WORKSHOP

SOCIAL ASPECTS

1. Major objective of this programme should be the preservation of human dignit and protection of health. Biogas plants preserves human dignity by providing privacy and ridding the scavenger carrying other people's excreta.

2. All programmes involving nightsoil disposal through anaerobic digestion be oriented to meet the needs of the community and should form part of a larger national goal.

3. Education, training and propaganda would have to be organised to generate awareness of these social and national needs. In all these measures, benefits including health and lessening of women's drudgery (by providing fuel and fertilizer) must be emphasised apart from their economic value.

4. Identification of target groups which will act as acceptors, users and promoters is necessary. Special emphasis should be placed on women who suffer the most for (i) lack of cooking fuel and (ii) increasing loss of privacy, and who are primarily responsible for rearing a new generation.

5. Inhibiting factors, too, need to be identified. Economic status, age, fear of "dirtiness" and caste barrier were identified by the workshop. (Caste barrier is an inhibition to community biogas plants). Women's propensity to avoid being seen while entering the toilet is also an inhibitor. In this there is a paradox: those, who suffer the most from the disappearing bushes and jungles and need more privacy of the latrine, also tend to shy away from the latrines.

6. Persons dislocated from traditional carriage and cartage of nightsoil must be absorbed elsewhere so that they do not impede the adoption of nightsoil-fed biogas plants.

7. User participation in planning and implementation of biogas plants is the critical factor. On this will depend the success or failure of the programme. Women who are the main beneficiaries of the system, should be involved in the formulation and implementation of the projects as well as in the dissemination of information.

8. Voluntary agencies must be involved and enabled to play an increasing role in motivating the people to dispose of nightsoil hygienicaly as also aesthetically through biogas plants.

9. Children should be educated in the use of toilets. The benefits of toilet-linked biogas plants should be inculcated in them through literature suitable for them, with illustration which should be brought out in regional languages.

10. Women's education programme and onsite training should be organised by voluntary agencies to generate awareness and acceptability of those systems.

11. Grants by the Government of India for plants fed wholly or partially by nightsoil should be on a higher scale than for plants fed by other feed-stocks. This would be justified becuase nightsoil plants serve health objective much more.

12. School textbooks should include a chapter on sanitary toilet-linked biogas systems.

HEALTH ASPECTS

1. On site disposal systems for human waste are best suited for this country. 'Onsite' disposal through anaerobic digestion in a biogas plant is hygienically desirable and is also a very promising system.

2. While designing biogas plant for treatment of human waste, the specific parameters from health point of view have to be given primacy over all other considerations such as gas production.

3. Raw human waste should not be manually handled.

4. Undigested or semi-digested nightsoil should not be exposed to surroundings. Care must be taken to see that insects or animals do not get access to it.

5. Construction of toilets and feeding mechanism should be so devised that they are safe from health point of view and are easy to maintain hygienically and economically.

6. Pathogen survival time in the effluent slurry should be the primary concern in the design for the plant. Reports indicate that retention time in the whole system might vary from 30 days to 90 days depending on the environmental conditions on the site. The consensus in the workshop is to accept only those designs which fulfill health parameters i.e. maximum pathogen elimination.

7. Field studies are needed on pathogen survival in effluent from biogas plants.

8. In cost-benefit, the benefits for health should be included as a very important consideration apart from the economic value of biogas plants products.

REPORT OF TEHNICAL SESSION ON DESIGN, RESEARCH AND DEVELOPMENT

The most important parameter affecting anaerobic treatment of human waste are organic loading rate, solid concentration value and retention period in the digester. Secondary parameters are: use of water and rate of gas production, non-exposure of nightsoil to environment. These studies form basis of designing a nightsoil-fed biogas plant.

Selection of a design for a nightsoil biogas plant is governed by the criteria: digester efficiency for gas production, cost of construction, and public health aspects i.e. killing of enteric pathogens, viruses and parasitic eggs. These criteria were discussed at length. There was a consensus among all the participants that public health aspects should be the first requirement to be met by anaerobic digestion of nightsoil in a gas plant and subsequent treatment of effluent slurry. While designing biogas plant system there should be no compromise on the question of pathogen killing. In this connection the hydraulic retention period of nightsoil inside the anaerobic digester came up frequently for discussion. There was a difference of opinion on this aspect. The suggested in-digester retention period varied from 30 days to 70 days. It was felt that the retention period should be fixed for the worst operating conditions. Retention period of nightsoil in the entire system inside the digester and in the subsequent treatment system is more critical. Retention period inside the anaerobic digester, and the method and period of subsequent treatment of effluent slurry should be fixed on the basis of site situations. The difference between the designed retention period and the effective retention period is important. Due to phenomenon of short circuiting, the effective retention period is often less than the designed retention time. The digester should be designed to minimise the short circuiting of fresh charge.

Solid concentration in the digester was another topic of discussion. On the basis of laboratory and pilot plant studies the suggested solid concentration was 3 to 8%. The digester gets sick or tend to fail beyond 8% solid concentration. The flush volume of water per capita per use is a critical parameter for deciding solid concentration in the digester. About 2 litres of flush volume was suggested to ensure 3% solid concentration and maximum gas production. This figure led to a discussion on how for it is possible in practice to control use of flush water to a minimum. General experience is that due to the use of more than the suggested amount of flush water, the solid concentration inside the digester is much less than 3%, even below 1%. The design of latrine plan, flushing arrangement and feeding mechanism influence the water use; hence these should be a part of the system design. In designing the feeding mechanism, nightsoil should not be exposed to the surrounding at any stage, nor should manual handling be allowed. The question of filtration of fresh charge to increase solid concentration in the digestion came up during the discussions but the detailed data were not available.

To increase gas production efficiency of a nightsoil biogas plant, concept of mix feeding was introduced and discussed. Cattle dung and other soft biomas such as kitchen wastes green weeds, soft agricultural and crop wastes can be added to a nightsoil digester subject to the convenience of the site.

Different design concepts and details of some designs were presented. The designs were basically modifications of KVIC floating gasholder design and the Janta fixed-dome design to suit nightsoil as a feed material. One design which is a conversion of aqua-privy into a biogas plant was also presented and discussed.

RECOMMENDATIONS

1. Design of a nightsoil biogas system should include design of latrine pan, feeding mechanism, digester design inlet, outlet mechanism as well as subsequent treatment of effluent slurry.

2. While keeping public health aspects as the first requirement of a nightsoil biogas system, it is recommended that the benefit-cost ratio be increased by improving gas production efficiency and optimising manurial value.

3. The existing biogas plants running on nightsoil should be evaluated by competent agencies to provide feed-back to ongoing design efforts.

SLURRY TREATMENT AND ITS USE

AGRICULTURAL ASPECTS

Human waste is an important resource of plant nutrients, in quantity next to cattle waste, (3.2N 0.77 P2 05 $0.7K_2O$ 4.72). It is estimated that recycling of human waste in agriculture can help in adding of about 4.72 million tonnes of NPK to soils.

As spent slurry is rich in nitrogen, its drying leads to losses of nitrogen. Thus the ulitmate contribution of nitrogen is reduced. Drying is not a desirable method. The other aspect that needs to be examined relates to load of pathogens and enrichment of slurry with rock phosphate; super phosphate and preparation of organo-mineral-biofertizer was also emphasised.

The problems associated with transportation of slurry, its handling and utilisation was discussed and methods suitable for different situations were suggested. One method which received attention was the addition of 15% ammonia solution at the rate of 10" by weight to kill pathogens, in the spent slurry. The importance of spent slurry in terms of its residual effect on crops was also discussed.

The following recommendations emerged :-

1. An all-India Coordinated Research Project should be launched which should include all aspects of this system such as :

   a. the digestion process.

   b. designing of the system.

   c. devices & methods for disposal and utilization of spent slurry.

   d. agricultural aspects.

   e. health and pollution aspects.

   f. social and economic aspects.

   g. removal of H_2S from gas.

   Studies on survival of pathogens in the digester as well as during application of spent slurry in agricultural fields and fish ponds are particularly important.

2. Development of suitable mechanical devices to handle the effluent and thus to avoid its manual handling, should be encouraged.

3. Development of organo-mineral biofertilizer be encouraged.

4. Field trials need to be conducted on the use of different forms of spent slurry for manuring agricultural fields and fish ponds.

5. Effect of spent slurry on physico-micro-biological properties of soils should be studied in depth. (The project may include all other aspects like health and sanitation, socio-economic benefits and cost).

6. Spent slurry can be used for manuring crops after adequates dilution to bring down B.O.D. level to 500 mil. It can also be used for composting of other organic wastes.

7. The above mentioned studies need to be carried out through selected ongoing institutions in different agro-climatic areas. Some of the institutions which should be involved are NEERI, Safai Vidyalaya, AFPRO, H.P. Krish Viswa Vidyalaya, Palampur, Tamil Nadu Agricultural University Coimbatore, Punjab Agricultural University Ludhiana, Thapar Poly-technics, Patiala etc.

STRATEGIES FOR PROMOTION AND INTEGRATION WITH OTHER DEVELOPMENT PROGRAMMES

The following conclusions and recommendation emerged :-

i. There was need for exercising quality design and technical excellence.

ii. Appropriate and technologically fool-proof package should be developed. Need based package, taking care of various situations and factors (socio-economic, geographical etc.) be developed.

iii. People's participation and involvement needs to be encouraged at every step-right from planning and implementation to maintenance and evaluation. Emphasis is to be given on social aspects of the programme.

iv. There was a great need for standardization of procedures, and communication to special official sectors.

v. There should be an open mind for sharing experiences, learning and technical coopertions at various levels and even at appropriate international level.

vi. It is felt that adoption of multi-disciplinary approach in close association with allied departments, as health, sanitation, agriculture, forestry, fishing, has to be evolved for successful implementation of the programme. Such integrations will facilitate a package approach.

vii. There is a great need for creating mass awareness on the various aspects of the programme through appropriate promotional strategies for publicity with the use of print media.

The use of print and non-print material, audio visual aids and other promotional materials is necessary as the use of educational media can play a very important role.

viii. It is necessary to strengthen training programme at various levels ranging from the beneficiaries, masons, technical personnel and managers.

ix. The need for integration of the programme into the existing IRDP & NREP programmes and the national voluntary socio-economic schemes was emphasised.

x. Management skills need to be involved at various levels.

xi. Rational subsidies to be introduced and centres be opened at local level, block level and in district HQs. for training and dissemination of technology.

xii. Where gas for cooking was not in demand it could be used for lighting and farm machinery.

Assessment of feed-back and follow-up is required. Demonstration through Urja Village and Exhibition would help in this dissemination.

EPILOGUE

Shailendra Nath Ghosh

A high-ranking Western scientist - I forgot the name - once said: "Mankind may survive atom bombs but it will not survive flush toilets". He was pointing to a fundamental process of Nature - namely, the biogeochemical cycle. Man takes nutrients from the soil through the plants; man must return the nutrients to the soil in a manner which benefits the soil. If this cycle is broken, the very process that preserves natural balance and supports life on earth gets disrupted, imperilling not only man's own existence but all life on earth.

A well-known nuclear physicist of this country once said: "We in India would possibly have to go in for gobar gas plants because we do not have enough energy resources". He was only displaying his ignorance of the role of bio-geochemical cycle. Even if we had oil reserves one hundred times those of Kuwait, we would still need, in our longterm interest of existence, to return nightsoil, animal and plant wastes to the sources that gave us sustenance. If in the process of returning it, we can derive some further benefits such as fuel gas, so much the better.

Wastes recycled in a useful manner are a source of wealth. It is not that we merely forgo this wealth if we neglect to recycle any of the wastes - human, animal or plant. These untreated wastes do not remain idle: they flow to wrong places, raise garbage heaps, breed flies, choke drains, raise river beds, pollute water, breed mosquitoes, create health problems and raise mounting demands for hospital beds. Resources, actual or potential, in the wrong places, are disruptive of life-support systems. Shri Maheshwar Dayal in his Keynote address to this seminar pointed out that the pathogens from human wastes are responsible for 80 per cent of the diseases in India. Even if this single source was responsible for only half of this percentage of diseases, that would have been grave enough. Dayal's statement is corroboration of one form of disruption of the life process consequent on our failure to recycle the wastes sensibly. There are several other deleterious aspects, besides.

Coming back to the question of flush toilets, Wallace W. Wells in a chapter "Meaning, Ecology, Design, Ethics" in the book "Solar Architecture" bemoans: "Next to population, the world's number one problem is water. Half of the water used by the average family goes for flushing the John". . About flush toilets, David Del Porto went further. "The flush toilet causes problems in the following ways: it disrupts the natural water cycle by consuming large quantities of water that are not returned to the areas they came from: it pollutes the water that is used as a vehicle to transport the excreta; it pollutes the land that is needed to dispose of the sludge from septic tanks or treatment facilities; it creates large direct and hidden costs to design, construct and maintain the elaborate system that extends from pumping fresh water from the ground to monitoring the effluent from a sewage plant; it requires a large amount of energy for construction and operation. These are the major areas of impact, although there are ripple-effects into many other areas, such as the medical problems for those who drink contaminated water or the rapid depletion of a farmer's topsoil".

At the pole opposite the flush toilet-cum-sewerage system is the composting toilet, also known as "humus toilet", subserving the principle of recycling. Run properly, it minimises the spread of pathogens, prevents enormous waste of water and construction material, and yields a bonanza in the form of manure. As for cattle dung, its recycling as farmyard manure has been traditional practice on global scale. But in recent times, in a situation of growing firewood shortage, the dung is being increasingly burnt as fuel. A solution has been found in the processing of dung in an anaerobic digester, which yields methane as fuel and slurry as manure.

As a device for production of bio-energy and return of nutrients to the soil, the biogas plant is unique. Biogas plant can take nightsoil feed as well. Yet, the use of biogas plants has remained limited to a tiny fraction of the population, and the nightsoil biogas plants are still fewer. The number of nightsoil-fed biogas plants, whether on household level or community level, has remained small everywhere, with the sole exception of China.

Many participants in the workshop organised by CORT felt that this slow progress was due entirely to the social taboo against nightsoil. But if that had been the only problem, the environmental engineers would not have been divided on the issue of using nightsoil as a feedstock for biogas plants.

There is no question that deep seated social prejudices exist against the processing of nightsoil in any form. Smt. Savitri Madan and Dr. D.R. Gupta have, on the basis of their rich experiences, illustrated the stubborn nature of the problem. But it is also true that strong countervailing factors are operating now, illustrations of which were given in Dr. Amulya Chakravorty's paper. The present writer is deeply convinced that the problem of prejudice can be very effectively attacked by a new approach. An interesting experience of a consensus is worth recounting here.

A few years back, in an Inter-University seminar organised by the Department of Environmental Science of the University of Rewa (in Madhya Pradesh), it was found that the participants were in support of nightsoil fed biogas plants but there was a general attitude of pessimism about its social acceptability in near future. This impelled the present writer to make the following comments: "I find among the participants in this Seminar a large number of persons bearing surnames such as Pande and Misra. Let this Department, with its considerable strength of Faculty members and students, start within its campus a canteen fuelled by nightsoil-based biogas. When the *chapatis* and *pakoras* of this canteen are eaten by these topcaste people, news will spread to the villages like wildfire and the age old prejudices will crumble. My recommendation to the University Grants Commission will be that no recognition be given to any Department of Ecology of any College or University unless it has constructed nightsoil biogas plants and canteens fed by this gas".

The participants in the Rewa Seminar all agreed that this could be a potent way of countering the prejudices. The University authorities, the University Grants Commission, and the Governments of the States and of the Union would be advised to take this constructive approach instead of merely lamenting over people's prejudices.

I

CHOICE BETWEEN ALTERNATIVES

Point : Counter-Point

The problem facing nightsoil biogas plants is not merely the social prejudice. There are some very genuine problems which are inherent in the very use of nightsoil in aerobic digester. Technology has not yet produced operational guidelines for different climatic regions with their varying temperature regimens. There have not even been **large-scale tests** of (i) sanitary effectiveness; (ii) agricultural effectiveness; and (iii) economic effectiveness of human faeces-fed biogas plants and their products, conducted by scientific bodies, the authority of whose finding could be the basis of a consensus. As a result, different schools take different positions according to their predilections. Those who are inclined to nightsoil processing in biogas plants keep arguing that whatever the imperfections and the resulting hazards, the situation will be better than open défection. A school at the other end keeps arguing that human faeces-based effluent slurries, not quite free o from pathogens, will, by virtue of fluidity, spread the contamination wider.

The arguments of the latter school run as follows. Nightsoil's biogas potential, however great per unit of excreta, is negligible in the total because the per head output of human faeces in only one-twentieth (or even less) of the cattle's per head output of dung. This potential is insignificant in comparison with the total potential of biogas from cattle and plant wastes. This little amount of methane is not worth the risks of the faecal effluent slurry, which would pollute a greater mass than the solid excreta ever could. Sanitary disposal of excreta can be achieved by other means such as anaerobic composting of four to six months' duration or aerobic composting of four to five weeks' duration. "Composting is recycling enough, so far as nightsoil is concerned. Let us not aspire for gas from nightsoil because the faecal slurry produced in the process is far from safe".

At the bottom of all these objections is the feeling that at household or village community level, it is not possible to keep control over the quality of slurry and its subsequent products.

Let us now see how safe and sound are these alternatives-pit latrines in rural areas and sewerage system in popular cities - proposed by this school.

To take the latter (sewerage system) first.

Dimensions of the Costs of Sewerage System : The Problem of Urban Areas

This system is prohibitively costly. The idea of covering the whole of the urban area with sewerage is, therefore, foredoomed to failure. Moreover, it hurts at the very basic principle of recycling. Its wastefulness and its perils from the point of view of existence have been discussed earlier. Even in a country like the USA, many towns are seeking to avoid the sewering system. According to a study mentioned in the Proceedings of the Aspen Energy Forum (USA), 1977 the proposed sewering of the town of Groveland (Massachusetts) would require a **one-time charge of $ 3,400** (which would include the hook-up and plumbing work) in addition to annual tax increases and use-charges totalling $ 285 per year **for one** residence". It further went on to say that the town of Pepperell (Massachusetts) which had been using individual septic tank systems, was pressurized for constructing a sewer system in order to improve water quality in the area. But a study of interceptor sewers and lateral sewer lines divided by the number of houses would be unbearably high: and when the costs of in-house fixtures and plumbing and the operation and maintenance costs of the plant etc. are taken into account this would be higher still. Since that was a tiny town, the estimated cost **per home,** over a 20-30 year period, came to $ 30,000 i.e. more than Rs. 3.5 lakhs. In India's populous towns and under India's cheaper material-and-labour cost structure even if the per-family construction cost comes to only ten thousand rupees and the cumulative maintenance cost (over twenty years) comes to another ten thousand, these are bound to prove unsustainable. This is the reason why the sewer system in most cities is breaking up: and the uncovered sewers as also the storm water drainage channels are being used for open defecation. It is indeed an irony that sewerage systems, which pollute the sources of drinking water for downstream populations, are espoused as a measure for "safe" drinking water in relatively upstream regions.

If, in spite of these high costs of sewering, it has still been in vogue in cities, it is because 80-90 per cent of these costs have been paid out, in almost all countries, out of the state and federal revenues. This means, the rural populations have been made to contribute, by way of taxes, to the maintenance of city sewers.

These should give us the perspective that the waterborne excreta disposal system will have to fade away even from the urban settings and that "aerobic composting toilets" will have increasingly to come into vogue if biogas a plants fail to make headway in crowded cities. Already, aerobic composting systems have been developed for apartment buildings in which excreta are moved to large containers in the basement. Swedish and Norwegian authorities did extensive testing of these toilets and found these satisfactory in terms of sanitation. A number of states in the USA, including Washington, Maine,Massachusetts and New Hampshire, too approved of these aerobic composting toilets more than a decade back on the condition that suitable methods of disposal of graywater is developed. Composting by definition, is decomposition without putrefaction. Putrefaction makes it difficult for the soil and the plant to absorb the nutrients contained in the decomposing material. Putrefaction can be stopped by mingling animal (including human) waste with vegetational waste in the proportions ordained by Nature. As Sir Albert Howard used to say, "Animal and Vegetables must be mixed in correct proportions in their death, as in their life, processes". It is, therefore, heartening that the concept of connecting a chute to dispose of the kitchen waste into the basement composting toilet has meanwhile been developed. This will add to humus building material, prevent putrefaction and enrich the quality of the compost.

For everything there have to be safeguards and precautionary measures. Aerobic composting toilets, too, must guard against three major possibilities for contamination of the environment. To quote David Del Porto, again, (i) "the first composting chamber should be constructed with a concave, waterproof bottom so that liquids will not seep out before they have had a chance to evaporate"; (ii) "the toilet should be carefully built and screened to keep out insects which can transfer pathogens"; (iii) "the piles will need turning every week or two through an access door to keep the process from going anaerobic and to bring the cooler outsides of the pile into the middle, and the tool used for this should be kept in a way (perhaps inside each chamber) so as not to allow transfer of pathogens". Finally, the toilet must be made aesthetically satisfying. Flower vases around can possibly do this job.

Pit Latrines

Now to the pit latrine. James Cameron Scott's book "Health and Agriculture in China", based on investigations in early forties, contained a chapter "How Faecal-borne Diseases are Spread". In order to study the pathways of the eggs of the intestinal roundworm, Ascaris lumbricoides which is an index of faecal pollutions and could also be used as an index of public health problem, his team took samples of soils from the pit latrines, courtyards, living room floors from farm houses. The analyses showed that 85% of the samples from pit latrines, 60% from courtyards and 34% from living rooms were positive. The pit latrines, just across the courtyard and not far from the kitchen, were often the source of infestations. Scott's conclusion: "Apart from the insanitary nature of the pit latrine, its low efficiency for conserving nitrogen points to the need to replace it with something better".

It is true that subsequently water-seal pit-latrines came up to lessen the hazards of pathogen spread, insect breeding and odour. These are therefore, to be welcomed. But if a large number of families in the village take it up, it will be difficult to resist widespread groundwater contamination with ammonia (and pathogens). This is possibly the reason why people generally are unenthusiastic about the use of pit latrines.

Even the PRAI-type water-seal pit latrine - developed by the Planning Research and Action Institute of Uttar Pradesh - which was once regarded as quite suitable for small village communities (with an absorption pit about 3m deep and with 1m diameter) has failed to evoke much response even though Sri Ishwarbhai Patel had made a spectacular beginning by installing 1,96,000 PRAI-type latrines in the State of Gujarat.

All these experiences have led many concerned social thinkers to believe that the answer lies in "the adoption of multi-faceted waste re-use system with obvious benefits to the villagers". These benefits include: (i) cooking fuel; (ii) composted material for soil humus; (iii) algal culture; (iv) enrichment of fish ponds by purified waste water after secondary treatment of the effluent slurry. Therefore, there is likely to be a greater incentive for better upkeep of the biogas plants.

II

COMPLEXITIES OF NIGHTSOIL AS A BIOGAS PLANT FEED

It will, however be wrong to underestimate the complexities of operating biogas plants fed wholly or partly by nightsoil. Certain problems are intrinsic to the nightsoil feed. A few characteristic differences between cattle dung and human excreta have caused wide differences in their operational parameters. References to some of these differences are interspersed in the Workshop's papers. These are as follows: (1) The excreta production of an adult person is about 500 grams (it varies from person to person depending on food habits, health of the individual, age etc.) while a cow would yield dung about twenty times as much (10 kilograms) per day. A buffalo would yield even more. (2) Since the cattle dung contains much more cellulosic material which even the acid forming bacteria in the biogas digester finds it difficult to break down, the gas production from a kilogram of cattledung is only *half* as much as that from an equivalent quantity of nightsoil. (3) The nightsoil is richer in nutrients (N.P.K.) too. (4) Its pathogenic load is generally high. (5) Nightsoil, which contains carbohydrates, protein compounds and fats, is difficult to homogenise: the fats tend to float on the slurry top and tend to travel quicker to the outlet chamber without giving off enough gas or shedding their pathogens. (6) In a digester fed by both cattle dung and nightsoil, the nightsoil particles pose a special problem. These being smaller in size and lighter in weight - presumably this is the result of the human habit of eating cooked foods to cause their easy breakdown in the intestines - the slurry gets differentiated: separate layers are formed, the lightest layer tends to float on the surface, form a scum and remain outside the zone of the methanogenic bacteria's attack. (7) Nightsoil, having a very low C/N ratio, has a tendency to produce ammonia. Excess ammonia in the digester becomes toxic to methane producing bacteria, thus inhibiting the production of the very gas which is of interest to the user. (8) Nightsoil feed is in greater need of stirring for utmost possible homogenisation in a mixing tank before its entry into the inlet tank. Yet, this is the material which poses the greatest difficulty to stirring, by giving out offensive smell so long as it is kept in the pre-inlet tank exposed to the environment.

These are the reasons why the technology which is sufficient for operating cattle dung-fed biogas plants is not adequate for running plants which take nightsoil ever as a partial feed. Everything - the proportion of different feeds, the pre-inlet preparation, the calculations of in digester residence time, the utility or otherwise of a partition wall within the fermentation chamber, the distance and positional relation between the inlet point and the outlet point, the dynamic of the slurry in different stages of digestion and the possibilities of their mix-up, the remedies against excessive scum formation, the survival rate of the pathogens in the effluent slurry, the methods and duration of post-digestion treatment and the space requirements therefor - becomes a subject for critical re-examination when nightsoil is used as a feed. The CORT workshop has revealed sharp differences on almost each of these questions.

In what follows an attempt will be made to focus on these controversies and on the un-raised, yet unclear issues so that these can form the subjects for research and future discussions. An attempt will also be made to delineate the areas of consensus which emerged in the workshop.

III

CONTROVERSIES OVER SCIENCE QUESTIONS (PATHOGEN SURVIVAL, FEED MIXES, SLURRY UTILISATION)

The agreement was in recognition of biogas plant as a social need. That the biogas-cum-fertiliser plants have become a crying need for reasons of public health, for facing the deepening fuelwood crisis, for use of the digested slurry as soil fertiliser-cum-conditioner, for better cooking and relieving the women's drudgery, and for reasons of people's - more so the womenfolk's - privacy in defecation in the context of disappearing bushes and jungles was unanimously acknowledged. Biogas plant is an aid to afforestation. Unless biogas plants and solar cookers become ubiquitous, no amount of effort at afforestation can ensure the safety of the new plantings. Afforestation has to "walk on all fours" - conservation of old forests; widespread new plantings; biogas plants; and solar cookers (the last two are to prevent the growing pressures for deforestation).

Biogas plant is a measure for high agricultural productivity and also for renewable energy. It is, above all, a health measure. By killing pathogens and by contributing to tastier and more nourishing food production through manuring, it promotes health. Warnings were, of course, sounded by several participants that unless proper in-digester residence time of the faecal liquid was allowed and meticulous secondary treatment given, this very instrument of health promotion could turn into a tool for disease spread. The Ministry of Health, the Ministry of Agriculture, the Ministry of Forest and Environment, the Ministry of Social Welfare, apart from the Department of Renewable Sources of Energy should, therefore, be deeply interested in biogas programme.

However, despite the near-unanimity on the desirability of biogas plants, there were sharp differences among the participants on practically every scientific and technological question.

The following statements on the pathogen behaviour in the digester and the desired residence time would exemplify the divergences.

Dr. Shanta Satyanarayan et. al. of NEERI, in their background paper, mentioned that "at an average digester temperature of 28°C, some 67% Ascaris and 90% of hookworm eggs were destroyed during a detention period of 25 days". In contrast, Rahul Parikh of Agricultural Tools Research Centre, Bardoli said: "they (ascaris eggs) neither grow nor die at 27°C for 40 days. Parasite eggs can survive for 15-40 days at 20-30°C temperature".

Gaur and Khandelwal stated that "pathogenic enteric bacteria get killed if their actual residence time in the digester is 14 days at 35° C. The die-off rate of even the enteric viruses is 22% at this level of temperature and retention time".

H.N. Chanakya expressed that "the enteric virus can persist for 180 days at 20-30° C". Though these two statements are not exactly contradictory, these have the potential to set off two contrary trends. A biogas plant planner expecting an average of 30° C temperature may plan for 30 days (instead of 14 days at 35° C) while another person expecting the same temperature can insist on a minimum of 90 days.

Chanakya of ASTRA (Bangalore) considers residence time of 35-52 days *insufficient* for digesters fed by nightsoil, while D.R. Gupta of Thapar Polytechnic (Patiala) regards a residence time "not shorter than 14 days as sufficient" at a temperature not significantly lower than 30° C. Shri.Gupta's reason is that at this level of operation, pathogenic enteric micro-organisms, with a few exceptions, are effectively killed. His justification for this short residence time rests on two grounds. His first ground, if rephrased, would appear like this - "even at a level of operation, where 99% of pathogens are killed, there would still survive some micro-organisms of public health significance. Since we cannot in any case destroy pathogens 100 per cent, why should we not be content with an effluent slurry which has been rid of most pathogens." His second ground: the surviving micro-organisms will continue to die off because of lack of nutrients and hostile environment.

At Shri Gupta's opposite pole are AFPRO's Raymond Myles and Anil Dhussa who plead that "nightsoil must remain in the plant for at least 70 days to become free from pathogens and parasitic ova" Since public health is the overriding consideration and also because it is difficult to exercise control over millions of individual households' practices of composting etc, it is better to exercise utmost control in the digester design itself, "by fixing its hydraulic retention time for the worst operating conditions". In plain words, the residence time should be planned on the basis of the winter temperature, and therefore, the digester's volumetric capacity should be correspondingly large.

Dr. Mapuskar of Jyotsna Arogya Prabodhan (Dehu) Pune, does not favour this approach, for such a large volumetric capacity will mean heavier costs and be a deterrent to biogas plant propagation. Since an assured retention period of 40-45 days at 32-35 °C eliminates the viral, bacterial, and protozoal pathogens and since the worrisome helminth ova settle at the bottom of the digester and get enmeshed in the heavy sludge, there is no reason to extend the retention period beyond 40-45 days, he argues. His sympathies would be even for its reduction to 25-30 days provided a consciousness is generated for an assured retention period of the effluent for 25-30 days in an adjacent pit for secondary treatment.

Thus, the participant's personal predilections had the overriding role in their prescriptions. This could happen because there has been no systematic study of the behaviour of pathogens, type-wise, in different field conditions. Nobody has sought to reconcile the available data. After a finding has been obtained, none has even tried to indicate the range within which it is expected to remain valid or to work out the method of converting the reported values to different levels of temperature. Data without their source have also been creating confusion. Shri D.R. Gupta's data show a 90% die-off of helminthic ascaris within 15 days at 30 °C while, according to Dr. Mapuskar's data, the ascaris ova survive in the slurry after 30 days of anaerobic digestion at 32-35 °C and even thereafter, in the sludge. Our health research institutes had possibly no time to look into these data even though the nightsoil is credited to be the source of "80 per cent of disease" * and biogas plant its potential preventive.

Even the research done in a premier institute like NEERI has been perfunctory. Dr. Shanta Satyanaran could report the results of a series of experiments carried out by herself and by Trivedi at 37 °C. This temperature was chosen possibly because it was convenient for laboratory experiments. Hardly anybody would argue that this was a representative temperature of biogas plants in any significant areas. Since there are large variations in the digester temperature in different areas and in the same area in different seasons, it would be more helpful if NEERI and other research institutes could conduct pilot plant studies in different temperature ranges - and better still, in different areas.

On the question of the preparation of the slurry for the final use, too, there are wide differences. Dr. Gaur and Dr. Khandelwal would have no objection if the slurry could be directly applied to the soil without drying, provided it is ploughed in immediately. "Biogas digestion system avoids the loss of ammonia and hence slurry is richer in nitrogen content than solid organic manures produced aerobically. However, ammoniacal nitrogen is lost if the spent slurry is sundried. Therefore, either the ***slurry should directly be used on land without drying, which will will provide botd plant nutrients and water*** or it should be mixed up with either solid crop residues, farm and city organic wastes or already humified compost for maturity before transfer to fields. During composting, it should be mixed with phospatic fertilisers to reduce ammoniacal losses".(Italics added)

The controversy relates to the first alternative (direct use from the digester to the soil). In their clearance to such direct application, the authors evidently had the idea that the soil microbes would kill the remaining pathogens in the spent slurry. Shri Kshirsagar of NEERI, however, would call this approach extremely lax. He argues that "if labourers working on sewage farms are having a high incidence of infections from helminthic and intestinal pathogens, the workers who would be working with effluent slurries, too, would certainly be vulnerable. Lack of data in this respect cannot be construed as a positive

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* Reference: Shri Maheshwar Dayal's Keynote Address

indicator of safety in handling and using this material (i.e. sewage and nightsoil sludge) for fertilising land and fish farms". He has thus made out a case for sun-drying or aerobic composting of the effluent slurry. His warning against the direct utilisation of sludge (which is likely to contain the long-surviving ascaris and other pathogens) on land or fish farms seems justified. Enteroviruses surviving in the slurry which have shortcircuited their path (i.e. come out prematurely) and have also remained uncomposted can cause epidemics. Although the power of soil microbes in destroying the weakened pathogen is not in doubt, it cannot automatically be accepted that direct application of effluent slurry is harmless. There are findings that pathogens from raw nightsoil can penetrate the cell wall barriers of plant root systems and get into human food sources. If this is possible from raw nightsoil, why not from ill-digested effluent as well?

There are no convincing data to settle these differences. Sinha and Mazumdar of Sulabh International were very correct in saying that microbiological aspects have generally been ignored even though engineering aspects received some attention. Perhaps it is not microbiology alone, questions of science in general have been sidestepped.

Earlier, we have seen that our people do not have any guideline for mixes of feeds for ideal C/N ratio. There are suggestions that 10% human excreta be mixed with a 40% combination of cattle dung, foliage and other crop residues and the remaining 50% be water. This would mean a total of 90-95 per cent moisture content in the digester. Perhaps this is a workable proposition. But since different crop wastes have different C/N values, the formula for mixes of feeds should be placed on a firmer basis and, as far as possible, locale-specific. This kind of a call for concrete study can be a challenge to the local institutions of higher learning. Education can thus be lifted from lifeless cramming and imbibing of patented formulae to a creative endeavour. "Know thy own environment" is the first principle in learning as also in all other activities.

Expectedly, the proportion of ammoniacal nitrogen is more in the digested slurry than in the raw dung/excreta. (Ammoniacal nitrogen is more suitable for uptake by plant life). Anil Dhussa defined the proportion: while it was only 5.5 per cent of the total nitrogen in the original raw material, it (ammoniacal form of nitrogen) was as high as 17 per cent in the biogas **slurry.** The sludge value, too, is rich. It is composed of the dead bodies of anaerobic bacteria, the undigested or partially digested organic feed-stock, and all of the original inert (non-volatile) content of the input. Many scientists have tended to call this whole organic residue effluent a "single-cell protein biomass" (SCP), containing almost twice the concentrations - per pound-of nitrogen, phosphorous, potassium and trace elements, as compared to these constituents in the organic material fed into the digester. It is claimed that because most of the nitrogen has been converted to stable protein in the bacterial cell walls, losses due to ammonia release are much lower than from the manure which has been composted without the transformation through the biogas plant. "This nitrogen is released gradually over a three or four year span, thus reducing annual fertilisation requirements and increasing the organic matter percentage of the soil"

Now, if both the claims are correct - that is, on the one hand, we have a higher percentage of quick-release ammonia in the slurry; and that we have in the sludge a much - slower-release nitrogen than even in the organic manure - this would seem to offer the best in both the worlds. Questions, however, naturally occur: Has any study been made in field conditions on these claimed comparative merits? This would require studies of the results of application of organic manure on the one hand and of the product of a process of fermentation and transformation by biological agents, on the other. None of the scientific bodies in India has done this study, so far as we know.

Another issue which occasioned sharp differences was the extent of water use per call and its effect on the moisture/solids content of the feed. NEERI scientists' finding was that a 5-6% solid concentration is the optimum and 8.5% is the upper limit, which meant (i) that the moisture content should, at the very least, be 91.5% of the weight of the total content of the digester and (ii) that the optimal moisture content is 94-95 per cent. Moisture content below 91.5 per cent would cause ammonia build-up inhibiting methane production. Above 95 per cent, it would mean a fall in the rate of gas production per unit volume of the digester.

It has been found that in India the water use per call is quite high and it dilues the feed material so much that the solid concentration often comes to less than 3 per cent. The workshop, therefore, proposed that the water use per call be limited to 2 litres. This invited sharp reactions. Is such limiting of water use conducive to personal hygiene? Is it possible to keep the latrine pan clean with this little use of water? The problem seems manageable when it is considered (i) that nightsoil would have to be a minor portion of the total feed-stock in the interest of keeping down ammonia production; and (ii) that the other types of feedstock would not require equal amounts of water for dilution.

IV

CONTROVERSIES OVER DESIGN ASPECTS

On the question of design also, there were sharp differences, particularly on the issue of partition wall in the fermentation chamber, as in the KVIC model. AFPRO technologists feel that this partition, standing perpendiculary and covering the entire diameter, is positively harmful in a nightsoil-fed biogas plant. The nightsoil slurry, a portion of which has an inherent tendency to form a separate layer and float even in a raw state, gets an added impetus to travel upwards. While it overtops the partition wall to enter the second chamber, there is an easy intermixing of the digested and the ill-digested material due to the downward movement of a portion of the slurry and upward movement of another in the second chamber of the fermentation tank. This eneables the raw or ill-digested nightsoil to escape easily to the outlet chamber therefrom.

AFPRO concedes that even in the Janta model which it has adopted, there is scope for shortcircuiting: its extent, however, is much less. The school which has adopted the KVIC model does not agree. They allege that in the Janta model, wherein the inlet opening and the outlet opening face each other, the nightsoil has greater scope to escape, in an ill-digested state, to the outlet tank, despite the larger distance provided for by way of larger diameter. AFPRO is trying to meet this criticism by providing for a baffle-wall half-way through the diameter to maximise the sideways movement instead of the vertical.

Controversies like these would be solved by application of tracer techniques (isotopes) or at least by detailed chemical analyses of effluents from the plants of respective models. But no such comparative study is being done by any independent research body in the country.

Dr. Anjan Kalia of Himachal Pradesh Agricultural University has given his concept of a separate chamber for fresh nightsoil within the fermentation tank, by the creation of a "baffle wall" in a fixed-dome gas plant.

His purpose in creating a separate chamber for fresh nightsoil is to ensure that human excreta remains long enough in anaerobic conditions so that its pathogens could be effectively destroyed. Dr. Kalia has suggested a trial of this concept and it needs to be tried.

Another "design innovation" which was reported in the workshop was the model developed by the late Sri. M.V. Navrekar The avowed purpose of this design is to separate the ascaris ova (which alone have the largest survival time) in the beginning and thus avoid lengthening the slurry's residence time in the digester. A liquefying tank under a W.C. basin to receive the nightsoil and an intermediate siphon tank to separate the heavier constituents of the excreta (thereby the helminth ova) was suggested as the mechanism prior to the inlet into the biogas plant.

This raised questions as to (i) whether there are any data to prove that ascaris eggs got removed in the beginning by this system and if any samples were taken; (ii) whether heavy particles including silt and mud particles carried to the toilet by the users' shoes, too, do not settle at the bottom of the liquefying tank, occupying most of the volume, requiring frequent clearing; (iii) how the likely input of excess water is so be eliminated; (iv) whether the final slurry was tested for ascaris eggs after the usual residence time and compared with the findings from conventional plants of the same residence time. Here, too, unfortunately, there have been no scientific studies to substantiate or disprove the claim.

Dr. Mapuškar claimed that with an additional investment of about one thousand rupees, an aqua privy could be made to yield biogas and that this innovative design called "Malaprabha model" has been working satisfactorily in and around Dehu in Pune district of Maharashtra for the last five years. This information startled the workshop participants and was greeted with a lot of skepticism. The following questions were raised during and after the workshop discussions. (i) It is possible to install all these additional facilities - several vents, cleaning windows, rigid PVC pipe and construction of leak-proof RCC for the small additional amount suggested? If it is likely to cost more, why not have a proper biogas plant? (ii) If the privy is used by only five persons of a family, it might give only 0.2 cm. gas, which is of little use. It is worth considering only when it is used by at least 25-30 persons (to meet five persons' gas needs). But, then, would not the privy have to be constructed outside the family home for the use of neighbours and passers-by? (iii) Flat roof is never good as a storage structure. Will not, therefore, leakage be a haunting problem? (iv) How often the sludge disposal be needed? Despite all this skepticism, the fact remains that these Malaprabha latrines have been in existence and there have been no report of their hazards or wastefulness. In this case, too, one feels the lack of any independent body to do research, evaluation and extension work.

V

BIOGAS DESERVES TREATMENT AS A FRONTIER SCIENCE

In the context of this vacuum, a question becomes pertinent: if we could afford to spend Rs. 200 crores as annual subsidy to biogas plants, could we not spend even Rs. 10 crores for a National Institute for Biogas Research with centres in all regions? It is sad to reflect that our science advisers do not have any idea of the finely balanced nature of operation that a truly hygienic biogas-cum-fertilizer production demands or the complicated questions of science and technology it involves. For human survival, research in this field is far more important than in laser therapy or space exploration of nuclear energy. The more deeply one goes into its intricacies, the more one becomes convinced that it deserves to be treated as a "frontier science".

China's efforts in this direction have been exemplary. The Biogas Research Centre in China encompasses bioscience, environmental engineering and rural sanitation, structural engineering, agricultural engineering, training, extension work, instrumentation etc. Its mission-oriented research has taken China ahead of others in the field. In the context of India's foliar and crop residue characteristics, construction material and skill availabilities, intense research in this country in field conditions and laboratories has become urgent.

VI

THE CONSTRAINTS AND REMEDIES

We must now turn the physical constraints on the spread of biogas plants. We have earlier mentioned the difficulty of reconciling the demands of its proximity to latrine and the kitchen, distance from water source, the availability of space for post-digestion composting etc. In Chinese culture, which regards the frequent drinking of warm water as an antidote to intestinal infestation, the series of post-digestion composting pits near the household may not be a problem. But in the context of India's household situations and sensitiveness, the question of space would appear to be a formidable problem. The solution is, therefore, often sought in the establishment of community biogas plants. However laudable as an objective, it cannot succeed until cooperation has become a way of life. In a social climate where, in the name of modernisation, we are propagating and reinforcing commercial and self-centred values, community gas plants can only be a casualty. People will tend only to draw its gas and fertilizer without contributing their share of the inputs. Even in a country like China, where the state control on people's lives is much greater, community biogas plants are unlikely to prove a success at the present stage of people's concern for the society. The Chinese Biogas Manual says : "faced with the costs of digesters - a number of people concluded that work should concentrate on community rather than individual plants. **The designs and experiences recorded in this handbook demands a reappraisal of that judgement".** *(Italics ours)*.

Tackling Space Shortage Problem

But would biogas plant movement fail to progress in India on the ground of a feeling of shortage of space in or near the household? Underground fixed-dome structure does not require much additional space. It can be built in the basement/courtyard. In China, two biogas plants per family is not uncommon: it helps solve the family's easing problem when one plant is under desludging and cleaning operation. The requirements for wider space, which arise from Indian sensitiveness to excreta, can be got over by taking biogas science and technology to a level where it ensures (i) total absence of smell and (ii) freedom from causes of fear from pathogens. Clearly, this is possible. Maximum digestion and freedom from putrefaction go together; and effective digestion always kills pathogens. Even if a small percentage (2% or so) of pathogens remains in the effluent, these will surely get killed in the aerobic compost pile where temperature rises much higher and faster. Even the egg of the roundworm or ascarid which, with its thick protective albuminous sheath, has a remarkable capacity to survive long periods under severly adverse conditions, will not be able to escape.

Perfect digestion, even in North India's winter nights, can be achieved by better insights into the working of Nature. Judicious combination of aerobic and anaerobic treatment and understanding of the natural principle that the same forces that produce pathogens also produce their toxins can help in achieving perfect digestion.

Benefits of Prior Hydrolysis in Colder Regions

The Chinese practice of prior composting of the vegetable waste inputs *in the colder regions* is instructive. These wastes have in any case to be added when nightsoil is an input, in the interest of optimal operation. This method is as follows.

"In order to increase the rate of fermentation and raise the gas output, materials should be piled and composted before feeding into the pit - fibrous materials, especially straw, grass, weeds and maize stalks - must be thus treated because some of them have a waxy layer on the surface. Otherwise, not only is it a hard and lengthy process for them to rot, but once fed into the pit, they float up to the surface and tend to mix evenly with the other material. To pile and compost, cut the material into short pieces and pile up in layers about 50 cm. thick. It is best to sprinkle on (it) some material with a 2-5% lime or ash content, and then also to pour on some animal manure or waste water, then cake over the surface with clay. In summer, this piling and composting should last 7-10 days and in winter one month. When the material has thus been handled, the waxy surface layer is broken down,which in turn hastens the breakdown of the fibrous material".

Evidently, this is softening of the inputs before feeding into the digester - i.e. prior hydrolysis, which is quicker under aerobic conditions. It is interesting that the inputs pre-composted under basically aerobic conditions also imbibe anaerobic methanogenic bacteria discharged from the rumen of cattle along with the dung. This initial inoculum and the initial hydrolysis speed up the fermentation process in the pit. This offsets the disadvantages of the colder regions. This system of prior hydrolysis, however, needs to be avoided in warmer regions.

There is yet another benefit of this pre-composting when old and ripened vegetable material are part of the feed-stock. This reduces their carbon/nitrogen ratio to near-optimum. Normally,their C/N ratio is very high between 60:1 and 100:1 (nitrogen content being very low). With "pile rotting, the carbon-nitrogen ratio can be reduced to 16:1-21:1, which approaches the ideal environment for methane microbe. This does happen, possibly due to the release of carbon dioxide from the carbonaceous content of the biodegrading vegetable wastes under aerobic conditions.

Another practice of the Chinese is worth emulation. Before winter, they clean the pit and fill it with plenty of new material in order to better nourish the methane-producing microbes and stimulate them to greater gas production. When removing the old material, they leave one-third of the sediment layer. Better results are obtained when the new vegetable waste inputs have been pile-rotted in advance.

People in India have already been (i) covering the fermentation chamber and the inlet and outlet chambers with straw; and (ii) surrounding the perimeter of biogas pits with pile-rotting material **during winter**, to good effect. There is yet another technique which raises the digester temperature. It is the use of the solar heating technique to pour heated water into the digester during winter, subject to the permissible limit of dilution. (Its scope, however, is limited in the context of the Indian habit of liberally using water for post-defecation cleansing).

Toxins to pathogens

It is a law of nature that the wastes which have higher pathogen loads are also more productive of their toxins in the fermenting slurry. A series of experiments (in China) showed that "the ammonia content of the fecal liquid was 40% higher after fermentation than in the untreated pig faeces and urine. **This factor would accelerate the death of both the parasite eggs and pathogens".** (Italics ours)

It is also a peculiar law of nature that urine has a toxic effect on amoebae. J.M. Watson in his study (1945) on the effect of urine on **Entamoeba histolytica** proved this. Some Scientists concluded therefrom that "the Chinese nightsoil method (the use of raw liquid nightsoil combining the faeces and the urine), although apparently more likely to spread infection, may actually help to control it". Biogas Plant followed by composting is a far greater advance on the raw nightsoil method and can be free of obnoxious smell and pathogens. Therefore, there should not be overconcern to keep the biogas plant and the compost pit at a great distance from the living rooms provided meticulousness is observed in attaining the design objectives and testing of the slurry is done periodically for its pathogen content.

Genuine problem of space exists but oversensitiveness or undue fears need not aggravate the sense of shortage.

Problem of Servicing

One great obstacle to biogas movement is the lack of repair/servicing facility in the locales. Investors willing to set up biogas plants often point to the dysfunctional biogas plants and feel deterred. In a pattern of development, where all technical hands seek better material prospects in servicing consumer durables and tie-ups with large industries, servicing for biogas plants cannot retain their interest for long. Fortunately, a new movement for turning common men and women into masons with a biogas mission is being spearheaded by AFPRO, Agricultural Tools Research Centre at Bardoli, Gandhi Smarak Nidhi, Thapar Polytechnic and a few other voluntary agencies. This may turn the tide.

Need for Reordering National Priorities

Every family in the rural area including the poorest must be enabled to have a biogas plant of its own. The poorest will naturally deserve the most generous subsidy, **verging on a free gift.** The landless family, lacking its own cattle, will need to run the biogas plant on its own nightsoil and its collection of vegetational wastes. Subsidy on this scale, will, no doubt, be a huge burden on the public exchequer but that will be a far greater contribution to a lasting solution of the nation's energy problem than the petroleum refineries and nuclear plants together can ever be. Biogas plant deserves the highest priority as a public health promotion measure. Resources will be found for it, only when the priority to urban-centred hospitals (for cure, after allowing the propagation of diseases) and chemical fertilizer plants be reversed. It has to be recognised that biofertiliser is our greatest resource for soil fertility.

India's soils have become seriously eroded everywhere. These need fertilising composts universally. If a poor landless family has no space to adjoin the gas plant on its narrow strip of homestead, the village panchayat must buy from it the effluent slurry to do the composting on the community's land (for sale to land holders). There can be no soil improvement bypassing the biofertiliser-cum-soil conditioner.

Biogas plant is vitally linked with all aspects of the society's well-being health, forestry, agriculture, energy, non-conventional resources, science and technology. **It is basic to our survival.** Hence it needs to be the concern of all and demands high ranking in national priorities in terms of allocation. But "the plant can be dangerous"*in lax handling. That is why it deserves utmost concern, care and vigil.

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*International Reference Centre "Practical solutions in Drinking Water Supply and Wastes Disposal in Developing Countries (422.0 3)

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