# Recycling and reuse of human excreta from public toilets through biogas generation to improve sanitation, community health and environment

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The quantum of energy utilised is regarded as the yardstick of techno-economic status of any society. The continuous and uncontrolled use of conventional fossil and geochemical sources of energy has resulted in its fast depletion and consequently continuous price rise of petroleum products. Fossil fuels will not continue much longer to meet our energy needs. There is lack of availability of adequate energy to meet the minimum needs of people in peri-urban, slums and in rural communities. Due to lack of fuels, people spend most of their valuable time to collect fire woods for cooking in rural communities. Countless man days are lost resulting in stagnation of progress and productivity in such communities. If the condition continues, then in near future our rural masses would have sufficient food but may not have enough fuel to cook it.

Additionally, safe & hygienic way of disposal of human wastes is an increasing problem particularly in peri-urban and in rural areas resulting into high mortality, morbidity and decreasing community health, sanitation and consequently productivity. Continued urban migration, congregation of urban poor in slums without safe water supply and sanitation facilities and increasing resource constraints have all led to rapid deterioration in quality of life and community health in many developing countries which are likely to become further aggravated unless steps are initiated to improve sanitation through inter- sectoral co-ordination, people's participation, innovative and appropriate technology for safe management of human wastes and waste water treatment. Good sanitation coverage of a nation shows its socio-cultural development. In a developing country, it is an unaffordable task for the local governments/bodies to provide conventional sewerage and treatment system due to the fact that available technology has high operational & maintenance costs and that too without economic return out of the system. Since most of the local governments/bodies are not financially self sustained, they have little interest for the treatment of wastes. Human wastes from individual households and public toilets through septic tanks, finally lead to nearby river or low land areas causing severe pollution due to its higher Biochemical Oxygen Demand (BOD) and pathogen counts.

Public toilet is an unavoidable option for sanitation in slums and market places like markets, bus stands etc. Public toilets in unsewered areas are connected with septic tank system. Due to lack of sewage treatment system, effluent from such tanks passes through covered/uncovered drains and finally leads to adjoining river or water bodies of city/town, causing severe problems to aquatic lives, community health & hygiene and environment. Many important rivers in India are getting practically converted into drain to carry sewage of the town. Based on our practical experience, the paper describes about operation and maintenance of public toilets on pay and use basis in India and generation and utilisation of biogas from human wastes and on –site treatment of biogas plant effluent through a simple, convenient and cost effective technology for its safe reuse for agriculture/ horticulture, cleaning of floors of public toilets or discharge in any water body.

**Sulabh Public Toilet Complexes**

Provision of public toilet complexes at public places and in slums on "pay & use" basis is an important activity of Sulabh in the field of community health & hygiene and environmental sanitation. Sulabh has constructed so far over 6000 such public toilet complexes in different parts of the country, where maintenance is provided round the clock. These complexes are located at public places like bus stands, hospitals, markets etc. and in the slums. For the construction, operation and maintenance of these complexes, the organization plays the role of a catalyst and a partner between the official agencies and the users of the toilet complexes. Our experience revealed that when facilities for bathing is also provided with the community toilets, and above all they are kept clean, people have no hesitation in paying for the use. For washing hands soap powder is provided to users. User charge is Rs. one (2 US Cent) per use. Children are exempted from such charge.

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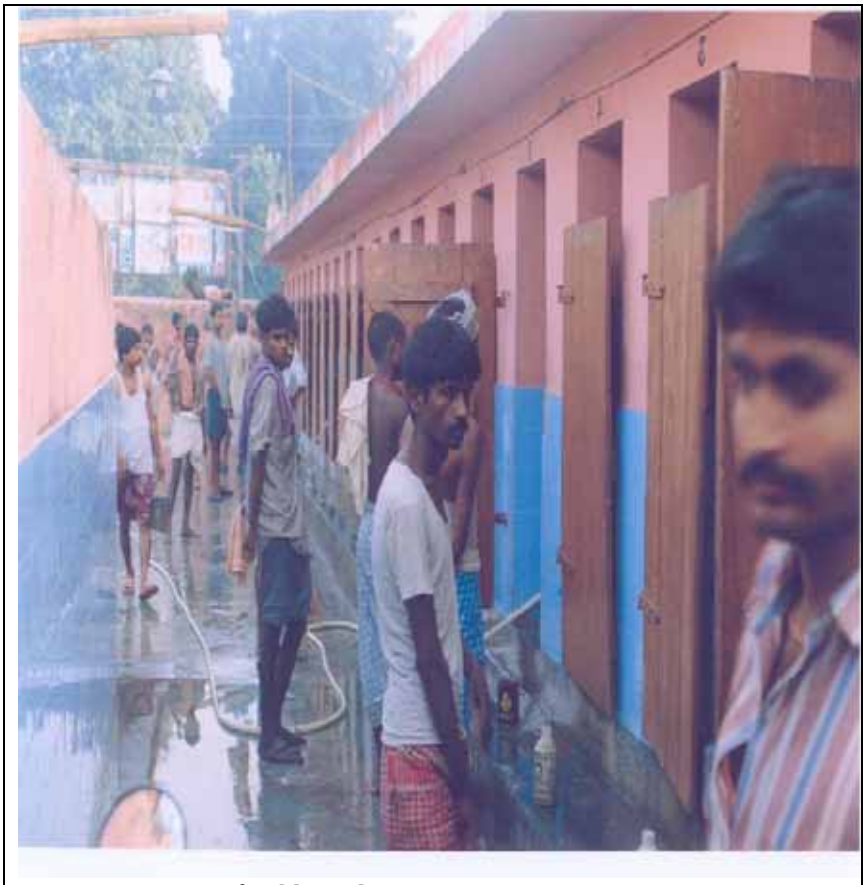


Picture1. A view of public toilet in use

The system of operation and maintenance of community toilets evolved by Sulabh has proved a boon for the local bodies in their endeavour to keep the towns clean and improve the environment. This is a unique example of partnership of local authorities, non-governmental organization, and the community.

**Public Private Partnership in quality service delivery:** The sustainable and affordable technologies developed by the organization have attracted various agencies towards management of human wastes. The 'pay & use' basis of maintaining a public toilet is saving annually a lot of money to the local bodies in maintaining the toilet complexes. Now, it is one time investment by the local government because maintenance of the toilet is being carried out by the user's contribution. As Sulabh is taking maintenance guarantee of the toilet complexes built by it for not less than 30 years, local governments as well as people have faith in the quality service by the Sulabh.

**Financial viability:** Since human excreta were considered a hated object, it was difficult for any one to consider financial viability of a project related to its disposal. However, Sulabh made it financially viable. The cost of construction is met by the local body. The maintenance of toilet blocks and day-to-day expenses is met from the user's charges. Sulabh does not depend on external agencies for finances and meets all the financial obligations through internal resources. All the toilet complexes are not self-sustaining particularly those located in slums and less developed areas. The maintenance of such toilet complexes is cross-subsidized from the income generated from toilet complexes in busy and developed areas.

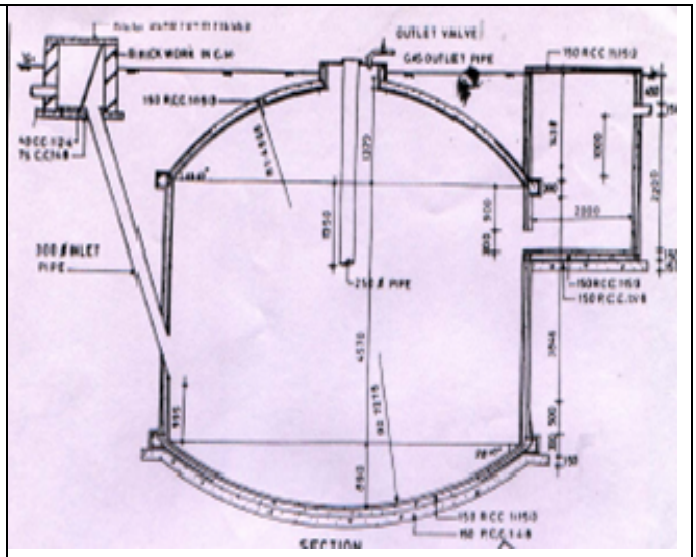
**Elimination of social stigma and psychological taboos:** Earlier there was social stigma and psychological taboo attached to handling of human excreta. It was also due to the fact that only people of lowest economic strata were supposed to be associated with this job. Due to financial viability now, people from higher social status are also engaged in the construction and maintenance of toilets.

**Employment opportunity:** Altogether there are 50,000 volunteers working with Sulabh who include technocrats, managerial, scientists, engineers, social scientists, doctors, architects, planners, masons and other non-revenue staff. Since Sulabh takes 30 years maintenance guarantee for the toilet complexes constructed by it, all the social workers associated with this work, get almost regular employment. Besides, workers associated with construction job also get almost full employment

**Biogas from public toilets**

Recycling and reuse of human excreta for biogas generation is an important way to get rid of health hazards from human excreta, besides uses of biogas for cooking, lighting and electricity generation. Biogas from public toilets has multiple benefits- improve sanitation, community health & hygiene, environment, make available quality liquid manure, in addition to uses of biogas for different purposes. To overcome the problems Sulabh developed an efficient design of biogas plant linked with public toilets under a project funded by the Ministry of Non- Conventional Energy Sources, Government of India that approved the design for implementation under its Central Financial Scheme. Under the system only human excreta with flush water is allowed to flow into biogas plant for anaerobic digestion. Bathing and cloth washing water is collected separately that is reused after sand filtration or discharged in drain after settlements. For biogas generation no manual handling of excreta at any stage is required. Hydraulic Retention Time (HRT) of feed material is maintained for 30 days. One cft of biogas is produced from the human excreta of one person per day. Human excreta based biogas contains 65-66% methane, 32-34% carbon oxide about 1% hydrogen sulphide and trace amounts of nitrogen and ammonia. Biogas is stored inside plant through liquid displacement chamber. Biogas plant is made up of Reinforcement Concrete Cement (R.C.C.); therefore, no recurring expenditure is required for its maintenance. Methane is the only combustible constituent which is utilised in different forms of energy. A thousand cft ($30m^3$) of biogas is equivalent to 600 cft of natural gas, 6.4 gallons of butane, 5.2 gallons of gasoline or 4.6 gallons of diesel oil.

**:ture 2. A public toilet linked biogas plant**




**agram 3. Section view of biogas plant**

**Basic parameters and operational criteria:**

Human excreta fed biogas plant system, especially those linked with community toilet complexes, have a number of limitations:

i) These are used by people from different socio-economic and cultural backgrounds whose food habits and toilet habits are different.
ii) Human excreta are malodorous and associated with psychological and religious taboos.
iii) It contains full spectrum of pathogens causing health hazards if not carefully handled.
iv) Variation in the number of users leads to variation in loading rate of the digester.
v) Wide variation in the frequency and quantity of water used for cleaning the pans and toilet floor, although the amount of water used for personal cleaning does not vary much.
vi) With direct gravity feeding arrangement, the feeding of the digester can at best be termed as intermittent or semi-continuous depending upon the frequency of use.

vii) The public conveniences are generally constructed in congested and busy areas where space is often limited.
viii) Energy input in the form of heating, mixing, pumping etc. has to be kept to the minimum.

Keeping in view of the above limitations, some additional basic criteria needs to the considered for the night solid based biogas plant:

i) There should not be any direct handling of excreta.
ii) Aesthetically it should be free from odour. It should not be visible at any stage.
iii) Cleaning water should not be more than two litres per use.
iv) Use of disinfectants for cleaning latrines should not be permitted.
v) Arrangements for the drying of slurry before using it as manure should be made.
vi) There is no direct control over the concentration of the feed material, loading rate, hydraulic retention time (HRT), temperature etc. The design criteria have to take all these into account, and the design parameters have to be flexible to accommodate the variations

**Functional design of the human excreta fed digester.**

| | | |
|---|---|---|
| 1. | Volume of feed material per user per day (Excreta +ablution and flushing water + Occasional cleaning water) | 4 litres |
| 2. | Volume of digested sludge per user per day | 0.00021 cum |
| 3. | Average hydraulic retention time (HRT) | 30 days |
| 4. | Cleaning (desludging) interval for digested sludge | half yearly |
| 5. | Expected average biogas production per user per day | 30 litres |
| 6. | Pressure of biogas inside the digester | |
| | (a)normal (connected to floating gas holder) | 20 cm |
| | (b) maximum (up to safety limit) | 120 cm |
| 7. | Slurry level inside the digester | |
| | (a) maximum (highest) | 1.0 metre below crown of the top dome |
| | (b) normal | 0.2 metre below maximum slurry level |
| 8. | Diameter: depth ratio | 1.5: 1.0 |
| 9. | Rise of top dome (h1) | D/5 |
| 10 | Rise of bottom dome (h2) | D/2 |
| 11 | Position of inlet pipe | H/3 below the top ring beam. |
| 12 | Position of outlet pipe | middle height of the cylindrical wall. |

According to the above consideration, the volumes required for different functions, for 1000 users (30 cum biogas / day) are as follows:

| | | |
|---|---|---|
| (a) | Effective digester volume | 120 cum |
| (b) | Space for digested sludge (half yearly desludging) | 38 cum |
| (c) | Space for scum | 19 cum |
| (d) | Total volume (excluding gas space above liquid level) | 177 cum |

Produced biogas is used for cooking, lighting though mantle lamps, and electricity generation. Cooking is the most convenient use of biogas. Biogas burner at reasonable price is available in the market that consumes about 25 cft of biogas per hour. Biogas is being supplied at nominal charge to nearby slum dwellers for cooking purpose. Mantle consumes 2-3 cft biogas per hour that gives illumination equivalent to 40 watt bulb at 220 volt. Electricity generation is through dual fuel engine coupled with alternator that runs on 80% biogas and 20 % diesel. Consumption of biogas is 15cft/BHP of engine/hr. Electricity from biogas is being used in toilet complex for operation of water pump and lighting purpose inside toilet complex and adjoining areas. Based on `Sulabh Model' design, 145 number of biogas plants of 35 to 60 cum per day gas production capacity have been constructed by Sulabh in different states of the country so far.

**SET ( Sulabh Biogas plant Effluent Treatment) System for reuse of effluent**

During biogas generation there is remarkable reduction (up to 85%) of BOD of effluent of biogas plant in comparison to its affluent value. In absolute term the BOD of effluent is around 125 mg/l. Similarly, pathogen count is still higher than the permissible limit of discharge in any water body. Such effluent contains good percentage of nitrogen, potash, phosphate and other micronutrients for plants, but its aesthetically bad odour, yellowish colour, high BOD and pathogen contents limit its reuse for agriculture/horticulture or safe discharge in water body.

In a public toilet linked with biogas plant, used by 1000 users per day, maximum 5000 lts of waste water is generated per day. For a continuous flow from the treatment system a flow rate of 5-6 LPM (Litre Per Minute) will solve the purpose.


Picture-4 Biogas plant effluent treatment system

After a series of experiments under a R&D project funded by the MNES, Sulabh has developed a simple and convenient technology named as SET (Sulabh Effluent Treatment) to treat such effluent. The technology is based on sedimentation and filtration of effluent through sand and activated charcoal followed by ultraviolet rays. The system consists of an overhead sedimentation tank of 2000 lts capacity with bottom conical shape fitted with valve. Effluent from outlet chamber of biogas plant is lifted to this tank and left for one and half hours to settle. It is passed through the sand filter column through Liquid Flow Meter at the rate of 6 LPM. From sand column effluent passes under gravity through an activated carbon column where carbon contact time is maintained for 5-6 minutes. Flow through the carbon column is upward. From this column it passes through U-V channel that helps eliminate bacteria and other pathogens. The treated effluent is colourless, odourless, pathogen free having BOD less than 10mg/l-quite safe for aquaculture, agriculture/horticulture purposes or discharge into any water body without causing pollution. It can also be used for floor cleaning of public toilets in water scarcity areas.

**Recurring expenditure**: The system requires 1 H.P. of electric motor to lift effluent to the overhead tank for maximum 3 hours a day i.e., 2.5 units of power a day is required. For operation of 3 nos. of UV ( 15 watts each) about one unit of power will be consumed per day. Such low consumption of electricity can easily be obtained through biogas. Expenditure incurred on the periodical replacement of activated carbon is very low that can easily out of the user's charges of the toilet complex.

**Advantages of the system**

- No manual handing of human excreta is required at any stage
- Aesthetically and socially accepted
- Technically appropriate and financially affordable
- Operational & Maintenance cost almost nil
- Biogas is used for different purposes.
- It provides complete ecological sanitation at community level in addition to biogas for different purposes
- Treated effluent is safe to reuse or discharge into any water body.
- In draught prone areas treated effluent can be used for cleaning of floor of public toilets.

**Social Problems with biogas technology**

There are some problems for social acceptance for the use of biogas from human excreta that can be enumerated as follows:

a) Misconceived feeling among people about biogas; people generally feel it unhygienic and dirty.
b) People generally do not accept use of biogas for religious purposes.
c) A fear of possible non-acceptance of eatables from the user's home by the villagers becomes a formidable deterrent.
d) People are generally unaware of the importance of health and sanitation and advantages of biogas technology

Biogas from human wastes is important not only for alternate source of energy also for improving sanitation, health and environment. However, there is still psychological taboo associated with it in some societies.The reuse of human excreta may gain acceptance even in societies having religious and cultural taboos associated with it as the values do change with time, advancement of education and awareness among the people. To have wider acceptability, the reuse of excreta must be demonstrated to be low cost, to provide real benefits to population with no risk to public health.