Waste Management 33 (2013) 2204–2210

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Hygienic quality of faeces treated in urine diverting vermicomposting toilets

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ARTICLE INFO

Article history:
Received 14 May 2013
Accepted 1 July 2013
Available online 6 August 2013

Keywords:
Fertiliser
Hygiene
On-site sanitation
Sanitisation
Urine diverting toilet
Vermicomposting

ABSTRACT

On-site sanitation solutions have gained much interest in recent years. One such solution is the urine diverting vermicomposting toilet (UDVT). This study evaluated the hygienic quality of the composted material in six UDVTs in operation in France. Samples were taken from three sampling positions in each toilet, with increasing distance from the fresh material. The concentration of *Salmonella* spp., *Enterococcus* spp., thermotolarent coliforms and coliphages were analysed and plotted against a number of variables. The variables found to have the greatest impact was the pH (for *Enterococcus* spp. and thermotolarent coliforms (TTC)) and time since last maintenance (coliphages). The pH was found to correlate with the material maturity. The current practise of maintenance can cause recontamination of the stabilised material and increase the risk of regrowth of pathogenic microorganisms. A modification in the maintenance procedure, in which a fourth maturation point is introduced, would eliminate this risk. UDVTs were found to be a good on-site sanitation option as the maintenance requirement is small and the system effectively reduced odour and concentration of pathogen and indicator organisms in human waste while keeping the accumulation of material down to a minimum. If the vermicompost is to be used for crops consumed raw, an additional sanitisation step is recommended.

1. Introduction

Sanitation is defined as the collection and treatment of human excreta to ensure the well-being of the individuals of a community (Group, 1987). The coverage of improved sanitation is high in high-income countries; toilet wastewater is treated centrally at treatment plants, so-called off-site sanitation, run by the municipality. In remote areas and in summer cottages the coverage of municipal sanitation is not as complete and on-site sanitation solutions are often practised (Lebersorger et al., 2011). The situation worldwide is very different: 1.2 billion people lack access to sanitation, the vast majority of these people live in low- and middle-income countries (UNICEF/WHO, 2012). The development of improved sanitation in these areas will most likely be on-site decentralised sanitation solutions and not the centralised solutions that have dominated the development in sanitation technology in high-income countries for half a century (Massoud et al., 2009). On-site sanitation systems can be very simple or more technologically complex (Franceys et al., 1992). Commonly available on-site sanitation systems today are composting latrines and urine diverting dry toilets (UUDT). The treatment of the collected fraction vary with system, it can be composted, stored, burned or treated in a small treatment plant (Strauss et al., 1997; Kavanagh, 2005). In some of these systems the collected fraction is viewed as waste that has to be collected in order to prevent environmental pollution and ensure the health of the community (Cilimburg et al., 2000), while it in other systems is viewed as a resource that can be used for food production if handled appropriately (Jönsson et al., 2008).

One way of treating the solid fraction from UDDTs (faeces and toilet paper) is by composting. The composting can be accelerated by the action of worms. Epigeic earthworms facilitates microbial decomposition by fragmenting the waste mechanically, maintaining aerobic conditions and changing the biochemical properties of the material (Loehr et al., 1985). The final material is highly porous with greatly improved water holding capacities and nutrients in forms readily available to plants (Dominguez, 2010). The most commonly used earthworm species in vermicomposting are *Eisenia foetida*, *Eisenia andrei* and *Dendrobaena veneta*, used because of their short life cycles, high reproduction rate, tolerance to a wide range of temperatures and endurance of handling (Dominguez and Edwards, 2010). In a vermicomposting toilet, the urine has to be diverted as the worms are highly sensitive to ammonia and inorganic salts (Dominguez and Edwards, 2011), thus the system can be defined as a urine diverting vermicomposting toilet (UDVT).

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http://dx.doi.org/10.1016/j.wasman.2013.07.007

The vermicomposting technology has been explored on a wide variety of organic wastes, including sewage sludge, municipal waste, pig and cow manure and human excrement (Dominguez et al., 2000; Aalok et al., 2008; Aira et al., 2002; Contreras-Ramos et al., 2005; Yadav et al., 2010). Buzie-Fru (2010) demonstrated the feasibility of using the vermicomposting technology as treatment of source separated faeces. In his thesis he developed and tested a continuous single chamber vermicomposting toilet. He found that optimal conditions for vermicomposting of faeces was at a moisture content of 65–80% at 20–25 °C, achieving 50–80% reduction in organic carbon after 96 days of treatment.

The main question with UDVTs is whether the processed material, aside from being stabilised, also can be considered hygienically safe. Numerous reports demonstrate the capacity of vermicomposting systems to inactivate Enterobacteriaceae, such as *Salmonella* spp., *Escherichia coli* and *Shigella* spp. (Contreras-Ramos et al., 2005; Monroy et al., 2009; Kumar and Shweta, 2011). However, opinions differ whether vermicomposting has the ability to destroy or inactivate parasites such as the intestinal worm *Ascaris* spp. (Eastman et al., 2001; Bowman et al., 2006; Hill et al., 2013), while little is known about its effect on viruses.

In this study, the hygienic quality of human waste treated in UDVTs – employing epigeic earthworm *Eisenia foetida* – that had been in operation between two and five years, was investigated. The concentrations of *Salmonella* spp., *Enterococcus* spp., thermotolarent coliforms and naturally occurring coliphages (used as indicator for animal viruses), as well as physico-chemical parameters, were analysed.

2. Materials and methods

2.1. UDVT system set-up

A schematic representation of the UDVT systems evaluated in this study is displayed in Fig. 1. The urine is diverted and infiltrated in the ground. The faeces and toilet paper land on a pedal operated conveyour belt and is transported to a back chamber where it is dropped and accumulated at the drop point (pos 1, Fig. 1). Approximately 1 m from the drop point (centre to centre), a bed of straw is laid (pos 3, Fig. 1; $\sim 1 \times 1$ m), into which around 2000 earthworms of species *Eisenia foetida* are placed at the time of installation. The installed earthworms, as well as the ones naturally present on the outside, can move freely in and out of pos 3. The number of worms is thus not constant but depend on the amount of material and condition (temperature, moisture level, pH, NH_3 concentration *etc.*) at pos 3. When necessary the material accumulated at the drop point is manually moved onto pos 3. The relocation of material from pos 1 to pos 3 is referred to as *maintenance*. The frequency of maintenance is not regulated but occur when the operator deem necessary. Roughly estimated, around 100–200 kg is relocated from pos 1 to pos 3 at maintenance, which occurs once or twice yearly, although less frequent maintenance occur at toilets with lower yearly number of users (once every two years). The worms present at pos 3 consume the organic material and thereby accelerate the decomposition. Pos 2 is the position between the drop point and the vermicompost and was selected in order to investigate whether a gradient in the concentration of pathogens and indicator organisms could be established.

2.2. Sampling sites

Six vermicomposting toilets, in operation between two and six years, were sampled. The different toilets were named site 1–6. The toilets were situated at altitudes between 200 and 2000 m above mean sea level (AMSL). Time since last maintenance (TSLM) varied between 100 and 720 days. Details of the sampled toilets are available in Supplementary material.

2.3. Sampling

Three random grab samples were collected from each position (1, 2 and 3), in total 9 samples per toilet. The material was collected in 50 mL centrifuge tubes (approximately 20–30 g per sample) and kept in a cooler until analysis, which occurred within a week of sampling. One replicate per sample was analysed for each parameter.

2.4. Microbial analysis

One gram of material was dispersed into 9 mL buffered 0.9% NaCl peptone water with 0.1% surfactant Tween 80 (pH 7) and further diluted to 10^{-5} of original concentration in the same buffer.

2.4.1. Salmonella spp.

The concentration of *Salm.* spp. was determined by most probable number (MPN) method using a three tube set-up. For the pre-enrichment, one gram of material was dispersed into 9 mL buffered peptone water and incubated at 37 °C for 17–18 h. Three plates of the selective medium Semisolid Rappaport–Vassiliadis (MSRV) were used for each dilution for the MPN analysis. Three drops of the pre-enrichment solution were inoculated onto the MSRV plate using a 10 µL inoculation loop. The plates were inoculated at 41.5 °C for 17 h. A grey-white, turbid zone around the drops indicate positive results. Positive results were confirmed with xylose lysine desoxycholate agar (XLD) plates (Oxoid AB, Sweden) containing 0.15% sodium-novobiocin. XLD plates were incubated at 37 °C for 24 h.

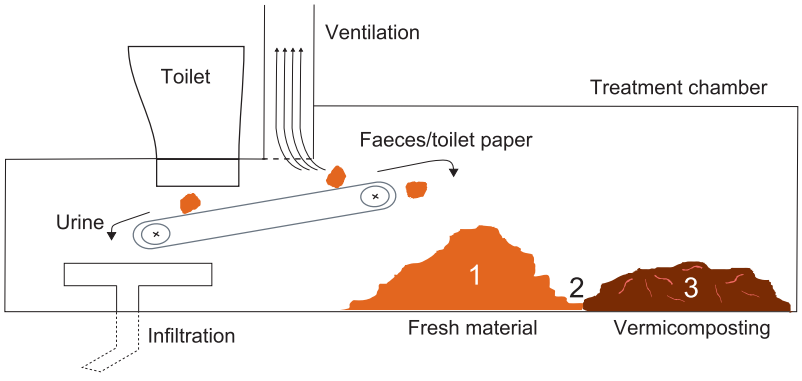

Fig. 1. Schematic representation of the set-up of the vermicomposting toilet treatment chamber, with sample position 1, 2 and 3 depicted (not to scale).