Modelling the filling rate of pit latrines

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ABSTRACT

Excreta (faeces and urine) that are deposited into a pit latrine are subject to biodegradation, which substantially reduces the volume that remains. On the other hand, other matter that is not biodegradable usually finds its way into pit latrines. The net filling rate is thus dependent on both the rate of addition of material and its composition. A simple material balance model is presented which represents the faecal sludge as a mixture of biodegradable organic material, un-biodegradable organic material and inorganic material. Measurements made on 2 pits in eThekwini, South Africa, were used to determine parameters for the model. Model predictions were then compared with data from 15 other pits in the same area and filling rate data from previous South African studies, which exhibit a 20th to 80th percentile range of 200 to 453 $\ell \cdot pit^{-1} \cdot yr^{-1}$. These comparisons indicated that the pits studied exhibited relatively low filling rates resulting from orderly disposal practices. The average composition of the pit (COD, biodegradable material and inorganic fraction) changes with age, which will impact on any subsequent sludge treatment process. Pit filling rates are greatly affected by the disposal of solid waste in addition to the faecal material. For the pits studied, the model predicts that the filling time could have been extended from 15 years to over 25 years if all solid waste had been excluded from the pit.

Keywords: Pit latrine, filling rate, biodegradation, solid waste disposal

INTRODUCTION

eThekwini Water and Sanitation are responsible for the provision of sanitation services in Durban. After the formation of the Municipality in 1999, about 60 000 ventilated improved pit (VIP) latrines were inherited from the incorporated local entities. The VIPs in eThekwini are lined single-pits and include the four necessities of a VIP: a pit 1.5 m deep (or deeper), a foundation and cover slab, a superstructure and a vent pipe with a fly screen (Mara, 1984). After sewerage reticulation had been extended to a number of residential areas and a more formal survey undertaken, it was found that there were 45 000 VIP latrines that had reached or were reaching the end of their service life, in that they were completely full. By June 2011, all 45 000 VIP pits had been emptied and were once again fully serviceable. A solid waste collection and removal service has been implemented. It is now proposed to empty all the VIPs on a 5-year cycle. In the initial round of emptying, the average age of the pit was approximately 14 years, and many of the pits were fill or overflowing and in urgent need of emptying. The municipality proposed that a 5-year cycle should be used for emptying since this was possible from an organisational point of view, and most pits are expected to require more than 5 years to fill. In addition, 5 years is the amount of time that a standard pit servicing an average family (5.5 people per household) will receive a volume of material equal to the holding volume of pit; or, in other words, the average pit will fill completely in 5 years if no degradation of pit contents occurs. The cost of emptying a pit, depending on removal method, content disposal location, accessibility of pit, and terrain, ranges between ZAR 300 and ZAR 1 250 per pit (Still and Foxon, 2012a). The cost of pit emptying is more closely aligned to the number of pits emptied than to the volume of pits emptied; thus, from an economic point of view, a better understanding of pit filling rates would assist in more cost-effective design of the pit emptying programme.

The four main processes in a VIP are: the filling of the pit, the transfer of water into and out of the pit, biological transformations, and pathogen die-off (Buckley et al., 2008). The pit contains a range of substances, including faeces, urine, anal cleansing material, and general solid waste. The contents of a VIP have an aerobic surface layer, but anaerobic conditions prevail in deeper layers. Thus the exposed surface of pit contents, especially newly added material, will be subject to aerobic biological processes. As the pit contents are covered over and oxygen supply is limited, conditions in the pit become anaerobic, and anaerobic biological processes dominate. The amount of time faecal sludge spends under aerobic conditions depends on the rate at which material is added to the pit, and pit dimensions (Buckley et al., 2008). Sludge accumulation in VIPs and strategies for emptying full pits were the subjects of a recent comprehensive research programme (Still and Foxon, 2012a,b; Still and O'Riordan, 2012).

MATERIALS AND METHODS

Overview

A simple material-balance model of the filling and degradation processes occurring in a pit latrine was developed, and compared with field measurements. The model considers the material found in a pit to be divided into two main categories: the so-called 'fine sludge' is that portion that is visually approximately homogeneous, with a maximum particle size of about 1 mm; and a component made up of un-biodegradable household 'coarse refuse' that has a much larger particle size, i.e., plastic bags, discarded cloth and other household detritus. Since no biological transformations occur in the coarse refuse fraction, it accumulates with time in the pit and therefore can

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