Design and Construction of A Low Cost Pit Latrine Emptier

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Abstract
Globally, an estimated 1.77 billion people have access to pit latrines as of 2013. About 90% of the households in Uganda use a pit latrine while 4% only use the ventilated improved pit latrine. In all regions of Uganda, there is lack of a low cost solution for emptying the pit latrines yet it can be designed and developed to help low income earners and communities like schools, hospitals to continuously use their pit latrines through draining them once they are full.A low cost pit latrine emptier (PLE) that is human powered using a hand pump to drain the feacal sludge from the pit latrine was designed and tested. Mainly waste water form soak pits, septage and water mixed with mud were used while testing the prototype of the PLE. This was carried out in the neighboring three homes and the flow rate was almost constant.Six tests were carried out using different kinds of waste water including muddy water (Makerere 1, mukwenda zone - Kampala) from 18th to 26th of May 2016. The average flow rate of the feacal sludge into the PLE was 4.29 liters per minute and this gave an efficiency of 53.5%The PLE indicted less resistance while pulling it to the disposal point where 8 minutes were taken to pull the PLE from the draining pit a disposal point which was at a distance of 100m. Discharging the waste water took 2 minutes after opening the globe valve and the PLE was pushed back to the draining site to drain more waste water.

INTRODUCTION

In the recent years, the magnitude of latrine waste and its management has become a problem due to augmenting industrialization, urbanization and increasing population density [WHO,2014]. Latrines require proper management and maintenance in order to achieve the sustainable Development Goal (SDG) number 6 which seeks to "Ensure availability and sustainable management of water and sanitation for all" [UN, 2015]. Most of the world's population relies on on-site facilities such as pit latrines as the main methods of providing sanitation in developing countries. As of 2013 pit latrines were used by an estimated 1.77 billion people. This is mostly in the developing world as well as in rural and wilderness areas [Cairncross et al. 2013].

In 2011 about 2.5 billion people did not have access to a proper toilet and one billion resorted to open defecation in their surroundings. Southern Asia and Sub-Saharan Africa have the poorest access to toilets/latrines. In developing countries the cost of a simple pit latrine is typically between 25 and 60 USD and ongoing maintenance costs are between 1.5 and 4 USD per person per year which is often not taken into consideration [Albonico et al. 2011].

According to the house hold and the toilet facility survey, about 86 % of the households in Uganda use a pit latrine while only 4 percent use a Ventilated Improved Pit-latrine (V.I.P) (See Figure 1). There was a slight reduction in the proportion of households that did not use any toilet facility from 11 percent in 2005/06 to 9 percent in 2009/10. The most recent report indicates that 90% had toilet facility and 8.3% did not have any toilet facility [UBOS, 2014].

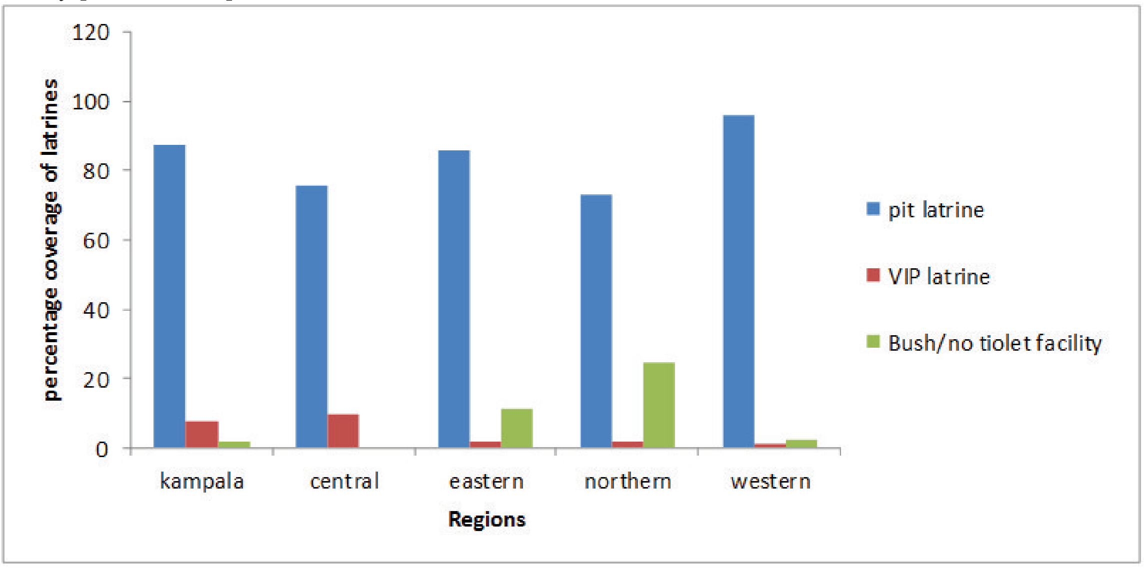

Figure 1: Percentage of toilet facility coverage in different regions of Uganda [UBOS, 2010]

Findings from Unicef Uganda's situation analysis (2015) indicate that the number of pupils in primary schools is much more than the available number of latrine stances. The pupils to latrine ratios are far beyond the recommended ratio by the government of Uganda which is 40:1 and is 74.5:1[Unicef, 2015]. This cause fast filling up of the latrines in schools and empting these latrines is expensive for most schools. For example a typical cesspool emptier would cost about 1.4 million Uganda shillings which is almost 10% of a typical school budget in rural Uganda.

METHODS

To come up with the low cost PLE, different methods were used ranging from reviewing the literature, conceptualization, design modeling using the solid edge and assembly of the final prototype of the PLE. While reviewing the literature, 3 previous concepts were considered as low cost solutions for draining the pits and basing on these designs (Mapet, Gulper and the cesspool emptier) (Muller, 1994) the final concept of the low cost PLE was obtained.

The low cost PLE consists of a vacuum tank that was painted to reduce corrosion tendency and improve on part appearance, the stand assembly which is made from cast iron square hollow sections (25″ x 25″) and is also painted to reduce corrosion and rusting ability. This kind of material was chosen with the aim of minimizing the overall weight of the low cost PLE, the hand pump, hose pipes and the fittings for these pipes including the valves, and the wheels to support the overall assembly of the low cost PLE [26].

The decision to use waste water instead of feacal sludge was based on the necessity of determining the correlation between use of a low cost PLE and the cesspool while holding other factors constant. More so the contents of the pit latrine are 80% liquid according to the experiment by Pandel (Pandel. et.al, 2012). If the feacal sludge had been used, disposal would require more money which was not available at the time of testing the prototype.

During the design modeling using the solid edge environment, the production drawing as shown in figure 2 was derived from the assembled 2D model of the prototype.

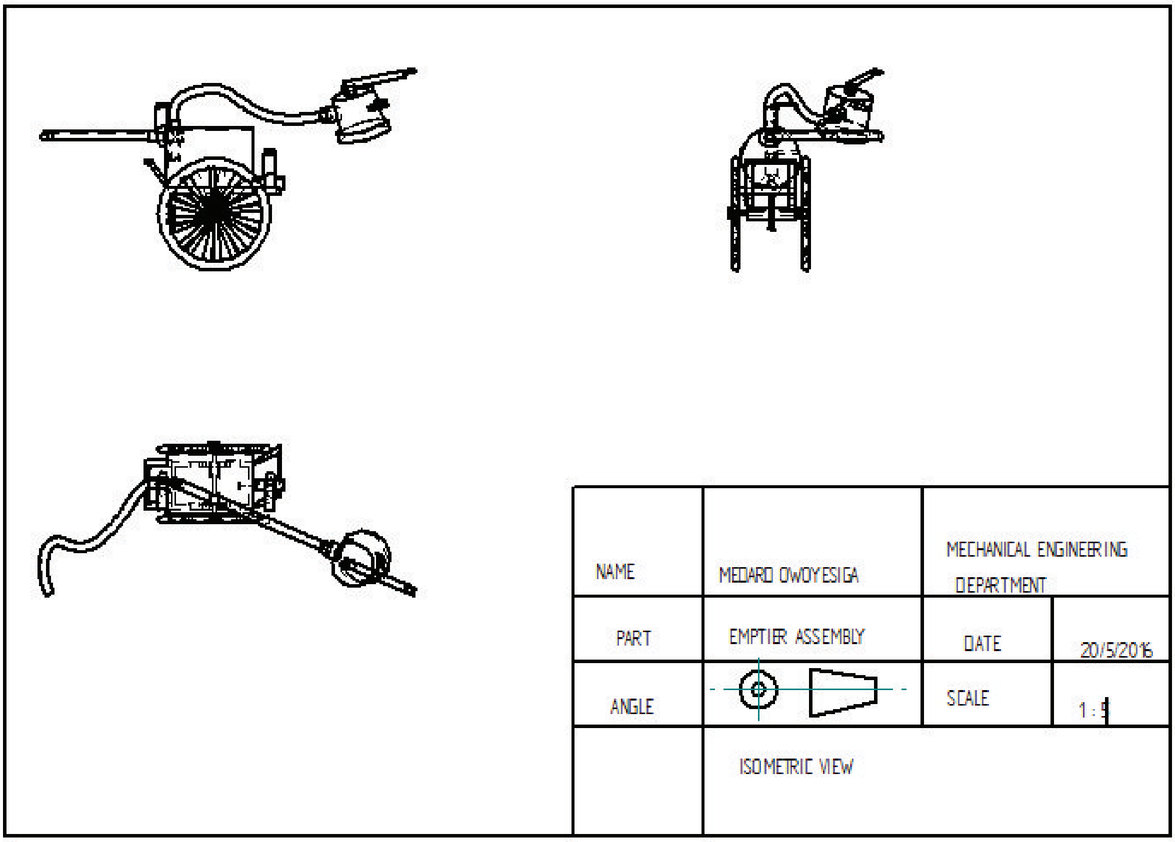

Figure 2: 2D production drawing of the low cost pit latrine emptier

The final assembly was constructed basing on the detailed design and estimated parameters like the flow rate, the delivery head and the pressure.

Testing of the prototype was done in three neighboring homes in mukwenda zone Kampala where the different kinds of waste water were used to test the different parameters like whether the system was air tight, the flow rate and the time taken to fill the vacuum tank. Figure 3 shows one of the experiments captured during testing of the low cost PLE prototype with septage.

Figure 3: Testing the prototype on 20th May 2016, photo taken by Onesimas

RESULTS AND DISCUSSION

Testing of the low cost PLE showed a good flow rate for a period of 9 days that was slightly variable on the force applied on the handle of the pump, the time taken to fill the vacuum tank, the air tightness of the experiment and the contents of the waste water. Overall there was a clearly slight decrease in the flow rate of the waste water because of its different kinds. The mean experimental flow rate varied from as high as 4.5 liters/minute on grey water and black water to as low as 4.09 liters/minute on muddy water. Table 1 below indicates some of the results obtained from testing of the low cost PLE.

Table 2: Results obtained from testing the prototype

Experiment number	**Volume output (liters/min)**	**Head(m)**
1	4.5	1.8
2	4.09	2
3	4.29	2.8
4	4.3	2.5
5	4.14	2.6
6	4.32	2.7

Over the entire testing period (18th May to 26th May 2016), the mean experimental flow rate was 4.29 liters/minute. When viewed in more detail (Figure 3), the overall volume flow rate was similar with variations that reflect particular floe limitations offered by the different kinds of waste water.

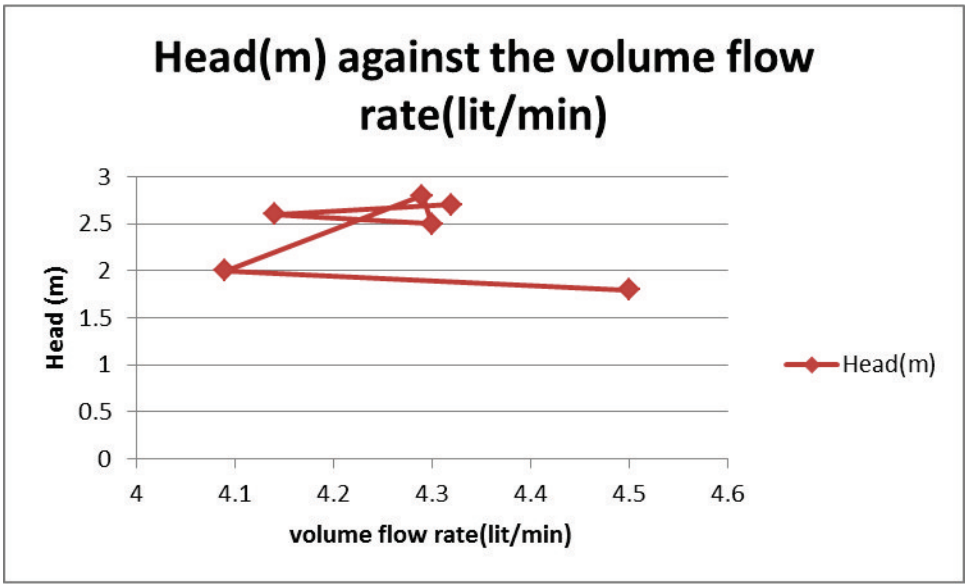

Figure 3: Flow rate pattern against the head

The maximum volume flow rate typically occurred just with grey water and was followed by slight decrease on black water. The expected flow rate obtained through the calculations was varied slightly in the actual operation of the PLE but a good flow rate was obtained practically (equivalent to 4.29lit/min). The flow rate increased whenever the force applied on the handle would be increased and whenever the experimental set up would be air tight.

CONCLUSION

This research designed a technology to passively drain the feacal sludge from pit latrines and tested it with waste water and muddy water to understand the influence of the flow factors on the PLE. The resultant low cost PLE is simple to construct from commonly found materials.

Testing of the low cost PLE indicates that draining grey water took 20 minutes to fill the designed vacuum tank. The average volume flow rate of the waste water over the testing period was 4.29lit/min (Period - 18th May to 26th May 2016).

This is a prototype unit and performance may be improved by design improvements in the subsequent units. Further research should conduct the same experiment with the PLE connected to a different pump e.g. foot pump in order to investigate the effect of flow rate and pressure on the PLE. In parallel, the social acceptability of the technology should be assessed and the results integrated into the future design optimization. Social acceptability of handling the human waste differs but has been accepted successfully globally.

The low cost PLE will require humans to periodically clean it and lubricate some of the parts for durability. Social acceptability should increase overtime as the benefits of the PLE become increasingly seen and valued and interaction between and the PLE operation is improved. This technology holds promise for the future but will require adoption to the different climates, availability of the local materials, cultural acceptance and some income levels.

REFERENCES

[1] Designing Wastewater Systems According to Local Conditions - David M Robbins Publication Date: Jan 2014 - ISBN – 9781780404769 (Dillon 1997; Dzwairo et al. 2006; Nichols et al. 1983)
[2] Cairncross S, Bartram J, Cumming O, Brocklehurst C. 2010a. Hygiene, sanitation, and water: what needs to be done? Plos Med 7(11):e1000365; doi:10.1371/journal.pmed.1000365 [Online 16 November 2010].
[3] Cairncross S, Hunt C, Boisson S, Bostoen K, Curtis V, Fung ICH, et al. 2010b. Water, sanitation and hygiene for the prevention of diarrhea. Int J Epidemiol 39(suppl 1):I193–I205.
[4] Feachem RG, Bradley DJ, Garelick H, Mara DD. 1983. Sanitation and Disease: Health Aspects of Excreta and Wastewater Management. New York:John Wiley & Sons Ltd.
[5] Reed B. 2010. Emergency Excreta Disposal Standards and Options for Haiti. Leicestershire, UK: DINEPA (Direction Nationale de l'Eau Potable et de l'Assainissement) and Global WASH Cluster.Available:http://wedc.lboro.ac.uk/resources/pubs/Emergency_EDS_and_options_for_Haiti.pdf [accessed 28 March 2013].
[6] WHO (World Health Organization)/UNICEF. 2012a. Estimates for the Use of Improved Sanitation Facilities: China. Available: http://www.wssinfo.org/fileadmin/user_upload/resources/CHN_san.pdf [accessed 1 April

2013].
[7] WHO (World Health Organization)/UNICEF. 2012b. Estimates for the Use of Improved Drinking-Water Sources: China. Available: http://www.wssinfo.org/fileadmin/user_upload/resources/CHN_wat.pdf [accessed 1 April 2013].
[8] Clasen T, Bostoen K, Schmidt W-P et al. Interventions to improve excreta disposal for preventing diarrhea (Protocol for a Cochrane Review). The Cochrane Library, Issue 2. Oxford: Update Software, 2008.
[10] The Lane J, Trouba D, Mara DD, Scott BE (2010) Sanitation and Health. PLoS Med 7: e363. doi:10.1371/journal.pmed.1000363
[11] Waddington H, Snilstveit B (2009) Effectiveness and sustainability of water, sanitation, and hygiene interventions in combating diarrhea. J Dev Effect 1: 295–335.
[12] Brouckraert CJ, Foxon KM, wood k(2013). Modelling the fill rate of pit latrines. Water SA 39(4): 555 – 562 crossref
[13] Daniel B, Reed B(2010). Disposal of latrine waste. Is biogas the answer? A review of literature, Loughborough University.
[14] Government of the Republic of Zambia (1994). National water policy. Ministry of water and energy development, Government of the Republic of Zambia, Lusaka
[15] Kvarnstron E, McConville J, Braken P, et al. (2011). The sanitation ladder – a need for a revamp? J water sanitation Hyg dev.1(2): 3-12. Crossref
[16] Straus M, Montagero A(2002). Faecal sludge management – Review of practices, Problems and initiatives EWANG/SANDEC
[17] Sudgen S (2013). The importance of understanding the market when designing pit emptying devices. Waterlines 32(3):1756 – 3488 crossref
[18] Todman Lc, Van Eeskert MHA, Templetion MR, et al. (2015). Modeling the fill rate of pit latrines in Ifakara, Tanzania. J. water sanit.Hyg Dev 5(1): 100 – 106 crossref
[19]Water and sanitation for the urban poor(WSUP)(2014). FSM services in Lusaka; moving up the excreta by management ladder, practical note #017
[20] Muller, M. & Rijnsburger, J. (1994) MAPET: A neighbourhood based pit emptying service with locally manufactured handpump equipment in Dar es Salaam, Tanzania. WASTE.
[21] Oxfam (2008) Manual Desludging Hand Pump (MDHP) Resources. [Online]. Available from: http://desludging.org/ [Accessed 22nd December 2008].
[22] Parkinson, J. (2008) Improving servicing of on-site sanitation – a neglected issue for the UN Year of Sanitation. Water21, December 2008, 40 – 42
[23] Parkinson, J. & Quader, M. (2008) The challenge of servicing on-site sanitation in dense urban areas: Experiences from a pilot project in Dhaka. Waterlines, 27 (2), 149 – 163.
[24] Pickford, J. (1995) Low-Cost Sanitation: A survey of practical experience. London, Intermediate Technology Publications.
[25] Pickford, J. & Shaw, R. (1997) Technical Brief No. 54: Emptying latrine pits. Waterlines, 16 (2), 15 – 18.
[26] Strauss, M.; Heinss, U.; Montangero, A. On-site sanitation. when the pits are full—Planning for resource protection in faecal sludge management. Ver. Wasser Boden Lufthyg 2000, 105, 353–360.
[27] Strauss, M.; Koné, D.; Koanda, H.; Steiner, M. Urban excreta management—Situation, challenges, and promising solutions. In Proceedings of the 1st International Faecal Sludge Management Policy Symposium and Workshop, Dakar, Senegal, 9–12 May 2006.
[28] UN Habitat. The State of African Cities 2008; The United Nations Human Settlements Programme: Nairobi, Kenya, 2008.
[29] Strande, L. The global situation. In Fecal Sludge Management: Systems Approach for Implementation and Management; Strande, L., Ronteltap, M., Brdjanovic, D., Eds.; IWA Publishing: London, UK, 2014; Chapter 1.
[30] WHO/UNICEF. Progress on Drinking Water and Sanitation—2014 Update. The World Health Organization: Genera, Switzerland, 2014. Available online: http://www.unicef.org/media/files/ JMP_2014_Update.pdf (accessed 1 December 2014)
[31] Hawkins, P.M. Emptying On-Site Excreta Disposal Systems in Developing Countries: An Evaluation of the Problems; IRCWD News: Duebendorf, Switzerland, 1982; pp.1–9.
[32] Water Aid Tanzania Country Programme. Pit emptying service using gulper technology. In Proceedings of the East Africa Practitioners Workshop on Pro-Poor Urban Sanitation and Hygiene, Kigali, Rwanda, 29–31 March 2010.