Practical Paper

Characterization of pit latrines to support the design and selection of emptying tools in peri-urban Mzuzu, Malawi

Rashid Chiposa, Rochelle H. Holm, Chimuleke Munthali, Russel C. G. Chidya and Francis L. de los Reyes III

ABSTRACT

The urban areas of many low-income countries must balance a rising demand for pit latrines for household sanitation provision against limitations in space, resulting in a need for pit latrine emptying services. This study was undertaken in the peri-urban neighborhood of Area 1B in the city of Mzuzu, Malawi, to examine the characteristics of household pit latrines for designing and selecting pit latrine emptying tools. We used 150 structured household surveys and field observations. From this, a subset was selected and 30 manual cone penetrometer tests were conducted at full latrines. Chemical oxygen demand analysis was also performed for 14 pit latrines. The results indicated that in addition to serving as a disposal for fecal matter, 90% of households also used pit latrines for domestic waste. Only 10% of the studied pit latrines were lined. The filling rate in the study area is calculated to be about three years, and no respondents reported previous emptying. It is suggested pit latrine emptying technology development focuses on a maximum tool diameter of 10 cm to fit through the keyhole (squat hole) and height of 146 cm to fit inside the superstructure, as well as supporting unlined pits and the ability to pump trash.

Key words | fecal sludge management, low-income countries, Malawi, pit emptying, pit latrine

Rashid Chiposa
Rochelle H. Holm (corresponding author)
Centre of Excellence in Water and Sanitation, Mzuzu University,
Private Bag 201,
Mzuzu 2, Malawi
E-mail: *rochelle@rochelleholm.com*

Chimuleke Munthali
Forestry Department,
Mzuzu University,
Private Bag 201,
Mzuzu 2, Malawi

Russel C. G. Chidya
Department of Water Resources Management and Development,
Mzuzu University,
Private Bag 201,
Mzuzu 2, Malawi

Francis L. de los Reyes III
Department of Civil, Construction and Environmental Engineering,
North Carolina State University,
Campus Box 7908,
Raleigh,
NC 27695, USA

INTRODUCTION

Many developing countries assumed they would follow the western example of sanitation (i.e., networked and water-based), and it is only recently that on-site sanitation and fecal sludge management (FSM) are being considered as national approaches (Strande *et al.* 2014). Pit latrines are the most common on-site household sanitation facility used in many low- and middle-income countries, but managing accumulated fecal sludge (FS) from pit latrines requires plans for emptying, transportation, treatment, and safe end-use or disposal (Strande *et al.* 2014).

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Many variables can affect pit latrine sludge, including environmental conditions and household practices, which impact the ability to pump the sludge during emptying operations. For example, household anal cleansing methods that are dominantly 'washing' versus 'wiping' would result in more water entering the pit latrine and impact the shear strength for pumping (Still & Foxon 2012a, 2012b). Additionally, tools for emptying must be able to physically access the pit latrine. While synthetic pit latrine sludge has been developed to assist in classifying emptying tool performance, there is limited *in-situ* work (Radford & Fenner 2013). The existing body of evidence which focuses on characteristics of FS and suitable tools for emptying of pit latrines and subsequent FSM in Africa has been growing, but is still predominantly localized to South Africa and Kenya (Seal 2015; Still & Foxon 2012a, 2012b; Still & O'Riordan 2012; Brouckaert *et al.* 2013).

In Malawi, 88% of the population uses pit latrines for household human waste disposal, yet there are weak national policies and local city regulations covering this sector (Malawi Government 2011; Holm *et al.* 2015). Mzuzu City, located in northern Malawi, has 27,338 households, and 90.1% of the households use non-waterborne toilets, which consist of mostly pit latrines. No household sewer system or organized household solid waste management services are available (Mzuzu City Council 2013). Households in the city with toilets flushing to septic tanks may still have pit latrines for backup. The city has three sludge ponds, primarily used for septic tank waste, which are not well maintained.

Pit latrine emptying tools must consider the latrine substructure and superstructure, environmental factors, household practices on use, and characteristics of FS. This study was undertaken in the city of Mzuzu, Malawi, to examine the characteristics of household pit latrines that must be considered when designing and selecting pit latrine emptying tools.

MATERIALS AND METHODS

This study was carried out in Area 1B, a peri-urban neighborhood in the city of Mzuzu, which is characterized by the Mzuzu City Council as a high density permanent residential area with no major industrial activities. There is an open-air market serving daily consumer demands, and several primary and secondary schools. All roads are earthen, characterized by potholes and gullies. The altitude ranges from 1,200 m to 1,370 m above sea level. Sandy clay soils are prevalent in the area. Piped municipal water supply is provided via in-home connections or community kiosks by the Northern Region Water Board, although there are also many shallow wells in the area (Mzuzu City Council 2013).

A total of 150 households, representing 30% of the neighborhood population, were purposively selected for this work in Area 1B based on the presence and usage of a household pit latrine. Purposive sampling was used due to the poor road network and general lack of maps for the area. A structured questionnaire was administered on household sanitation practices to the household head, including: religion, frequency of pit latrine use and type of domestic waste (greywater and trash) deposited in the pit latrine. Field observations were also made of the surrounding area and of the pit latrine characteristics using a structured checklist, including keyhole (squat hole) and superstructure dimensions plus water table at nearby shallow wells (where available). Key informant interviews were also conducted.

From the households surveyed, we selected a subset of 30 full pit latrines. A manual cone penetrometer (North Carolina State University, USA) was used to determine the penetration resistance with depth of *in-situ* FS. The penetrometer cone was lowered to the surface of the FS with the shaft upright until it stopped on its own and was measured. Then, the distance between the slab and the dropping mass anchor (2 kg) line was recorded as the anchor was repeatedly dropped. The penetration profile was based on the penetration distance below the top of the FS against the number of impacts for each of 30 pit latrines. Penetration depth varied at the 30 pit latrines based on the characteristics of the substructure. Following the penetrometer test, the pit latrines were emptied using the modified Gulper pump developed at Mzuzu University (Chipeta 2016), and pits were classified based on whether they could be emptied.

For 14 of the pits where penetrometer testing was conducted, chemical oxygen demand (COD) was analyzed as a general sludge parameter to determine the amount of organic constituents. Homogenized, unfiltered samples were collected during emptying operations and analyzed in triplicate for COD by the dichromate method (Radojevic & Bashkin 1999) at Mzuzu University (Mzuzu, Malawi).

The Republic of Malawi National Commission for Science and Technology approved the research protocol.

RESULTS AND DISCUSSION

Washers and wipers

All respondents (100%, $n = 150$) in the study were reported to be Christians. Based on the prevailing custom in the area, it is likely that those who self-identified as Christians are wipers and do not use water for anal cleansing. These results are similar to those of Still & Foxon (2012a, 2012b) from South Africa, where most people are also wipers.

Pit latrine usage rates

A majority of studied households (80%, 120/150) were owner occupied. Sixty-nine percent (103/150) of the pit latrines were privately used, and the rest were shared among two or three neighbors. The mean number of individuals per household was five, and consistent during both weekdays and weekends. Shared latrines may have a faster filling rate and may require more frequent emptying.

The filling rate of pit latrines is directly proportional to the amount of feces and urine added per user. Rose *et al.* (2015) reported a worldwide median fecal wet mass production of 128 g/cap/day, with a median dry mass of 29 g/cap/day. Still & Foxon (2012b) suggested pit emptying programs to be based on 60 L per person per year. Based on these data, for the mean pit volume in our study (825 L), the filling rate per household in Area 1B per pit would be about three years. Currently, there is no organized end-product use or resource recovery from the pit latrine sludge in Mzuzu City. Pit latrine emptying and associated treatment technology needs to be designed for household fecal waste from a potential 24,632 households producing 7,389,000 L/year.

Household pit practices

Approximately half of the households (52%, 78/150) discarded greywater (such as from washing clothes or dishes) into the pit latrines. Respondents reported adding greywater into pit latrines to reduce smell and/or to reduce the pit latrine volume. However, the addition of greywater to pit latrines may change the viscosity of FS making it easier to pump, although negatively affecting the stability of the pit lining during pit emptying operations.

Most respondents (87%, 131/150) reported throwing domestic waste materials into the pit latrine. This was also observed by researchers. Pit emptying tools need to be able to pump both fecal waste and domestic waste material.

Most respondents (85%, 128/150) also reported use of pit latrine additives. Households in Area 1B using pit latrine additives cited such reasons as reducing unpleasant odors, killing flies and germs, and increasing latrine lifespan by degrading the material inside the pit. The most common (114/128) additive reported was wood ash, while other households added either an active ingredient of co-trimoxazole granules (6/128) or sodium hypochlorite solution (8/128). All pit additives were observed to be readily available in the local market. During the time of study, the cost of chlorine was MK998 (USD$1.50)/750 mL bottle while co-trimoxazole was MK5,250 (USD$8)/500 g. However, chemical additives have not demonstrated any ability to reduce sludge volume (Still & Foxon 2012a, 2012b). Our study indicates that the households have a basic awareness of maintaining pit latrines and some willingness to pay for pit latrine care.

Sanitation projects

No households ($n = 150$) reported that sanitation projects or education had previously been undertaken in the study area. Further, no respondents ($n = 150$) had ever had their pit latrine emptied.

In the study area, and other similar peri-urban areas of Mzuzu, manual pit emptiers are charging MK20,000/pit (USD$30) to shovel full pit latrines by hand and with illegal disposal. However, there are only two or three active manual pit emptiers in Mzuzu City. In addition, vacuum tankers, which can not access all roads in the neighborhood studied, for emptying FS in Mzuzu focus on septic tanks. Alternatively, the cost for a household to hire a local sanitation business to install an improved, lined, pit latrine (inclusive of substructure, superstructure, labor, and materials) is MK335,000 (USD$500).

Pit latrine structure

Only basic pit latrines (with and without a cement slab) were found. There were no ventilated improved pits, composting, or pour flush latrines. All pit latrines in the study area had immovable superstructures, and none had an access hatch to the pit specifically for emptying operations external to the superstructure.

In the study area, pit emptying tools must enter through the keyhole, or the broken slab, but must also be able to fit within the footprint of the pit latrine superstructure. There was a general lack of standardization of the pit latrine superstructures. The height and length of the superstructure ranged from 146 to 211 cm (mean 178 cm) and from 64 to 198 cm (mean 143 cm), respectively. The superstructure width ranged from 64 to 156 cm (mean 100 cm). The keyhole length and width were 15 to 30 cm (mean 23 cm) and 10 to 22 cm (mean 16 cm), respectively.

Out of the 150 studied pit latrines, 15 were found to be lined. Pit depth ranged from 118 to 198 cm (mean 159 cm). The pit diameter ranged from 51 to 110 cm (mean 80 cm). As pit emptying is often limited to lined latrines due to the potential for collapse, only 10% of the latrines in the study area would be able to utilize most of the pit emptying tools currently available on the global market (Thye *et al.* 2011).

Environmental factors

The minimum water table in Area 1B was 15 m below ground surface ($n = 30$ wells), which is below the depth of all studied pit latrines. Combined with the soil type and field observations in the study area, it is assumed that water content from the pit latrine is infiltrating into the surrounding soils.

Physical and chemical characteristics of FS

Our study is complementary to the penetrometer tests on 109 pit latrines in Kibera, Nairobi, Kenya, that investigated how FS varies with depth (Seal *et al.* 2015). For our study, at 30 full pit latrines, penetrometer measurements were taken in advance of emptying operations. The manual penetrometer proved to be a useful tool to show variability in the FS with depth (Figure 1). However, penetrometer results did not cluster to show trends in FS characteristics that may be easier to empty, as anticipated, unemptiable pits were seen at all levels. Although many factors can affect whether pit emptying operations are successful, in this study, sludge with similar penetrometer profiles did not necessarily perform equally. As an example, some pits were not able to be emptied due to the high trash volume. Sludge in all cases would generally be classified as dry, and no watery layer was found at any depth. The technical challenge of emptying dry pit latrines is that technology such as the screw auger tool (Rogers *et al.* 2014) needs to first provide fluidization of the FS, or the addition of water to the pit, before emptying operations.

The pit latrines in this study showed low variation in mean COD, despite not being emptied before. The mean concentration of COD was 45,447 mg/L ($n = 14$), within a range maximum of 51,471 mg/L and minimum of 38,679 mg/L. This result indicates the sludge was of medium strength (Strand *et al.* 2014). This finding is important for both pit emptying tools, and the design and operation of treatment technologies, for example, the opportunity of FS for biogas generation.

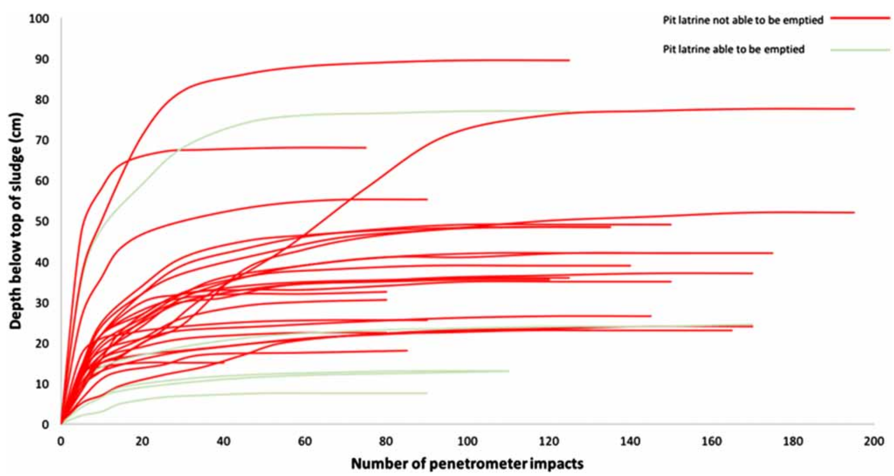

Figure 1 | Penetration profile for 30 pit latrines in the study area.

CONCLUSIONS

Gathering household-specific data combined with environmental and chemical data provides a snapshot of the current situation of pit latrines in Mzuzu, Malawi, and the data can be used to optimize the selection of pit latrine emptying technologies. The pit latrine contents in the study area were characterized as dry, despite greywater being added by many households. It is also surprising that none of the pits had been emptied before, indicating there is both degradation and leaching occurring in the pit. It is suggested that pit latrine emptying technology development focuses on a maximum tool diameter of 10 cm to fit through the keyhole (squat hole) and height of 146 cm to fit inside the superstructure, as well as supporting unlined pits and the ability to pump trash. The following areas have been identified for further research: 1) understanding of pit latrine layers of varying resistance using a penetrometer; 2) *in-situ* FS laboratory analysis for total nitrogen (mg/L) and total suspended solids (mg/L); and 3) assessment of pit latrine characteristics in other areas of Malawi.

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