

Research Paper

Knowledge, attitudes and practices (KAP) on fecal sludge resource recovery and reuse in Dar es Salaam, Tanzania

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ABSTRACT

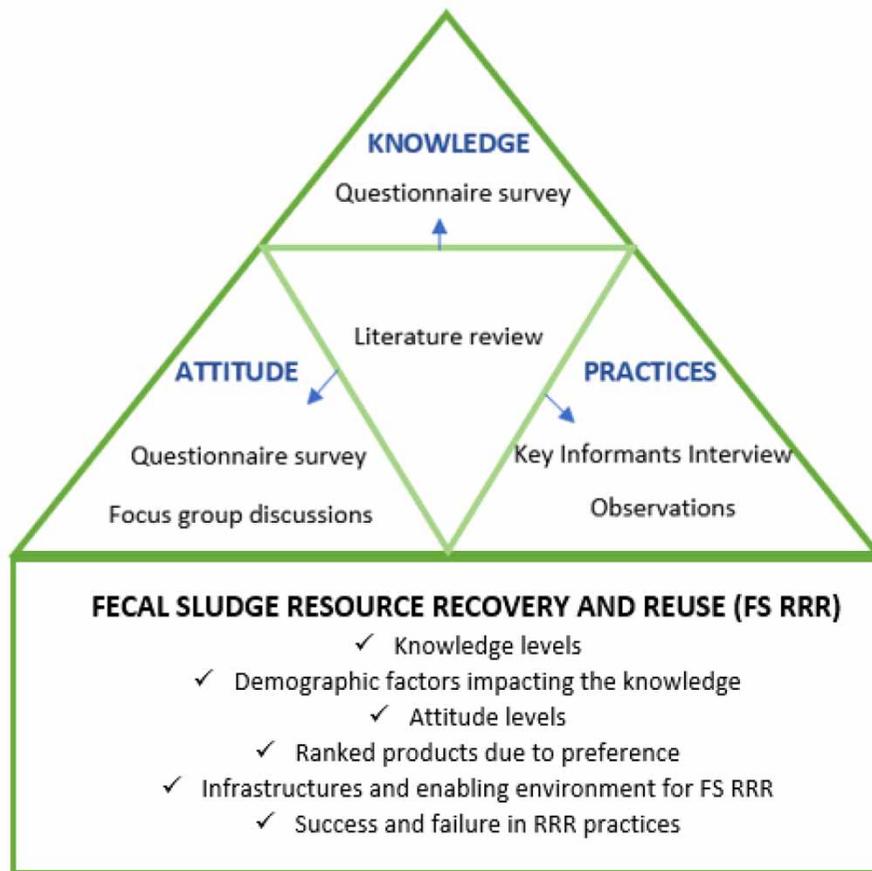
Resource recovery and reuse (RRR) of fecal sludge (FS) from onsite sanitation systems describes the concept of turning human waste into valuable end products. However, studies on peoples' perceptions of FS-derived products are still limited. Guided by the knowledge, attitudes and practices framework, and data from a survey of 395 households, focus group discussions and key informant interviews, this article explores how residents in three unplanned settlements of Dar es Salaam, Tanzania view FS RRR (FS-RRR). Results indicate that residents' knowledge about FS-RRR is moderately low. Moreover, residents generally have negative attitudes toward using FS-derived products, except for those not directly consumed, such as biogas or FS-briquettes. Additionally, only a few residents have engaged in any FS-RRR practices. We conclude that to increase local acceptance of FS-RRR will require significant efforts by a multitude of actors, not least to dispel myths linked to human waste, but also to raise awareness and demonstrate the benefits and safety of FS-derived products. The Tanzanian government must take the lead in this process and should start by prioritizing the improvement of fecal sludge management (FSM) to enable such a shift.

Key words: attitudes, fecal sludge, FSM, knowledge, practices, resource recovery

HIGHLIGHTS

- The existing knowledge, attitudes and practices on fecal sludge resource recovery and reuse among residents were explored in three selected unplanned settlements.
- Low-to-moderate knowledge of resource recovery and negative attitudes have been identified.
- Training, awareness campaigns, public participation and private sector involvement are recommended.

GRAPHICAL ABSTRACT



INTRODUCTION

Recent estimates show that currently 2.8 billion of the global population use onsite sanitation systems (OSSs) including pit latrines and septic tanks for their sanitary needs (Andriessen *et al.* 2019). It is estimated that over 50% of generated fecal sludge (FS) in low- and middle-income countries (LMICs) is unsafely managed, thus posing high environmental and public health risks (Strande 2014). In Dar es Salaam (DSM), Tanzania, where over 90% of the population uses OSSs, it is estimated that as much as 57% of FS is haphazardly disposed of into the environment without treatment (Brandes *et al.* 2015). Resource recovery and reuse (RRR) of FS provides an incentive to appropriate FSM by recovering nutrients and converting some of it into valuable end products, thereby reducing waste loads and environmental pollution (Diener *et al.* 2014). To date, however, barriers such as inadequate sanitation technologies and practical implementation failures in places where it has been piloted have been identified as hindering effective adoption (Strande 2014).

In DSM, only two projects aimed at promoting FS-RRR have been implemented so far. One entailed the construction of 33 urine diversion toilets at the household level to recover urine intended for urban agricultural activities (Kasala *et al.* 2016). Another RRR initiative involved the construction of decentralized wastewater treatment systems (DEWATS) to use treated wastewater for aquaculture and recovering biogas for domestic cooking needs (MoW 2018). Both initiatives, however, have experienced significant technical challenges resulting in unsatisfactory outcomes. In the case of the urine diversion toilets, as many as 80% of the toilets did not operate effectively 1 year after construction, and a recent monitoring study of the DEWATS showed that 38% suffered from improper and inadequate operation and maintenance and 29% failed to generate biogas (McGranahan 2015; MoW 2020).

While these studies focused on assessing the construction and performance of promoted FS-RRR technologies, little is known about peoples' perceptions of these technologies and their end products. Even though it has already been established

that successful technology adoption is highly dependent on peoples' acceptance of that innovation (Davis 1985). More specifically, peoples' decision to adopt a new innovation is influenced by the degree of knowledge and positive attitudes they have about that innovation (Meena *et al.* 2012), as well as the opportunities given to the prospective users to experiment or test it out (Rosly & Khalid 2018). The purpose of this article is to close this research gap by exploring residents' views on FS-RRR, drawing on the knowledge, attitudes and practices (KAP) framework (Muleme *et al.* 2017). But given that FS-RRR projects in DSM are currently largely inactive, the analysis of *practices* in this article is limited to exploring the *potential for practice* by assessing the availability of FS-RRR infrastructure and the enabling environment for the promotion of FS-RRR. By focusing on the views of prospective users of FS-RRR, we attempt to provide sanitation stakeholders, including policymakers and future innovators, an increased understanding of existing barriers and opportunities to advance and promote the FS-RRR concept and adoption of FS-RRR practices in Tanzania.

METHODOLOGY

Study areas

The study was conducted in three unplanned urban settlements of DSM, namely Manzese, Kipawa and Keko. These study areas were selected based on their size, high population density and future expected population growth, in addition to demonstrating similar sanitation context and FSM challenges also found in other urban areas of LMICs (Brandes *et al.* 2015).

Definition of terms

In this article, *knowledge* is defined as community familiarity or understanding, acquired through experience or education by discovering, and/or learning (Meena *et al.* 2012). *Attitude* is defined as individuals' thoughts and/or expressed feelings about a specific phenomenon (Almasi *et al.* 2019). In this context, the focus is on what and how individuals think and feel about past FS-RRR pilot projects and the possible future use of different FS-derived products. *Practices* is defined as the observable actions that individuals or collective groups have engaged in or envision to engage in linked to a specific phenomenon, in this case FS-RRR promotion or use of end products (Muleme *et al.* 2017). *FS-derived products* refer to the manufactured end products following different treatment processes to safely remove harmful bacteria and pollutants of raw FS (Kengne *et al.* 2014). Diener *et al.* (2014) categorize these products into five groups: (1) solid fuel from dried and carbonized FS, here named FS-briquettes; (2) biogas fuel from digested wet FS; (3) proteins derived from FS to be used as animal feed; (4) dried FS to be used as construction material, here named as bricks and (5) composted FS to be used as soil conditioner, here named as compost. *Note:* In this study, vegetables were added as an additional agricultural end product obtained after the application of FS-derived soil conditioner.

Research design and methods

The study employed a cross-sectional, mixed-method approach to collect and analyze the data. Primary data collection took place during different periods between September 2017 and November 2018 and included a household survey, key informant interviews (KIIs) and focus group discussions (FGDs). We complemented the primary data with secondary data obtained from research articles, reports, government statistics and policy documents.

Sampling

Household survey

A total of 400 households were sampled to participate in the survey, proportionally distributed according to the population size across the three study sites. A total of 142, 132 and 126 households were sampled in Keko, Kipawa and Manzese, respectively. A systematic random selection method was applied to identify respondents from residential households listed with the local government offices in each settlement.

Focus group discussions

A total of six FGDs were conducted, two in each of the study ward areas. The number of participants ranged from six to 12 per FGD session. Each sub-ward chairperson was requested to propose 12 names of residents from their areas of jurisdiction, equally divided by gender and representing residents, community leaders, Environmental Health Officers and Community Development Officers from each sub-ward. The names from the proposed lists were then contacted to confirm participation. In total, 53 residents, both male (39.6%) and female (60.3%) agreed to participate in the FGDs with a distribution of 18 from Keko, 16 from Kipawa and 19 respondents from Manzese.

Key informant interviews

A total of 19 KIIs were conducted. The KII involved informants familiar with or working directly on FSM in DSM, including Ministry of Health, Ministry of Water, Dar es Salaam Water and Sanitation Authority and several non-governmental organizations working in the sanitation sector. Each key informant was sampled using *snowball sampling*.

All respondents in the primary data collection process participated voluntarily with their consent, and all empirical data presented here are kept anonymous to secure their privacy.

Data collection process to examine KAP attributes

Knowledge

Data used to explore FS-RRR knowledge were obtained predominately from the household survey. A mobile phone application known as *Epicollect5* was used to record the data. We customized the questionnaire to include both open- and closed-ended questions in English, but during data collection, respondents were asked the questions in Kiswahili to ensure a clear understanding of the questions and a high response rate (Almasi *et al.* 2019). A total of four enumerators from higher learning institutions were recruited and trained to assist with survey data collection. The training included translating oral responses directly from Kiswahili and record these into the software in English. Pretesting was done with 40 respondents, 10% of the sample size to ensure that survey questions were clear and relevant and give enumerators the possibility to practice using the software.

Residents were requested to provide their knowledge of the RRR concept and attitudes toward the six most commonly known FS-derived products (Diener *et al.* 2014). Questionnaire statements contained both assessments using a 4-level Likert scale (where 1 = ‘completely unknown’ and 4 = ‘well known’) and open-ended questions. In the given open-ended questions, respondents were then allowed to elaborate on the criteria for their preferences. Responses on preference criteria were then clustered into common themes and later on presented to key informants who ranked their importance based on their expertise.

Attitudes

To explore attitudes about FS-RRR, we relied primarily on data from FGDs and KIIs. Six FGD sessions, each between 45 and 60 min long, were conducted in Kiswahili and audio recorded using a mobile phone. The audio data were then transcribed into Microsoft Word. Data on attitudes were collected using three steps. The first step was to collect the respondents’ affective attitudes, i.e. their emotional reactions toward the products presented (Abun *et al.* 2019). In this study, these emotional reactions were triggered by showing respondents’ photos of the most commonly FS-derived products (Figure 1) and hearing a description about their content and use.



Figure 1 | Photos of FS-derived products and one product obtained from the use of FS fertilizer displayed in the FGDs: (a) FS-briquettes, (b) biogas, (c) compost, (d) vegetables, (e) proteins for animal feed and (f) bricks (Kengne *et al.* 2014; Borda-Africa 2017).

Second, respondents were asked to individually rank the products on a Likert scale, based on their own acceptance of each FS-derived product from 1 to 5 signifying: (1) strongly agree, (2) agree, (3) neutral, (4) disagree and (5) strongly disagree.

The third step involved combining the results from the previous two steps and applying aggregative multi-criteria decision analysis (MCDA) (Katukiza *et al.* 2010). In this analysis, two FS-derived products were compared at a time and given scores on a scale of 1–5 (1 being the lowest and 5 the highest) to identify respondents' overall attitudes.

Practices

To ascertain an understanding about peoples' engagements in the past and possible future FS-RRR, we relied on data from KIIs, the household survey and observations during field visits. Observations of existing FS-RRR practices in study communities and the city were focused on assessing the functionality of each technology.

The collected data were then analyzed using thematic clustering, where available technology, past and current FS-RRR efforts as well as the enabling environment to perform FS-RRR were identified and grouped.

Data analysis

Quantitative data

Factors determining respondent's knowledge about FS-RRR and FS-derived products were analyzed in three stages. The first stage involved the collection of information through a question with binary answers (Yes/No) for the respondents with and those without FS-RRR knowledge, respectively, and results were presented in percentage (%).

In the second stage, associated demographic factors were analyzed using bivariate analysis, starting with the Chi-square test (χ^2) followed by logistic regression. In the binary logistic regression analysis, the probability of respondent's knowledge on a scale of 1 = Yes and 0 = No was translated into likelihoods (Sperandei 2014). The logistic regression equation was expressed as follows:

$$\text{logit}(p) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \cdots \beta_k X_k + \varepsilon \quad (1)$$

where p is a probability of residents being knowledgeable on FS-RRR. $\beta_{1,2,\dots,k}$ are generated coefficients of each predictor or determining factor $X_1, 2, \dots, k$ of respondents' knowledge of RRR at intercept or reference group β_0 , and ε is an error term with a 95% confidence interval (95% CI). All quantitative data were analyzed using the R software 4.0.2 (2020) and SPSS version 20. Analysis results were tested at $p < 0.05$ significant level.

The third analysis stage involved the determination of a knowledge index (KI) to show participants' knowledge about different FS-derived products using a 4-point Likert scale. The KI for each FS-derived product was expressed using the mathematical equation adopted from Meena *et al.* (2012):

$$\text{KI} (\%) = \left(\frac{\sum p_i q_i}{AN} \right) \times 100 \quad (2)$$

where p_i is the response frequencies based on the Likert scale (q_i): $q_1 = 1$, $q_2 = 2$, $q_3 = 3$, $q_4 = 4$. N is the total number of respondents and A is the highest weight on a Likert scale. The modified Bloom's cut-off points were used to identify KI levels in three groups as high knowledge (80–100%), moderate level knowledge (50–79%) and low knowledge (<50%).

The analysis of each respondent's attitude toward different FS-derived products was carried out in two steps. The first step entailed the ranking of FS-derived products based on participants' preferences. The MCDA method was then used to combine average scores of the FS-derived products ranked during the FGDs against the preference criteria weighted by experts during the KIIs. The final scores of preference criteria were obtained by the formula expressed by Katukiza *et al.* (2010) as follows:

$$F = \left[\sum_{i=1}^n \left(\frac{a_i}{c} \right) \right] \times G \quad (3)$$

where F is the normalized final score used for ranking the products, n is the number of parameters defining the criteria, a is the average score from product by FGDs, c is the total of the average scores from product by FGDs and G is the experts' weighted scores of preference criteria.

The second step for attitude analysis was done by developing the attitude index (AI) to ascertain respondents' overall attitude levels toward the most common six FS-derived products. The AI was determined using data collected on a 4-point Likert scale using the mathematical equation developed by Meena *et al.* (2012) and expressed as follows:

$$AI (\%) = \left(\sum \frac{p_i q_i}{AN} \right) \times 100 \quad (4)$$

where p_i is the response frequencies based on the Likert scale (q_i): $q_1 = 1$, $q_2 = 2$, $q_3 = 3$, $q_4 = 4$. N is the total number of respondents, and A is the highest weight on a Likert scale. The modified Bloom's cut-off points were used to group AI in different levels as positive (80–100%), neutral (60–79%) and negative (<60%) (Ain *et al.* 2017).

Qualitative data from interviews

The qualitative data were organized and analyzed using a content thematic approach (Muleme *et al.* 2017). In this approach, the transcribed qualitative data are grouped into themes and triangulated against secondary data from peer-review research and institution reports.

Ethical considerations

A written research permit to be able to carry out the study was requested from and granted by the Directorate of Research at the University of Dar es Salaam. Moreover, municipalities were approached individually to obtain their written consent before the start of the research. Finally, each household member was asked for individual consent before participating, and no personal identifiers were recorded to ensure anonymity.

RESULTS

The household survey attained a 98.8% response rate, with a total of 395 questionnaires completed, including 123 (31.2%) for Manzese, 140 (35.4%) for Keko and 132 (33.4%) for Kipawa. Respondents were predominately female (71%) and ages of participants ranged between 35 and 64 years old. Results show that 50% of respondents depend on small businesses for their income generation, while 25% of the respondents were either retired or unemployed.

Knowledge of FS-RRR

Results from the household survey indicate that there are differences in the respondents' knowledge of FS-RRR both between and within locality subgroups. Overall, the findings show that less than half of the respondents in each study area are knowledgeable about FS-RRR. Keko ward had a slightly higher value (42%) followed by Kipawa (37%) and then Manzese (32%). Results also show that public sanitation-related community meetings and locally existing demonstration sites were the main events and means for the majority of community members on the sub-ward level to get exposure to FSM and FS-RRR. One resident from Keko explains how these events played out in the community:

'A local NGO, CCI organized community members in federation groups, trained them, processed financial loans to families and demonstrated the construction of the Ecosan (urine diversion) toilets, where most of us participated and got experience on the operations of the toilets.' (Male in FGD, Keko)

Survey results also confirm this, indicating that 54% of respondents from Keko, compared to 38% in Manzese and 36% in Kipawa, attended at least one sanitation information meeting per year. These results show that the residents in Keko have had more opportunities to increase their knowledge about FS-RRR through local training sessions and demonstrations, which we already know are critical components to influence individual decisions toward acceptance of any new innovation (Rosly & Khalid 2018; Russel *et al.* 2019).

Beside differences in exposure to FSM, FS-RRR and FS-derived products influencing knowledge levels between study sites, the household survey also analyzed the role certain demographic factors may play on residents' FS-RRR knowledge. Table 1 shows the analysis, indicating that gender is a major contributing factor to FS-RRR knowledge at $p < 0.05$.

The logistic regression analysis (Table 2) gives further details of this association by indicating that female respondents have about 40% less knowledge about FS-RRR compared to the male respondents in the survey.

Table 1 | Association between resident's knowledge on FS-RRR and demographic variables across study areas

Demographic variable	Response category	Knowledge		Combined	χ^2 -value	p-value
		Yes	No			
Study area	Keko	59 (42.1%)	81 (57.9%)	140	2.583	0.275
	Kipawa	50 (37.9%)	82 (62.1%)	132		
	Manzese	40 (32.5%)	83 (67.5%)	123		
Gender	Male	52 (46%)	61 (54%)	113	4.637	0.021*
	Female	97 (34.4%)	185 (65.6%)	282		
Age	15–35	41 (4.2%)	61 (59.8%)	102	0.453	0.797
	35–64	88 (37.3%)	148 (62.7%)	236		
	>64	20 (35.1%)	37 (64.9%)	57		
Education	No education	12 (32.4%)	25 (67.6%)	37	0.567	0.753
	Primary education	91 (37.8%)	150 (62.2%)	241		
	Secondary and above	46 (39.3%)	71 (60.7%)	117		
Occupation	Entrepreneur	95 (37.0%)	162 (63.0%)	257	6.577	0.254
	Civil servant	3 (42.9%)	4 (57.1%)	7		
	Private sector	12 (57.1%)	9 (42.9%)	21		
	Farmer	14 (41.2%)	20 (58.8%)	34		
	Retired	7 (50%)	7 (50.0%)	14		
Toilet ever being emptied	Unemployed	18 (29%)	44 (71.0%)	62	0.005	0.514
	Yes	77 (37.6%)	128 (62.4%)	205		
	No	72 (37.9%)	118 (62.1%)	190		

*Statistically significant at $p < 0.05$.**Table 2** | The logistic regression table showing factors affecting respondents' knowledge of FS-RRR

Variable name	Variable categories	β	Exp(β)	95% CI of Exp(β)	p-value
Location	(Manzese = ref group)				
	Kipawa	0.235	1.265	0.699–2.046	0.371
	Keko	0.413	1.511	0.869–2.493	0.109
Gender	(Male = ref group)				
	Female	–0.457	0.615	0.395–0.959	0.032*
Age	(Old (>60) = ref group)				
	Young (18–35)	0.218	1.243	0.635–2.437	0.526
	Middle age (35–60)	0.095	1.100	0.601–2.014	0.757
Education	(Secondary education and above = ref group)				
	No education	–0.300	0.741	0.339–1.619	0.452
	Primary education	–0.066	0.936	0.595–1.473	0.776
Occupation	(Unemployed = ref group)				
	Entrepreneur	0.360	1.433	0.784–2.623	0.243
	Civil servant	0.606	1.833	0.372–9.028	0.456
	Private sector	1.181	3.259	1.171–9.071	0.024*
	Farmer	0.537	1.711	0.713–4.108	0.229
Toilet ever being emptied	Retired	0.894	2.444	0.749–7.975	0.138
	(Yes = ref group)				
	No	0.014	1.004	0.675–1.524	0.945

Ref group, reference group; CI, confidence interval.

*Statistically significant at $p < 0.05$.

This finding corresponds with results from research conducted in similar cultural and socioeconomic contexts in other LMICs (Diener *et al.* 2014; Mkanga & Ndezi 2014). Generally, men in this cultural context are more physically mobile than women who are more restricted to their homes or neighborhoods, thus limiting women's access to information and

networks (Mendum & Njenga 2018). Moreover, since cultural norms in sub-Saharan Africa dictate that men are the designated head of the family (in a typical family consisting of a married couple with children), it is also these men who predominately hold primary decision-making power over matters that affect the whole family (Mendum & Njenga 2018). Our study found that the majority (69%) of households have men as household heads. It is therefore more likely that these men represent their household at community meetings or trainings, giving them more exposure to any technological innovations introduced into the community compared to females who are not household heads (Routray *et al.* 2017).

The logistic regression analysis (Table 2) further reveals that residents' occupation is another contributing factor to increased knowledge. Indeed, respondents who work in the private sector are 3.5 times more likely to be knowledgeable about FS-RRR than those working in other sectors or unemployed. From our survey results, we observe that more than half (52%) of respondents who work in the private sector are men. Subsequently, being a man and also engaged in the private sector increase the chances of having knowledge about FS-RRR through more opportunities for physical mobility, participating in community trainings and access to networks beyond the local community (Mendum & Njenga 2018).

Results from the KI are visualized in Figure 2. On average, participants across all three study areas have low-to-moderate knowledge levels about the presented FS-derived products. Kipawa residents were found to have higher knowledge levels overall and Manzese the lowest levels. Knowledge about protein for animal feed derived from FS was found to be low among all respondents, most likely because past FS-RRR projects have ever targeted such end products.

Attitudes toward FS-derived end products

The immediate emotional reactions from the 53 FGD participants upon seeing the displayed photos of the FS-derived products and accompanying oral descriptions were negative. These negative feelings could be explained by both limited knowledge about FS-RRR and persisting cultural norms and taboos toward human waste in Tanzania (Chaggu 2004). The quotes from two FGD participants exemplify how these norms are expressed in Tanzanian society:

'We have been grown up told and believe that faeces are waste, since it comes out of our bodies, we cannot take it back and use. Even my religious belief doesn't allow me to be involved in handling human waste or consume the product from it.' (Male in FGD, Keko)

'I would consume the product resulted from fecal sludge only if the source will be intentionally hidden or completely unknown to me. It is very disgusting if I realize its source is human faeces or urine.' (Female in FGD, Manzese)

These feelings of disgust against the reuse of human waste are not limited to Tanzania; however, the majority of countries in the world are considered feacophobic (Chaggu 2004). Our analysis on peoples' preferences criteria for the different FS-derived products shows that those products that have direct or indirect links to human contacts, ingestion or fear of foul smell score the lowest, because they trigger peoples' emotions of disgust and violate existing religious norms. These products are such as vegetables fertilized with urine, poultry fed from FS-derived proteins for animal or food cooked using biogas.

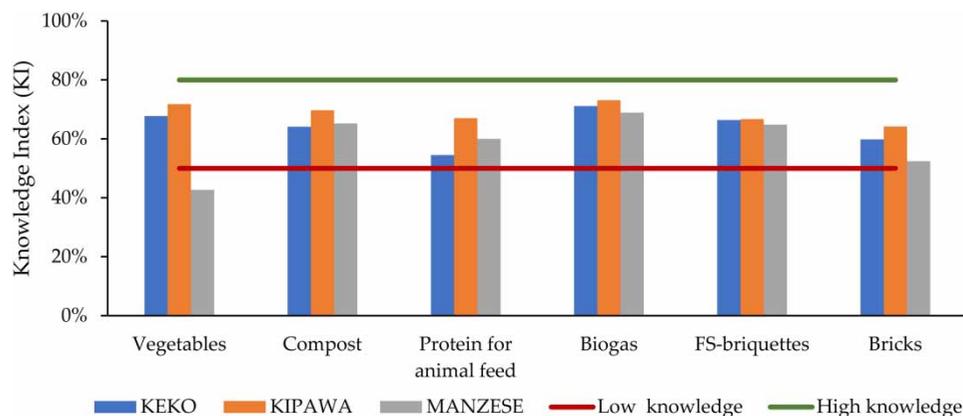


Figure 2 | A bar chart diagram showing respondents' KI (%) for different FS-RRR-derived products in each study area.

Consideration of the role these criteria play in the Tanzanian context is therefore critical when introducing any FS-derived products into a community who has never used such products before. The analysis further shows that the criteria that influence peoples' acceptance most are the *cost* of the product, the *awareness* they have about its use and the *quality* of the product. Furthermore, it is observed that FS-briquettes are perceived to fulfill all of these preferences, without triggering emotions of disgust and violating religious norms (Table 3).

The importance given to cost in this context is not surprising, especially not since residents here belong to the low-income segment of the city's population (Kasala *et al.* 2016).

Upon further analysis, it was found that FS-briquettes also ranked the highest when scores were combined and weighted against the other products (Table 4).

This finding is similar to a study from neighboring Uganda, concluding that even though several FS-derived products were in high demand in the city of Kampala, FS-derived briquettes took precedence over other products (Diener *et al.* 2014). The authors concluded that the reasons for this are that FS-briquettes can be used exactly in the same way as wood charcoal with lower levels of disgust feelings. Another reason is that the product quality can be maintained over time, and because the carbonization process involves temperatures between 300 and 700 °C, any health concerns that people may have from using it are eliminated (Muspratt *et al.* 2014).

Our combined findings align well with the conclusions made in Uganda and could also explain why our calculated AI only shows a *positive* attitude toward FS-briquettes at 96.6%, in comparison with other products. A *neutral* attitude was expressed toward compost (63.8%) and an overall *negative* attitude toward all the rest of the products: biogas (45.7%), vegetables (9.4%), protein for animal feed (6.0%) and bricks (6.0%). It should also be noted here that the positive attitude toward FS-briquettes could also be linked to expressed challenges with current cooking fuels, e.g. wood charcoal, as seen in the following quote:

'The availability of wood charcoal depends on season. During the rainy season, it is difficult to get since we import from upcountry regions, hence its price also fluctuates with seasons.' (Male in FGD, Kipawa)

Table 3 | Scoring FS-derived products based on preference criteria on a scale of 1 (low) to 5 (high)

	Awareness (+)	Cost (-)	Quality (+)	Health (+)	Religious taboo (-)	Disgust (-)	Smell (-)
Vegetables	4	4	4	4	1	2	4
Compost	3	3	3	5	4	4	5
Protein for animal feed	4	4	4	4	4	2	2
Biogas	5	5	5	5	5	2	2
FS-briquettes	5	5	5	5	5	4	4
Bricks	4	5	4	1	3	5	1
Total scores	25	26	25	24	22	19	18

Note: Each product was scored against the seven preference criteria, where the criteria either enhanced (+) or diminished (-) acceptance.

Table 4 | Combined scores from FGDs scores and weighted scores from experts to obtain the final ranks for each FS-derived product

Weighted score (G) (%)	Awareness 15	Cost 1	Quality 4	Health 26	Religious 2	Disgust 45	Smell 7	Normalized score (F)	Rank
Vegetables	2.40 ^a	0.15	0.64	4.33	0.09	4.74	1.56	13.91	5
Compost	1.80	0.12	0.48	5.42	0.36	9.47	1.94	19.59	2
Protein for animal feed	2.40	0.15	0.64	4.33	0.36	4.74	0.78	13.41	6
Biogas	3.00	0.19	0.80	5.42	0.45	4.74	0.78	15.38	4
FS-briquettes	3.00	0.19	0.80	5.42	0.45	9.47	1.56	20.89	1
Bricks	2.40	0.19	0.64	1.08	0.27	11.84	0.39	16.82	3

^aNormalized score for vegetables with respect to respondent's awareness is calculated by $4/(25) \times 15 = 2.4$.

If residents then perceive FS-briquettes to be a viable alternative to using wood charcoal, or a possible future business opportunity, because they believe it could lead to reduced expenses and reliable access, then this will likely have a positive influence on their attitudes toward FS-briquettes as observed by adopters elsewhere (Gabrielsson *et al.* 2019).

FS resource recovery practices

Currently, FS-RRR practices in DSM are limited. The only FS-derived product tested in a community setting in the past was fertilizer recovered from the *EcoSan* – Urine diversion toilets piloted in Kipawa and Keko (Mkanga & Ndezi 2014; McGranahan 2015). To date, these toilets have been abandoned and the project ceased, in part due to lack of financial resources for operation and maintenance, safe handling, transportation and storage of urine and faeces, which led to unsustainable practice (Strande 2014).

From our observations of the existing sanitation infrastructure in DSM, we have seen that the city lacks appropriate sanitation technologies to promote FS-RRR. Currently, the majority of FS that is emptied, collected and transported from household OSSs are treated in waste stabilization ponds, which by design do not consider resource recovery (Brandes *et al.* 2015). The only existing FS-RRR technology currently in place is three smaller DEWATS operated by private and non-governmental institutions. All these DEWATS have demonstrated management challenges, due largely to their limited size and too large influx of FS, leading to poor performance and inadequate treatment (Borda-Africa 2017). As the supervisor of one of the city's DEWATS explains:

'Due to the high FS service demand compared to the size and capacity of the DEWATS, the upgrading of this plant was thought as construction of new DEWATS in other locations to reduce the transportation distance and cost.' (DEWATS Supervisor)

What this statement highlights is that the current infrastructure available to recycle FS is not enough in DSM and a clear future plan to address increasing FS loads in the city is missing. Indeed, this is evident in the fact that existing sanitation guidelines and regulations only consider treatment and reuse of wastewater, not FS (Brandes *et al.* 2015). Moreover, the current guideline for small-scale DEWATS, while comprehensive, including planning, design, implementation, operation and maintenance, still neglects the management of FS or septage (MoW 2018). This contributes to a policy gap in the formalization of FS-RRR practices, as explained by one key informant:

'We have guidelines for design and construction of latrine technology options and human waste management, but no guideline specific for resource recovery. Even the new National Sanitation Campaign only emphasizes the use of improved sanitation options and safe disposal of human waste.' (Key Informant, Ministry of Health)

To promote FS-RRR and advance sustainable FSM practices in Dar es Salaam and beyond, future sanitation policies must therefore address this policy gap.

DISCUSSION

Our study results indicate low levels of knowledge, negative attitudes and limited practice of FS-RRR and the use of FS-derived products among residents in DSM. These rather discouraging findings could give probable justification for discontinuing the promotion of FS-RRR in Tanzania, but we think that this would be premature. We argue that there are valuable findings from this study that could contribute toward advancing the promotion and uptake of FS-RRR in DSM and beyond, if these findings are incorporated into stakeholders' future FS-RRR project plans and national FSM policies.

To build knowledge and change attitudes about the FS-RRR concept, more awareness-raising campaigns, community training and demonstrations of FS-RRR technologies and FS-derived products must be conducted: because 'seeing is believing', and dispelling myths linked to human waste cannot be done without people seeing, touching and smelling the products with their own senses (Rosly & Khalid 2018; Russel *et al.* 2019). Targeting the right people to participate in these community events is the next step. Our study shows that it is women in particular who lack knowledge about FS-RRR in DSM, and largely also express negative attitudes toward FS-derived end products because of this. Targeting women and encouraging their participation in future training programs and awareness-raising campaigns is therefore of critical importance if we aim to raise overall community knowledge levels and change attitudes (Meena *et al.* 2012; Diener *et al.* 2014; Mkanga & Ndezi 2014).

Given the existing taboos associated with FS-derived products, particular attention must be put on sensitization and awareness creation about FS-RRR. It is suggested that this can be done by taking advantage of already existing community-based organizations to facilitate and ease this dialog on an otherwise sensitive topic, since these organizations have already built trust with community members (Russel *et al.* 2019).

Indeed, conducting these trainings with already formed and established local women's groups has proved successful in other waste-related projects and is therefore likely to be equally effective for the promotion of FS-RRR (Diener *et al.* 2014; McGranahan 2015). With regard to people's occupation, it was established that people working in the private sector have access to more information and exposure to innovations. Targeting these people to act as community champions could therefore prove crucial to motivate participation in community events and shape attitudes (Ain *et al.* 2017). Moreover, targeting demonstrations and trainings on end products that people already have positive attitude towards, such as FS-briquettes, may have a higher likelihood of being accepted and possible adoption (Ain *et al.* 2017). If training is also targeting those primarily responsible for using the product, i.e. women, they may have a higher appreciation for their direct benefits (Gabrielsson *et al.* 2019; Russel *et al.* 2019).

To encourage a shift toward FS-RRR practice, our study has highlighted that there is currently a tremendous infrastructural deficit and policy gap standing in the way of advancing the implementation of FS-RRR in Tanzania. The promotion of the FS-RRR concept is also hindered by a significant shortage in human resources in the sanitation field as a whole, especially in FSM, and this reduces the number of people that would otherwise advocate and lobby the government about the multiple benefits that FS-RRR may have on sanitation, energy, agriculture, human health and the environment (Gabrielsson *et al.* 2019). To change this, the enabling environment for FS-RRR practice must therefore be enhanced. To start this process, we argue that the Tanzanian government must prioritize city-wide sanitation planning and direct more funds toward technologies that improve the process of safe emptying and transport of raw FS from OSSs. Because currently many households, especially in unplanned settlements, resort to unhygienic FS desludging, leading to poor FSM and posing a barrier for recycling of FS (Seleman *et al.* 2020). Seleman *et al.* (2020) recommend an integrated action plan to address this problem, where sanitation stakeholders in DSM join hands to transform policy, cultural norms and infrastructural dimensions. We concur with these recommendations, because FS-RRR, like FSM, is a cross-cutting issue and, therefore, needs a multi-sectoral approach to be addressed. In this case, that means the involvement of actors and ministries representing sanitation, water, environment, health, energy, urban planning, gender and local development (BORDA-AFRICA 2017; MoW 2018). Ultimately, to address these interconnected issues, the Tanzanian government must take the lead.

CONCLUSION

In this article, we aimed to explore the existing KAP linked to the RRR of FS among residents in three unplanned urban settlements of Dar es Salaam. Our study shows that community acceptance of any new sanitation innovation is highly influenced by what people know and how they perceive that innovation. To promote the FS-RRR concept and advance sustainable FSM in Dar es Salaam and beyond, we therefore conclude that stakeholders will have to work together in an integrated way to prioritize and increase people's knowledge and understanding about the benefits of FS-RRR for their communities. We identify three key areas to focus these efforts on. First, knowledge about what FS-RRR entails, including clarifications on existing restrictions to using products produced from human waste, must be discussed and raised in local communities, especially among women. Second, demonstration units should focus on showcasing end products that people are already positive about to allow people to experience how they are produced and used. Third, sanitation management institutions should facilitate stakeholder forums to encourage and develop inclusive policies and guidelines to improve FSM that provides safe availability of raw material for FS-RRR. In summary, our study shows that it will take more than just functioning technology to scale up FS-RRR adoption in Tanzania. Indeed, understanding what people need to know, how they feel and what it takes for them to use it is just as critical if we want it to succeed.

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DATA AVAILABILITY STATEMENT

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

REFERENCES

- Abun, D., Magallanes, T., Foronda, S. & Incarnacion, M. 2019 Investigation of cognitive and affective attitude of teachers toward research and their behavioral intention to conduct research in the future. *Journal of Humanities and Education Development* 1 (5), 2581–8651. <https://doi.org/10.22161/jhed.1.5.2>.
- Ain, N. M., Azfar, M., Omarulharis, S., Azfar, H., Maryam, A., Hafizah, S., Adibah, B. & Akmal, N. 2017 Knowledge, attitude and practice of dengue prevention among sub urban community in Sepang, Selangor. *International Journal of Public Health and Clinical Sciences* 4 (2), 73–83.
- Almasi, A., Mohammadi, M., Azizi, A., Berizi, Z., Shamsi, K. & Shahbazi, A. 2019 Assessing the knowledge, attitude and practice of the Kermanshahi women towards reducing, recycling and reusing of municipal solid. *Resources, Conservation & Recycling* 141, 329–338. <https://doi.org/10.1016/j.resconrec.2018.10.017>.
- Andriessen, N., Ward, B. J. & Strande, L. 2019 To char or not to char? Review of technologies to produce FS-briquettes for resource recovery from fecal sludge. *Journal of Water Sanitation and Hygiene for Development* 9 (2). <https://doi.org/10.2166/washdev.2019.184>.
- Borda-Africa 2017 *Demonstration of Decentralised Wastewater Systems in Dar es Salaam*. Available from: <https://Borda-Africa.Org/Fecal-Sludge-Management-in-Tanzania/Demonstration-of-Decentralised-Wastewater-Systems-in-Dar-Es-Salaam> (accessed 18 April 2020).
- Brandes, K., Schoebitz, L., Kimwaga, R. & Strande, L. 2015 *Shit Flow Diagram (SFD) Promotion Initiative Dar es Salaam Tanzania*. Final Report. Eawag and SFD, Dubendorf, Dar es Salaam.
- Chaggu, E. J. 2004 *Sustainable Environmental Protection Using Modified Pit-latrines*. PhD Thesis, Issue 3554, Department of Environmental Technology.
- Davis, F. D. 1985 *A Technology Acceptance Model for Empirically Testing New End-User Information Systems: Theory and Results*. PhD Thesis, Massachusetts Institute of Technology.
- Diener, S., Semiyaga, S., Niwagaba, C. B., Muspratt, A. M., Gning, J. B., Mbéguéré, M., Ennin, J. E., Zurbrugg, C. & Strande, L. 2014 A value proposition: resource recovery from fecal sludge – can it be the driver for improved sanitation? *Resources, Conservation and Recycling* 88, 32–38. <https://doi.org/10.1016/j.resconrec.2014.04.005>.
- Gabrielsson, S., Myers, J. & Ramasar, V. 2019 Linking the water-food-energy nexus to sanitation: will it save and improve lives. In: *Water Sustainable Development and the Nexus: Response to Climate Change*. (V. Grover & A. Alfarrá, eds). CRC Press, Florida, p. 242. ISBN 9781498786515.
- Kasala, S. E., Burra, M. M. & Mwankenja, T. S. 2016 Access to improved sanitation in informal settlements: The case of Dar es Salaam. *Current Urban Studies* 4, 23–35. <https://doi.org/10.4236/cus.2016.41003>.
- Katukiza, A. Y., Ronteltap, M., Oleja, A., Niwagaba, C. B., Kansime, F. & Lens, P. N. L. 2010 Selection of sustainable sanitation technologies for urban slums – a case of Bwaise III in Kampala, Uganda. *Science of the Total Environment* 409, 52–62. <https://doi.org/10.1016/j.scitotenv.2010.09.032>.
- Kengne, I., Diaz-Aquado, B. M. & Strande, L. 2014 End use of treatment Products. In: *Fecal Sludge Management: Systems Approach for Implementation and Operation*, pp. 203–226. Available from: http://www.eawag.ch/forschung/sandec/publikationen/ewm/dl/fsm_book.pdf.
- McGranahan, G. 2015 Realizing the right to sanitation in deprived urban communities: meeting the challenges of collective action, coproduction, affordability, and housing tenure. *World Development* 68, 242–253. <https://doi.org/10.1016/j.worlddev.2014.12.008>.
- Meena, M. S., Singh, K. M., Malik, B. S., Meena, B. S. & Kanwat, M. 2012 Knowledge index for measuring knowledge and adopting scientific methods in treatment of reproductive problems of dairy animals. *Journal of Agricultural Science* 4 (10), 81–88. <https://doi.org/10.5539/jas.v4n10p81>.
- Mendum, R. & Njenga, M. 2018 Gender and energy and the rationale for resource recovery and reuse (RRR) for energy. In: *Recovering Bioenergy in Sub-Saharan Africa: Gender Dimensions, Lessons and Challenges*. CGIAR Research Program on Water, Land and Ecosystems (WLE), International Water Management Institute IWMI, Sri Lanka, pp. 1–4. Available from: http://www.iwmi.cgiar.org/Publications/wle/rrr/resource_recovery_and_reuse_series-special_issue.pdf.
- Ministry of Water (MoW) 2018 *Guidelines for the Application of Small-Scale, Decentralised Wastewater Treatment Systems: A Code of Practice for Decision Makers*. Dar es Salaam, Tanzania.
- Ministry of Water (MoW) 2020 *Design, Construction Supervision, Operation and Maintenance (DCOM) Manual*. Dodoma, Tanzania, Vol. I (4).
- Mkanga, M. & Ndezi, T. P. 2014 *Building Citywide Sanitation Strategies from the Bottom Up: A Situational Analysis for Dar es Salaam City, Tanzania*. Research Report. Department for International Development (DFID).
- Muleme, J., Kankya, C., Ssempebwa, J. C., Mazeri, S. & Muwonge, A. 2017 A framework for integrating qualitative and quantitative data in knowledge, attitude, and practice studies: a case study of pesticide usage in Eastern Uganda. *Frontiers in Public Health* 5 (318), 1–15. <https://doi.org/10.3389/fpubh.2017.00318>.

- Rosly, R. M. & Khalid, F. 2018 Evaluation of the 'e-Daftar' system using the technology acceptance model (TAM). *Creative Education* **9**, 675–686. <https://doi.org/10.4236/ce.2018.95049>.
- Muspratt, A. M. A., Nakato, T., Niwagaba, C., Dione, H., Kang, J., Stupin, L. J., Regulinski, J., Mbéguéré, M. & Strande, L. 2014 Fuel potential of faecal sludge: calorific value results from Uganda, Ghana and Senegal. *Journal of Water, Sanitation and Hygiene for Development* **4** (2), 223. <https://doi.org/10.2166/washdev.2013.055>.
- Routray, P., Torondel, B., Clasen, T. & Schmidt, W. 2017 Women's role in sanitation decision making in rural coastal Odisha, India. *PLoS ONE* **12** (5), 1–17. <https://doi.org/https://doi.org/10.1371/journal.pone.0178042>.
- Russel, K. C., Hughes, K., Roach, M., Auerbach, D., Foote, A., Kramer, S., Briceño, R. & Saul, C. 2019 Taking container-based sanitation to scale: opportunities and challenges. *Frontiers in Environmental Science* **7** (190), 1–7. <https://doi.org/10.3389/fenvs.2019.00190>.
- Seleman, A., Gabrielsson, S., Mbwette, T. S. A. & Kimwaga, R. 2020 Drivers of unhygienic desludging practices in unplanned settlements of Dar es Salaam, Tanzania. *Journal of Water Sanitation and Hygiene for Development* **10** (3), 512–526. <https://doi.org/10.2166/washdev.2020.179>.
- Sperandei, S. 2014 Lessons in biostatistics understanding logistic regression analysis. *Biochemia Medica* **24** (1), 12–18. <https://doi.org/10.11613/BM.2014.003>.
- Strande, L. 2014 The global situation. In: *Faecal Sludge Management: Systems Approach for Implementation and Operation* (Strande, L., Ronteltap, M. & Brdjanovic, D., eds). IWA Publishing, London, pp. 1–14.

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