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Analysis of Bedding Layer Material & Configurations of Tiger Toilet

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Abstract:
This paper describes the analysis of bedding layer materials of a novel on-site sanitation system, the Tiger Toilet, which is a pour-flush vermifiltration toilet for rural households. With the help of the Swachh Bharat initiative, people who were openly defecating can now use the Tiger Toilet for an improved sanitation lifestyle. The bedding layer of the toilet digester is where the worms live and where the faecal solids are trapped. Bedding layer materials were examined for two reasons: 1. to trap the maximum amount of faecal matter coming from pipe outlet and 2. To provide maximum filtration to the wastewater in bedding layer. So, with such development, it is believed that the Tiger Toilet has the potential to become a superior and low cost form of onsite sanitation technology.

Keywords: Bedding layer, Tiger Toilet, Vermifiltration

I. INTRODUCTION

A majority of the world's population has little choice in terms of on-site sanitation technology. Most rely on pit latrines, cesspits and septic tanks. A major problem associated with these systems is that they require emptying, which can be costly, inconvenient and hazardous. Approximately 200 million latrines and septic tanks worldwide must be manually emptied each year, by workers descending into the pit equipped with buckets and spades. Furthermore, the final disposal of faecal sludge by any of these methods is often simply by dumping into the immediate environment, thereby reintroducing pathogens into the environment, which were previously safely contained in the pit or tank [1] .In contrast to the traditional waste processing, vermicomposting results in two useful products- the earthworm biomass and the vermicompost.[2] New on-site sanitation technologies need to be developed which reduce the frequency of emptying and which not only contain, but also treat the waste, so that handling and disposal are safer activities. Worm-based sanitation systems ('vermifilters') may provide a solution since they can reduce the solids in the system, due to the net loss of biomass and energy when the food chain is extended. It is flushed with a water seal, thus reducing odours and flies which carry pathogens and helping to meet user aspirations for modern sanitation [1]. This approach has the potential to reduce both the frequency of emptying and the size of the sanitation system, making it particularly suitable for rural areas and peri urban areas. Furthermore, worms have the ability to reduce pathogens to the level so that the formed by-product, vermicompost, which is dry, making it easier to handle and transport. Also, research has shown that worms are able to process feces under both wet and dry condition [3]. The two processes—microbial process and vermiprocess simultaneously work in the vermifiltration. Earthworms further stimulate and accelerate microbial activity by increasing the population of soil microorganisms and also through improving aeration (by burrowing actions). Dissolved and suspended organic and inorganic solids are trapped by adsorption and stabilized through complex biodegradation processes that take place in the 'living soil' inhabited by earthworms and the aerobic microbes Earthworms intensify the organic loadings of wastewater in the vermifilter soil bed by the fact that it granulates the clay particles thus increasing the 'hydraulic conductivity' of the system. They also grind the silt and sand particles, thus giving high total specific surface area, which enhances the ability to 'adsorb' the organic and inorganic from the wastewater passing through it.[6] The 'Tiger Toilet' is an innovative flushing on-site sanitation system and it works by vermifiltration. The solids are trapped at the top of the vermifilter by the bedding layer, where the composting worms live and convert fresh faecal matter into vermicompost. Liquids filter through this layer and the drainage layer beneath and then permeate into the soil or suitable drain [1]. User satisfaction levels of Tiger Toilet were high, with 100 per cent of respondents being either very satisfied (60 per cent) or satisfied (40 per cent) with the 'Tiger Toilet'. The main reasons given were the use of worms and the lack of smells [4]. *Eisenia fetida*, commonly found around the globe, is the most effective earthworm for vermicomposting human faeces. It derives its colloquial name, the Tiger worm, from the ridges along its length. The Tiger worm can be easily raised in a facility known as a wormery, atarp filled with a mixture of soil and cow dung that provides food for the worms. It is important to raise worms in a wormery before seeding them into a Tiger toilet because they will die if subjected directly to fresh human faeces without a period of conditioning. Also study has shown that worms are capable of converting faecal sludge into vermicompost and cocoons hatch in its presence [3]. Bedding layer is a layer where worms live and helps in degradation of faecal sludge. As Earthworms body acts as a "biofilter" it plays an important role in the Tiger Toilet. This layer also acts as a primary filter media and plays an important role in restricting the faecal solids and vermicompost to enter the drainage layer. So, analysis of bedding layer materials plays an important role in enhancement of Tiger Toilet working. We want to find the best material that can trap faecal solids and vermicompost from falling through but also be compatible with worms and allow them to pass through if they need to escape something at the surface, such as high temperatures.

II. MATERIALS AND METHODS

Methodology

We have divided the research in three phases: Preparation and physical test, Lab experiments with worm and feces and Analysis of data.

Phase I – Preparation and Physical Test

1. To determine surface areas and shapes of active zones in existing digester we travel to villages to measure size of both active zones and of digester surface area. We also take photos of ideal shapes in healthy digester. From all this collected data, we determine ideal shape and size of active zone for small scale vemifilters.

2. We did background research into different materials. The materials are selected on the basis of following parameters: -

1) To trap faecal matter-

- The material should be able to trap the faecal matter.
- It should be cheap and easily available.
- The movement of worms should be possible for maximum degradation of faecal matter.

2) Filtration material-

- Material should not clog the whole system as backwashing is not allowed.
- Material should be so fine that vermicompost and faecal matter should not pass through it.
- It should be cheap, easily available.
- As worms are resting over it, so material should not be harmful to worms.

3. To find the best material to trap the faecal matter, we will use only water and vermicompost (which include control without any material). For that we build a model system with an inlet pipe delivering “flush” water at a similar flow rate to actual flushes. We will use visual observation to assess effectiveness and will select one material for further research with worms and feces.

4. To test filtration material for efficient water percolation, we determine infiltration rate of water through four different types of sands. From this experiment, we choose three types of sand for further experiment with vermicompost. In this experiment, we have decided to analyze effluent for vermicompost particles from different filtration materials set up. We will test TS and TDS of effluent water by vacuum filtration method and select two materials from results for final small scale vemifilters.

Phase II – Lab Experiments with worms and faeces

During this phase, we will set up prototypes (small scale vemifilters) in lab with selected materials for all combinations in triplicate with worms. We will observe all bins in acclimatization period which is of minimum one month duration. After acclimatization period, analysis of effluent for all required parameters like COD, BOD, pH, Turbidity, Total faecal coliform E-coli, Nitrate, TS and TDS etc will be done.

Phase III – Analysis of data

The obtained data from various tests and observations will be analyzed and compared with the influent results to get the percentage removal by system.

Details of set up of lab experiments

1) Sand Infiltration Column Test

In lab infiltration columns were constructed out of 77.5 cm tall metal sheeting, mesh fabric and tape. A column has an elliptical base measuring 14.0 x 15.5 cm. The entire column was then tightly wrapped with waterproof tape and a length of tape measure was secured to the inside of the column. Finally, 0.25 m^2 sections of mesh were secured to the base of the columns with tape. The mesh prevents the soil sample from falling out of the column and clogging the drainage bed, but its openings are large enough to permit free flow of water.[5] A heated metal pipe was used to perforate four large buckets at their base and a PVC tap was threaded through to make a drain. Then the base of the buckets was filled with 20 cm of washed gravel so that the height of the gravel was 10 cm above the outlet spigot. Water was poured through the gravel bed to confirm that the system allowed free drainage of water. The columns were then centered in the buckets and backfilled with washed gravel for stability. For Infiltration rate testing four different types of sands are used.

1) Regular Sand (River sand)
2) Sieved Crushed Rock Sand
3) Crushed Rock Sand
4) Sieved Washed Crushed Rock Sand

These tests serve to determine the infiltration rate of the sand. The test columns were filled with 0.06 m^3 of sand. The volume necessary to fill the column to a depth of 30 cm. For test the column was first saturated to create standard initial conditions. Then a graduated container was used to measure 10 L of water that was slowly added to the column in a spiral motion so as to minimize any compaction of the surface. A stopwatch was started as soon as all of the water had been added, then the water depth was recorded after every 5seconds until the surface of the sand was just glistening with water. This procedure was repeated in triplicate for each sample.

2) To trap faecal matter

To perform actual site conditions, the experiment will be set up as full scale models rather than prototype. The slope of actual pipe provided at site will be taken into consideration. The 30cm experiment set up consists of different layers and vermicompost with 5cm thick faecal matter trapping material. We select different material based on the factors like cost, possible worm movement and easy to install in site which include chicken mesh crumbled into a ball, plastic fibers crumbled into a ball, natural geotextile, aggregates, wooden chips (OR wooden shradings) etc. for set up installation. Also, control set up with no material will be installed for comparison.

3) Filtration Experiments

In filtration experiment set up we have decided to take three different layers of aggregates, filtration material, and vermicompost each of 10 cm thickness. Different materials which are selected for this experiment include Glass media or Glass beads, Regular Sand (River sand), Sieved Crushed Rock sand, Sieved washed crushed rock sand and natural geotextile.

Method to be followed during Experiment

A) For Trapping Fecal matter:

After selecting materials for experiment a full-scale model will be prepared in lab.Model’s shape & size is determined from the survey data of actual tiger toilets on the sites. The shape, surface area of active zone is collected from sites. After averaging all the relevant data dimensions of models are finalized as 90×80×30 cm. For experiment flushes of water through a pipe arrangement made with required slope is the base. Total 10 flushes each of 20 liters will be done on each model (set up). The photographs and videos will be taken to analyze the percentage of area covered by the fecal matter.

B) For Filtration Experiment:

In filtration experiment, 5 liters of water will be filtered through each system and it will be collected in a flask and measured. The test of TS and TDS with vacuum filtration will be carried out to assess if any vermicompost is coming out of the prototype set up and if it is coming them the amount should be known. After physical test, will be performed, the two best materials will be selected for trapping faecal matter and one from filtration material. Then prototypes will be set in triplicate with combination of each material. Also, control prototype will be installed for comparison.

III. RESULTS AND DISCUSSIONS

Phase I results are explained below.

3.1 Phase I results-

1) Sand infiltration column test –

During this test results were recorded after every 5 seconds and three trials for each type of sand are performed. After the analysis of the test data, it is found that sieved washed crushed rock sand is the best. Whereas crushed rock sand column gets clog due to fines present in it. Also, sieved crushed rock sand is found better than regular sand. So, for further testing of filtration material, crushed rock sand has discarded and the rest three are used. The infiltration rate of different types of sand are as shown in Table I.

IV. CONCLUSION

From sand infiltration test analysis, we conclude that Sieved washed crushed rock is best for filtration purpose and suggested for further research with worms and feces.

Table.1. Sand Infiltration Column Test Results

Sr No.	Type of Sand	Trial 1 (cm/sec)	Trial 2 (cm/sec)	Trial 3 (cm/sec)	Average (cm/sec)	Average (mm/hr)
1	Regular sand (River sand)	0.4	0.233	0.367	0.333	0.925×10^{-3}
2	Sieved crushed rock sand	1.267	1.133	1.2	1.2	3.33×10^{-3}
3	Crushed rock sand	0.013	0.04	0.033	0.0286	0.07944×10^{-3}
4	Sieved washed crushed rock sand	2	-	1.8	1.9	5.277×10^{-3}

V. REFERENCES

[1] C. Furlong., W. T. Gibson, M. R. Templeton, M. Taillade, F. Kassam, G. Crabb, R.Goodsell, J. McQuilkin, A. Oak, G. Thakar, M. Kodgire, R. Patankar (2014), The “Tiger Toilet”: From Concept to Reality, IWA specialist conference on Municipal Water Management and Sanitation in Developing Countries, AIT, Bangkok, Thailand,106-111

[2]K.Yadav, V.Tare, M.Ahammed (2011), Vermicomposting of source separated human feces by Eiseniafetida: Effect of stocking density on feed consumption rate, growth characteristics & vermicompost production, waste management 31(1162-1168).

[3] C. Furlong, W.T. Gibson, R. Patankar, S. Savant &A.Oak (2015),Faecal sludge treatment by vermifiltration: proof of concept,38th WEDC International Conference, Lough borough University, UK

[4]C. Furlong, W.T. Gibson, A. Oak, G. Thakar,M. Kodgire, and R. Patankar. (2016). Technical and user evaluation of a novelworm-based, on-site sanitation system in rural India, Practical action publishing, Loughborough University, Waterlines Vol. 35(2).

[5] E. Hylton(2016) ,The Tiger toilet: An investigation of the rate of kinetic filling and infiltration properties of a vermifiltration pit latrine, Master of Engineering Thesis, Imperial College London.

[6] Rajiv K. Sinha, Gokul Bharambe and Uday Chaudhari, "Sewage treatment by vermifiltration with synchronous treatment of sludge by earthworms: A low-cost sustainable technology over conventional systems with potential for decentralization", springer science, 2008

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