DESIGN AND DEVELOPMENT OF BIO-DIGESTER SYSTEM FOR EFFICIENT WASTE MANAGEMENT IN BIO-TOILET

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ABSTRACT

Bio toilet is a toilet system based on decomposition mechanism, it decomposes in the digester tank human excretory waste using specific high graded anaerobic bacteria further converting it into methane gas, carbon dioxide gas and water. The throwing (disposal) of human waste is a difficult problem in the current scenario. Now-a-days, we are using a drainage sewer pipe system to convey human waste from one point to another, but it is good for metropolitan cities where the drainage system is good or working effectively, simultaneously, in rural areas there is no proper sewer system, though the disposal of human waste is a very problematic condition. To overcome the above problems in rural areas the concept of a biodigester is very useful, because it didn't create any effluents to dispose of. So, we are constructing an economical bio toilet at village Rampur, Bhaangadh block, Greater Noida. And tests performed on the effluent of bio-toilet. For constructing the bio toilet, we design a bio digester tank of required volume in which anaerobic degradation happens.

Keyword- *Bio-toilet, saw dust, bacteria, working mechanism*

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1. INTRODUCTION

Bio-Toilet treats human waste by a biological process in a digester tank using high graded bacteria (aerobic or anaerobic) further converting into methane gas, carbon dioxide gas and water. It is also known as a dry toilet. The bacteria worked for a lifetime once applied. The zero-waste bio-toilet technology uses psychotropic bacteria like Clostridium and Methanobactin. Waste from toilets is sent to a bio-digester tank for anaerobic digestion, where methane gas is produced which can be used for multiple purposes like for generation of electricity and firing up of a gas stove. After the anaerobic digestion other than methane gas water is produced which we use for recharging the ground water table. Leftover materials like humanure can be used for farming and gardening.

2. LITERATURE REVIEW

Working of bio toilet (IR-DRDO) human excreta when come in contact with anaerobic bacteria, it gets converted into water and methane gas through a series of process like anaerobic bacteria digestion hydrolysis, acidogenesis, acetogenesis and methanogenesis. Fecal matter is a space composed of fats, carbohydrates and protein. In the first step, they are converted to simple sugar, fatty acids and amino acids. In the next step, this breaks for alcohols, carbonic acids, water, hydrogen. In third steps acaricide, hydrogen and carbon dioxide are formed. Carbon dioxide, methane and water are formed in the last step.

Trials of Microphor friendly bio toilets (1993-95) by Indian Railway in AC coaches Failure due to

- Foul smell from tank
- Cockroaches & flies' infestation
- Clogging of tanks
- Regular dosing with bacteria and enzymes
- Manual removal of residual solid waste

Trials with integral coach factory modified bio toilets (1995-96) Failure due to

- Visible fecal matter from the tank
- Tanks getting filled non-biodegradable waste
- Foul smell

DRDO's Approach

- Laboratory investigation
- Design and fabrication of digester
- Laboratory trials

Director RDSO approached DRDO in 2004 for the solution in view of the expertise in the field of bioremediation of human waste at low temperature areas.

3. WORKING OF BIO-TOILET

It treats human waste by a biological process in a digester tank using high graded bacteria (aerobic or anaerobic) further converting into methane gas, carbon dioxide gas and water.

The biodigester where we got zero waste uses psychotropic bacteria like Methanosarcina and clostridium, these bacteria can live in hot or cold climates and depend on waste to survive. The bacteria once applied worked for a lifetime. These bacteria break down the human excreta into methane gas and water. Waste which we get from the toilet is sent into the bio-digester tank where the anaerobic digestion process takes place. We can use methane gas which is produced in tanks for different purposes like firing gas stoves and for generation of electricity. And other leftover materials like humanure are used for farming and gardening. It works with the variation of temperature and geographical limitations.

The whole process of the bio-digester tank is divided into four-part, hydrolysis by using hydrolytic bacteria is the first process in which small molecules are soluble and quickly go into solution once the chemical bonds are broken. After the completion of first process the next process is acidogenesis in which the product of hydrolysis is decomposed by acidogenic bacteria which produce aldehydes, alcohols, and volatile fatty acids and acetates together with CO_2 and H_2, in this process we are using acidogenic bacteria. After completion of acidogenesis the next process is acetogenesis in this process we are using acetogenic bacteria. After completion of acetogenesis process the last process is Methanogenesis in this process steps which is performed in methanogens process are acetate fermentation to CH_4 and CO_2 and H_2 to H_2O oxidation.

4. BACTERIA USED IN CERTAIN PROCESS

i) ***Hydrolysis*:** In hydrolysis process, large polymers are converted into simple monomers they are quickly going to solution once the chemical bonds are broken. These bacteria are facultative anaerobic and anaerobes breaks the unique bond of the soluble particle bye by compound with water. Some hydrolytic bacteria are leuconostoc, mesenteroids, lactobacillus bifermentans lactobacillius, and leuconostoc, etc.

ii) ***Acidogenesis*:** This is the fermentation stage where the end product of hydrolysis process is decomposed to produce aldehyde alcohols and volatile fitty acids and acetate with H_2 and CO_2. Some acidogenesis bacteria are clostridium, ruminococcus, pseudomonas, microcrccus, Escherichia.

iii) ***Acetogenesis*:** It is the second last stage of the decomposition process, in this stage, sub-sub-step of the acid-forming and completed through resulting in acetate, carbohydrate fermentation, CO_2, H_2, that can be utilized by methanogens. Some acetogenesis bacteria are acetobacterium, acetoanaerobium, eubacterium.

iv) ***Methanogenesis*:** The final step methanogens are fermentation of acetate to CH_4 & CO_2 and oxidation of H_2O & H_2. Such bacteria are Methanobrevibacter gottschalkii, Methanosarcina barkeri, etc.

5. ESTIMATION OF PROJECT AND FACTORS

Estimation of friendly bio toilets should be done precisely because it depends upon the number of users and the end population. Because effluent is obtained on a daily basis. The correct amount of waste should be known, so no further issue should be generated in future for functioning of friendly bio toilets.

Estimation of a friendly bio toilet depends upon locality, availability of water where it has to be constructed. Some factors, such as locality, availability of labor cost, budget, which majorly affect the estimation of projects.

Duration of serviceability means for how many years it can function is also considered during costing an estimation of the friendly bio toilet.

International Journal for Research in Engineering and Emerging Trends (IJREET), Volume 7, Issue 1, MAY, 2023
ISSN: 2545-4523 (Online)

6. METHODOLOGY

STEP 1: **S**iting of digester in this step we try to determine soil type and water table conditions on that particular location.

STEP 2: Mark and dig ground based on size as per dimension of digester tank. We used a digester tank dimension of (1000 mm X 1200 mm) with depth 1000 mm. And we can also increase or decrease the dimension of the digester tank as per requirements. Here we are designing it for 10 family members.

STEP 3: Providing slope for the digester tank, where we are providing the slope of 1:20 for better gravity flow of sludge.

STEP 4: Soak hole construction.

Prepare a water drain area, in this step we are constructing a soak hole for water is one of the outputs of anaerobic reaction performed by respective bacteria. In the soak hole where the water stored in the soak pit can easily percolate in the soil mass. After a long period of time, this percolated water helps in increasing the level of ground water table.

STEP 5: Installation of digester bed in the pit. We are fitting all the artificial reinforced concrete slab of grade M25, all the gaps are filled by the same grade of mortar.

STEP 6: Add multiple filtration material. Permeable wall of coarse aggregate bounded by two-sided wire mesh. Provide fiber net or mosquito net.

STEP 7: Add required bacteria in 1st chamber and after adding required bacteria in the camber, seal the digester tank.

7. DESIGN CONSIDERATION OF BIO-TOILET

Size of bio-digester tank or reactor of friendly bio toilet is determined as:

a) Loading rate of water, such as the correct amount of urine, water used in flush and cleaning of ceramic commode, must be taken under consideration of speedy degradation due to higher water content.
b) Rate of drying, evaporation rate of urine, cleaning water or wastewater taken under consideration because degradation of waste requires more amount of water.
c) Weather conditions such as, temperature, pH, moisture content, availability of oxygen are the several environmental key factors, which directly or indirectly affects the decomposition rate of bio decomposable matter or fecal waste.

Moisture content should be maintained approx. between 60 to 65% for optimum decomposition.

Pungent smells controlled by thermophilic conditions by pathogenic bacteria lead to degradation or decomposition and make the process more efficient in the process in the composting reactor.

Mixing of waste in Chamber should be done properly because is a bulk material the toilet paper with waste with waste content cellulosic and usually degraded by fungi and microorganism (not dominant in reactor).

8. IMPORTANCE OF BIO-TOILET

- Easy digestion of human waste
- Movable
- Less cleaning processes
- Consume less amount of water
- High life time for cleaning of septic tank

8.1 Advantages of bio-toilet

- It is a very quick and short process for installation of a biodigester (artificial tank), it takes 4 to 7 days.
- The size of the biodigester can be built as per desired number of users.
- In the biodigester the waste that remains saves money because it does not require any exhaustion.
- It is a bit cheaper to Design and construct a bio digester.
- After installation, the bio digester does not require high maintenance.

8.2 Disadvantages of bio-toilet

- Bio toilets work very poorly in areas with extremely low temperatures.
- Because in this process the bacteria responsible for breaking down the fecal require an optimum temperature of 30°C to 40°C.
- The fecal wastes that enter the first chamber of the biodigester require adequately mixed with water to simply break down the fecal waste. i.e., largest waste particles require broken down first which can take quite a while.
- The effluents should fully decompose in this process. No further effluent can be produced.

8.3 Limitations/ drawback

- Friendly bio-toilet facing many drawbacks including decomposition of human excreta where the end product such as CO_2 are released in atmosphere and liquid discharges are being thrown in open areas.
- These end products such as sludge used as a manure for crops and wasted gasses are the best source of energy and can be converted into electricity easily.
- For capturing these certain gasses, we require a highway setup which is uneconomical for the people.

9. LIST OF CLEANING AGENT USED

- Cleaning agents for the commode pan & wall protector are Harpic/ Retoil/ Domex.

- Cleaning agents for Ceramic Toilet fittings are Taski R1/ Taski R6 (johnson diversey) or sigla natural of Eco-Lab.
- Disinfectants used for friendly bio toilets are Brands Stride or Antibac of Ecolab or collin or Lizol.

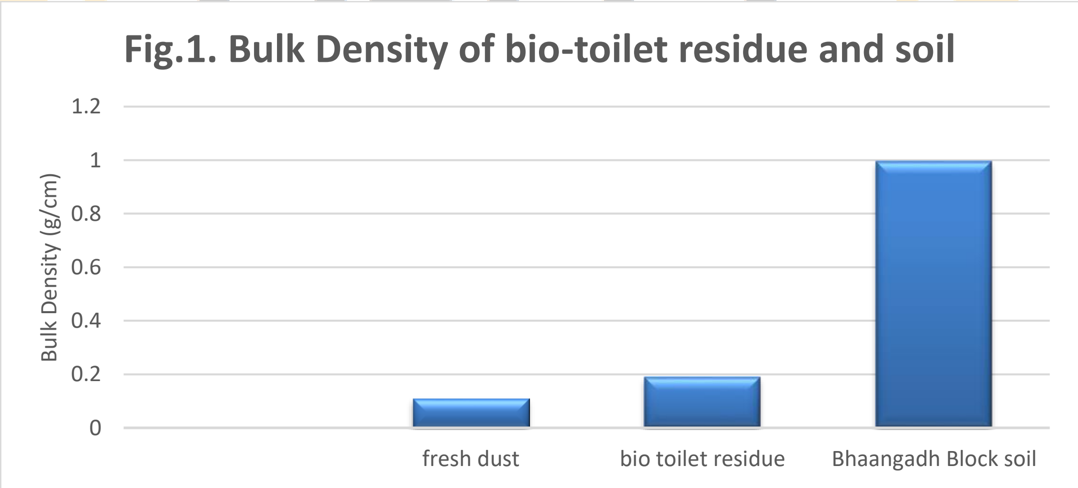
10. OBJECTIVE OF BIO-TOILET

Around 80% of rural households have water for only five hours a day and over 70% of households do not have access to toilets. This activity is introducing a bio-toilet system which disposes human waste and saves energy, conserves water and produces energy in the form of biogas. Replacement of soak pit toilet because, failure of septic tank and soak pit.

11. TESTS AND EXPERIMENTAL RESULTS OF EFFLUENTS

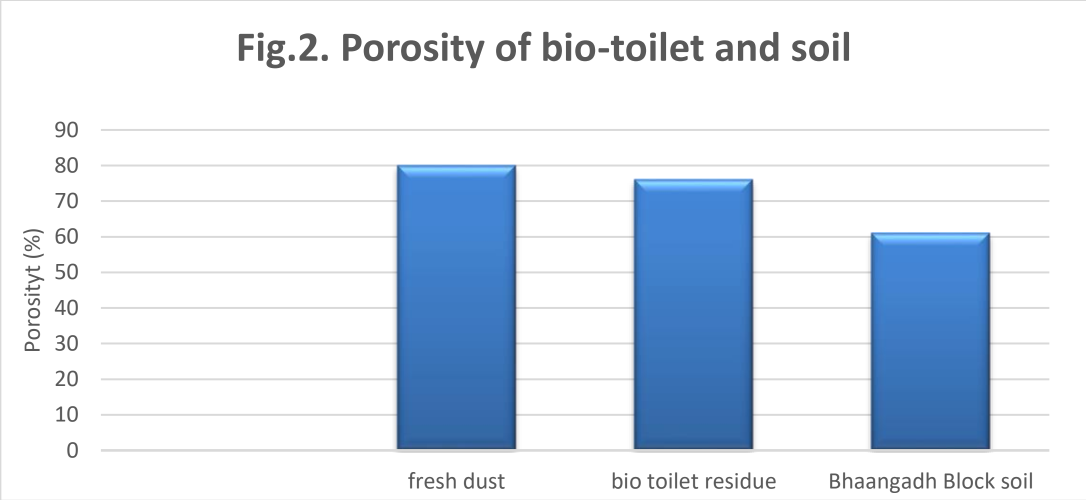
11.1. *Bulk Density*

Fresh sawdust had a bulk density of 0.11g/cm^3, according to Figure 1, while bio-toilet residue had a density of 0.19g/cm^3. These numbers are comparable to the bulk densities of Todomatsu, Karamatsu, and Ezomatsu sawdust, which are, respectively, 0.14, 0.19, and 0.15 g cm^3 (Horisawa et al. 1999). Because of the bio-toilet residual sawdust's low bulk density, adding it to soil will increase the porosity of the soil.



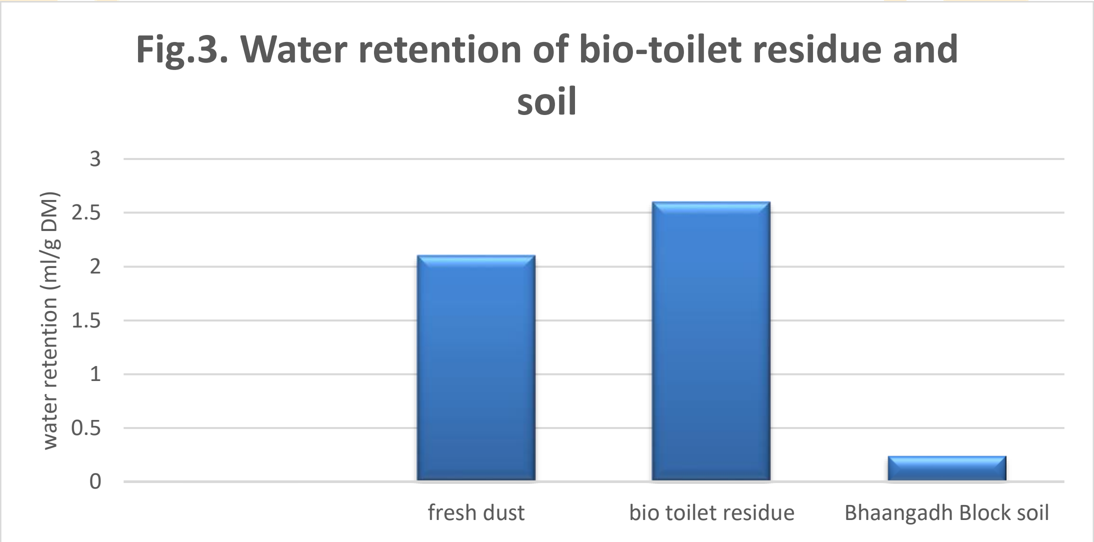
11.3. *Porosity*

The substance that makes up sawdust is a solid matrix with interconnected pores or voids. Water and air can move through sawdust materials because the empty spaces are interconnected (Nield and Bejan 1992). Results indicated that the porosity of bio-toilet residue dropped from 80 to 76% when compared to fresh waste. The covering of the sawdust surface with feces-urine-decomposed products is most likely what is to blame. Sawdust void space decreased as a result. Figure 3 demonstrated that the bio-toilet waste had greater porosity than the soil in Bhaangad block (76% vs. 61%). Research suggests that adding bio-toilet waste to soil might increase soil permeability.



11.4. *Water Retention*

Similar to soil, sawdust materials can hold water both in the pore spaces between the particles and as a film covering on the individual particles. When water seeps into sawdust, these pore spaces will become filled with water. In accordance with Figure 3, the water retention of bio-toilet waste was 2.6 ml g^{-1}, which was around ten times greater than that of Bhaangadh Block soil. Consequently, replacing soil with bio-toilet waste would enhance the amount of water that is available in a growing medium.



11.5. *Moisture content, pH and EC*

Low airflow rates must be used to prevent drying and subsequent partial biodegradation because moisture content significantly decreased in trials when high airflow rates relative to the organic load were supplied (F/S ratios 5 and 10). In the majority of experiments, pH rose from 7.6 to more than 8 a bit. When the testing was discontinued, EC continued to rise during biodegradation, typically reaching levels close to 6 mS/cm. Other factors did not exhibit a definite tendency with regard to the variation in organic load.

12. SUMMARY

Bio-toilet treats human waste by a biological process in digester tank using high graded bacteria (aerobic or anaerobic) further converting into in methane gas, carbon dioxide gas and water. through series of steps of hydrolysis, acidogenesis, methanogenesis. Fecal matter is composed of fat, carbohydrate and protein. The bio digester technology provided in bio toilet. It makes our environment ecofriendly and secured. Mobile toilets using biotechnology are useful. The disposal process is easy and the digestion of human waste is totally different from the normal toilets. Chlorination process clean by the fecal matters using bio-toilets the cost of corrosion can be minimized.

12.1. Conclusion

Because of its high porosity (76%), low bulk density (0.19 g cm^3), high water retention (2.6 ml g^{-1}), and neutral pH, residual sawdust from bio-toilets is a beneficial soil conditioner (6.90). In comparison to Bhaangadh Block soil, which had N, P, and K concentrations of 0.05, 0.17, and 0.11% respectively, bio-toilet residue had N, P, and K contents of 1.73, 1.15, and 1.03%, respectively. The condition of the soil as a growing medium for jatropha was enhanced by mixing Bhaangadh block soil with bio-toilet residual sawdust, as shown by the increase in leaf number, leaf area, and stem diameter.

And the proposed dimension of the bio-toilet is most economical design.

13. REFERENCE:

1. *Bio Toilet information from DRDE technology (2011-12).*
2. *Handbook on IR-DRDO BIO TOILET for open line maintenance of Maharajapur, Gwalior (2007).*
3. *Handbook of the secretary, Life Sciences Research Board*
4. *Directorate of Life sciences Defense Research & Development*
5. *Del Porto, d. and Steinfeld, C.: The composting toilets system book. Centre for Ecological Pollution Prevention (CEPP). Concord Massachusetts, 1998.*
6. *Kitsui, T. and Terazawa, M.: Environmentally friendly toilets for the 21st century, bio toilets (ST; Dry closet: DC). Page 120-121.in proceeding of 10th international symposium on wood and pulping chemistry. Japan 1999.*
7. *Almeida M.C, Butler D. and Friedler E. (1999). At-source domestic wastewater quality. Urban Water 1, pp 49-55.*
8. *Terazawa M. (1997). Biological cleanup and recovery of organic wastes using sawdust as an artificial soil matrix. Division of Environmental Resources, Graduate School of Agriculture, Hokkaido University, Japan.*