Physics and Chemistry of the Earth xxx (2017) 1–7

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

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

Designing local solutions for emptying pit latrines in low-income urban settlements (Malawi)

W.C. Chipeta [a], R.H. Holm [a, *], J.F. Kamanula [b], W.E. Mtonga [c], F.L. de los Reyes III [d]

[a] Centre of Excellence in Water and Sanitation, Mzuzu University, Private Bag 201, Mzuzu 2, Malawi
[b] Department of Chemistry, Mzuzu University, Private Bag 201, Mzuzu 2, Malawi
[c] Department of Water Resources Management and Development, Mzuzu University, Private Bag 201, Mzuzu 2, Malawi
[d] Department of Civil, Construction, and Environmental Engineering, North Carolina State University, Campus Box 7908, Raleigh, NC 27695, USA

A R T I C L E I N F O

Article history:
Received 17 May 2016
Received in revised form
17 January 2017
Accepted 17 February 2017
Available online xxx

Keywords:
Fecal sludge management
Gulper
Low-income countries
Pit emptying
Technology
Unplanned settlement areas

A B S T R A C T

A lack of effective options in local technology poses challenges when onsite household sanitation facilities are eventually filled to capacity in unplanned settlement areas within Mzuzu City, located in northern Malawi. Vacuum trucks currently dominate the market but focus on emptying septic tanks in the more easily accessible planned settlement areas, rather than servicing the pit latrines common in unplanned settlement areas. As a result, households in the unplanned settlement areas within Mzuzu rely primarily on manual pit emptying (i.e., shoveling by hand) or digging a new pit latrine. These practices have associated health risks and are limited by space constraints. This research focused on filling the technological gap through the design, development, and testing of a pedal powered modified Gulper pump using locally available materials and fabrication. A modified pedal powered Gulper technology was developed and demonstrated to be capable of lifting fecal sludge from a depth of 1.5 m with a mean flow rate of 0.00058 m^3/s. If the trash content was low, a typical pit latrine with a volume of 1 −4 m^3 could be emptied within 1−2 h. Based on the findings in our research Phase IV, the pedal powered Gulper modification is promising as a potential emptying technology for lined pit latrines in unplanned settlement areas. The success rate of the technology is about 17% (5 out 30 sampled lined pit latrines were successful) and reflects the difficulty in finding a single technology that can work well in all types of pit latrines with varying contents. We note that cost should not be the only design criteria and acknowledge the challenge of handling trash in pit latrines.

1. Introduction

In Malawi, pit latrines dominate in both urban and rural households for human waste disposal (National Statistical Office and ICF Macro, 2011). Removing fecal sludge (FS) from full pit latrines may be performed by either manual or mechanized techniques, which may include hand tools, vacuum trucks, pumping systems, or mechanical augers (Mikhael et al., 2014; Rogers et al., 2014; Thye et al., 2011). While the emptying method depends on the type of pit latrine, site accessibility, the type of equipment owned by the service provider, and the level of expertise, in many low-income countries, the top criteria is the local availability of the emptying method (Mikhael et al., 2014). This availability is also complicated by the fact that physical properties are variable between and within pit latrines (Radford and Fenner, 2013).

In Malawi, national and local legislation covering the removal of FS from onsite household sanitation facilities is weak (Holm et al., 2015). Our research focused on Mzuzu City, located in northern Malawi. The city population is estimated to have reached 157,612 people in 2015 based on annual growth trends (UN-Habitat, 2011). Mzuzu City has no sewage system. Rapid urbanization has led to the formation of several low-income unplanned settlement areas within the city limits, mostly on the periphery of the city. Within the city, 48% of the population lives in informal settlements, and 94% of residents in these areas use pit latrines or septic tanks (Mzuzu City Council, 2013). The Mzuzu City Council is unable to provide adequate fecal sludge management (FSM) services due to limited financial resources, technology options, and technical capacity (UN-Habitat, 2011). Therefore, sanitation entrepreneurs using vacuum trucks address this need, primarily focusing on

* Corresponding author.
E-mail address: rochelle@rochelleholm.com (R.H. Holm).

http://dx.doi.org/10.1016/j.pce.2017.02.012

emptying septic tanks in the easily accessible formal areas of the city. Other globally available technology options, such as the power earth auger and manual diaphragm pumps, are not available to sanitation entrepreneurs in Mzuzu. Hence, households in the informal urban settlements within Mzuzu primarily rely on the current locally available options, predominantly manual pit emptying (i.e., shoveling by hand and illegal disposal) or digging a new pit latrine. These practices have associated health risks and are limited by space constraints.

The lack of effective and locally available emptying technologies hinders efforts toward improving sanitation and public health in unplanned settlement areas within Mzuzu City, and is likely similar to the situations observed in other low-income countries. This research focused on filling the technology gap through innovation involving the design, development, and testing of a pedal powered Gulper modification using locally available materials and fabrication.

2. Materials and methods

2.1. Research design

The design, development, and field testing of a novel pedal powered Gulper technology on actual pit latrines in Mzuzu was undertaken from February 2014 to June 2015. A trial and error process was used, and quantitative data on the performance of the pedal powered Gulper pump was collected at each phase. Research observations and lessons learned were obtained and continuously assessed.

2.2. Study location

Area 1B is a high-density low-income informal residential urban settlement within Luwinga ward on the northern edge of Mzuzu City, Malawi. The study settlement has a population of 319 households (Mzuzu City Council, 2013).

2.3. Sampling method

To test the modified Gulper technology in Area 1B, purposive sampling was used to select 30 lined household pit latrines. The method was chosen because sludge characteristics in pit latrines vary, regardless of being from the same city, area or even adjacent households (Niwagamba et al., 2014). Additionally, differences in user practices, such as diet and anal cleansing material, as observed by Still and Foxon (2012) in South Africa, similarly apply to the sampled pit latrines within Area 1B (Chiposa, 2016). This study attempted to limit this variability by using a geographically limited study area. Because unlined pits have the potential to collapse during pit emptying, they were excluded from the study.

2.4. Materials

We attempted to improve on two existing technologies available in Malawi: the treadle pump used throughout Malawi for irrigation, and the arm powered Sludge Gulper developed by the London School of Hygiene and Tropical Medicine and designed for pit emptying (Mikhael et al., 2014). Limitations of the Gulper included its length (1.5 m), decreased effectiveness with denser sludge, and slow rate of emptying. Current ongoing modifications of the Gulper by Water for People (2014) and the Rammer technology were excluded in this study. This research focused on development of local innovation to pump FS.

2.5. Design process of pit emptying technology

Context-specific design criteria were formulated to develop an effective household pit emptying technology for low-income informal urban settlements in Mzuzu:

- Materials and spare parts of the technology developed must be locally available
- Extraction time of FS should be within 1–2 h
- Health risks for operator and serviced household should be lower than those for manual pit emptying
- Portable (less than 50 kg)
- Able to pump FS from a depth of 1.5 m
- Effectively remove trash in the pit latrines
- Achieve a discharge rate of 0.001 m^3/s
- Simple to operate (requiring no formal education)
- Cost of technology should be less than U.S. $200

A conceptual design was developed based on the criteria, and the required materials were obtained for fabrication by local welders. The fabricated technology was first tested on a mud slurry, used to simulate FS, to determine initial performance parameters. These parameters facilitated the evaluation of each phase against the established design criteria. Based on the evaluation assessments, the concept was subsequently improved and redesigned in each successive phase. Only Phase IV was tested on household pit latrines.

2.6. Testing procedure

The procedure for the pit latrine testing in Area 1B was as follows:

Step 1: Briefing the testing team on health and safety issues
Step 2: Administering the consent form for each household owner/occupant of the sampled latrines
Step 3: Inspecting latrine structure for cracks
Step 4: Measuring the latrine superstructure (door, squat/key hole, floor slab)
Step 5: Removing trash with a manual hook. Two types of manual hooks were used, one shaped as a claw (three U-shaped hooks) and the other a sweeping brush with 6-inch nails. Both had a maximum height of 2 m and a 40-cm handle. The volume of trash removed per pit was measured using a 20-L (0.02 m^3) pail.
Step 6: Fluidizing sludge in the pit latrines using water. Fluidization was performed in increments of 0.02 m^3 by volume using manual agitation with a trash removal hook to improve consistency.
Step 7: Measuring flow rates of the modified pedal powered Gulper by filling a 20-L pail until the maximum Gulper length of 1.5 m was reached.
Step 8: Cleaning the test site around the pit latrine
Step 9: Disposing FS at city sludge ponds
Step 10: Cleaning and sanitizing pit emptying equipment

2.7. Analysis

Statistical analysis was performed using Excel 2013 and Statistical Package for Social Sciences (SPSS) version 16.0.

2.8. Ethics

The study received ethical clearance from the Republic of