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Enhancing faecal sludge management in peri-urban areas of Lusaka through faecal sludge valorisation: challenges and opportunities

J M Tembo^{1*}, E Nyirenda¹ and I Nyambe²

¹University of Zambia, School of Engineering, Lusaka, Zambia

²University of Zambia, School of Mines, Lusaka, Zambia

*Email : wazatemboj@gmail.com

Abstract. Lusaka, the capital city of Zambia, has two million inhabitants with 70% residing in peri-urban areas. Ninety (90) % of this population employ pit latrines for excretion generating approximately 22,680 tons of faecal sludge per annum. This sludge is inadequately managed hence of the generated amount, over 60% remains within the residential environment thereby compromising both the environment and public health. To foster a solution to this problem, a study was commissioned to assess faecal sludge valorisation potential and how it would impact on Faecal Sludge Management. The study evaluated policy, institutional and regulatory frameworks, sanitation practices including latrine construction and usage aspects and also characterised the faecal sludge for selected parameters relevant to valorisation. Four peri-urban areas were adopted as study sites. Policy issues together with existing institutional and regulatory frameworks were assessed through literature review. Sanitation practices were evaluated through physical observations, focus group discussions, interviews and questionnaire administration. Faecal sludge characterisation was through sampling and analysis. It was observed that there are policy gaps in fostering faecal sludge valorisation. Sanitation practices and latrines construction also do not favour valorisation. The quality of the raw sludge has potential for valorisation though again, some parameters like solid waste content require drastic changes in sanitation practices in order not to compromise the reuse potential of the sludge. It was concluded that if faecal sludge management is to be enhanced through valorisation, there is need to have policies promoting pit latrine faecal sludge reuse and strengthened regulatory and institutional frameworks in this respect.

1. Introduction

Faecal Sludge Management (FSM) has continued to be a world-wide challenge to sanitation provision especially in developing countries. Between 65 and 100 % of the urban population of most Sub-Saharan African countries access sanitation exclusively through onsite systems [1]. For these countries, pit latrines prevail especially in peri-urban areas [2]. However, pit latrines have one drawback in that their capacity is limited. They fill up after some time making them unusable [3][4]. When a latrine gets full, two options are available for its ultimate fate: It can be buried and a new one dug to replace it; or it can be emptied and put back into service [5][6]. In high density areas where space is a challenge, the latter option is more appealing.

The success of pit emptying in any locality requires the availability of a system which adequately addresses all aspects of FSM including safe faecal sludge emptying, transportation, treatment and disposal [7]. However, these systems are rarely available in low cost areas of most developing countries. It has been observed that lack of incentives is one of the factors contributing to the absence of adequate FSM systems in low cost areas of developing countries [8]. The perception that faecal sludge is a waste and not a resource is one major reason for the observed lack of incentives in FSM service provision. It is suggest that one way in which FSM can be improved is through valorisation [8]. Initial steps towards faecal sludge valorisation include creation of an enabling environment [9]and identifying potential areas for its reuse which needs to be coupled with an understanding of the quality aspects. The quality aspects need to be understood to know exactly what needs to be done to enhance the valorisation potential.



Lusaka, the capital city of Zambia, is home to over two million inhabitants [10]. About 70 % of this population resides in peri-urban areas [11][12]. It is reported that over 90% of people residing in peri-urban areas of Lusaka use pit latrines [13]. This translates to 1.26 million people employing pit latrines as a means of excreta disposal in the city. With an excreta generation rate of 1.5 litres per capita per day [14], this population generates about 1,890m³ of fresh excreta every day which converts to over 22,000 tons of sludge per annum when biodegradation aspects are factored in. Most of this sludge remains within the residential environment where it continues to compromise the environment and public health. The major reason for this is the absence of effective and efficient FSM systems in these areas. This paper looks at faecal sludge management in peri-urban areas of Lusaka; the existing policy, legal and institutional frameworks, practices, quality and associated challenges and opportunities for faecal sludge valorisation with regards to improving FSM.

2. Experimental

2.1. Study areas

The project identified four peri-urban areas from within Lusaka. These included Chaisa, George, Kanyama and Madimba compounds (Figure 1).

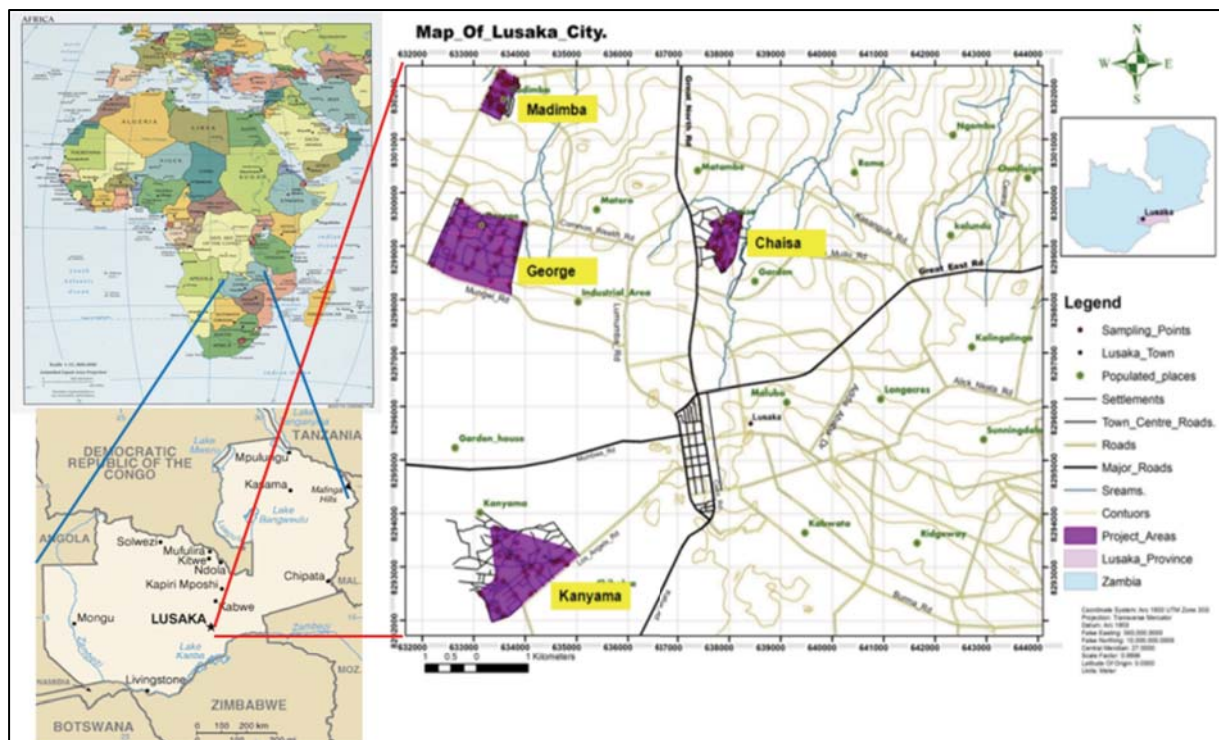


Figure 1. Map showing location of project sites.

The four selected study sites represented a full spectrum of the geophysical environments within the city. Kanyama and Madimba compounds are predominantly on dolomite. George compound sits on dolomite in the south but the central part including the north eastern parts are sited on schists. Chaisa is exclusively on schist formation. Within the compounds, areas are affected differently in terms of drainage. Madimba is mostly waterlogged throughout the year. Other compounds have areas that are water logged throughout the year as well as those that only get affected during the rainy season. The degree to which they are affected also differs depending on nature of the terrain. This selection was in order that effects of the hydrogeological aspects on faecal sludge quality could be captured.

2.2. Desk study

Desk study was cardinal in the assessment of the effectiveness and adequacy of policy, legal and institutional frameworks as they relate to faecal sludge management in Zambia. Desk study was also important in the garnering of information and knowledge available on the aspects of sanitation practices and faecal sludge management in relation to beneficiation prospects in low income areas.

2.3. Field work

Field work involved Focus Group Discussions (FGDs), questionnaire interviews and in-depth interviews. These were used to gather data on sanitation practices. Characteristics and nature of the latrines was assessed through physical surveys and measurements as well as interviews. Faecal sludge characterisation was through sampling and analysis of samples. Samples were collected from the top and bottom layers of each of the pits used as sampling points. From each layer, three samples were collected and then put in a container to formulate a composite sample. Three samples were then collected from the composites for analysis at the laboratory. Sample analyses were in accordance with the Water Research Commission analytical protocols which are based on the American Standard for Water and Wastewater Analysis [15].

3. Result and discussion

3.1. Policy, legal and institutional framework

Policy, together with legal institutional frameworks are critical ingredients to fostering reuse prospects of faecal sludge. Effective and responsive policies and regulations are critical in formulation of effective FSM systems [9]. However, the study revealed that there are policy, legal and institutional gaps relating to FSM in peri-urban areas. There are policies and legislative instruments that guide the provision of sanitation services in peri-urban areas of Zambia. However, the study showed that most of them apply to FSM in the general context of sanitation. Some of the applicable policies include: the 1994 National Water Policy; the 2004 National Decentralisation Policy; and the Sixth National Development Plan (SNDP). Legislative instruments in place which apply directly or indirectly include: the Environment Management Act of 2011; the Water Resources Management Act No, 21 of 2011; the Water Supply and Sanitation Act No. 28 of 1997; the Public Health Act (CAP 295); the National Health Services Act (CAP 315); and the Local Government Act (CAP 281). However, there is no a single policy or statute specific to management of faecal sludge from pit latrines especially with respect to reuse.

Several institutions are responsible for sanitation provision in peri-urban areas. However, until recently, these institutions have not been very visible in these areas. For example, through the Water Supply and Sanitation Act of 1997, commercial utilities were formed to take up the water supply and sanitation service provision to areas within the jurisdiction of the local authorities. However, most utilities only took up the reticulated sewerage systems leaving peri-urban areas to fend for themselves. Even where interventions are being designed in these areas, the approach has mainly been to provide reticulated systems. However, due to the nature of some of the peri-urban areas in terms of the layout of housing units and geological conditions which are rocky, it is clear that many areas will remain on pit latrines for a long time to come hence if nothing is done to enhance FSM like incentivising the faecal sludge chain, these challenges will continue in perpetuity.

Clear, effective and responsive policies are paramount to addressing the challenges. Statutes specific to FSM should also be enacted which clearly spell out and enforce aspects related to faecal sludge which are relevant to faecal sludge valorisation. Examples here include statutes that spell out latrine designs and usage. Formulation of Institutions with a clear mandate on enhancing FSM from the perspective of valorisation is important. In the current arrangements, aspects of FSM, especially in peri-urban areas, are just one of the main responsibilities of responsible institutions and this has seen them being relegated into oblivion hence exacerbating poor sanitation.

3.2. Sanitation practices

Over 90% of the people in peri-urban areas of Lusaka used pit latrines [13]. The study showed that the designs of facilities were not regulated. Most of the facilities were used as receptors of both excreta and grey water which impacted of the faecal sludge quality from these units.

Generally, there were no formal desludging services in the project areas. Hence, where it was impossible to dig a new latrine when the old ones filled up, the only solution was informal desludging. Due to limited capacity to appropriately dispose of the sludge removed from the latrines, or simply due to the desire to cut down on costs, informally desludged pit contents still ended up within the domestic environment. However, much as it was acknowledged by residents in these areas that latrine emptying was the solution to sustained access to the facilities, not a single latrine from the more than 100 pits that were assessed was constructed with provision for desludging. It was only after the pit got full that issues on how to appropriately desludge arose. In most cases, desludging was done by enlarging the squat hole or by breaking the side wall to access and scoop out the sludge. However, as the latrines were usually constructed from low quality materials, this process compromised the structural integrity of the latrines. Cases of latrine collapses due to desludging had been recorded. This was an aspect that could be addressed by imposing standards on the design and construction of facilities.

The study revealed that the high solid waste in the latrines was as a result of several reasons. Firstly, most latrine designs were not user-friendly to young children. Because of this, children usually defecated on the ground within the premises of the household after which the excreta was picked and deposited into the latrine. The picking up of the excreta was through a scooping tool like a shovel or hoe. Therefore, when the excreta was picked, an appreciable amount of soil would also be collected which would also end up in the latrine. Secondly, the socio-cultural perceptions and stigma attached to menstruation in most of the Zambian culture, leads to disposal of menstruation waste in a manner that ensures maximum secrecy. Unfortunately, in peri-urban areas, pit latrines serve as one of the most appropriate means of disposal that ensures secrecy. Lastly, the lack of solid waste management systems leads to deliberate disposal of the waste in pit latrines. Solid waste negatively impacts on the beneficiation potential of the sludge. If not addressed, even when latrines are designed with a provision for desludging, the solid waste could still complicate the desludging and treatment processes.

3.3. Cost of desludging

Adequate FSM requires that desludging aspects are addressed. In Lusaka, to respond to the challenges of inappropriate desludging, formal desludging means were piloted in some of the peri-urban areas. However, the cost of desludging was high for most people resident in these areas. Desludging was through 60 litter barrels and the costs were US\$40, US\$ 60 and US\$ 70 for 12, 24 and 32 barrels respectively. A survey on household income levels revealed income levels of less than 1US\$ per capita per day with the majority living on a hand to mouth basis. This implied that faecal sludge emptying systems, although a solution to the FSM challenges faced in these areas, was out of reach for most residents and required subsidization.

The study revealed that the setup with respect to desludging was such that the whole cost of desludging, transportation and disposal was borne by the client. It is suggest that one way in which financing of the faecal sludge chain could be subsidized is to allow for income generation through resource recovery from waste derived products [16]. This is because the faecal sludge would generate income at the various stages of reuse like biogas generation. The generated income can then subsidise desludging thereby contributing to enhanced FSM in peri-urban areas.

3.4. Faecal sludge quality

Faecal sludge was characterised from the perspective of parameters that impact on valorisation. These included solids and moisture content, microbiological parameters, chemical parameters including metals and organic matter. No clear variations in quality were observed with respect to study sites.

The average solid waste content in the faecal sludge from the pit latrines was around 20% expressed as percent of unit weight of solid waste per unit weight of dry solids. This definitely has negative impacts on valorisation. In the production of biogas, high waste content would result in rapid filling up of the reactors hence increasing on the cost of operation. This had been a challenge at a biodigester that was being piloted in one of the project sites. At the reuse stage, the high waste content would make the sludge objectionable and would thus reduce its value. Therefore, regulation of latrine usage is imperative for effective faecal sludge valorisation as elaborated in section **Error! Reference source not found.**

Moisture content ranged between 50.4 ± 2.8 and $99.2 \pm 2.8\%$ indicating high variability. This showed that whilst some faecal sludges were thick and could possibly not be desludged using suction action, others were watery and similar to wastewater.

Microbiologically, the faecal sludge, as expected, had high prevalence of microorganisms with Total Coliforms averaging $29.1 \pm 9 \times 10^9$ and $28.7 \pm 9 \times 10^9$ CFU/100ml of sample in the top and bottom sludge respectively. Prevalence of *Ascaris Lubricoides* was at 56% with viability at 27%. *Cryptosporidium Parvum* had a 90% prevalence rate in numbers averaging 22 ± 5 and 14 ± 6 in the top and bottom sludges respectively. The presence of all these microorganisms was indicative of the high risk the sludge posed with respect to potential for diseases transmission. This implied that in valorising faecal sludge, measures to guard against transmission of diseases need to be instituted.

The concentration of heavy metals was found to be very low ranging from zero to a few micrograms per gram of the dry solids (Table 1). Analysis of the faecal sludge for base metals also indicated low concentrations (Table 2).

Table 1. Average concentration of heavy metals in latrine sludge.

Element	Source of Sample	Range (μ /gTS)	Mean (μ /gTS)	Mean Dev	STD
Copper	Top Sludge	0-300	17.2	± 1.4	
	Bottom Sludge	0-345	18.8	± 2.0	
Cobalt	Top Sludge	0-124.3	5.5	± 4.0	
	Bottom Sludge	0-27.7	3.4	± 2.0	
Cadmium	Top Sludge	0-23.4	1.9	± 2.0	
	Bottom Sludge	0-67.6	5	± 3.7	
Zinc	Top Sludge	0-134	8.7	± 4.4	
	Bottom Sludge	0-90	8.2	± 5.7	
Chromium	Top Sludge	0	0	0	
	Bottom Sludge	0	0	0	
Lead	Top Sludge	0-4	0.08	± 0.1	
	Bottom Sludge	0-13	0.25	± 0.3	

The low concentrations of heavy metals are indicative of the potential for reuse of the sludge in both agricultural activities as well as a biogas generation. Copper, lead, chromium and zinc inhibit anaerobic digestion by inactivating enzymes within microorganisms [17]. However, all these were low with concentrations ranging from not detectable to only a few micrograms per gram of the total solids (Table 1). Therefore, anaerobic digestion of this sludge cannot be impeded by the presence of heavy metals. Similarly, heavy metals were well below the threshold for reuse in agriculture. European Union Standards prescribe $20\text{-}40\mu\text{g/gTS}$ for Cadmium, $1,750\mu\text{g/gTS}$ for copper, $750\text{-}1,200\mu\text{g/gTS}$ for Lead and $2,500\text{-}4,000\mu\text{g/gTS}$ for Zinc. All these were above the concentrations recorded in Table 1 indicating that heavy metals would not be a problem if the sludge was used in fertigrating crops.

Concentration of base metals is an important aspect that needs consideration where the sludge is to be used in agriculture especially from the perspective of the Sodium Adsorption Ratio (SAR). When sodium is present in water in higher proportions than calcium and magnesium, it may cause permeability problems. To this effect, SAR was computed using proportions of Na, Ca, and Mg in the sludge. The results showed that the metals in the sludge were not in proportions that would promote sodicity problems (Table 3).

Table 2. Average concentration of light metals in latrine sludge.

Element	Source of Sample	Range ($\mu\text{g}/\text{gTS}$)	Mean	Mean	STD
			($\mu\text{g}/\text{gTS}$)	Dev	
Sodium	Top Sludge	2.4-164	17.6	± 5.1	
	Bottom Sludge	1.1-182	17.8	± 5.6	
Potassium	Top Sludge	1.9-195	24	± 7.7	
	Bottom Sludge	1.4-115	20	± 5.2	
Calcium	Top Sludge	1.4-140	15.6	± 4.9	
	Bottom Sludge	1.5-136	16.5	± 5.2	
Manganese	Top Sludge	2.6-117	13.5	± 4.9	
	Bottom Sludge	0.3-70	11.2	± 4.8	

Table 3. Computation of sodicity based on average values.

Element	Average Weights		Milliequivalents	
	Top Sludge	Bottom Sludge	Top Sludge	Bottom Sludge
Na	17.6	18.0	0.8	0.8
Ca	15.6	16.5	0.8	0.8
Mg	13.5	11.2	1.1	0.9
SAR			1.1	1.2
STD			<3	<3

Organic matter measured as COD revealed high concentrations averaging 1.5 gCOD/g TS. Biodegradability measured through volatile solids averaged around 65% g VS/g TS indicating more than 50% biodegradability. Based on these two parameters, it is evident that the sludge is a potential raw material for biogas generation. The organic matter is also an important constituent in soil conditioning properties of sludge.

4. Conclusion and recommendation

From the study, it was concluded that FSM has continued to pose a challenge in peri-urban areas of Lusaka. This was because of the lack of incentives in sanitation service provision in low income areas coupled with absence of policy to address the problem. The study showed that it is imperative to incentivise FSM in the peri-urban areas which incorporates desludging and reuse due to i) The environment in these areas does not favour burying of pits when they get full making desludging the most suitable option for addressing the problem of full latrines. This is because of lack of space and also hostile geology which makes excavation impossible; ii) The quality of the sludge has reuse potential save for a few parameters like microorganisms and solid waste content that require interventions for effective and safe reuse; and iii) Promoting reuse would subsidise the desludging costs and hence contribute to enhanced sanitation in the service areas. The study also revealed that for faecal sludge to be effective, it is imperative that the following are addressed:

- i) Formulation and implementation of specific, effective and responsive policy to deal with FSM in peri-urban areas from the perspective of reuse;

- ii) Regulation of the design and construction of the latrines so that desludging when required can be facilitated; and
- iii) Regulation of latrine usage to avoid usage that negatively impacts on the faecal sludge's potential for valorisation. This can be through statutes or/and bye laws.

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