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Pump it up: making single-pit emptying safer in rural Bangladesh

Abstract

Safe emptying and disposal of fecal sludge from pit latrines in rural areas has become a priority for the Government of Bangladesh. In this paper, we calculate the volume and characterize the hazards of managing sludge to identify technologies for safely emptying rural single pits. In Bhaluka subdistrict, an estimated 15,000 m^3 of sludge is produced annually. Physical, chemical, and microbial analysis of samples of sludge taken from pit latrines indicate that the sludge has a high moisture content of around 90%, a C:N ration of 10:1, and a helminth presence of 41 eggs/g. In a field test of alternative emptying technologies, simple pumps such as the gulpher emerged feasible for use in rural area, due to the liquid nature of sludge, narrow roads, and limited incomes of rural households. The results suggest that current practices of emptying liquid sludge manually without any protective equipment poses risks to those who handle sludge, and the process needs to be semi-mechanized with immediate effect. These results are being used by the Bangladesh government to design policy for sludge management. In the near future, an organized service that safely empties single-pits and transports sludge for treatment needs to be urgently designed.

Keywords: sanitation, rural, fecal sludge, emptying, disposal, single-pit latrines, Bangladesh

Introduction

Several countries have made rapid progress towards the elimination of open defecation during the last ten to twenty years. Of these Bangladesh is one of the most notable. Between 2003 and 2015 the rate of open defecation in rural areas of the country is estimated to have fallen from 42% to 2 % (BRAC, 2015; WHO/UNICEF, 2004; WHO/UNICEF, 2015). Taking population growth into account, this represents an additional 40 million rural people using latrines during this period, a majority of whom live in rural areas. This rapid expansion in access to latrines was achieved through a variety of onsite interventions, but the most popular is the single pit latrine, commonly constructed by digging a pit and lining it with concrete rings before adding a slab and super structure. Single-pit latrines are considered to be a relatively cheap and effective method for separating humans from their excreta (O'Loughlin et al., 2006).

When they fill up, single-pit latrines need to be emptied immediately if the latrine is to remain in use. Handling fecal sludge is associated with a number of health risks that include bacterial, viral and protozoan infections (Dzwairo et al., 2006; Fewtrell et al., 2005; Fuller et al, 2015; Pruss et al., 2014). In Bangladesh, attention to this important component of sanitation has been given only recently; the Ministry of Local Government convened a National Committee for Fecal Sludge Management (NCFSM) in 2015 to draft frameworks for sludge management in rural and urban areas of Bangladesh. Among other things, the NCFSM is also working to identify technologies that would safely empty sludge from pits.

Current practices for emptying pits include the use of simple tools such as buckets, spades and ropes. Pits are emptied manually using a bucket. Pit emptiers often do not use any protective equipment while emptying pits; they use neither gloves nor other hand protection, and often disrobe to prevent their clothes from being soiled. Working in groups of 2-3: one emptier often climbs into the pit to empty it, while other(s) pass filled buckets to empty the contents nearby. Figure 1 shows the types of tools that are used. This emptying practice brings pit emptiers into close contact with fecal sludge, and requires an immediate solution.

Figure 1: Simple tools currently used for pit emptying

To identify appropriate technologies for emptying pit latrines, it is necessary to first assess the volume of sludge that needs to be transported annually, which is based on the numbers of pits and their frequency of filling. Second, the exact nature of the hazardous materials to be emptied needs to be characterized in order to identify appropriate strategies to reduce risks to those who would handle sludge. Finally, appropriate, locally available technologies for safer emptying of pits need to be identified.   We examine these three factors for one subdistrict in Bangladesh. The subdistrict is envisioned by the NCFSM as the scale at which services would be designed.

Methods

We designed and carried out the study in Bhaluka subdistrict, which lies in Mymensingh district (Figure 2). The Census of 2011 records 91, 547 households in rural Bhaluka; the average household has approximately 4 people (Ministry of Planning, 2012). Ninety-two percent of all households use a latrine, with 67% of the households having access to a sanitary latrine, often a pit latrine (Ministry of Planning, 2012) Bhaluka subdistrict is broadly representative of a rural district that is not affected by groundwater salinity.

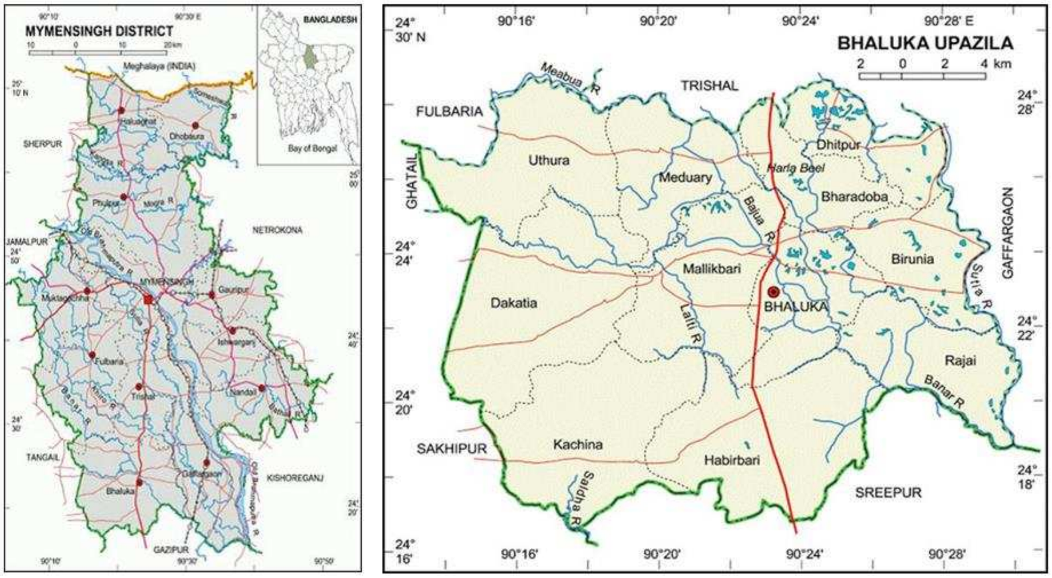

Figure 2: Bhaluka Upazila

Calculating volume of fecal sludge produced annually

To determine the volume of fecal sludge that needs to be transported the performance of a sample of latrines was studied. Data on the performance of thirty pits was used as the basis for estimating sludge accumulation rates. First, data from six single-pit latrines was collected during June 2014 in Bhaluka. A two-stage selection process was used; first six unions within the subdistrict were selected, and then one household with a pit latrine in each of the selected unions. The budget for studying pits was modest; consequently unions within Bhaluka were purposively selected on the basis of known geology, to provide some variation in the quality of sludge. Households were purposively selected because samples of fecal sludge (discussed in the next subsection) needed to be drawn from pits that were near-full.

Groundwater salinity can affect conductivity of and pathogen activity in sludge and hence have an influence on rates of accumulation. Bhaluka upazila is not known to have a particular issue with groundwater salinity. To account for changes in sludge composition due to salinity, samples were also taken from pit latrines in the following subdistricts known to have groundwater salinity: Phultola in

Khulna district (February 2014); Chhagalnaiya in Feni district (June 2014); and Senbagh in Noakhali district (August 2014). These additional districts were selected as they have been the focus of single-pit latrine interventions by BRAC, a major non-governmental organization based in Bangladesh, especially in the past nine years. The time of sample collection was varied to allow for the effect of rainfall on the composition and rate of accumulation of fecal materials in pit. Again, unions and households in each of the subdistricts were sampled purposively, with six unions selected in each subdistrict, and one pit in each union. Lastly, samples were also taken from one union in Gazipur Sadar subdistrict of Gazipur district (four pits, February 2014, and 4 pits in July 2014), a semi-urban area with low salinity, for comparison. Table 1 provides a summary of the pits from which data and samples were collected.

Table 1: Samples of fecal sludge from 30 pit latrines

Subdistrict	District	No. unions	Pits/union	Total pits (=samples of sludge)
Bhaluka	Mymensingh	6	1	6
Phultola	Khulna	6	1	6
Chhagalnaiya	Feni	6	1	6
Senbagh	Noakhali	6	1	6
Gazipur Sadar	Gazipur	1	6	6

From each of the thirty pit owners, information on the number of regular users of the pit, and the last time the pit was emptied, was elicited. Then the pit was opened, and the height of the sludge, and depth and diameter of the pit, were measured.

Additionally, information on pit latrine depth and age was collect from BRAC which has been responsible, between 2006-2014,for installing 9,000 single pit latrines in Bhaluka.

Sampling and testing fecal sludge

To characterize the hazards associated with handling fecal sludge, samples were collected from all of the sampled pit latrines. After the pit was opened, and the height of the sludge was measured with a pre-calibrated measuring stick. The stick was marked for bottom, mid and top layer sludge. Samples were drawn from each of the three layers. The stick was washed with fresh water and potassium-free soap prior to each sampling. Sludge collected from each layer was kept in a separate air-tight labeled plastic bottle.

The samples were transported to the laboratory in an ice box and stored in the freezer below 0 C. Before analysis, a homogeneous test sample was created for each study latrine by mixing sludge from each layer of the latrine in equal proportion. Physical and chemical properties of the sludge were analyzed at the Bangladesh University of Engineering and Technology (BUET) and microbiological tests were carried out at the International Centre for Diarrheal Disease Research, Bangladesh (ICDDR, B). The methods and protocols followed for physical, chemical and biological tests are described in Evans et al., 2015.

Testing pumps in the field

A literature review of emptying tools and technologies was undertaken. The use of a hand-held pump to empty the pits would reduce the likelihood of laborers coming into contact with fecal sludge and small hand-held models are available in Bangladesh. Machines such as a Vacutug or Vacuum tanker can also be used to empty pits, which further reduces contact with fecal sludge. Completely mechanized systems have the advantage that fecal sludge can be transported away from the pit latrine in the truck itself but these have higher capital costs than hand-held models.

A short online survey was implemented with a panel of 31 WASH experts across the globe, who had worked in sanitation in developing countries. The purpose of this survey was to short-list a set of pit emptying technologies that could be tested in rural Bangladesh.

Subsequently the research team engaged a team of pit emptiers to test the selected technologies. Four households in Pakhirchala Village in Bhaluka upazila whose pits were close to being full volunteered to have their pits emptied. We chose to empty pits that were close to being full, in order to understand how selected technologies performed according to the capacity of pits. The research team trained pit emptiers, who primarily collect and sort solid waste in the subdistrict headquarter town, in the use of the technologies, and observed the process of emptying. These emptiers were asked to provide feedback on their experiences of using the selected technologies, and the suitability of using these technologies with respect to depth of the pit, damage to the latrine, emptying time, ease of use in rural areas, ease of handling and labor requirements. In addition, interviews were held with one group of pit emptiers in Dhaka City, to provide feedback on the technologies they had used during the course of their work. Pit emptiers from Dhaka were included in the study because they are more familiar with the use of the semi-mechanized and mechanized equipment and could provide feedback based on longer experience of use.

Ethical Conduct

The University of Leeds Faculty of Mathematics and Physical Science, MaPS and Faculty of Engineering joint faculty research committee approved this study. All official and regulatory permissions necessary for conducting research in Bangladesh were coordinated and obtained by NGO Forum for Public Health.

Participation in this research was voluntary, and not remunerated. Potential participants were informed of the aims and purposes of the research, and the amount of time they would have to spare to provide the research team with the relevant data. Data was collected only after individuals/households had agreed to participate. All responses are anonymous and cannot be used to identify individuals or households.

Results and Discussion

Volume of fecal sludge to be transported

From the thirty sampled pits, depth varied from 0.91 – 3.05m. The diameter of all study pits was standard at 0.83m. Records provided by BRAC show that pits constructed by BRAC typically have an average of three concrete rings lining the pit and they all have the standard diameter of 0.83m. Each ring is around 1 m is depth.

Pit filling rates were estimated based on the reported time since the previous pit emptying event, the number of regular users of the latrine and the current amount of fecal sludge in the pit for the thirty sampled pits. Filling rates were calculated as 30-50 liters per person per year and typically this was associated with a period of approximately 4 years between emptying events. These findings were confirmed by a household survey which showed that the mean age of pits was four years, and while only 20% had been emptied, the rest would be emptied shortly. These results are consistent with the literature, see for example Franceys et.al (1992), Still et.al (2009) and Brouckaert et.al (2013). Latrines are likely to fill up faster than this where non-household members are using them, or where water tables are high and more slowly where the number of users is lower or water tables deeper. These results are reported in Balasubramanya et al., 2016, a companion paper to this paper.

Inspection of the thirty pits revealed that many have some additional depth available for sludge storage below the lowest ring. We assumed this depth to be 0.50 m in most cases. We also assumed that households would tend to empty their pits when the contents reached to within a half-ring height of the top of the pit. Using these assumptions and data on pit depth from BRAC, this gives an average capacity per latrine pit of 733 liters.

From the Census of 2011, we know that the average size of the household is around four persons. Assuming that the mid-point estimate of sludge accumulation (40 l/person/year) applies across our sample this means that pits will fill up on average once in 3.68 years (three years and eight months).

The total number of pits that would therefore need to be emptied in Bhaluka is 20,760 and the total volume of sludge to be emptied each year is just over 15 million liters (15,000 m^3).

It is worth considering how these results convert to the national level. Taking into account the fact that at least 40 million rural people have started using single pit latrines in the past ten years, there may be as many as 8 million relatively new single-pit latrines in rural Bangladesh. A conservative estimate therefore suggests that as many as 2 million pit latrines will need to be emptied annually, and this would be associated with a volume of sludge of 1,466 million liters (1.46 million m^3).

Risks with handling fecal matter

The resulting mean physical, chemical and microbiological characteristics of fecal sludge samples are reported in Tables 2 and 3. Typical moisture content is high at 90% confirming that most pits contain relatively heavy wet sludge. On average, the carbon to nitrogen ratio found in fecal sludge samples is (10:1). The results reported in Tables 2 and 3 are consistent with those summarized by Niwagaba et.al (2014) although it is interesting to note the relatively low numbers of helminth eggs reported.

Table 2: Physical and chemical characteristics of sludge samples from single pit latrines (n=30 pits)

District	Moisture (wt%)	pH	Conductivity (mmho/cm)	TVS (wt%)	TOC (wt%)	TN (wt%)	C/N	PO_4-P (wt%)
Gazipur Sadar	83.68	7.35	3.34	68.56	36.38	3.7	9.52	2.1
Senbagh	88.1	7.08	5.02	68.65	37.23	3.91	10.09	2.13
Phultola	91.34	7.94	4.76	74.37	39.32	3.66	10.91	2.25
Bhaluka	90.54	7.73	3.51	68.09	54.34	3.15	12.83	1.67
Chhagalnaiya	90.54	7.81	4.58	77.88	41.19	3.98	11.12	2.49
Mean	88.84	7.58	4.24	71.51	41.69	3.68	10.89	2.13

Notes:

TVS = Total volatile solids; TOC = Total organic carbon; TN = Total nitrogen; C/N = carbon to nitrogen ratio
In each district, a one-time sample was drawn from each of six pits. In each case prior to laboratory testing a composite sample was created by mixing samples taken from the bottom, middle and top of each pit. Percentages by weight and masses were calculated after drying.
Source: Authors' data

Table 3: Microbiological characteristics of sludge from single pit latrines (n=30 pits)

District	Total coliforms, cfu/g	E. coli, cfu/g	Helminth eggs	
			egg/g	Group
Gazipur Sadar	5.20E+06	3.50E+06	20	Ascaris lumbricoides
Senbagh	7.90E+04	2.30E+04	119	Ascaris lumbricoides, Trichuris trichiura, Enterobius vermicularis, Hymenolepis nana
Phultola	1.40E+05	9.80E+04	32	Ascaris lumbricoides, Hymenolepis nana,
Bhaluka	1.90E+05	9.00E+04	13	Enterobius vermicularis, Taenia spp
Chhagalnaiya	1.80E+06	7.60E+05	23	Enterobius vermicularis, Ascaris lumbricoides,
Mean	1.50E+06	9.00E+05	41	

Notes:
Cfu = colony-forming units
In each district, a one-time sample was drawn from each of six pits. In each case prior to laboratory testing a composite sample was created by mixing samples taken from the bottom, middle and top of each pit.
Source: Authors' data

Microbiological characteristics reported in Table 3 confirmed the challenge in handling fecal sludge. In particular, the prevalence of helminth eggs is a concern. One particular fecal sludge sample from Senbagh had the highest number of helminth eggs (511 eggs/g), which made a strong influence on reported mean values. The values fall within the range quoted in previous research (Strauss et al., 1997). The variability in helminth eggs is likely to have an impact on the risks faced by those who handle sludge, as well as the costs of treating it before disposal or re-use.

Feasibility of pumps

The experts interviewed through the online survey were unanimous in suggesting that completely mechanized processes such as the Vacutug were not likely to be viable in Bangladesh (Opel and Bashar, 2013). With narrow roads, and latrines often located in the interiors of villages far from roads, vacuum trucks would not be able to access pits for emptying. Semi-mechanized processes were considered more viable due to lower risks than manual processes, and lower costs than completely mechanized process. Four pumps—gulper, diaphragm, diesel, and electric—emerged as popular options for testing (Figure 3). The first two pumps do not require fuel; the last two.

(a) Gulper pump

(b) Electric pump

(c) Diesel pump

(e) Diaphragm pump

Figure 3: Pumps chosen for testing

Table 4 provides a summary of experiences of using the selected pumps. The pit emptiers reported that the diesel and electric pumps were heavy and bulky to handle. The costs of energy also made them unpopular options. The diesel pump, especially, was reported to be suitable for only deep pits, and heavy to transport around. The high costs of using these pumps might also render the charges that would be levied on households too high.

Table 4: Comparing different pumps to gauge feasibility of use in rural areas

	Gulpher	Diaphragm	Diesel	Electric
Capital costs/ Purchasing costs (BDT)	10-15K	25-30K	20-25K	10-15K
Energy requirements	None	None	Diesel	Electricity
Maintenance costs (annual, BDT)	1-2K	1-2K	3-5K	2-3K
Ease of use in rural areas	Difficult	Easy	Difficult	Easy
Ease of handling	Difficult	Easy	Difficult	Difficult
Minimun labour requirement (per pit)	2	1	2	1
Van needed for transporting pump	Yes	No	Yes	No
Ideal pit depth	3-5ft	3-10 ft	10-15 ft	3-10 ft
Probable emptying charges to be levied (per pit; BDT)	0.5-1.5K	0.5-1.5K	1.5-2K	1.5-2K
Spillage during emptying	Yes	No	Yes	Yes
Probability of damaging latrine during use	High	Low	Med	Low
Preparation time (minutes)	15-20	10-15	20-30	15-20
Pit emptying time (minutes)	20-30	15-20	5-10	101-5

Notes:
This information comes from debriefing sessions with emptiers the research team had worked with, as well as emptiers in Bhaluka who had used these pumps. In 2014, 2015, and 2016, 1 USD = 78.5 BDT.

The diaphragm emerges as the option most suited to rural areas. While the capital cost is relatively high, it does not require energy to operate, and is easy to maintain. It is lightweight, and does not require a van or cart for transportation. The pump is easy to handle, needs only one person to operate, and its use involves a reasonable amount of time to prepare and empty the pit. The charges levied on households would be lower, and are comparable to what households whose pits were emptied in the study reported to be currently paying for manual emptying. Finally, it is unlikely to damage the pit latrine sub-structure or toilet super structure.

Conclusions

Bhaluka is characterized by high rates of access to latrines, and it is estimated that 15 million liters of sludge is generated annually. This sludge has a high water content, and high levels of helminth eggs and fecal coliforms. Current emptying practices involve using simple tools and bare hands. This poses risks to those who handle sludge.

An organized service for emptying should incorporate into its design the use of pumps for minimizing risks to those who handle sludge. Given the nature of the sludge, and the manner in which pit emptiers dispose sludge from pits currently, introducing the use of protective personal equipment that reduces skin contact with sludge could be a first step. Additionally, the liquid nature of the sludge renders the use of a pump for emptying a feasible technical solution. A field test of a few options were carried out in the field in 2014, where a diesel, electric and non-fuel based pumps (gulper and diaphragm) were used to empty pits. Despite it higher purchasing costs, the diaphragm emerged as the more feasible option, as it has no fuel costs, is light in weight, can be operated by one person, can serve a variety of pit depths, and minimizes spillage of sludge.

The characteristics of sludge, and current methods for its emptying motivate the need for a service introduces safe practices for handling sludge. In addition, current methods of disposing sludge also suggest that the transportation of emptied sludge needs to be urgently considered. This is displayed in Balasubramanya et al., 2016, a companion paper to this paper.

The current practice of emptying pit latrines poses a significant risk those who handle it. But simple technologies such as the use of a pump can reduce exposure to pathogens. These aspects need to be incorporated into any sludge management system.

Finally, any solution around sludge management will involve designing service delivery models that transport sludge for treatment and disposal. To design a robust and sustainable model, the costs of service delivery; the nature and size of equipment and labor needed; and the ability of the government and households to contribute to the financing of such a system needs to be understood. This is explored further in Balasubramanya et al., 2016b, which is in review, using data and results presented in this current paper.

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