Comparative risk of pit latrine sludge from unplanned settlements and wastewater in Mzuzu City, Malawi

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Most developing countries use existing knowledge and infrastructure for wastewater in the treatment, reuse and disposal of faecal sludge. There is need to have a clear picture of the risk faecal sludge poses in relation to wastewater if effective treatment, disposal and reuse systems are to be implemented. Little work has been done to quantify the risk faecal sludge poses in relation to wastewater in a localized setting. This study quantifies the comparative risk of faecal sludge from pit latrines in unplanned settlements in Mzuzu City and wastewater. A total 80 sludge samples were obtained from 20 pit latrines in five unplanned settlement Laboratory characterisation was performed for Organics (chemical oxygen demand and biochemical oxygen demand), nutrients (total ammonia nitrogen and total phosphorus) and pathogens (Escherichia coli and helminth eggs) were determined through laboratory analyses. Documentation review was used to get wastewater characteristics. The study found a higher risk (comparative risk >1; p < 0.0001) for organics and nutrients in pit latrine sludge as compared to wastewater. Pit latrine sludge was found not to pose significantly higher public health risk from both E. coli (comparative risk <1; p < 0.0001) and helminth eggs (comparative risk < 1; p < 0.165) than relation to wastewater.

Key words: Faecal sludge, environmental risk, public health risk, faecal sludge treatment.

INTRODUCTION

Many developing countries are adopting faecal sludge management as a long-term and sustainable strategy for...
improving access to sanitation in unplanned settlements in urban areas (Mara and Alabaster, 2004; WHO/UNICEF, 2017). Faecal sludge treatment, reuse and disposal in these countries are mostly carried out using existing knowledge and infrastructure for wastewater management (Blackett et al., 2014). Since faecal sludge and wastewater differ in their characteristics, there is need for a clear picture of the risks faecal sludge poses in relation to wastewater if effective faecal sludge treatment, reuse and disposal systems are to be implemented. Little information is available in the existing body of knowledge for comparison (both directly and implicitly) of risks in faecal sludge and wastewater (Doku, 2002; Koné and Strauss, 2004; Bassan et al., 2013; Strande et al., 2014). While these studies can give a crude indication of the global comparative risk between faecal sludge and wastewater, limited work has been done for localized settings. This study assessed the comparative risk of faecal sludge from pit latrines and wastewater in unplanned settlements in Mzuzu City in Malawi. This was done by characterizing pit latrine sludge and comparing its characteristics with those of wastewater. In this study, comparative risk was defined as the ratio of parameter levels in pit latrine sludge to levels in wastewater. The study focused on both environmental and public health comparative risks. Environmental risk was considered in terms of organics (biochemical oxygen demand and chemical oxygen demand) and nutrients (total ammonia nitrogen and total phosphorus). Public health risk focused on pathogens (Escherichia coli and helminth eggs). An understanding of the risk arising from treating, disposing and reuse of faecal sludge, thus important, in ensuring sustainability of the environment and water resources (SDG 6) and public health (SDG 3).

**MATERIALS AND METHODS**

**Study area**

The study was carried out in five unplanned settlements in Mzuzu City in Malawi namely Salisbury Lines, Luwinga, Katoto, Chibanja and Chibavi (Figure 1). Based on settlement categorization for Mzuzu, the settlements fell under medium density areas (Luwinga), high density permanent areas (Katoto and Chibanja), high density traditional areas (Chibavi) and informal areas (Salisbury Lines). All the settlements were not getting waste collection services from
Sampling

Sludge samples were obtained using grab sampling from a total of 20 pit latrines in these informal settlements in October 2014. The sampling was done in conjunction with an established pit latrine emptier and generally followed the procedure utilized by the emptier when engaged to empty filled-up pit latrines. Verbal informed consent to obtain sample from a household latrine was obtained from the head of the household. No identifiable information was collected in relation to the households from whose pit latrine sampling was done. Purposive sampling was employed in the study whereby only latrines with a minimum column depth of 1.5 m of sludge that were viscous enough to be sucked by a vacuum tanker were included. Depth and viscosity of the pit latrine sludge were determined by driving a marked wooden plank into the sludge. In each latrine, sludge samples were collected at four depths (the surface, 0.5, 1 and 1.5 from the sludge surface). This sampling scheme was informed by the theoretical classification of layers occurring in pit latrine as proposed by Bakare et al. (2012) and illustrated in Figure 2. The underlying reasoning in the framework is that sludge characteristics vary by layers as a result of differences in predominant chemical and biological processes in individual layers. Thus, the sampling targeted a wider variation of sludge in the latrines. Sludge samples were preserved and transported to the Malawi Polytechnic Laboratory in plastic sample transport box filled with ice. At the polytechnic laboratory, the samples were kept at 4°C in the refrigerator.

Documentation review of studies at local and global level was done to get parameter values in wastewater. Major studies informing wastewater characteristics for Malawi included Sajidu et al. (2005), Chipofya et al. (2010) and Chipofya et al. (2011).

Laboratory analyses

In the laboratory, the pit latrine sludge was characterized for organics (biochemical oxygen demand and chemical oxygen demand), nutrients (total ammonia nitrogen and total phosphorus) and pathogens (E. coli and helminth eggs). Chemical oxygen demand and biochemical oxygen demand were determined through titration (BS 6068, 1988). Total ammonia nitrogen, total phosphorus and E. coli were analyzed using standard methods in AOAC (2000). Total ammonia nitrogen was determined by titration, total phosphorus (TP) by colorimetric method and E. coli by membrane filtration. Helminth eggs were quantified using the modified USEPA Method (Schwartzbrod, 1998). Each analysis was duplicated for each sample with the average taken as the final result. One sample t-test, at 0.05 significance was performed in Microsoft Excel to compare mean parameter values and calculate the comparative risk of pit latrine sludge and wastewater.

RESULTS

Organics

Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) levels in sludge samples from the 20 latrines and wastewater are presented in Figures 3 and 4, respectively. Both BOD (t = 21.3, 79 d.f., p < 0.00001) and COD (t = 24.8, 79 d.f., p < 0.00001) were higher in pit latrine sludge than wastewater. BOD levels in latrine sludge ranged from 1437 to 5563 mg/L with an average of 3011 mg/L. The mean BOD comparative risk was 3.7. COD levels in pit latrine sludge ranged from
Kalulu et al. 153

Figure 3. Biochemical oxygen demand in pit latrine sludge and wastewater.

Figure 4. Chemical oxygen demand in pit latrine sludge and wastewater.

9072 to 48021 mg/L with a mean value of 21317 mg/L. The mean comparative risk for COD in pit latrine sludge as compared to wastewater was 26.

Nutrients

Figures 5 and 6 present data on total ammonia nitrogen (TAN) and total phosphorus (TP) content, respectively. Levels of both TAN (t = 7.88, 79 d.f., p < 0.00001) and TP (t = 24.5, 79 d.f., p < 0.00001) in pit latrine sludge were higher than levels in wastewater. TAN in pit latrine sludge ranged from 0 to 1284 mg/L with a mean value of 273 mg/L. This gave a mean TAN comparative risk of 22.8. TP ranged from 105 to 590 mg/L with a mean value of 331 mg/L. The mean TP comparative risk for pit latrine sludge in relation to wastewater was 62.5.

Pathogens

E. coli and helminth egg counts results are presented in Figures 7 and 8, respectively. E. coli counts in pit latrine sludge were lower than counts found in wastewater (t = 294.9, 79 d.f., p < 0.00001). The E. coli counts in pit latrine sludge ranged from 2700 to 71200 cfu/100 mL.
with a mean count of 24798 cfu/100 mL and a mean comparative risk of 0.04. Helminth egg counts in pit latrine sludge did not differ from wastewater ($t = 1.4, 79$ d.f., $p = 0.165$). The helminth egg counts ranged from 0 to 2091 eggs/g TS with a mean count of 126 eggs/g TS. The helminth egg comparative risk of pit latrine sludge to wastewater was 1.7.

**DISCUSSION**

The higher levels of organics and nutrients in pit latrine sludge as compared to wastewater can be explained by the dilution in wastewater whose major constituent is water. In addition, the disposal of solid waste and use of additives in pit latrines, which is unlikely to happen in the wastewater stream, could also be attributed to the difference (Kalulu et al., 2016; Chiposa et al., 2017). The major forms of solid waste thrown into pit latrines included paper, cobwebs and vegetative waste. Common additives used in the latrines include greywater, commercial products (co-trimoxazole granules and sodium hypochlorite) ash, soap, used engine oil and paraffin. These additives are used for odour control,
latrine fill-up rate reduction and killing flies and germs in latrines.

The comparative risks from this study were generally lower as compared values (37.8 for COD, 31.0 for BOD and 54.2 for TAN) deduced from literature (Doku, 2002; Metcalf et al., 2003; Koné and Strauss, 2004; Bassan et al., 2013; Strande et al., 2014). Since wastewater characteristics display low variability, the higher comparative risk values in literature could be explained by higher levels of organics and nutrients in pit latrine sludge investigated in these studies in comparison to sludge from Mzuzu. Latrine use habits and diets, and sludge retention period in the latrine could be some of the reasons for this difference (Bassan et al., 2013). Only TP had a higher comparative risk (62.5 than the global value of 21.2) which could be attributed to low utilization of detergents and other cleaning materials in wastewater streams in developing countries like Malawi.

Despite the fact that pit latrine sludge pose more risk than wastewater for organics and nutrients, the study showed that faecal sludge did not pose significantly greater public health risk than wastewater. Lower \textit{E. coli}
counts in the sludge could be attributed to die-off as a result of exposure to high levels of ammonia, sludge retention time and predation within the latrines (Montgomery and Elimelech, 2007; Arthursun, 2008; Niwagaba et al., 2009). The insignificant difference between helminth eggs in wastewater and pit latrine sludge could be explained by the eggs in the pit latrine sludge not being exposed long enough to harsh conditions to lead to significant die-off. Helminth eggs are very resistant and are known to take a subjection to unfavourable conditions ranging from several months to years to be inactivated (Jimenez et al., 2006; Strande et al., 2014).

Based on the study design, the comparative risks obtained in the study might not give the best picture on the ground. The study did not characterize wastewater in Mzuzu City as such values used could be different from the actual parameter levels in the city. Considering that faecal sludge is at present co-treated with wastewater, the actual risk faecal sludge poses to the urban environmental might not be high due to dilution of faecal sludge by wastewater. A better picture could be obtained by improving the current design by characterizing influent faecal sludge and wastewater before mixing them in the treatment plant. The products (effluent and sludge) from the co-treatment should also be characterized and used to calculate the comparative risk. Additionally, volumes of faecal sludge and wastewater being co-treated need to be considered to obtain the actual comparative risk.

Conclusions

This study gives a picture of comparative risk between pit latrine sludge and wastewater within a localized setting. The study demonstrated that pit latrine sludge was riskier in terms of organics and nutrients. However, pit latrine sludge did not pose a higher risk than wastewater in terms of pathogens.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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