A Novel Onsite Sanitation System: The Tiger Toilet

Pooja P. Alaspure[1], Prof. Sangmesh Ghale[2]
[1] Department of Environmental Engineering
[2] Department of Civil Engineering
[1, 2] D.Y.Patil College of Engineering Akurdi, Pune, Maharashtra, India.

Abstract- *This paper gives review on the 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. This paper also focuses on the bedding layer study of Tiger toilet. 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.[2] In 2015, it was estimated that 2.4 billion people globally had no access to improved sanitation facilities. Of them, 946 million defecate in the open. Of these 564 million live in India. In rural India, where 61% of the population defecates in the open, it is practiced among all socio-economic groups. In urban India, 10% of the population practice open defecation.

From this scenario, 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. 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.

The 'Tiger Toilet' is such 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. The best part of this system is that worms are able to process faeces under both wet and dry conditions which make it more helpful in water scarcity regions.

Eiseniafetida, 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]

Partners from Imperial College London, the London School of Hygiene and Tropical Medicine, Bear Valley Ventures, the Institute for Transformative Technologies and PriMove India collaborated to bring the Tiger toilet from the prototype phase to its current successful installation in over 500 households across western India.[10] The Tiger toilet is viewed as a financially competitive, low-tech option as a part of the Swachh Bharat Abhiyan (Clean India Mission) to provide a toilet for all and end open defecation in India by

October 2019. 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'.[2] The main reasons given were the use of worms and the lack of smells.

On-site sanitation includes facilities which are self contained in collecting and treating sullage and excreta within the site. It is contrast to sewerage system where sewage is removed from the site.

Requirements of On-site sanitations are-

- Adequate space for locating toilets and leach pits
- Porous subsoil to absorb liquid content of excreta
- Groundwater at depth greater than 1.5 m from ground level.

There are various on-site sanitation technologies being used around the world like pit latrines, ventilated improved pit latrines, composting toilets, Two-pit pour flush toilet etc. The average estimate of the cost of a pit latrine by respondents was 26,000 rupees (ranging from 12,000 to 40,000 rupees) and a septic tank was 48,000 rupees (ranging from 40,000 to 60,000 rupees).The cost of the Tiger Toilet was estimated to be on average 21,000 rupees(ranging from 15,000 to 30,000) [8].Thus Tiger Toilet proves as an innovative on-site sanitation system, is an affordable, compact, long-lasting and low-maintenance solution using composting worms('Tiger worms', Eisenia fetida).

II. LITERATURE REVIEW

Furlong et.al.(2014) [2] , describes the journey of a novel onsite sanitation system "Tiger Toilet" which is based on the wet vermifiltration. Lab experiments and field trials which prove the principle of faecal waste treatment are explained in this paper. The lab experiments are performed at the Centre for Alternative Technology (CAT), Wales. Two lab-based experiments were undertaken to explore specific design criteria such as system configuration, feed distribution, worm density and water loading. Lab Experiment 1 suggests that in these vermifilters the treatment of effluent is through the separation of faecal matter by the bedding layer, rather than through subsequent treatment/filtration in the drainage layer(s) or additional bedding layer. Lab Experiment 2 indicates that the worms have a preference for wetter systems compared to dryer systems. After lab experiments, Field trials are done in India. Ten 'Tiger Toilets' are set in rural villages approximately 60 km in Pune in Maharashtra state. The permeation rates of the soil in this village ranged from 0.4-26 mm/seconds. All ten vermifilters were monitored weekly using structured observations and interviews. Influent and Effluent samples were taken monthly and analyzed for COD and Thermotolerant coliforms. The results gained in the field are broadly consistent with the lab-scale and first prototype data and show that the field vermifilters had been working well for over six months.

Furlong et. al. (2015 b) [3] , gives explanation of experiments and assesses the potential of the technology named as Tiger Toilet. The study is carried out to determine the ability of composting worms to digest faecal sludge, to explore the key factors which may affect sludge processing such as worm density and to determine the volume and pathogen reduction which occurs during the conversion to vermicompost. For this experiment, eighteen cylindrical plastic vermifilters were constructed in the lab and feed amount varies from two to eight liters. The total volume of sludge added was 62 liters. From the experiment it is concluded that no undigested sludge was recovered from vermifilters. Also 1 kg of sludge was converted into 0.2 kg of vermicompost (dry weight). The experiment shows that the conditions generated in the system are able to reduce faecal coliforms and remove Ascaris spp eggs. During the experiment effluent quality was measured only once. Removal efficiencies of TS 90-93%, COD 89-94 %, FC 90-99.9 %, Ascaris spp 85-98% was achieved.

Furlong et. al. (2016) [4] , studied technical performance and user acceptance of Tiger Toilet is explained in detail. The Tiger Toilets which were installed in rural India was tested for over 12 months. Technical parameters which were monitored over this period included: usage, temperature, accumulation of faecal matter and vermicompost, presence of worms, and influent and effluent quality.The mean temperature across the systems over the six months was 30°C. The vermifilters were found to be cooler during the day, when they were in use, and hotter at night when unused. After 12 months the depth of the vermicompost varied between 1 cm and 9 cm (mean = 4 cm). As the area of the vermifilters is 1.1 m2, this means between 11 and 99 kg (mean = 44 kg) of vermicompost were generated in one year. Total solids reduction was consistently high across the systems. The effluent infiltrated into the soil and further treatment may occur through the action of soil microorganisms. Also sludge mass reduction is occurred due to the bioconversion to vermicompost. From this frequency of emptying is estimated as once every five years. Also the result from the paper shows that effluent quality in terms of COD, thermotolerant coli-forms, and total solids was improved significantly by this system. Survey results shows that user satisfaction level with the system is high.

Yadav et. al. (2011) [7] , describe the study of vermicomposting toilets with different layer combinations of faeces, soil and vermicompost. In the Experiment 1 and 2, SVFV combination (Soil- vermicompost- Faeces-vermicompost; bottom to top layers) was used whereas in experiment 3, VFV combination (vermicompost- faeces-vermicompost; bottom to top layers) was preferred. Experiment 1 was performed with an objective to determine optimum stocking density for feed consumption rate. Feed consumption rate in kg-feed/kg-worm/day was estimated by determining the weekly change in feed quantity and dividing it by earthworm biomass weight. Earthworm biomass growth was taken as the increase in total live earthworm biomass collected from the vermicompost. The number of cocoons produced was also counted at the end of the vermicomposting process. Total weight of cast was estimated on a weekly basis and the daily cast production rate was calculated based on the weekly cast production. Experiment 2 was carried out with an objective to assess the optimum stocking density for earthworm biomass growth and reproduction Initial stocking density is an important parameter affecting the biomass growth rate and vermicompost production rate. For bioconversion of faeces into earthworm biomass, a stocking density of 0.50 kg/m2 was found to be optimum. Higher stocking density values resulted in reduction in earthworm number, weight of individual earthworm and cocoons production rate.

Sinha et. al. (2008) [9] , explains treatment technology of verrmifiltration. They also gives brief explanation on earthworm study, earthworm's ability of ecological adaptation for survival in harsh environment, its power of reproduction and rapid rate of multiplication, behavioral studies. The mechanism of worm action in vermifiltration system of sewage is explained in detail in this paper. 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.

Mudziwapasi et. al. (2016) [11] , assesses the potential synchronous treatment and detoxification of raw sewage during small-scale vermifiltration. A pilot small-scale bioreactor was packed with the worm, Eisenia fetida, in a static black-soil medium. It was operated at a hydraulic loading rate of 0.193 m3/m2/h and a hydraulic retention time of 0.481 hr. Average removal efficiencies for BOD5 and TSS of 90.6% and 98.4% respectively were recorded after vermifiltration. Also it was found that the vermifilter was more efficient than the negative control in pollutant removal. But there was no statistically significant difference between the negative control and the vermifilter in the reduction of total coliforms and faecal coliforms. Results indicate that COD, turbidity, TDS, TSS, and BOD5 have a close association and major influence on reducing acute toxicity. The high reduction in toxicity, BOD5 and TSS in vermifiltration of raw sewage indicate the success and potential of vermifiltration in clarification, detoxification and biological treatment of raw sewage.

Ngo et. al. (2016) [6] , In the chapter," Value added product from the sludge" author gives special attention to the production of value-added bioproducts from wastewater sludge for the purposes of not only producing sustainable and environmentally friendly products but also solving waste disposal problems. Authors explain all the previous studies which are carried out using different types of earthworms for waste disposal. It is found that in all treatments, during the final stages of the process, when the earthworm population was bigger and more active, important reductions in organic nitrogen content and a high nitrification happened. This implies that earthworms are able to modify conditions, resulting in the rapid conversion of ammonium into nitrates.

Sinha et. al. (2010) [10] , focuses on different earthworm species suitable for vermifiltration of waste water, critical factors affecting vermifiltration of wastewater and advantages of vermi-filtration technology over conventional wastewater treatment. During the study, they have successfully experimented in vermicomposting of 'MSW', vermifiltration of 'municipal & industrial wastewater', vermiremediation of chemically contaminated soils' and production of 'cereal & vegetables crops' with amazing results. Wastes are degraded by over 75% faster, BOD and TDSS of wastewater is reduced by over 95% and growths of crop plants are enhanced by 30–40% higher over chemical fertilizers.

Hylton (2016) [5] , studies the technical parameters of Tiger toilet system. The objective of her research is to determine the rate of kinetic filling of vermicompost and thus estimate the time to fill of the Tiger toilet, to develop a methodology that can be applied to large-scale monitoring of kinetic fill rate data and also Gain a better understanding of the infiltration rate through the Tiger toilet media. Based on this research, it is estimated that, cuboid pits require emptying every 5.9 ± 0.2 years and cylindrical pits require emptying every 8.2 ± 0.6 years. She concluded that, as more data is collected, a more accurate model may be a sinusoidal curve with a quadratic trend to characterize both the seasonal changes and the overall increasing fill rate.

III. MATERIALS AND METHODS

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 faeces.

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 [1] 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.

IV. EXPECTED RESULTS

During this research, two best materials will be selected from results of Phase I to trap fecal matter and one material for efficient filtration. In phase II, effluent analysis results of small scale vermifilters give the suitable material for both the cases comparing all biological parameters.

V. CONCLUSION

The ‘Tiger Toilet’ is such an innovative flushing on-site sanitation system and it works by vermifiltration. This technology is also a recent development in the field of sanitation which uses earthworm. Furthermore, worms have the ability to reduce pathogens and they form dry by-product, vermicompost which is easy and safe to handle, transport and dispose. Hence this technology is environment friendly and cost effective.

VI. ACKNOWLEDGEMENTS

This work will not have been possible without the support of the team at PriMove India of Tiger Toilet project and their invaluable partners providing assistance with planning and execution of the field work. I am extremely thankful to Ajeet Oak, Rohit R. Patankar, Gauri Thakar and Suvarna Savant from Primove Infrastructure and development consultants Pvt.Ltd. for their continuous guidance, support, encouragement and valuable contribution in accomplishment of this project work. Special thanks go to Walter Gibson of Bear Valley Ventures and Dr. Roger Sathre of the Institute for Transformative Technologies for acting as experts during the development of the research objectives. I extend my gratitude towards Michela Catena of the ITT (Institute for transformative technologies). Thank you for her valuable contribution.

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