PIT LATRINE ADDITIVES: LABORATORY AND FIELD TRIALS

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Pit latrines are on-site sanitation systems for accumulation and stabilization of faecal matter, urine and probably some other materials added to the system over a certain period of time. However, the process of anaerobic decomposition of materials in pit latrines is slow, resulting into build up of organic waste, odour production and fly nuisance which could pose significant risks to public health and the environment. There are various claims from suppliers and manufacturers that the use of bio-additives for the treatment of sludge content from pit latrines reduces the bulk of the sludge content in the pits. Field and laboratory trials were undertaken with two different bio-additives. In the field trials, the rate of accumulation was estimated from the distance between the pedestal and the surface of the pit contents while in the laboratory trials, the effect of the bio-additives on mass loss from pit latrine contents was investigated. In both cases, treatment with bioadditives was compared to treatment with water only, and to comparative experiments with no intervention. In both trials, the bio-additives had no beneficial effect on either the accumulation rate, or the rate of mass loss.

INTRODUCTION

In South Africa, apart from management of household solid waste and sludge produced from waste water treatment works, the country is presently faced with problems related to proper management of sludge content from various pit latrines spread around the country. In eThekwini Municipality alone, over 100,000 pit latrines can be found within the municipality’s boundaries and many of these pits are full. The municipality has proposed various options to handle sludge content when these pits are full such as discharge of sludge to main sewers, sea outfalls, waste water treatment works, burial onsite, disposal at landfill sites, agroforestry, further dewatering and treatment and/or processing to produce agricultural fertilizer.

Apart from all these options proposed to handle sludge content from pits when they become full, there is an ongoing argument that Bio-additives (microbe or enzymes-based products) can reduce or reverse sludge accumulation in pit latrines by enhancing the biological activities taking place in the pit latrine. Various suppliers of Bio-additives claim that sludge volumes or accumulation rate of sludge within the pit latrine can be reduce considerably when Bio-additives are added to pit contents thereby reducing the frequency of emptying. This has motivated research into the accumulation rate in pits and the effects of Bio-additives on sludge accumulation rate in pit latrines.
Foxon et al [1] reviewed the literature for scientific studies into the use of bio-additives with faecal sludges, and concluded that, while it was apparent that some of the commercial bio-additives are capable of metabolising within a faecal sludge, there was no independent evidence that suggested that these products could actually control sludge accumulation rates in pit latrines. Foxon et al. [1] conducted laboratory-scale trials in which the effect of bio-additives on mass loss from laboratory-scale samples of pit latrine sludge was investigated. This study found that there was no significant difference between the rate of mass loss from faecal sludge as a result of auto-digestion (biological activity due to the existence of micro-organisms naturally present in the sludge) and the rate of mass loss when samples had been treated with a bio-additive. Foxon et al [1] proposed that the failure of bio-additives to accelerate sludge digestion was due to the fact that the amount of active micro-organism added in a dose of bio-additive was insignificant compared to the amount of micro-organisms naturally present in the sludge. However, data was not presented to support this hypothesis.

While the 2009 study convincingly demonstrated that accelerated mass loss through sludge digestion was not achieved by adding bio-additives at the prescribed dosage rate in laboratory experiments, it was felt by a number of players in the industry that the laboratory study did not adequately represent the conditions that may be found in a pit latrine. In this study, field trials and laboratory trials were undertaken on two different commercial bioadditives to determine whether the two types of measurement gave similar results and to determine whether the bio-additives show promise in the management of sludge accumulation rate.

MATERIALS AND METHODS

Part a: laboratory trials
The laboratory trials followed the same methodology as presented in [1]. A sample of VIP contents, sampled from the surface of the pit beneath the pit pedestal, was mixed and divided into sub-samples of known mass (approximately 300 g each) that were placed in 300 mL screw-top honey jars. The experiment was divided into different treatments, i.e. with different additives and reference treatments.

For additive treatments, bio-additive treatment rate was determined as mass (or volume) additive per surface area of the pit [g/m²] based on the manufacturers recommended dosage, and the same dosing rate was applied to the smaller surface area of the honey jars. Tests were performed in three or five replicates. Two reference treatments (or controls) were included for comparative purposes: (i) no addition of water or chemicals (control); (ii) addition of water (water reference).

The honey jars were incubated for 30 days at approximately constant temperature in a humidity-controlled fume cupboard and the mass of each jar was recorded with time. These data were used to determine the rate of mass loss from each jar as a result of biological activity in the jar. Mass loss due to dehydration may also have occurred, but was limited by maintaining a high relative humidity in the fume cupboard and thus reducing the driving force for evaporation. The mass loss data was used to determine the rate of mass loss from each sample for each measurement period.
Part b: Field trials

Thirty pit latrines were selected from a community within eThekwini municipality. The same two bio-additives as used in the laboratory trial were used in the field trial. Since all the additive suppliers suggest that the sludge contents in pits should be adequately wet and if it is known that any chemical or substances has been added to the sludge in the pits, water must be added before the treatment commences. All pits except the pits in which placebo was used was flushed with water (20 ℓ) to neutralize the effect of whatever substances/chemicals that as been added to the pit previously and to erase the effect of water on the shape /level of sludge originally present in the pit.

Each bio-additive type was tested on 8 pit latrines selected randomly from the test community, making up a total of 16 pit latrines that had additive treatments. For these 16 pits, additives were dosed to the pits according to the manufacturers instructions (Table 1). The remaining 14 pit latrines served as reference and control experiments; Since it was advised that bio-additives be added with water to the pits, the reference experiment aimed to isolate the effect of adding water to pit contents on the sludge accumulation rate. In these pits, 10 ℓ of water was added to each of the 7 reference pits on a weekly basis. The remaining 7 pits were not subjected to any treatment. Each of these 4 types of treatment were randomly allocated to the 30 pits on a geographical basis to reduce the probability that any differences could be attributed to geographical differences. A summary of the different treatments is presented in Table 2.

<table>
<thead>
<tr>
<th>Table 1: Pit latrine dosing schedule for the field trials</th>
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<tbody>
<tr>
<td>Additive</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
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<table>
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<tr>
<th>Table 2: Allocation of treatments to 30 experimental pit latrines</th>
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</thead>
<tbody>
<tr>
<td>Pit Number</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>1-8</td>
</tr>
<tr>
<td>9-16</td>
</tr>
<tr>
<td>17-23</td>
</tr>
<tr>
<td>24-30</td>
</tr>
</tbody>
</table>

The rate of pit sludge accumulation was determined by taking three measurements of distance between the pedestal and pit surface for three locations directly under the pedestal using a laser distance measure. (i.e. three measurements within an area of 0.06 m²). These measurements were averaged to give an indication of the distance between the top of the sludge heap and the pedestal. These measurements were repeated after a 3 month interval, and the difference in sludge heap height was calculated as an indication of sludge accumulation rate.
Pit latrine sludge contents
The material composition of any particular pit will include faeces, urine and cleansing materials. It is impossible to predict the material composition of any particular pit without physically observing what is in the pit or digging out the contents of the pit since many households make use of the pit for different purposes; either for their basic sanitation needs or for both their sanitation needs and storage of solid refuse. Hence, depending on the user habits, a large variety of materials in addition to faeces such as newspaper, magazines, broken glass, bottles, rags, plastic bags, and a range of other household waste materials could be found in the pit. It has been widely documented that the wide variety of materials which are discarded into pits have a detrimental effect on the efficiency of the degradation processes taking place in the pit and could also enhance the rate in which sludge accumulates in pit latrine [2,3,4,5].

According to Still [4], about 10 to 20% of the material composition in a pit can be made up of non-degradable materials; this value may be lower or higher depending on the household habits. Hence, it is expected that there will be a considerable variation in the organic contents, moisture content, non-biodegradable content and micro-organism population of different pits. The amount of biodegradable or non-biodegradable material present in a pit latrine will therefore determine the efficacy of any Bio-Additive added to sludge contents in the pit latrine.

Bio-additive description
The two product used are identified as product A and Product B. According to the supplier, product A was described as a concentrated bacterial powder for use as a waste digest ant in septic systems, VIP toilets (pit latrines), grease traps, drain lines, food processing plants and for similar waste and odour control problems. Product A has the following characteristics as stated by the suppliers;

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
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<tbody>
<tr>
<td>Total bacterial count</td>
<td>5 billion cfu/g</td>
</tr>
<tr>
<td>Appearance</td>
<td>Tan, free flowing powder</td>
</tr>
<tr>
<td>Odour</td>
<td>Yeast-like</td>
</tr>
<tr>
<td>pH</td>
<td>Neutral</td>
</tr>
<tr>
<td>Effective pH range</td>
<td>5.5-10.5</td>
</tr>
<tr>
<td>Effective Temperature Range</td>
<td>7-60°C</td>
</tr>
</tbody>
</table>

There was no definite description given by the suppliers for product B but the product was brownish in colour and the suppliers stated the benefits of this product as follows:
- Elimination of bad odours at pit toilets
- Remove flies and insects
- Stop spreading of diseases from the sewage
- Reduce solids level
- Sewage decomposed to compost.

Figure 1 shows the preparation of the bio-additive before application to the pit was done.
RESULTS

Part A: Laboratory trial
For each of the treatments, consecutive mass measurements on a particular honey jar were used to calculate the mass lost from the jar over the period between the two measurements. Thus for each replicate within a treatment, their were between 2 and 5 pseudo-replicate of mass loss rate, and for each treatment there were a number of replicate experiments. The mass loss data for each replicate with each treatment were plotted against time, and it was found that there was no systematic change in the mass loss rate with time during the 30 days of these experiments. The rate of mass loss was then averaged for each treatment and 95% confidence intervals on the mean were calculated. The results are presented graphically in Figure 2. It can be

![Graph showing rate of mass loss from honey-jar samples of pit latrine sludge subject to different treatments.](image)

Figure 2: Box and whisker plot showing rate of mass loss from honey-jar samples of pit latrine sludge subject to different treatments. The box for each data set represents the range of the 95% confidence interval on the mean, while the whisker shows maxima and minima from within each data set.
Figure 2 indicates that while there is significant variation in the measurement of mass loss rate in these experiments, there is no significant difference between the rate of mass loss for each of the 4 treatments. Consequently, this data is in agreement with the conclusions of [1] that bioadditives do not enhance the rate of solids loss through biodegradation over naturally mediated autodigestion.

Part B: Field trials
This study is not complete at the time of writing this paper and thus only two points in time were obtained for each pit. These points were used to calculate a change in height over a 3 month period. The results are depicted in Figure 3.

Figure 3: change in height of pit latrine contents over a period of 3 months for treatment with two additives (A and B), with water only (C) and with no treatment. Low values (below 0) indicate a net reduction in the height of the pit latrine contents, while higher values (above 0) indicate that the sludge contents are accumulating.

Figure 3 shows a net decrease in pit contents height over the first 3 months of the experiment. However the changes observed are mostly small – close to the tolerance of the laser distance meter under field conditions. It is profoundly interesting to observe that the reference treatment, where only water was added to experiments showed a systematic decrease in pit contents height, and ANOVA showed that in all cases the net change in height values were significantly different for pts treated with water than for any of the other three treatments.

These results suggest that the bio-additives do not bring about a reduction of pit contents. However, it is proposed that some reduction in sludge accumulation rate (and in the amount of sludge accumulated) can be achieved by the addition of water alone. These data do not show whether the apparent reduction in pit latrine contents volume was due to flattening of the pit contents through the addition of water, such that the overall reduction in volume was negligible, or through enhanced biodegradation rates as a result of the addition of water. What the data do show is that there is no apparent reduction in the rate or volume of pit latrine sludge as a result of treatment with bioadditives.

DISCUSSION
Two different types of test were carried out to test the efficacy of bio-additives for controlling sludge accumulation rates, on a laboratory scale and in the field. In both
cases, there was no significant reduction in sludge accumulation rate due to treatment with commercial bio-additives. However, the data suggest that a lowering in the height or in the rate of height increase in a VIP pit may be achieved by the addition of water, either by washing away soluble components or by improving conditions for sludge degradation by increasing the moisture content of the sludge.

The result that adding water can increase the rate of degradation was not observed in the laboratory trial. This implies that the decrease in sludge level in the field trial due to the addition of water (or water and bio-additive) can probably not be explained completely by increasing biodegradation rates at the higher moisture content since this explanation would result in higher mass loss rates in the laboratory scale experiment. Instead, flattening of the surface by pouring water onto the highest part of the pile and increased leaching from the pit may play a part in the apparent reduction (and reversal) of sludge accumulation inferred by Figure 3.

Owners of the pits for all four treatments were regularly questioned about their experience of their pits during the trial. Pit owners did not know what treatment had been applied to their pits. Most pit owners reported that bad smells and fly problems were reduced as a result of the treatments, but this was also true for the reference pits where water was added, and those where nothing was added!

CONCLUSIONS

The aim of the study was to investigate the effect of bio-additive on pit latrine sludge content. According to the manufacturers of these bio-additives, these additives are capable of reducing bulk sludge contents in the pit latrine. The results of this study did not provide any evidence that bio-additives can reduce sludge accumulation rate. Rather, the data indicate that addition of water may have an effect in controlling sludge accumulation rate, although this result was not seen in the laboratory tests.

ACKNOWLEDGEMENTS

The authors wish to thank the eThekwini municipality and the community for their assistance. This work was funded by the Water research Commission and eThekwini Water and Sanitation Services.

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