DO PIT ADDITIVES WORK?

Studies conducted by the Water Research Commission to date indicate that products marketed to slow or halt the filling of pit latrines do not work. A fifth of South African municipalities indicate that they purchase additives as part of their sanitation management programme. A typical additive treatment costs up to three times as much (R20-35/month) as manually emptying a pit over a 5 year cycle (R500-R1,500). If an additive does not effectively reduce the rate at which pits fill, the cost of dosing pits with these products has no benefit, and reduces the available municipal resources available for effective pit sludge management through mechanical emptying of the pit.

What are pit additives?

There is a large potential market for commercial pit latrine additives consisting of packaged micro-organisms and/or enzymes that are understood to assist in biological degradation processes in pit latrines. These products are marketed on their purported ability to either reduce the pit filling rate, or to actually decrease the volume of material in the pit. Some products also claim to reduce odour and insect problems.

Table 1 gives a list of claims supporting the use of pit latrine additives; these include accelerated sludge breakdown, accelerated removal of pathogenic micro-organisms, destruction of odour-causing components, degradation of specific sludge components, elimination of fly larvae, and changing pit conditions to promote sludge breakdown. Until recently, there was virtually no reliable scientific literature on the subject.

A series of WRC projects have tested a wide selection of pit latrine additives on pit sludge under a range of field and laboratory conditions. None of these studies have indicated that the additives make any difference to the rate at which sludge accumulates in the pit latrine, or to the odour or fly problems of the pit latrine.

What controls pit filling rates?

The filling rate is determined by the difference between how fast material is added to the pit and how fast degraded by-products leave the pit, which is in turn controlled by the rate at which solids are broken down to liquid and gas products by biodegradation processes. The filling rate can be calculated as:

filling rate = addition rate – biodegradation rate

Therefore, in order to decrease the filling rate, either the amount of material added must be decreased, or the biodegradation rate must be increased.

Material entering the pit: addition rate

A single adult produces approximately 110 ℓ of faeces and 440 ℓ of urine per year. Added to this volume is anal cleansing material – toilet paper, newspaper or other materials. If municipalities do not provide reliable solid waste collection, the pit latrine is also likely to be used for disposal of household rubbish. Thus, a single adult could add between 600 and 800 ℓ of faeces, urine, anal cleansing material and rubbish to the pit each year or 160 to 360ℓ of solids per year.

Faeces and kitchen waste constitute the main biodegradable components in the pit sludge. Faecal matter itself is made up bacterial cells constituting between 40 and 60% dry mass or up to 80% of wet mass of fresh faeces (Stephen and Cummings, 1980; Carboje et al., 1990) although many of these are not active.

Material exiting the pit

As material accumulates in a pit, micro-organisms from the sludge and the soil break the sludge down into gases, liquids and inorganic matter. The gases escape from the pit into the air and liquid leaches into the surrounding soil, transporting dissolved components (acids, ammonia, soluble organic material) with it.

Where oxygen is present in the pit – usually on the sludge surface and to a limited extent in the upper reaches of the soil around the walls of the pit (blue zone in Fig. 1) – aerobic micro-organisms metabolise available biodegradable material from faeces and kitchen waste, converting it to more bacterial cell matter and soluble and gaseous by-products. Dead bacterial and human intestinal cells are also a food source for active bacteria, although not all components of a cell are biodegradable.

The bulk of the pit contents are anaerobic since oxygen cannot penetrate into the sludge. (Orange zone in Fig. 1)

Anaerobic micro-organisms operate in this region: these micro-organisms break down organic material in the absence of oxygen to end-products of CO_2 and methane and some soluble intermediate products. These micro-organisms metabolise slowly. A significant amount of breakdown occurs aerobically while sludge is exposed to air on the surface of the pit. Below the surface, slow biodegradation occurs until the material is completely stabilised.

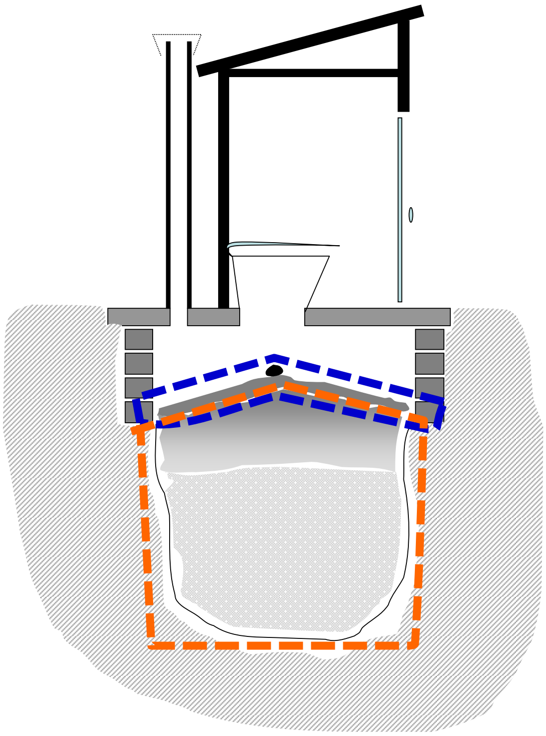

Figure 1: Zones of aerobic digestion (blue) and anaerobic digestion (orange) in the pit

Thus material exits the pit through the leaching of urine and other liquid components through the walls and base of the pit and as gaseous CO_2 and methane as a result of biological activity.

Filling rate = materials in – materials out

Of the 600ℓ or more of material per householder per year added to the pit (of which 160ℓ or more are solid), measurements on real pits indicate that only 20 to 60ℓ of pit sludge eventually accumulate. An average pit fills at a rate of 200 - 500 ℓ per year, depending on the number of users, and the volume of rubbish disposed of in the pit. Thus between 63% and 94% of material added to a pit eventually disappears as a result of natural processes, depending on how much of the material is biodegradable.

How efficiently and rapidly these processes take place depends on factors such as temperature, pH, moisture and oxygen. Fungi, maggots, and other organisms also play a role in helping material break down. Cleaning products and insecticides applied to control breeding of flies may kill micro-organisms in the pit and impede the rate of degradation. There will always be some material which cannot degrade and as long as the pit is in use this will continue to accumulate until the pit is full.

Have any additives been proven to reduce filling rate?

The Water Research Commission has tested 20 different additives currently on the market in South Africa but none has been found to have a statistically significant effect on the degradation of sludge.

Laboratory trials

Two batches of laboratory trials were undertaken between 2007 and 2010. In the first trial, 11 additives were tested and 2 additives were tested in the second trial. In each trial, samples of VIP sludge were taken from the surface of the pit beneath the pit pedestal and were dosed at the rate indicated by the manufacturer. There were two control treatments: one in which only water was added, and one in which nothing was added.

Figure 2: Laboratory trial of two pit additives

The jars were incubated for 30 days at approximately constant temperature and the rate of mass loss as a result of biological activity in the jar was monitored.

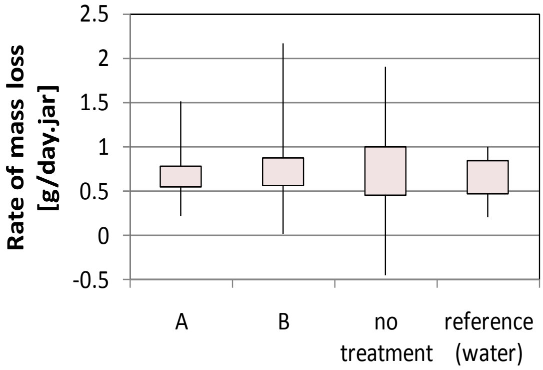

Figure 3: Box and whisker plot of mass loss rate showing 95% confidence region (box) and min and max values (whisker)

Significant mass loss was observed in all treatments. This was due to natural processes, not to the additives.

Field trials

A field trial was conducted in 2009/2010, consisting of 30 pits divided into 4 treatments: two additives (A and B); a reference group to study the effect of adding 10ℓ water to pit contents weekly; and a control group that did not receive any treatment.

Measurements were taken at 0, 3 and 6 months using a laser distance measure. These measurements were repeated at 3 and then 6 month intervals, and the difference in the height of the sludge heap was calculated to determine the sludge accumulation rate. There was no significant difference in sludge accumulation rates between the two additive treatments and the group dosed only with water.

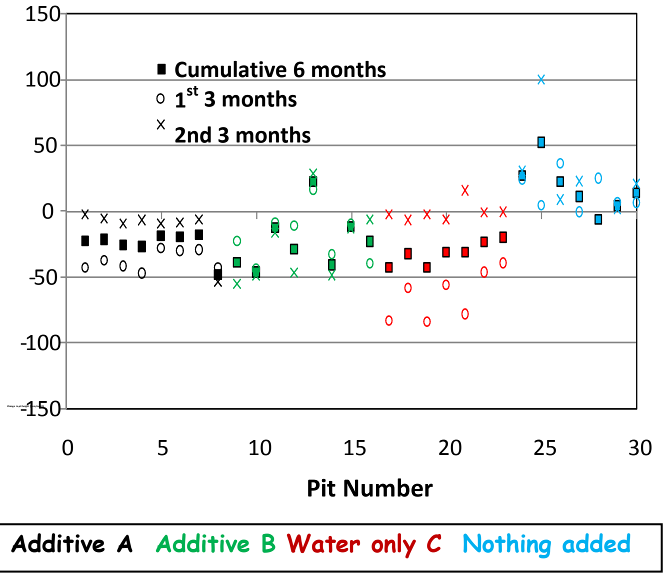

Figure 4: Sludge height in pits treated with one of two additives or water and controls measured at 3 month intervals

The group of pits that served as the control (nothing added) seemed to experience higher accumulation rates (Fig. 4). However, it was proven that the apparently reduced filling rates of the additive and water treatments was due to flattening of the sludge heap as a result of constant water addition.

In a field trial on a different pit additive in 2010, similar results were obtained; filling rates were measured for pits treated with an additive, coloured water, molasses and water or nothing for 16 weeks. For the first 8 weeks, the additive was dosed at the rate specified by the manufacturer; thereafter, it was dosed at double the recommended rate. There was no difference in accumulation rate between treatments (Fig. 5).

While all users in the first three treatment groups indicated that there had been a reduction in odour since the start of the trial, the researcher found at least two latrines with bad odours in each group, suggesting that user feedback may sometimes reflect what the user wishes to be true, what the user believes about the product, or what the user believes the researcher wishes to hear, rather than the reality.

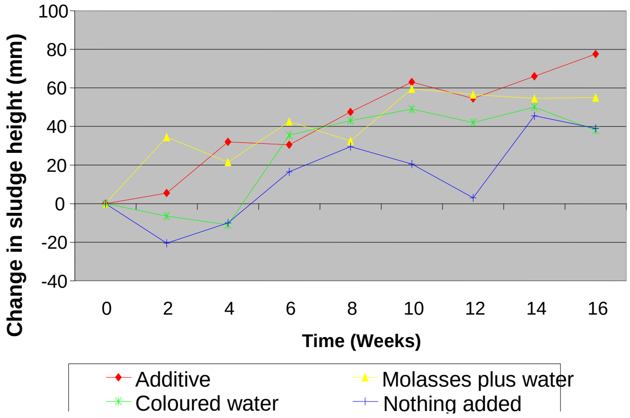

Figure 5: Changes in sludge height in pits treated with additive and control groups over 16 weeks

Similar results have been found in an independent study (Redhouse, 2001, cited in Carter and Byers, 2006).

How can the effectiveness of pit additives be verified before they are put on the market?

South Africa does not yet have an independent standards board for testing new additives that come on the market. This means that when a manufacturer puts a product on the market which claims to reduce pit contents, this has not been verified. An independent standards board with a standardised laboratory test protocol is needed in South Africa in order to assess each new pit additive that comes onto the market to determine whether it has any effect on pit contents and under what conditions. Legislation is also needed to prevent sellers of pit additives from making unsubstantiated claims about their products.

The future of pit additives

To date, no additives have been proven effective and the presence of the necessary bacteria in the pit already suggests that it is unlikely that an additive will ever enhance processes already happening in typical pits in a significant way. However, the biology and dynamics of pits are complex, and should a product be developed which significantly impacts the filling rate of pits, it would be of enormous significance, reducing the costs and health risks associated with manual pit emptying.

Myth busting – why pit additives don't work

The assumption driving the development of pit additives is that digestion is not already occurring as efficiently as it could be in the pit. But pits already contain many of the micro-organisms needed to break down sludge and these metabolise the sludge naturally to the extent that the conditions of the pit allow. Additives that are dosed to the pit will be limited by the same conditions experienced by the micro-organisms originating from faeces or the surrounding soil.

The main reason why pit additives do not change the pit filling rate is that *the quantity of bacteria introduced to the pit by dosing additives is insignificant compared to the number already present in the faecal sludge*. Similarly, while some additives operate on the logic of adding more nutrients to the sludge to feed bacteria and encourage their growth, faecal sludge is already rich in nutrients.

Table 1: Claims made for pit latrine additives, and the reasons why these are not true.

Claim	Reality
Products contain micro-organisms that can biologically break down the material in the pit to harmless compost products and or CO_2 and water.	The amount added in a dose of pit additive will be many millions of times smaller than the amount of active micro-organisms already in the pit.
Nutrients present in the additive ensure optimal growth conditions for micro-organisms to break down pit contents.	Pit sludge has no nutrient limitation; all nutrients required to sustain microbial life (nitrogen, phosphorus, potassium etc.) are present in excess of the growth requirement of micro-organisms.
Chemicals or biochemical additives stimulate the micro-organisms in the pit to break down pit sludge faster.	Micro-organisms work as fast as they can in any given system. There is no chemical or biochemical product that will alter the system, i.e. pit conditions such that the general conditions are more conducive to rapid growth.
Addition of aerobic micro-organisms create aerobic conditions in the pit that result in rapid degradation.	A system is aerobic or anaerobic depending on how much oxygen is present, NOT on how many oxygen-utilising micro-organisms are present. Addition of aerobic micro-organisms does not add extra oxygen!
Accelerated breakdown of pit sludge prevents fly larvae from growing in the pit sludge.	There is no evidence of accelerated sludge breakdown. However, even if there were, this would not prevent flies from laying eggs in the top layers were fresh material is constantly being added.
Addition of non-pathogenic bacteria in the sludge out-compete and in fact eat disease-causing pathogenic micro-organisms in the pit sludge, rendering it safe.	Pathogenic micro-organisms bacteria and viruses usually do not survive outside of their host (the human) for an extended period, especially under pit conditions. The major health hazard of pit sludge that has been in the ground for an extended period is helminth (worm) eggs. These have been shown to be able to survive conditions in pit latrines for periods exceeding 10 years and are impervious to pit additives.
Odours are reduced as a result of accelerated sludge breakdown.	In all the research undertaken as part of the WRC projects, researchers did not notice any reduction in odour, even when householders claimed that odours were less.

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