Research Paper

Drivers of unhygienic desludging practices in unplanned settlements of Dar es Salaam, Tanzania

Amour Seleman, Sara Gabrielsson, Tolly S. A. Mbwette and Richard Kimwaga

ABSTRACT

Desludging is considered a key step in urban sanitation improvement. Nevertheless, in most urban unplanned settlements, desludging is performed in an unhygienic manner, risking public health. This study used a combination of qualitative and quantitative methods to analyse the underlying factors for unhygienic desludging in three urban unplanned settlements of Dar es Salaam, Tanzania. Factors for unhygienic desludging were analysed using logistic regression analysis and the Integrated Behavioural Model for Water, Sanitation and Hygiene (IBM-WASH), respectively. It was found that 23.7% of the surveyed houses practised unhygienic desludging. Plot physical inaccessibility, outdated laws that stipulate low penalties and the lack of routine data were found to be key contextual factors. Furthermore, perceived inability to control unhygienic desludging among community members and the lack of feeling of shame among those performing unhygienic desludging are the key psycho-social factors. Technological factors contributing to continued practice of unhygienic desludging can be linked to the weakness in existing desludging technologies and general skepticism about the performance of manual desludging hand pumps. This paper concludes that unhygienic desludging in Dar es Salaam is likely to continue unless such factors are considered and integrated into the city's sanitation improvement plans.

Key words | Dar es Salaam, non-sewered sanitation, safely managed sanitation, unhygienic desludging, unplanned urban settlements

Amour Seleman (corresponding author)
Tolly S. A. Mbwette
Richard Kimwaga
Department of Water Resources Engineering,
   College of Engineering and Technology,
University of Dar es Salaam,
P. O. Box 35131, Dar es Salaam,
Tanzania
E-mail: *matipula@hotmail.com*

Sara Gabrielsson
Lund University Centre for Sustainability Studies,
Lund University,
Box 170, SE-221 00 Lund,
Sweden

HIGHLIGHTS

- The study investigated drivers underlying the current poor state of desludging and potential improvement measures.
- The study took place in urban unplanned settlements where a majority of low income urban dwellers live and sanitation situation has remained persistently poor.
- The use of mixed method approach have allowed for broader analysis of the local context, technological and psycho-social dimensions of sanitation challenge.
- The study have identified key factors and possible solutions for improvement of FSM in urban unplanned settlements.

INTRODUCTION

Desludging is recognized as an important strategy for urban sanitation improvement, particularly in unplanned urban settlements (UN-Water 2019; UNICEF & WHO 2019). In unplanned urban settlements (UUSs), land space for the construction of new sanitation facilities to replace those filled up by accumulating faecal sludge (FS) is lacking (Strande *et al.* 2014). Thus, desludging remains the only option to keep the facilities usable (Strande *et al.* 2014). Nevertheless, desludging services have remained inadequate in most UUSs. Residents in these areas use sanitation facilities which are full beyond their safety levels. Alternatively, they desludge them using unhygienic desludging methods, thus posing public and environmental health risk potentials (Strande *et al.* 2014).

Research and information on the magnitude of unhygienic desludging is scant, and low- and medium-income countries (LMICs) have had little success in estimating the proportion of their population with access to safe desludging practices (UNICEF & WHO 2019). On average, it is estimated that cities in LMICs only safely manage 50% of the total amount of FS generated (Strande *et al.* 2014). The remaining amount either is left in pits for a long period or haphazardly disposed of in the surrounding environment posing serious public and environmental health risks (Strande *et al.* 2014).

Hygienic desludging plays an important role in the sanitation service chain and the attainment of Sustainable Development Goals (SDGs). The SDGs target 6.2 aspires to achieve safely managed sanitation for all by 2030 (UN-Water 2019). Hygienic desludging ensures effective and safe removal of FS from onsite sanitation facilities located in areas where safe final disposal of FS onsite is infeasible. Furthermore, the hygienic desludging eliminates open defecation (OD) through limiting release or spillage of FS (Jenkins *et al.* 2015). Being one of the components of the sanitation service chain, hygienic desludging facilitates the effective collection of FS for further processing and subsequent re-use (Strande *et al.* 2014). In this regard, the prevailing persistence of unhygienic desludging practices merits thorough investigation to enhance the benefits of hygienic desludging to human health and the environment.

Recently, there has been increasing recognition among sanitation practitioners on the multidimensional structure of the sanitation service system (Dreibelbis *et al.* 2013; Tilley *et al.* 2014). A well-functioning sanitation system is intertwined through contextual, psycho-social and technological dimensions. These dimensions, as described by Dreibelbis *et al.* (2013) under the Integrated Behaviour Model for Water, Sanitation and Hygiene (IBM-WASH) framework, influence sanitation service delivery at multiple levels of structure/societal, community level, household, individual and habitual level. Tilley *et al.* (2014) emphasized further the need to consider drivers of behavioural change in planning for improvement of faecal sludge management (FSM). However, the idea has not yet been put into practice. The purpose of this study was to determine drivers of unhygienic desludging practices by investigating contextual, psycho-social and technological factors influencing current desludging practices in UUSs of Dar es Salaam. It is as an attempt to contribute to the call for more sustainable sanitation solutions appropriate for LMICs (IWA 2019; UN-Water 2019).

METHODS

Study area

The study was conducted in Dar es Salaam involving the three wards of Manzese, Keko and Kipawa. The three wards were randomly selected among UUSs from Ubungo, Temeke and Ilala municipalities, respectively. The wards were selected among UUSs where unhygienic desludging was reported to be prevalent (Brandes *et al.* 2015; Jenkins *et al.* 2015). Generally, in Dar es Salaam, about 60% of residential plots are located in high water table areas. During the two rainfall seasons, January to April and November to December, sanitation facilities are affected by the rising water table (Brandes *et al.* 2015). Data collection was undertaken between June and September 2018, a low rainfall season ranging between 8.7 and 15.6 mm (URT 2019).

Definition of terms used

In this study, hygienic desludging methods include vacuum tankers, manually operated equipment such as Gulper or Vacutug technology. Unhygienic desludging methods included any kind of manual emptying using manual tools, pit diversion and flooding out (Jenkins *et al.* 2015). Manual pit emptying is hygienic only when used along with appropriate personal protective equipment (PPE) and the sludge is transported to a treatment plant (WHO 2018). As most of the manual pit emptying practices involve climbing down into the pit, which is hazardous (Strande *et al.* 2014), or draining sludge into an adjacent temporary hole on the property after breaking open the side of the pit, then manual pit emptying has been classified as the unhygienic desludging method.

Study design

The study employed a cross-sectional study design employing a combination of both qualitative and quantitative methods for data collection and analysis. Qualitative methods involved key informants interview and focus group discussion (FGD) while quantitative method included research household survey and observation of the physical condition in study areas.

Quantitative data collection

Sampling procedure

Quantitative method was employed in undertaking the household surveys. The sample size for the household survey was estimated using the formula by Israel (1992) expressed as $n = N/[1 + N(e)^2]$, where $n =$ sample size; $N =$ total population; $e =$ sampling error. The population used was a projection from the 2012 National Census Report obtained from municipal councils. The total population (N) for Kipawa, Manzese and Keko was 224,140 people. Therefore, with a sampling error of 5%, using the above formula, the sample size for the study was approximated to 400. The sample was distributed among the study areas proportional to the population size. The sample sizes for Kipawa, Manzese and Keko were 133, 124 and 143,

respectively. Within the wards, the sample size was evenly distributed among sub-wards and systematic random sampling was applied to obtain the study houses.

Data collection procedures

The household survey was conducted in Kiswahili using the questionnaire customized in the Epicollect5 software and installed into smartphones. The questionnaire comprised mostly closed-ended questions. Pre-testing was carried out to test the usability of smartphones, relevance, and flow of questions in the questionnaire. Data were collected by trained field survey assistants from higher learning institutions who worked under the supervision of the principal investigator.

During data collection, plot accessibility was assessed by measuring the size of the access roads to the houses and was done by pacing. An access road of 4 m width and above was regarded as accessible while a road width of less than that was regarded as inaccessible (Mchome 2017). The topography assessed the natural landscape of the area, particularly location of the plot, whether located in flat or low land. Whether the house was located in a flat or low lying area was assessed by observing the terrain in relation to the possibility of parking a vehicle in the area. Lined pit referred to the pit that is strengthened to prevent its wall from collapse. The assessment of pit lining was based on owner self-reporting. Furthermore, toilets were further categorized as being wet or dry type depending on whether water is required for directing excreta to the pit (wet) or categorized as dry when water is not required for directing excreta to the pit and water is not the dominant anal cleansing material.

Qualitative data collection

Key informant's interviews

Before the quantitative study, interview with 19 key informants from the government and non-government organizations (NGOs) was conducted. Six informants were drawn from government, three were vacuum tanker operators, and ten from NGOs that implement sanitation upgrading projects in Dar es Salaam. A snowball sampling

was applied for selection of NGOs until the data collected became saturated.

Focus group discussions

Overall, the study conducted six FGD sessions, two sessions in each study area. Two sessions were planned because of availability of financial resources and time. Plans were made to reach a maximum of 12 participants per session (Cook & Crang 2004) which would make a total of 72 participants for the entire study. However, four participants missed the sessions. Therefore, in total, 68 participants participated in FGDs at a distribution of 23, 22 and 23 for Manzese, Keko and Kipawa, respectively. Participating in FGDs were landlords (house owners), tenants, pit emptiers, community leaders (ten cell leaders, Ward Councillor), and the government officers, particularly the Environmental Health Officers (EHOs) and Community Development Officers (CDOs), who steer sanitation programmes in the particular ward. Landlords and tenants were selected randomly from the list of names of landlords and tenants proposed by each sub-ward chairperson. Each sub-ward chairperson was requested to propose three names for each group of landlords and tenants from their areas. The selected individuals were asked for their consent to participate and were informed of the participation being voluntary.

Data analysis

Data analysis was performed in stages. First, quantitative data were analysed to describe the current desludging situation and associated factors using bivariate analysis with x^2-test. In order to predict factors associated with unhygienic desludging practices, a model-based approach was adopted where two models were run: the logistic regression model for quantitative data and the IBM-WASH for analysis of qualitative data. With the logistic regression analysis, a model of the form $logit(\pi) = \alpha + \beta X + \varepsilon$ was run. In the formula, π is the probability of using unhygienic desludging methods given a set of explanatory variables denoted as X; β is a vector of regression coefficients, α is a reference group that represents individuals employing hygienic desludging methods in every variable and ε is an error term (Hosmer & Lemeshow 2000). The dependent variable

was modelled against various categorical variables that can be grouped as structural factors (e.g., type of toilet and lining), plot physical accessibility, topography and demographics.

As detailed by Jenkins *et al.* (2014) and Thye *et al.* (2011), the lined pit has the potential of being desludged because of pit strength, in contrast to non-lined pits which may collapse during desludging. Wet type toilets generate less dense faecal sludge that can be easily pumped, whereas the dry toilets accumulate dense faecal sludge that is hard to pump. Plot physical accessibility and, in particular, the distance from the vehicle parking area, road width and topography are other factors influencing desludging. Age, gender, education and socio-economic status (SES) of the household head plays a key role in sanitation improvement (Dreibelbis *et al.* 2013); the influence of these factors on desludging was also analysed. For the analysis of SES, we used house rent per month as proxy indicator for SES with a cut off point between the two groups made from the median value. House rent of up to TZS 30,000 = (US$ 13.12) corresponded to low SES while house rent of TZS (31,000) and above (US$ 13.57) corresponded to higher SES. All quantitative data were analysed using SPSS version 20 and variables were considered significant at $p < 0.05$.

In the analysis of factors associated with unhygienic desludging using IBM-WASH framework, the study performed thematic coding under three dimensions (contextual, psychosocial and technological) across all five levels of IBM-WASH framework (societal/structural, community, interpersonal/household, individual and habitual) (Dreibelbis *et al.* 2013). Themes under each dimension and level were identified. The IBM-WASH model is an appropriate analytical framework to use in this case study because it is both multidimensional and multi-scalar.

Ethical considerations

A written research permit with Ref. No. AB3/12(B) was granted by the University of Dar es Salaam. Permission for collecting data in the field was sought from all levels of government administration from the national level (ministry responsible for health and the ministry responsible for regional administration and local government) to the sub-ward level. At the residential house level, the purpose of the

study was explained and verbal consent was sought after explaining the purpose of the study, method and expected results. Interviewees were free to terminate the interview at any time they wished. No personal identification was recorded but the GPS coordinates of the house location were taken.

RESULTS

House occupancy and demographics

A total of 395 respondents participated in the household survey (98.8% response rate). The number of respondents was nearly equal across the study areas: 123 (31.2%) for Manzese, 140 (35.4%) for Keko and 132 (33.4%) for Kipawa. The majority of the respondents, 204 (51.6%), were from residential houses occupied by both landlords and tenants, 118 (29.9%) from residential houses owned and occupied by families and 73 (18.5%) were occupied by tenants. All but one reported their highest level of education attained. The majority of the respondents, 240 (60.8%), had primary school education followed by 94 (23.9%) who had attained secondary school education. Others, 29 (7.4%), 23 (5.8%) and 8 (2.0%), had not attended any formal education, attained higher-level education and attained informal education, respectively.

Desludging situation

A total of 190 (47.7%) reported having performed desludging in the past when the toilet was full. As seen in Figure 1, unhygienic desludging is common in all study areas and nearly a quarter of the residents reported using unhygienic desludging methods when their pits were full of faecal sludge.

Table 1 shows the association between unhygienic desludging and various factors. Unhygienic desludging was more common in Keko and Manzese than in Kipawa. It is further seen from Table 1 that unhygienic desludging is common in low lying areas and is more common among residents who lack space for vehicle parking within 30 metres.

Overall, in all wards, vacuum tankers were the most common desludging methods (accounting for 75.4%), followed by manual pit emptying (Figure 2). It is likely that there was under-reporting of flooding out practices. This could be attributable to the fact that many toilets in the communities were observed to be connected with flood outlet pipes. Residents claimed that they are using the pipes for discharging grey water, but it was clear that also FS was desludged this way (Figure 3).

Determinants of unhygienic desludging using logistic regression analysis

Table 2 presents the logistic regression analysis results of predictors of unhygienic desludging. The parameter estimates for most of the selected variables were positive, suggesting a contribution to the unhygienic desludging practice. As further seen from Table 2, lack of space for vehicle parking (including desludging vehicles) was a statistically significant factor, thus suggesting that
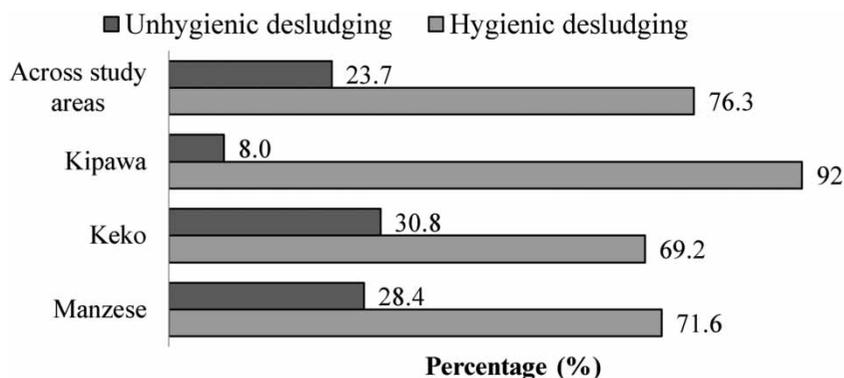

Figure 1 │ Distribution of reported unhygienic desludging across study areas.

Table 1 │ Association between unhygienic desludging and some variables across study areas

Variable	Response category	Desludging		Combined	X^2-value (DF)	*P*-value
		Unhygienic, n (%)	Hygienic, n(%)			
Study area	Manzese	25 (28.4)	63 (71.6%)	88	9.336 (2)	0.009**
	Keko	16 (30.8)	36 (69.2%)	52		
	Kipawa	4 (8.0)	46 (92.0)	50		
Age group	18–40 years	7 (23.3)	23 (76.7)	30	0.000 (2)	1.000
	41–60 years	17 (23.3)	56 (76.7)	73		
	≥61 years	15 (32.4)	49 (76.6)	64		
Sex of the landlord	Male	30 (23.4)	98 (76.6)	128	0.013 (1)	0.908
	Female	15 (24.2)	47 (75.8)	62		
Rent per month in TZS[a]	≥14,000/ =	9 (17.6)	42 (82.4)	51		
	≤30,000	19 (23.2)	63 (76.8)	82	1.351 (1)	0.245
	≥31,000	9 (13.3)	50 (84.7)	59		
Topography	Low lying	15 (42.9)	20 (57.1)	35	8.726 (1)	0.003**
	Flat areas	30 (19.4)	125 (80.6)	155		
Space for parking within 30 m	No space	29 (42.6)	39 (57.4)	68	21.069 (1)	0.000**
	Space available	16 (13.1)	106 (86.9)	122		
Plot accessibility	Inaccessible	37 (25.7)	107 (74.3)	144	1.330 (1)	0.249
	Accessible	8 (17.4)	38 (82.6)	46		
Type of toilets	Traditional latrine	24 (33.8)	47 (66.2)	71	7.534 (3)	0.057
	VIP latrine	2 (10.5)	17 (89.5)	19		
	Pour flush	15 (20.8)	57 (79.2)	72		
	Septic tank	4 (14.3)	24 (85.7)	28		
Toilet category	Dry type	22 (26.5)	61 (73.5)	83	0.649 (1)	0.420
	Wet type	23 (21.5)	84 (78.5)	107		
Pit lining	Partially lined	19 (26.8)	52 (73.2)	71	0.594 (1)	0.441
	Fully lined	26 (21.8)	93 (78.2)	119		

[a]1US$ = Tshs 2,286.7. Bank of Tanzania exchange rate as of 3rd September, 2018 available online at www.bot.go.tz.
**Statistically significant.
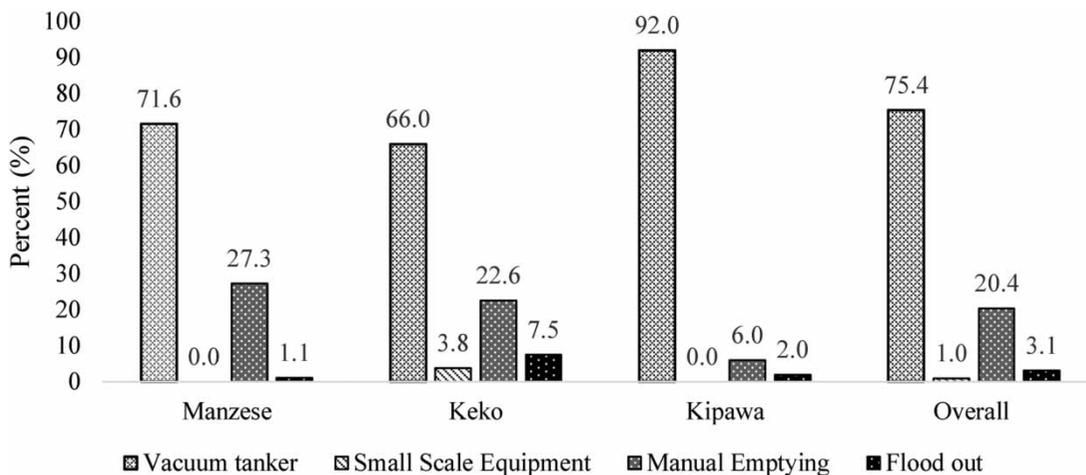
Figure 2 │ Type of desludging methods used across study areas.

Figure 3 | Flooding out pipes connected to the toilet pits.

unavailability of space plays a key role in reliance on unhygienic desludging methods. Results further indicate that residents in Keko were more likely to practise unhygienic desludging than other study wards. One of the reasons for this observation in Keko is linked to the large number of houses that lack space for parking in this area. In Keko, 74/140 (45.4%) of residential houses lack space for parking. Table 2 further shows that residents who have attained secondary school or higher-level education have higher odds of practising unhygienic desludging than those who have not attained any formal education. However, most of the independent variables were statistically not significant, probably because of the small sample size.

Analysis of drivers of unhygienic desludging using IBM-WASH

Contextual factors

Societal/structural contextual factors: Three structural factors were identified to contribute to unhygienic desludging: lack of monitoring and evaluation system for desludging, lack of guidelines on installation of mechanism for identification of latrine filling up ahead of time, and outdated laws that stipulate relatively low penalties against manual pit emptying and onsite disposal or flooding out. Concerning routine monitoring of desludging practices, the study found that desludging services or practices are lacking in the routine sanitation and hygiene monitoring and evaluation (M&E) system. As such, the magnitude of the desludging problem goes unnoticed.

It was further found that national sanitation and hygiene guidelines lack instructions on the installation of features for observing when the pit is getting full, especially for toilets with an offset pit such as pour flush. As a result, residents are unaware of when the pit becomes full and cannot, therefore, prepare financially for hiring hygienic desludging services.

'*For toilets like this (flush with offset pit) it is difficult to see whether it is getting full or not, it is until you see excreta on the pan when you notice that the toilet is full, and this happens when you have no cash at hand to pay for a vacuum truck*' [HH survey respondent in Manzese].

On analysis of regulations for desludging and FSM in general, the study found that regulations used for the control of open discharge of FS through flooding out or onsite disposal through methods such as pit diversion are outdated such that penalties are relatively low. Taking an example of the Ilala Municipal Council, the penalty for indiscriminate discharge of domestic wastewater as stipulated under the Local Government Act (LGA) of 2002 is TZS 50,000 (US\$ 21.9). This penalty is lower than the minimum desludging costs of TZS 100,000 (US\$ 43.7), which poses the risk for the violators to ignore the regulation (Mintz 2014). In Tanzania, domestic wastewater discharges are regulated under the Public Health Act (PHA) No. 1 of 2009 where section 86 empowers municipalities to enact by-laws concerning domestic wastewater discharges (URT 2009). The PHA stipulates a penalty of TZS 500,000 (US\$ 218.7) which is ten times higher than the penalties the municipalities currently charge.

Table 2 | Logistic regression model on the use of unhygienic desludging methods

	B	S.E.	Wald	DF	Exp (B)	95% C.I. for EXP(B)	*P*-value
Study area							
Manzese	Ref						
Keko	1.866	0.959	3.788	1	6.463	(0.987, 42.316)	0.052
Kipawa	1.191	1.125	1.122	1	3.292	(0.363, 29.839)	0.289
Age group							
18–40 years	Ref						
41–60 years	1.158	0.899	1.659	1	3.182	(0.547, 18.527)	0.198
≥61 years	1.054	0.771	1.871	1	2.870	(13.003, 0.171)	0.171
Sex							
Male	Ref						
Female	−0.291	0.686	0.180	1	1.338	(0.348, 5.137)	0.672
Education level							
No formal education	Ref						
Primary	−0.211	0.946	0.050	1	0.810	(0.127, 5.172)	0.823
Secondary and higher	−1.685	0.801	4.428	1	0.185	(0.039, 0.891)	0.035**
House rent/month in TZS[a]							
≤30,000	Ref						
≥31,000	−0.094	0.695	0.018	1	0.910	(0.253, 3.554)	0.892
Topography							
Low lying	Ref						
Flat area	0.891	0.711	1.569	1	2.438	(0.605, 9.827)	0.210
Space for parking within 30 m							
Not available	Ref						
Available	2.421	0.680	12.659	1	11.258	(2.967, 42.726)	0.000**
Plot physical accessibility							
Inaccessible	Ref						
Accessible	0.930	0.750	1.537	1	2.583	(0.58, 11.022)	0.215
Toilet type							
Traditional pit	Ref						
VIP latrine	1.461	1.399	1.094	1	4.321	(0.278, 67.069)	0.296
Pour flush	−0.047	1.713	0.001	1	0.954	(0.633,27.431)	0.978
Septic tank	0.174	1.052	0.027	1	1.190	0.151,9.352)	0.869
Pit lining							
Partially lined	Ref						
Fully lined	0.346	0.709	0.239	1	1.414	(0.352,5.675)	0.625
Toilet category							
Dry	Ref						
Wet	0.462	1.186	0.152	1	0630	(0.062, 6.437)	0.697
Constant	−5.380	1.64	10.757	1	0.005		0.001

[a]1US$ = Tshs 2,286.7. Bank of Tanzania exchange rate as of 3rd September, 2018 available online at www.bot.go.tz.
**Statistically significant.

Community level contextual factors: At the community level, two main contextual factors were found to contribute to unhygienic desludging: characteristics of the built environment and the natural physical environment. The built environment of the study areas is characterized by a lack of space for parking vehicles. Residential houses resort to the use of unhygienic desludging as large vacuum tankers cannot access the plots. Space was observed to be an important factor because hygienic desludging in the study area depends solely on vacuum trucks, which require good access roads and space for parking. In another case, the physical environment of the study areas is characterized by steep topography, low lying areas and high water table. Low lying areas influence draining of FS to watercourses, and also make it difficult for the vacuum tankers to drive up a hill when full of sludge (Strande *et al.* 2014). Residents in Keko and Kipawa reported frequent events of vacuum tankers failing to drive up hills when full of sludge, especially during the rainy seasons. Figure 4 depicts the observed concentration of unhygienic desludging in low lying areas.

Furthermore, a high water table was found to be a major contributing factor for reliance on unhygienic desludging. Due to the high water table, water percolates into the pit resulting in toilets filling up fast, especially during rainy seasons. Some residential houses are required to desludge every three months. This situation results in desludging being seen as one of the very expensive services to incur.

Interpersonal or household contextual factors: With regard to interpersonal/household contextual level, unclear distribution of responsibility for desludging between the landlords and the tenants was found to be the most important factor influencing unhygienic desludging. In rented houses, responsibility for desludging is usually not explicitly stated in any contract. The general practice is, therefore, to share the charges for desludging between the landlord and the tenant. The challenge, however, emerges when one of the parties does not have money at hand to contribute to the cost when the toilet is full. In most cases, residents resort to releasing small amounts of FS through flooding out, until enough money is collected for hiring a vacuum tanker.

Individual level factors: The analysis of data found that gender roles and wealth play an influencing role in unhygienic desludging. In the study areas, it was observed that men spend most of their time away from home doing income-generating activities while women stay at home and carry out family-related activities such as housekeeping, cooking and care for the young and those going to school. Because men spend much time outside their home, they have less of an incentive to incur a cost for desludging once the toilets require desludging. Women, on the other hand, experience the full latrine more by sight and smell, hence have more incentive to desludge. Since men are generally in charge of finances, landlords are concerned about facing difficulties in contacting male tenants for desludging cost-sharing. This observation also links with the prevailing unstable and fluctuating income flows among residents in UUSs. The quantitative part of the study found that across the study areas, only 206 (52.2%) had at least one family member with a bank account, most of whom further reported to have only the minimum allowable balance in their accounts.

Habitual level contextual factors: At the habitual contextual level, it was found that there is a reliance on toilets for management of culturally sensitive wastes such as used menstrual pads and underwear (Figure 5). Solid items are thrown into the pits and eventually clog the desludging equipment, increase desludging time and lead to high energy consumption. Operators were reported to discontinue pumping the pit content when they find large quantities of solid waste. Improvement of desludging in these areas should, therefore, go together with education on the proper disposal and management of solid waste, especially taboo-ridden and culturally sensitive waste such as menstrual waste, which is often disposed of in the latrine pit (Gabrielsson 2018).

Psycho-social factors

Community level psycho-social factors: Two major psycho-social factors were found to influence unhygienic desludging at the community level: low collective efficacy explained by perceived low ability among the community members to control unhygienic desludging practices and lack of shared values about unhygienic desludging. Most residents in the study areas have low self-confidence in controlling unhygienic desludging for two key reasons. First, the practice is
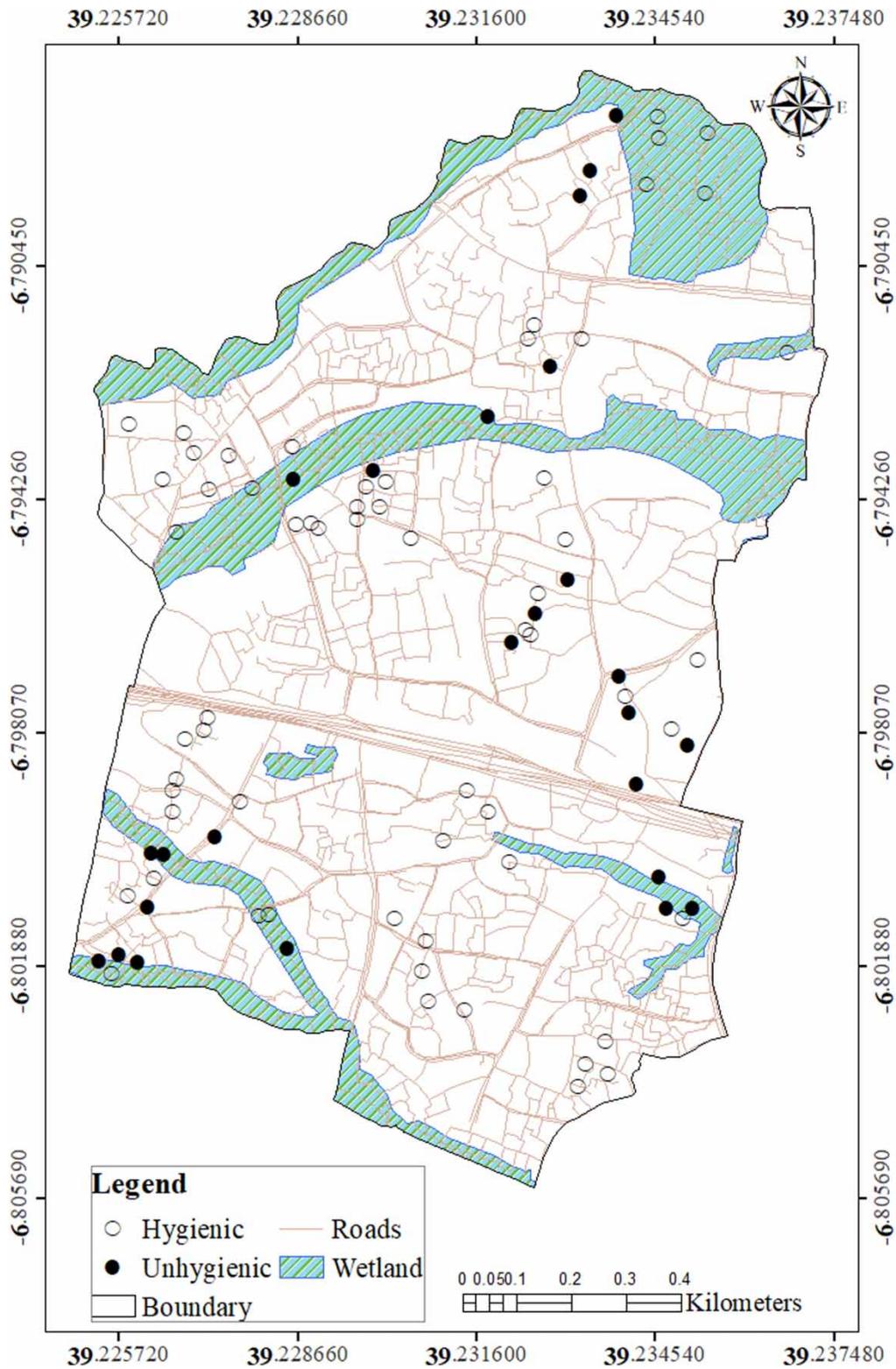
Figure 4 | Map of Manzese ward highlighting the concentration of poor desludging practices in low lying areas.

Figure 5 | Solid items thrown into pits in the study areas.

widely spread and socially sanctioned in the society. More-over, even government institutions, well-off families and private institutions practise it. Some residents in the study areas pointed out that many public institutions, including schools, apartments and even prisons practise flooding out. Private actors such as owners of guest houses, hotels and student hostels also adhere to the norm. Second, land-lords often silence tenants who would like to report unhygienic practices to the authorities by threatening them with eviction. Residents thus perceive the problem as being out of their control.

'For us downstream, there is no point of curbing FS discharge as institutions up streams – some public institutions – discharge, even larger quantities of FS than what we do from households' [Resident in Kipawa].

Furthermore, at the community level, the study found a lack of shared values around hygienic desludging as an important

underlying factor. In the study areas, unhygienic desludging is not considered a shameful behaviour and, therefore, there is no moral incentive for individual households to practise hygienic desludging. This lack of shared values in the community could then explain the low demand for com-munity-based initiatives to use, maintain and deliver manual desludging hand pumps (MDHP) across communities where such technologies would be more contextually appropriate, accessible and affordable to residents (Strande *et al.* 2014).

Interpersonal/household psycho-social factors: At the interpersonal/household level, aspirations for high performing technologies and services were identified as the main factors linked to unhygienic desludging. Residents explained what they aspire to regarding desludging equipment and the toilets. The communities aspire to a technology that is capable of controlling spillage during desludging to protect children's health as children usually walk with bare feet around the premises. The technology should also eliminate direct contact with faeces for the workers and should mini-mize seeing and smelling the FS during the process.

'We need to be informed of an improved toilet that is 'washable' yet desludgeable' [FGD participant in Keko].

The comments were given regarding the Gulper and the inability of vacuum trucks to pump sludge from some non-sewered sanitation facilities. Thus unhygienic desludging is resorted to due to the aspirational hygienic desludging methods that are currently lacking.

Individual level psycho-social factors: At the individual level, limited knowledge of how vacuum tankers work was also identified as a key factor contributing to the prevalence of unhygienic desludging. Vacuum trucks are seen as inef-fective for desludging some types of non-sewered sanitation systems existing in the community, such as VIP latrines.

'Vehicles pump out water and leave mud and other solid wastes at the bottom, the toilet then fills faster than when it was newly constructed; And another thing, some oper-ators arrive with the tank half full of sludge from another place and operators restrict users from examining the tank thoroughly' [Resident in Keko].

Habitual psycho-social factors: Timing of unhygienic desludging was also identified as one of the major psycho-social factors at the habitual level contributing to the prevalence of unhygienic desludging. Across study areas, unhygienic desludging is performed during the night and when it rains, taking advantage of the absence of inspections at these times. The practice has had negative consequences for those using MDHPs, as they have a low customer base, making the business unprofitable. The introduction of desludging hand pumps in Keko has ceased because of lack of customers and all Gulper groups that previously had been established were non-functional, thus leaving communities with only two desludging options to choose from: vacuum trucks and manual emptying.

Technological factors

Societal/structural technological factors: At the societal/structural level, it was found that skepticism among institutions on the performance of MDHPs, particularly the Gulper, acts as a significant barrier against their wider promotion.

> '*I have never seen a manual desludging pump that is effective. I think research should come up with simple technological options that are decent. Technologies that are safe, fast, easy to operate with minimum supervision from an institution, the one that protects operators from getting into contact with pit contents or does not expose pit contents to the customers*' [Key informant from government institution].

Technological factors at community level: At the community level, unavailability of services at this level was found to be an important factor for over-reliance on unhygienic desludging. In study areas, locations, where residents can access services physically or can obtain a phone number to call for safe desludging services, were lacking. This is contrary to other basic infrastructure services, such as water supply and solid waste collection where water kiosk and solid waste collection centres have been provided or identified, respectively.

Technological factors at interpersonal/household level: Technological factors at the interpersonal/household level that contribute to unhygienic desludging include the lack of clear modality for accessibility and affordability to the technology needed for desludging, in this case, the need for cost-sharing for hiring desludging equipment. In rented houses, landlords take the lead for collection of contributions and decide on the desludging methods to use or size of the vacuum truck to be hired. The problem arises when the toilet fills within a short period of desludging. Tenants thus become skeptical about the amount of money paid to the operator or the size of the vehicle hired. The dissatisfied tenants find it difficult to contribute next time the pit gets full. When this happens, toilets stay full for a long time without being desludged or the landlord discharges some amount of FS to shrink the FS volume, and action referred to as 'kupunguza', in Swahili (shrink) or he/she may decide to wait for the pit content to shrink by itself during the dry season.

Technological factors at individual level: At the individual level, the study found several factors that contribute to unhygienic desludging with the main ones being perceived notion among households that desludging technologies do not have power to pump dense FS and the perception that the price for the service is too high for the low quality service provided. Residents also had the perception that vacuum trucks only pump water and leave the thickened FS in the bottom of the pit. Many residents, therefore, think that manual pit emptying is the most efficient desludging method of all. The labelling of the vaccum trucks may be one explanation for this perception.

> '*The vacuum trucks are labelled 'wastewater', and not 'faecal sludge', hence it's not surprising for it to pump water only as how it is labelled*' [Resident in Manzese].

Technological factors at habitual level: It was found that the use of vacuum tankers is affected by ineffective operations leading to perceived high cost. Some dishonest drivers are reported to arrive on-site with the tank half full of sludge from another place.

> '*One time when I discovered that the amount pumped was small, they promised me to come back for the remaining amount, but I never saw them again*' [Resident in Keko].

Owing to all these factors, desludging costs via vacuum trucks are consequently perceived as being exorbitantly

high among most residents in the study areas. This is yet another reason for not hiring them, although they most likely desludge the pits with the least health risks to the operators and the surrounding environment, compared to the alternatives.

DISCUSSION

This study has assessed the drivers of persistent unhygienic desludging in unplanned urban settlements of Dar es Salaam, Tanzania. Nearly a quarter of the residents rely on unhygienic desludging methods with manual pit emptying and flooding out being the major forms. The analysis of factors through quantitative data analysis showed that unhygienic desludging is associated with lack of space for vehicle parking within 30 m. This observation is influenced by the reason that the vacuum tanker is the sole remaining method for hygienic desludging following the cessation of services that used to be offered by the small scale desludging operators. Unhygienic desludging is associated with several factors related to structural design of toilet facilities, socio-economic and demographic factors; however, the relationship was found to be statistically not significant. Non-significance of the analysis may be a result of low sample size for running logistic regression analysis (Hosmer & Lameshow 2000), however the qualitative analysis was able to identify several other factors that influence unhygienic desludging.

Analysis of qualitative data under IBM-WASH across all dimensions of contextual, psycho-social and technological factors found that the contextual factors contributing to unhygienic desludging are plot inaccessibility, low penalties against manual desludging and flooding out of FS as well as lack of routine data that indicates the magnitude and trend of the problem. The study further found that the perceived inability to control unhygienic desludging among community members and the lack of shared values against the flooding out practices are the key identified psycho-social factors. Concerning technological factors, it was found that technology weakness and skepticism on the performance of MDHP are responsible for the continued reliance on unhygienic desludging in UUSs.

Narrow lanes resulting from the congestion of houses limit large vacuum tankers from accessing residential plots. These findings echo the problem of lack of accessibility in UUSs as widely reported in the literature (Strande *et al.* 2014). In Dar es Salaam, small scale desludging equipment has the potential of providing alternative hygienic desludging services in areas with narrow lanes; however, an enabling environment for their operation needs to be created and research on their suitability need to be sustained (Seleman *et al.* 2019).

The study found that municipal regulations for the control of unhygienic desludging are outdated with penalties nearly equal to half the charges of the hygienic desludging. With low penalties set lower than good practice, there are high possibilities for violation of regulations (Mintz 2014). As the PHA has set stringent penalties against the haphazard discharge of FS, the municipalities ought to repeal the by-laws to reflect the penalties stipulated in the PHA (URT 2009). When stringent penalties are set, residents in low lying land and high water table areas currently facing frequent desludging may need to consider adoption of other sanitation systems suitable for a high water table level such as mount latrines and simplified sewers (Katukiza *et al.* 2012).

The observed technology weakness has also been reported in other studies (O'Riordan 2009; Keller *et al.* 2017). Vacuum tankers have low efficiency in pumping dense FS, reaching a distance of over 50 m from the parking area, deeper latrines of over 3 m and FS with high solid waste content. In this case, residents whose toilets have dense FS, have the bottom contents of the pit left intact. Hence, they receive a service that is not worth their investment in hiring for the desludging process. Several studies have also reported the low performance of MDHPs. The field evaluation of selected MDHP, or equipment in Free Town, Sierra Leone, documented low performance of the Gulper II and Sludge digger (Keller *et al.* 2017). Similarly, the study on modified Gulper in Malawi recorded a low success rate of about 17% (Chipeta *et al.* 2017). As such, the use of MDHP as an alternative method for hygienic desludging is jeopardized and merits skepticism, which was observed in this study. The prevailing skepticism on their performance leads to the low promotion of their use and lack of service at the community level as a sequel.

Jenkins *et al.* (2015), in another study on unhygienic desludging in UUSs in Dar es Salaam, found that reliance

on the unhygienic practice is, in part, because of lack of access to hygienic desludging services; this concurs with the results from this study but that is not the sole reason. Moreover, that study suggested income as one of the main limiting factors for accessing hygienic desludging, results that are similar to the findings of this study obtained through qualitative analysis. In this study, however, analysis of the association between unhygienic desludging and SES was statistically not significant. Instead, the analysis indicates that households of both low and high income are likely to practise unhygienic desludging. The reason for that has more to do with location of the settlement (low lying areas) and limited space for parking a vehicle during desludging.

The world is looking forward to achieving universal access to safely managed sanitation and elimination of open defecation by 2030 (UN-Water 2019). This goal is likely to be jeopardised by the persistence of unhygienic desludging practices, which can be regarded as another form of OD. Findings from this study show that drivers of the unhygienic practice are both multi-dimensional and multi-scalar. As such, collective actions based on the implementation of an integrated behavioural approach targeting both individuals, households and communities are key for sanitation improvement in Dar es Salaam and beyond (Safari *et al.* 2019).

CONCLUSIONS

Unhygienic desludging persists in UUSs of Dar es Salaam. Plot inaccessibility, outdated laws that stipulate low penalties and the lack of routine sanitation monitoring about the spread, magnitude and trend of the problem are identified as key contextual factors underlying this persisting practice. The study further found that perceived inability to control unhygienic desludging among community members and the lack of shared values against flooding out of FS as the key psycho-social factors maintained the status quo of unhygienic desludging practices. The prevailing reliance on unhygienic desludging is also exacerbated by the weakness and low performance of the available desludging technologies, including vacuum trucks and small scale desludging equipment. Improvement in FSM, particularly

concerning desludging, ought to consider the multiple forces that hinder safe and reliable desludging. A necessary step to start the improvement process is to make amendments of municipal by-laws to reflect requirements of the Public Health Act 2009 on flooding out practices. Other steps include institution of routine monitoring for desludging services as well as investing in education and behaviour change to increase people's understanding about sanitation facilities suitable to their local context and the available desludging technological options.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

REFERENCES

Brandes, K., Schoebitz, L., Kimwaga, R. & Strande, L. 2015 *SFD Promotion Initiative Dar es Salaam, Tanzania*. Final report. Eawag and SFD, Dubendorf and Dar es Salaam.

Chipeta, W. C., Holm, R. H., Kamanula, J. F., Mtonga, W. E. & de los Reyes, F. L. 2017 Designing local solutions for emptying pit latrines in low-income urban settlements (Malawi). *Physics and Chemistry of the Earth, Parts A/B/C* **100**, 336–342. https://doi.org/10.1016/j.pce.2017.02.012.

Cook, I. & Crang, M. 2004 Doing ethnographies. *Journal of Business Ethics* **44**, 0–103. https://doi.org/10.1063/1.2756072.

Dreibelbis, R., Winch, P. J., Leontsini, E., Hulland, K. R. S., Ram, P. K., Unicomb, L. & Luby, S. P. 2013 The integrated behavioural model for water, sanitation, and hygiene: a systematic review of behavioural models and a framework for designing and evaluating behaviour change interventions in infrastructure-restricted settings. *BMC Public Health* **13** (1). https://doi.org/10.1186/1471-2458-13-1015

Gabrielsson, S. 2018 *Towards Sustainable Menstrual Health Management in Tanzania? Policy Brief From Lund University Centre for Sustainable Studies.* Lund, Sweden. Retrieved from https://www.lucsus.lu.se/sites/lucsus.lu.se/files/policy_brief_mhm_saragabrielsson.pdf.

Hosmer, D. & Lameshow, S. 2000 *Applied Logistic Regression,* 2nd edn. John Wiley, New York, USA.

Israel, G. 1992 *Determining Sample Size.* University of Florida Cooperative Extension Service, Institute of Food and Agriculture Science EDIS.

IWA 2019 IWA Water and Development Congress & Exhibition, Sri Lanka, 1–5 December, 2019. Retrieved from: https://www.waterdevelopmentcongress.org/.

Jenkins, M. W., Cumming, O., Scott, B. & Cairncross, S. 2014 Beyond 'improved' towards 'safe and sustainable' urban sanitation: assessing the design, management and functionality of sanitation in poor communities of Dar es Salaam, Tanzania. *Journal of Water, Sanitation and Hygiene for Development* **4** (1), 131. https://doi.org/10.2166/washdev.2013.180.

Jenkins, M. W., Cumming, O. & Cairncross, S. 2015 Pit latrine emptying behavior and demand for sanitation services in Dar Es Salaam, Tanzania. *International Journal of Environmental Research and Public Health* **12** (3), 2588–2611. https://doi.org/10.3390/ijerph120302588.

Katukiza, A. Y., Ronteltap, M., Niwagaba, C. B., Foppen, J. W. A., Kansiime, F. & Lens, P. N. L. 2012 Sustainable sanitation technology options for urban slums. *Biotechnology Advances* **30** (5), 964–978. https://doi.org/10.1016/j.biotechadv.2012.02.007.

Keller, M., Chingoma, L. & Fawz, A. 2017 Manual pit emptiers, Freetown, Sierra Leone. In *GOAL, 4th International Faecal Sludge Management Conference.* Retrieved from https://www.susana.org/_resources/documents/default/3-2742-7-1488815391.etalpdf.

Mchome, E. E. 2017 A framework of space standards for roads widening in upgrading informal settlements for improvement of traffic mobility and accessibility: the case of Dar Es Salaam City. *International Journal of Humanities and Social Sciencs* **7** (6), 77–87.

Mintz, J. 2014 Assessing national environmental enforcement: some lessons from the United States' experience. *Georgetown International Environmental Law Review* **26** (1), 1.

O'Riordan, M. 2009 *Investigation Into Methods of Pit Latrine Emptying.* Partner in Development, Ipswich, MA, USA.

Safari, J., Mohamed, H., Dimoso, P., Akyoo, W., Odhiambo, F., Mpete, R., Massa, K. & Mwakitalima, A. 2019 Lessons learned from the national sanitation campaign in Njombe district, Tanzania. *Journal of Water, Sanitation and Hygiene for Development* **9** (4), 754–764. https://doi.org/10.2166/washdev.2019.274.

Seleman, A., Mbwette, T. S. A., Gabrielsson, S. & Kimwaga, R. 2019 Reviewing the potential and constraints of modified technology options for faecal sludge management in Dar es Salaam, Tanzania. *Tanzanian Journal of Engineering and Technology* **38** (2), 245–259.

Strande, L., Ronteltap, M. & Brdjanovic, D. 2014 *Faecal Sludge Management: Systems Approach for Implementation and Operation.* IWA Publishing, London, UK.

Thye, Y. P., Templeton, M. R. & Ali, M. 2011 A critical review of technologies for pit latrine emptying in developing countries. *Critical Reviews in Environmental Science and Technology* **41** (20), 1793–1819. https://doi.org/10.1080/10643389.2010.481593.

Tilley, E., Strande, L., Lüthi, C., Mosler, H.-J., Udert, K. M., Gebauer, H. & Hering, J. G. 2014 Looking beyond technology: an integrated approach to water, sanitation and hygiene in low income countries. *Environmental Science & Technology* **48** (17), 9965–9970. https://doi.org/10.1021/es501645d.

UNICEF & WHO 2019 *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2017: Special Focus on Inequalities.* Launch version July 12 Main report Progress on Drinking Water, Sanitation and Hygiene. Retrieved from: https://washdata.org/reports

United Republic of Tanzania (URT) 2009 *The Public Health Act, 2009.* Retrieved from: https://www.ilo.org

UN-Water 2019 *United Nations World Water Development Report 2019.*

URT 2019 *Tanzania in Figures in 2018.* National Bureau of Statistics, Dodoma, Tanzania.

World Health Organization 2018 *Guidelines on Sanitation and Health.* WHO, Geneva, Switzerland.