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The rate of vermi-compost accumulation within ‘Tiger Toilets’ in India

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Abstract: Tiger Toilets use a worm-based ecosystem to degrade human waste and have recently been demonstrated as a cost-effective innovation in on-site sanitation. The benefits over traditional pit latrines include slower fill rate, fewer odours, and safer emptying. However, a question remains around how to measure the rate of accumulation of vermi-compost and predict the fill rate into the future. In this study, fifteen Tiger Toilets of varying installation ages in the villages of Jejuri, Bhalgudi and Walhe/Adachiwadi, in Maharashtra province, India were investigated to determine the rate of filling. A laser measure was used to define cross-sections of the depth to vermi-compost layers within the Tiger Toilet digesters. Bench-scale column tests were used to estimate liquid infiltration rates from the digesters into the surrounding soils. Changes over time in the interior digester conditions were photographed and a video camera was installed in selected digesters to confirm and observe the worm activity *in situ* under red light. Calculated fill rates of the Tiger Toilets were significantly lower compared to estimated fill rates of traditional pit latrines of a similar size and usage rate. The infiltration of the liquid fraction of the waste into the surrounding soil was observed to be a key factor in filling.

Keywords: On-site sanitation; vermifiltration; sustainability; vermi-compost, tiger worms

1. Introduction

Pit latrines are the primary means of on-site sanitation for an estimated 1.8 billion of the world's population [1]. Traditional pit latrines have several shortcomings: they eventually fill; they may emit odours associated with wet sludge and its anaerobic degradation; there may be hazardous exposure of sanitation workers to pathogens during the emptying of the latrine; and there are environmental and public health impacts of waste disposal [2,3]. The process of emptying pits is not only hazardous to users and the environment but can also be costly for users [4]. Furthermore, pits may leach pathogens and chemical contaminants into groundwater used for drinking water [5].

The Tiger Toilet was developed to address these concerns [6,7]. It involves using worms (tiger worms, *Eisenia fetida*) to transform faecal matter into vermi-compost and an effluent liquid that is treated to an environmentally safer standard than that from traditional pit latrines. The vermi-compost is a dry, odourless, non-pathogenic solid that accumulates within the

digester below the toilet, whilst the effluent liquid is able to drain into the surrounding soils. Vermifiltration has been shown to be effective when implemented on a large scale. For example, in China, worms have been used to treat wastewater and sewage [8,9,10], and to continuously treat wet sludge at the village scale [11]. However, Furlong et al. [6] were the first to show that tiger worms could effectively degrade human faeces in a continuous, flushed system for use in an onsite, household-scale sanitation system. The vermifiltration design was improved during the pilot phases of technology development by testing different bedding layers, worm masses, feed rates and feed methods to make for simpler construction and reduced cost. Since its conception in 2013, over four thousand Tiger Toilets have been constructed in both rural and peri-urban communities across India.

In previous vermifiltration research studies, a 98.65% reduction in faecal coliforms over a 24-hour period was found [12] and field tests found significant removal of chemical oxygen demand (COD), thermotolerant coliforms and total solids from the effluent [13]. Tiger Toilets are also highly efficient at reducing the solid fraction of the waste; in a day, earthworms can eat their body weight in waste and their castings are reduced 50% by weight and 40–60% by volume [14]. Indeed, earthworms in constructed wetlands have been shown to help prevent clogging [15].

A number of methods have been devised to estimate the fill rate of traditional pit latrines using mass balance models [16,17,18] which have suggested that water flow into and out of the latrines as well as disposal of solid waste and faecal material affect the fill rate. However, this is the first study to investigate the fill rates of Tiger Toilets.

The objectives of this study were to determine the rate of filling of the Tiger Toilets that have been in use by households in Maharashtra province, India for up to three years; to gain a better understanding of the liquid infiltration rate through the digester into the soil; to directly observe the feeding patterns of the worms; and to gain a better understanding of their activity within the digesters.

2. Materials and methods

2.1 Site selection and study area

-- Insert Figure 1----

The following criteria were considered in the study site selection: (i) age of the Tiger Toilet – to gather data for toilets of a range of ages to allow for the rate of accumulation to be estimated and the filling time to be extrapolated; (ii) location – for logistical reasons, to maximise the time at each location and minimise the travel distance; (iii) design – both older masonry designs and the newer concrete designs were assessed to allow for both filling times to be evaluated and to collect data from the oldest available Tiger Toilets; and (iv) willingness of the Tiger Toilet owners to participate in the research.

The three experimental sites and one control site selected in Maharashtra province are shown in Figure 1. Adachiwadi (Walhe), located 62 km from Pune, is the location of the original trial Tiger Toilets, with 31 Tiger Toilets which had been in use for over two years at the time of the study; Bhalgudi, a rural settlement less than 45 km from Pune with over 35 Tiger Toilets that had been in operation for over a year; and Jejuri, a peri-urban settlement located 49 km from Pune had 169 Tiger Toilets that had been functioning for approximately two months. A fourth location, Velhe, which is a rural settlement less than 45 km from Pune, was selected as

a control and had two newly constructed Tiger Toilets.

2.2 Description of the Tiger Toilet

The original Tiger Toilet digester design used in India was circular and constructed out of brick while the updated design is cuboid and comprised of eight pre-cast concrete slabs which correspond to the vertical walls (Figure 2), with holes to allow for hydraulic connection with the surrounding soil [19]. The bottom consists of a boulder layer directly connected to the soil (bedrock). Data from both designs were used in this study.

The Tiger Toilet consists of an enclosed concrete superstructure with a latched door and a porcelain, squat toilet pan connected to a PVC pipe with a U-bend that empties into a specially engineered vermi-filtration digester (Tiger Digester) [19]. Ready access to water is important because the Tiger Toilet is a wet system that operates linked to a pour-flush system. The U-bend creates a water seal that prevents odours and insects from moving between the digester and the superstructure. To create the digester, drainage layers made of graded media are installed, then a biomedial layer is added on top and seeded with tiger worms (Figure 2). The digester provides an ideal habitat for the tiger worms and facilitates liquid infiltration. Further information on the typical construction of Tiger Toilets can be found in Oxfam's recent design manual [20].

-- Insert Figure 2----

The digesters were all charged in January and February in the years of their construction, and this allowed for easier comparison between the toilets by removing the confounding factor of the seasonal variations in fill rate that could be created by water entering a toilet in the monsoon season. Maharashtra experiences its monsoon season from June to September, when the region receives most of the 468 – 4659 mm/year of average rainfall [21,22]. The temperature conditions are favourable to the mesophilic tiger worm, as the mean temperature range is from 12 – 39 °C [21].

2.3 Sampling

2.3.1 Estimating the fill rate

The bedding depth above the graded media layer was used to estimate the fill rate. At the initiation stage, the depth in the digester was comprised of a layer of biomedial seeded with tiger worms [6,7]. Over the subsequent months and years, vermi-compost accumulated from the breakdown of faecal matter. To estimate the fill rate of the Tiger Toilet and the infiltration rate of the surrounding soil, the following data were collected onsite: the surface area of the digester; the depths to the vermi-compost surface and to the top of the aggregate layer; soil samples surrounding the Tiger Toilet [13]; and a survey of the toilet owner, to gather information including the number of users of the Tiger Toilet. Crude farming implements were used to remove the heavy concrete slabs that seal the digesters. A UA40A laser measure was used to measure the depth to the surface of the vermi-compost and to the aggregate layer [18] and a

standard tape measure was used to measure the surface dimensions of the digester.

2.3.2 Depth measurements

Two measurements were used to determine the depth of the bedding layer: the depth to the vermi-compost surface and the depth to the aggregate layer. Depth measurements were taken from directly above the point of interest using the top of the digester as a datum. To measure the depth to the aggregate layer, a stick was used to uncover the graded media in two locations near the edge of the digester, taking care not to disturb any worms. For the depth to the vermi-compost, measurements were taken from multiple points instead of a single point to reduce error from the uneven surface of the vermi-compost. The measurements from different points with the laser measure were averaged to determine the depth to the aggregate layer and bedding depth [18]. Once data collection was complete, the digester was resealed after ensuring that the two concrete slabs were completely flushed to avoid rainwater inflows. The use of the laser prevented direct contact with faeces in the digester and allowed for faster and less cumbersome data collection.

-- Insert Table 1----

At each of the three villages, depth measurements were collected from five Tiger Toilet digesters (Table 1), first in the dry season (March) and again in the monsoon season (July) to determine if the rate of fill changes seasonally. This is especially relevant given the importance of water inflows on the fill rate. The data collected was used to determine the average volume of vermi-compost and to estimate the fill rate. At each digester, a photo was taken from above the inlet pipe to provide evidence of the range of observed ecological and physical states of the digester.

2.3.3 Digester surface dimensions

For the cuboid designs, an 11x11 grid provided sufficient granularity to characterize the surface of the 84 cm x 84 cm cuboid concrete designs (Figure 3). To create the grid, two tape measures were anchored around the edge of the digester and a third was used to span the digester (as shown in Figure 2 image 4). The points of interest (every 8.4 cm) were marked on the tape measures with labelled masking tape to speed the process of data collection and avoid errors in the placement of the laser measure.

-- Insert Figure 3----

The cylindrical, red brick digesters have a diameter of 125 cm. Thus, an arch length of 49.1 cm divides it into eight equal segments. A cut string of that length was used to mark the circumference. The numbered points were marked (Figure 3). To create the grid, a tape measure was used to span the digester across each numbered axis. The points of interest (every 12.5 cm) were marked on the tape measure. This method provided the most granular coverage near the centre of the digester where the most worm activity occurs and where it was also assumed would correspond to the greatest variation in bedding depth from the rest of the digester.

2.3.4 Soil sample collection and Infiltration testing

Fifteen medium-sized buckets were labelled with a site ID (village and pit number). A simple farming hoe was used to collect a soil sample near each Tiger Toilet. The top 10 cm of vegetation and soil were removed before collecting a sample of at least 0.06 m³, which was the volume necessary to conduct the column infiltration test on a column with an elliptical base measuring 14.0 cm x 15.5 cm. Once complete, the surface was smoothed as much as possible to ensure that the resulting hole would not create a hazard for pedestrians. All samples were taken in areas that were not frequented by foot traffic.

Two infiltration tests were completed according to standard method ASTM D3385 [23]. The first used 30 cm of soil alone and the second used a 'mock digester' created by adding 10 cm layers each of washed gravel, river sand, and vermi-compost on top of the soil layer. The layers were scaled approximations of the drainage and bedding layers of a functioning Tiger Toilet. These tests served to determine the infiltration rate of the soil and to investigate if the soil is the limiting infiltration layer for the Tiger Toilet. For both tests, the column was first saturated to create standardized initial conditions. One litre of water was then slowly added to the column in a spiral motion to minimize any compaction of the surface. A stopwatch was started as soon as all the water had been added, and the water depth was recorded every minute until the surface of the soil or vermi-compost was glistening with water. This procedure was repeated in triplicate for each sample. The soil-only and mock digester infiltration tests were both completed with the same soil sample.

2.3.5 In situ video imaging of worm activity

One Tiger Toilet digester was selected for filming due to its visually healthy vermi-compost layer, proximity to a power source, and willingness of the property owner to participate in this part of the study. A small 'DBPower' camera with 170° lens, 12 Megapixels and 1080p equipped with Wi-Fi was used to record the active faecal area within the digester while in operation. The Wi-Fi allowed for the camera's image to be reviewed with the use of a smartphone application. Two red and one white standard 10W household lightbulbs were used to ensure that the images captured had enough exposure. The bulbs were hung from the lid of the digester approximately 20 cm above the digester's surface. The red light was used to remove a significant portion of white light and still illuminate the surface, such that the worms were not deterred by photosensitivity [24].

The camera was set up to record for at least two-hour periods, taking a photo every 11 seconds, resulting in at least 650 frames. One period was recorded overnight. The images were converted into video format at one frame per second using GoPro Studio video editing software. The footage was reviewed and the observations of sludge influent and rate of the worms digesting newly introduced waste were analysed using the time recorder of the video. The users were advised to continue to use the toilet as they would normally, to allow for the imaging to best represent the typical processes inside the digester. These images gave a good indication of the degradation rates within the digester, and informed hypotheses about how the rate may change over time as the digesters age.

2.3.6 Informal discussions with users

An informal survey was conducted with each toilet owner to determine the number of users, understand toilet usage habits and identify any problems with the functioning of the Tiger Toilet that they had observed to-date.

2.3.7 Modelling and validation

Each of the depth-to-vermi-compost measurements recorded for the digesters were modelled in MATLAB fitting linear, quadratic, cubic and thin plate spline interpolations to the data and plotting them for comparison. These fits were then validated with the use of MATLABs Curve Fitting Toolbox and the validation data collected from each of the sample sites.

For the purposes of this study, toilets were considered to be ‘full’ when the vermi-compost reached a depth of 45 cm above the aggregate layer, yielding effective full volumes shown in Table 2. For each digester, the two depth-to-aggregate measurements (one in the centre and one near the edge of the pit) were averaged to determine the depth of the aggregate layer. The average of all depth-to-vermi-compost measurements for each digester ($N = 121$ for cuboid and $N = 44$ for cylindrical) was used to calculate the volume of vermi-compost.

-- Insert Table 2----

-- Insert Figure 4----

Each of the depth-to-vermi-compost measurements recorded was used to create a contour plot using the surf function in MATLAB as shown in Figure 4. The plot was set to have the bedrock layer at $(x, y, 0)$ so that the integration along the x- and y-axis produced the volume of the digester contents. To increase the accuracy of the plots, the data was fitted using linear, quadratic, cubic and thin plate spline interpolations in MATLAB built functions and plotted for inspection and comparison. The accuracy of the fits was validated using the Root Mean Square Deviation (RMSD) and the Residual Sum of Squares (SSE). These were then output into Microsoft Excel, and the model with the best fit was selected. Subsequently the volume of the digester was evaluated with the ‘quad2d’ function, which made it possible to evaluate the accuracy of the initial estimations.

The associated systematic and random errors were determined to interpret and contextualise the calculated volumes of vermi-compost. For dimensions of the digester, ± 0.5 cm was assumed. The UA40A laser measure has a reported manufacturer’s systematic error of ± 0.15 cm. Length of Depth Measurement was ± 1.1 cm errors associated with the angle of the laser measurement. The maximum deviation from vertical was taken as 3° , to account for the difficulty in keeping the laser measure vertical while leaning over the digester to take measurements. Error in depth of vermi-compost was calculated as ± 2.3 cm in total. The systematic error on the calculated volumes of vermi-compost ranged from 25-32%.

3. Results

3.1 Determining the trend in fill rate

The linear, quadratic and exponential trend lines were fit to a plot of digester age (in years, x-axis) against the calculated volume of vermi-compost (in m^3 , y-axis) to determine the pattern of fill as shown in Table 3. The y-intercept and the R^2 values were used to measure the fit. The

y-intercepts are fairly similar and provide reasonable representations of the initial volume of vermi-compost present in the bedding layer when the digester was seeded with worms.

-- Insert Table 3----

The exponential fit had the lowest R^2 value of 0.34, followed by the linear model with an R^2 value of 0.38. The linear model estimated that the cylindrical design could have taken 26 years to fill, which is more than twice the time period predicted by the exponential model. Previous studies suggest this fill rate is unlikely. Furlong et al. [6] previously reported that the faeces from ten people over the course of a year yielded between 79-130 kg of vermi-compost. This yield was scaled for the average number of toilet users in this study (3.5). Even with factoring in secondary degradation and the outflow of soluble by-products of vermi-composting, 26 years is outside the range of a reasonable prediction for time to fill based on observations to-date.

Thus, the quadratic fit had the maximum predicted R^2 , providing the most robust and physically-justified estimate of the fill pattern. Mays and Hunt [25] reported a transition to quadratic dependence observed for severe clogging in porous media across data from six studies representing 43 experiments. Conceptually, it is also expected that soil pores around a digester will clog over time, reducing the rate of infiltration and increasing the fill rate.

-- Insert Figure 5----

Using the quadratic trend line to predict fill rate, the cuboid design is expected to fill in 5.9 ± 0.2 years and the cylindrical design in 8.2 ± 0.6 years as shown in Figure 5. As the trend line is fit based on the combined data for all the cuboid and cylindrical designs, the maximum headroom is taken as a constant. The difference in time to fill between the two designs is likely due to the difference in total surface area of each design rather than fundamental differences in the worm activity within the two designs.

Since the time to fill depends on the size of the digester, it is a design variable. Fill time can be extended by increasing either headspace height or cross-sectional area. The key point is that the fill rate is lower, so regardless of the size, the time to fill will be longer than an equivalent pit latrine. The time to fill for the cuboid design is more than double the 2.8 years predicted for a similarly sized traditional pit latrine, and the cylindrical design will operate almost 3 times as long as a traditional pit latrine before emptying is required [26].

3.2 Infiltration rates

The soil-only and mock pit infiltration tests were both completed with the same soil sample. The null hypothesis stated that: The mean of the time to drain 1L of water for the soil-only infiltration test is equal to the mean of the time to drain 1L of water for the mock pit infiltration test. From Table 4, all of the p-values were greater than the α value of 0.05, thus the null hypothesis failed. This result supports the alternative hypothesis that the soil is the limiting drainage layer on the Tiger toilet.

-- Insert Table 4----

The average infiltration rate was 0.95 mm/min for soil only and 1.73 mm/min for the 'mock digester'. Furlong et al. [13] selected sites for the Tiger Toilet field trials based on soil percolation rates of < 25 seconds/mm or > 2.4 mm/second using British Standards Institution code [27]. However, all of the measured infiltration rates for this study were under this standard by at least an order of magnitude. When the Tiger Toilet was used at one digester prior to data collection, standing water from the 5 L flush was still visible after 1.5 hours of data collection. This evidence does not in itself confirm the validity of the experimental infiltration rates, but it indicates that the results of the experimental infiltration rates seem reasonable. If the area directly under the inlet pipe of the digester remains saturated for extended periods when the Tiger Toilet is in operation, the spatial distribution of the tiger worms could be affected. Additionally, the accumulation of vermi-compost over time could change the liquid infiltration rate.

3.3 User survey information

Each user reported using the Tiger Toilet an average of two times per day, using 5-15 L of water per flush. An additional inflow of 5-15 L of water was added twice a week when the toilet was cleaned with ash. These results indicate that anywhere from 300-1080 L of water was entering the digesters each week from flushing. On average, 84 L of water entered the digester each day. Results from the infiltration tests on the soil samples show an average infiltration rate of 0.95 mm/min. From this, the daily infiltration capacity of the cuboid design is 966 L and the cylindrical design is 1678 L. Thus the digesters would be expected to be dry as the limiting layer is capable of infiltrating all of the influent water. However, the fact that many digesters were damp or even close to saturation indicates that the *in situ* infiltration rate is significantly lower than that found in the experimental tests. Some of these observations in the field were made during or post monsoon, when the surrounding soil may well have been wet, and this could have been a factor in reducing the *in situ* infiltration rate at this time of year. Overall, the users were very positive about the Tiger Toilets, understood the benefit of using worms and appreciated especially the reduced smell compared to traditional pit latrines.

3.4 Imaging of worm activity

The camera imaging confirmed that the worms rapidly emerge in large numbers to consume the newly introduced waste material, before returning below the surface (Figure 6). Worms were found in high density surrounding the influent pipe. The worms appeared to feed mainly from the sides and beneath the faeces rather than the top. Other creatures - large cockroaches, spiders and small bugs - were also observed in the digester.

-- Insert Figure 6----

3.5 Limitations of the study

Soil samples were only taken at a depth of 10 cm due to labour and safety constraints. It is possible that the geology and thus hydraulic properties change with depth, but this could not

be measured in this study.

Assumptions were made that all digesters in a village would experience similar fill rates due to similar climate, soil properties, wildlife, diets and lifestyles. All Tiger Toilets in a given village are located within 400 meters of each other and the living standard is fairly homogenous in each location.

It was difficult to effectively track the number of users, though this is also a challenge with studying the fill rates of traditional pit latrines.

The systematic error on the calculated volumes of vermi-compost when using all of the collected data points ranged from 25-32%. This uncertainty has implications for the determination of the volume of vermi-compost and thus the fill rate, as reflected in the uncertainty bounds on the fill times reported above.

4. Discussion

Conceptually, a quadratic fill rate fits well with current knowledge of the dynamics of the Tiger Toilet. Over the first year, the infiltration rate through the digester is at its maximum; the drainage layers are observed to be relatively undisturbed and there are limited obstructions inhibiting the flow of water through the digester. Over time, the soil pores and drainage layers become increasingly clogged by vermi-compost and the soluble by-products of biodegradation of organic matter [14,28]. These phenomena will reduce the infiltration rate over time, leading to a more rapid fill rate [18]. The trend may be more accurately characterized as a sinusoidal function that follows a quadratic trend, capturing the increase and decrease in the fill rate over the change in seasons (as water ingress rates vary with rainfall) as well as the overall upward trend in the total volume of vermi-compost.

These results provide further evidence of the importance of understanding water flow through the digesters, as these data indicate that the monsoon season can slow or even temporarily reverse the fill rate. Despite the Tiger Toilets in Bhalgudi being 10 months older than those in Jejuri, the average volume of vermi-compost was lower. This phenomenon is likely attributed to the fact that Bhalgudi lies in a lush valley that experiences heavy rainfall and significant overland flow during the monsoon season. Tiger worms prefer a moist environment, but they will drown if there is too much water. Furthermore, Todman, et al. [18] found that pit latrines with a watery top layer tended to have a faster fill rate. Thus reducing the quantity of standing water in the pits, e.g. by improving drainage, should be an area for future design improvements.

Overall, it is estimated on average that the fill rate of Tiger Toilets is approximately one-half to one-third of the rate of a traditional pit latrine of equivalent size and with the same number of users, though limited data were available for the latter and this comparison is based on fill values for pit latrines reported in the literature [26]. In addition to the less frequent need for emptying, it is also crucial to emphasise that the material that is filling in the Tiger Toilets is mainly vermi-compost, not faecal sludge, thus the emptying of Tiger Toilets when full would be a much safer process.

5. Conclusions

This study provides evidence that vermifiltration toilets such as the Tiger Toilets have significantly reduced fill rates compared to traditional pit latrines. Liquid infiltration rate is a key factor influencing the fill rate and this will change over time as the soil pores become

clogged with vermi-compost. The worms consume newly introduced waste rapidly and hence reduce odours. The projected fill rate from this study fits with the conceptual understanding of the fill rate increasing over time due to vermi-compost clogging the soil pores around the digester. Based on this fill rate estimation and the toilet usage conditions considered in this study, it is suggested that the cuboid design will require emptying every 6 years and the cylindrical design will require emptying every 8 years.

As more data is collected with older Tiger Toilets, an updated model may be able to better characterize the overall increasing fill rate. It is recommended that large scale monitoring of selected Tiger Toilets should be completed every 4 months to include data from the dry, monsoon and post-monsoon seasons. Overall, the Tiger Toilet is recommended as a low cost, onsite sanitation option for use at the household scale in the developing world. This study will help to inform in-country policy makers on decisions for promoting appropriate, affordable, sustainable and equitable on-site sanitation.

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Conflicts of interest

There are no conflicts of interest to declare.

Data availability statement

The data that support the findings of this study are available from the corresponding author, [MNS], upon reasonable request.

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Figure 1. Map showing data collection sites in Maharashtra province, India: Bhalgudi, Jejuri, Adachiwadi (Walhe) and Velhe [source: Google maps]

Figure 2. From left to right: The creation of a Tiger Toilet digester (image 1-3); positioning of tape measures around the digester (image 4); and a complete Tiger Toilet with adjoining superstructure (image 5)

Figure 3. Location of data collection points for cuboid design (left) and cylindrical design (right)

Figure 4. Example of a fill depth contour plot from cross-sectional laser measurements for a cuboid and a cylindrical Tiger Toilet design

Figure 5. Projected quadratic trend line illustrating the projected time to fill and adjusted for average number of toilet users (3.5) in this study

Figure 6. *In situ* monitoring of worm activity in a Tiger Toilet digester

Figure 1

Figure 2

Figure 5

Figure 6

Table 1. Description of data collection sites and number of Tiger Toilets sampled

Site (Number)	Age in March [years]	Age in July [years]	Tiger Toilet Shape	Construction Material	Distance from Pune [km]	Type of Settlement
Jejuri (n = 5)	0.17	0.58	Cuboid	Concrete	49	Peri-urban
Bhalgudi (n = 5)	1.00	1.42	Cuboid	Concrete	45	Rural
Adachiwadi (n = 5)	2.00	2.42	Cylindrical	Red brick	62	Peri-urban

Table 2. Calculation of the effective volume of the cuboid and cylindrical Tiger Toilet designs

	Maximum Head Room (m)	Surface Area (m ²)	Effective Volume (m ³)
Cuboid design	0.450	0.706	0.318
Cylindrical design	0.450	1.227	0.552

Table 3. Measures of goodness of fit and predicted times to fill for each trend line. 'x' is the age of the toilet in years, and 'y' is the volume of vermi-compost in m³ (n = 30)

Type of Trend Line	Fitted Equation	R ² Value	y-intercept	Time to fill in years (cuboid pit)	Time to fill in years (cylindrical pit)	Probability (p) of occurrence (%)
Linear	$y = 0.0185x + 0.0556$	0.38	0.0556	13.9	26.8	50
Quadratic	$y = 0.0075x^2 - 0.0011x + 0.0638$	0.41	0.0638	5.9	8.2	75
Exponential	$y = 0.058e^{0.2121x}$	0.34	0.0580	7.9	10.6	25

Table 4. Measures of average infiltration for soil only and mock pit

Site	Ave Infiltration Rate [mm/min] Soil only	Ave Infiltration Rate [mm/min] Mock Pit	Soil v. Mock Pit Two Tailed Paired T-Test	
			α	P-value
Jejuri (Cuboid)	0.98	1.32	0.05	0.40
Bhalgudi (Cuboid)	0.63	0.76	0.05	0.81
Adachiwadi (Cylindrical)	1.18	2.00	0.05	0.16