Research Paper

Assessing the promotion of urine-diverting dry toilets through school-based demonstration facilities in Kalisizo, Uganda

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ABSTRACT

Urine-diverting dry toilets (UDDTs) are designed to recover nutrients and organic matter from human excreta for agricultural reuse. Their wider implementation could help address problems in areas where water scarcity limits coverage of sanitation systems and declining soil fertility jeopardizes nutritional security. Demonstration facilities can improve stakeholders' views of UDDTs; however, it is uncertain whether these facilities should be located at households or institutions. Using a novel methodological approach that included qualitative data collection before and after introduction of demonstration UDDTs and quantitative monitoring of treatment conditions, this study evaluated changes in local attitudes and knowledge resulting from a UDDT promotion strategy at two primary schools in Uganda. Before introduction, students had little knowledge of UDDT facilities, while most attitude-related statements conveyed negative viewpoints and skepticism. After introduction and six months of operation, students exhibited increased knowledge, and 68% of attitude-related statements conveyed positive opinions that focused on the UDDTs' long-term economic value and their role in creating a more hygienic school environment. These changes were seen in facility users and in other students at the schools who were non-users. In the future, with these improved perceptions, students could become compelling representatives for UDDTs within their communities, potentially increasing adoption.

Key words | ecological sanitation, food security, health, latrine, sub-Saharan Africa, sustainable development goals

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INTRODUCTION

Urine-diverting dry toilets (UDDTs) and other ecological sanitation (Eco-San) systems are designed to protect human health and recover nutrients from human excreta for agricultural use (Esrey *et al.* 2001). They can help address declining soil fertility in countries where growing populations' nutritional security is threatened (NEMA 2010). It is estimated that 22% of the global phosphorus demand could be met through nutrient recovery from human feces and urine (Mihelcic *et al.* 2011). Waterless UDDTs can also provide appropriate sanitation for people without sufficient water supplies. Globally, 2.4 billion people live without improved sanitation (UN 2015), and water scarcity is a barrier to access for up to 46 million (Fry *et al.* 2008). A comparison between UDDTs and pit latrines provides further support. Pit latrines are used by an estimated 1.77 billion people worldwide (Graham & Polizzotto 2013) and are the most prevalent sanitation technology in Uganda (UBOS 2011), this study's location. However, they are often

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associated with an odorous, fly-infested, unhygienic atmosphere (Jenkins & Sugden 2006), while rocky or loose soils, or high groundwater tables, may hinder pit excavation, increase installation costs, and heighten risk of collapse (Kaggwa *et al.* 2003). In contrast, UDDTs are permanent, aboveground structures not dependent upon water availability or soil conditions (Langergraber & Muellegger 2005).

UDDTs separate urine from fecal vaults, where desiccant materials (e.g., wood ash) are added to promote dry, alkaline conditions that reduce insects and odors (Breslin 2002). Given sufficient time, UDDTs have been shown to inactivate multiple pathogens, including *Schistosoma mansoni*, *Trichuris trichiura*, and hookworm (WHO 2006), although more resistant organisms (e.g., *Ascaris lumbricoides*) may remain a concern (Hawksworth *et al.* 2010; Mehl *et al.* 2011). While structurally similar to composting toilets (Mehl *et al.* 2011), UDDTs differ in that pathogen reduction occurs through alkaline desiccation, rather than aerobic decomposition (Esrey *et al.* 2001). Given low improved sanitation coverage in many countries (UN 2015), issues of water scarcity and adverse soil conditions, and the importance of recovering nutrients from domestic waste to enhance food security (Verbyla *et al.* 2013), UDDTs represent a compelling alternative that can be promoted alongside other sanitation options.

Recently, sanitation promotion efforts have shifted from providing hardware subsidies to creating demand for locally available products (Weidner *et al.* 2010; Fry *et al.* 2015). UDDT promotion in particular must address complexities, including installation costs, which are generally higher than those of pit latrines (Rajbhandari 2008; Uddin *et al.* 2011), increased user responsibilities (Kaggwa *et al.* 2003; Mehl *et al.* 2011), and agricultural reuse of resources embedded in waste. Even with training, communities may resist using human excreta in agriculture (Manyanhaire & Mutangadura-Mangeya 2009; Wilbur 2014). If products are viewed negatively, operation may suffer, potentially causing unhygienic conditions and system failure.

Demonstration Eco-San facilities have been shown to successfully address these complexities in various contexts (e.g., Breslin 2002; Shayo 2003; CRS 2010; Shewa *et al.* 2010). An unresolved question concerns whether to locate demonstration facilities in households or institutions. Because ownership is not always well-defined in public settings, some studies recommend first introducing facilities in households (e.g., Austin 2003; Langergraber & Muellegger 2005). At a rural South African school, for example, teachers were not committed to ensuring that students used UDDTs properly, and the systems failed (Austin 2003). Thus, because feelings of ownership may be absent, toilets in institutional settings may present greater challenges than household facilities. In contrast, prior studies have also shown that institutional demonstrations can be successful. For example, institutional facilities in Zimbabwe improved local attitudes toward UDDTs (Guzha & Musara 2003; Manyanhaire & Mutangadura-Mangeya 2009). Similarly, a study in Nepal noted the potential for schools to establish awareness of Eco-San concepts among students, who then create demand (Rajbhandari 2008). In East Africa, schools are often seen as community centers and models for development, making them ideal locations for demonstration facilities (CRS 2010). Generally, the merits of demonstration UDDTs in household or institutional settings are likely to depend upon local context and implementation methods.

Commonly, the effects of installed facilities have been assessed through surveys, interviews, and/or focus groups conducted some time after facilities have been introduced (CRS 2010; Uddin *et al.* 2011; Kamuteera *et al.* 2013), and/or through monitoring of facility operation (Shayo 2003; Mehl *et al.* 2011). However, these methods have not been combined with an assessment of attitudes and knowledge before demonstration UDDTs have been introduced in school communities. This more comprehensive approach could reveal specific changes resulting from exposure to demonstration facilities.

The objective of this study was to investigate how local attitudes and knowledge of UDDTs were affected by a promotion strategy involving community-influenced design, installation, training, and monitoring focused around demonstration facilities introduced in primary schools. This strategy, which has been similarly applied in other contexts (Gacheiya & Mutua 2010; Müllegger & Freiberger 2010), was evaluated using a novel methodological approach, in which knowledge and attitudes were qualitatively assessed before and after facility introduction, and in which operational conditions (pH, temperature, moisture content) were quantitatively monitored. The importance of school sanitation is well-established, especially for female students

(Mara *et al.* 2010; UNICEF 2012). Because schools function as centers of community activity and students can be compelling change agents (Miller 1998; CRS 2010), this promotion strategy and assessment methodology could be widely applicable for promoting UDDTs in schools and identifying facilities' effects on local communities, especially in regions facing water scarcity, nutritional insecurity, and/or adverse soil conditions.

METHODS

This study took place in Uganda. The country's climate is tropical, with temperatures ranging from 16 °C to 31 °C and annual rainfall between 700 and 2,000 mm (UBOS 2011). Specifically, the study was conducted in two primary schools in Kalisizo, a small town in southern Uganda of approximately 10,400 residents (Kalisizo Town Council 2011) surrounded by rural villages, farmland, and forests. The lead author served in Kalisizo for three years as a water, sanitation, and hygiene engineer with the U.S. Peace Corps as part of his graduate education (Mihelcic *et al.* 2006). The study evaluated a project undertaken by the non-governmental organization Brick by Brick Uganda, which operates in Rakai District, where Kalisizo is located. UDDT coverage in Rakai District has not been well-documented but was estimated at below 1% (Rakai District Health Office, personal communication). For comparison, pit latrine coverage was 84% in 2010 (UBOS 2011).

Saint Andrews Matale Hill Primary School and Uganda Muslim Education Association Kalisizo Primary School, hereafter referred to as School 1 and School 2, respectively, were government-aided Universal Primary Education schools (ODI 2005). Each had an enrollment of 300 to 500 students and a garden used to grow food for lunch. The project involved the introduction and operation of one demonstration double-vault UDDT at each school. Local skilled masons, employed by Brick by Brick, constructed the facilities. Detailed information regarding UDDT design and construction is available in Appendix S1 (see Supplementary materials, available in the online version of this paper). The school communities were involved in planning and construction activities, providing design input and supplying materials, unskilled labor, and workers' meals. Both institutions selected female students in their sixth year to use the facilities, and one teacher at each school was chosen to supervise operation. Student users and faculty received training on facility operation and agricultural reuse. After operation commenced, monitoring visits were conducted approximately once per month for ten months. During monitoring visits, facility conditions were assessed using an evaluation guide (Trimmer 2015).

To evaluate how the project affected local knowledge and attitudes, two phases of focus groups were conducted. Phase 1 occurred prior to installation and training, while Phase 2 took place after six months of use. Phase 2 also included key informant interviews with students and teachers identified by school administrators as being most involved in facility operation. Table 1 provides an overview

Table 1 | Breakdown of qualitative data collection activities

Data collection phase	Data collection method	Participant category	Location	Number of participants
Phase 1	Focus groups	Female students	School 1	10
		Male students	School 1	10
		Female students	School 2	10
		Male students	School 2	10
		Female parents	Kalisizo Town	9
		Male parents	Kalisizo Town	9
Phase 2	Focus groups	Female student users	School 1	10
		Female student non-users	School 1	10
		Male student non-users	School 1	10
		Female student users	School 2	10
		Female student non-users	School 2	9
		Male student non-users	School 2	10
	Key Informant interviews	UDDT operators at intervention schools	School 1 and 2	6

of these activities. By comparing results from the two phases, changes in attitudes and knowledge were identified.

In Phase 1, focus groups included 58 students and parents from Schools 1 and 2. Approximately two-thirds of the participants were students under 18 years of age. Phase 2 focus groups included 59 participants, all of whom were students. Approximately one-third of these participants had used the demonstration UDDTs, and approximately one-half of Phase 2 participants had also participated in Phase 1. Two teachers and four students, identified by school administrators as those most involved in operation, were interviewed individually. Given that this study's main focus concerned changes in knowledge and attitudes among students, and that Phase 2 focused especially on comparing the experiences of users and non-users, parents were not included in Phase 2. Since no parents had used the demonstration facilities, information from them was less relevant to the study goals. Moreover, it had become apparent during Phase 1 that parents often had many other commitments, and available transportation to the schools was limited. Therefore, given these concerns, Phase 2 focus groups were limited to students at Schools 1 and 2. Further details regarding the qualitative data collection and analysis methods employed in Phases 1 and 2 are available in Appendix S2 (see Supplementary materials, available in the online version of this paper).

Focus groups and interviews were also conducted in Kasensero, a separate village where UDDTs had previously been installed. This step allowed the schools to be compared with another community having greater experience with UDDTs. Full results from Kasensero are available in Appendix S3 (see Supplementary materials, available in the online versionof this paper).

To complement the qualitative methods, quantitative measurements of moisture content, pH, and temperature in fecal vaults and stored urine were collected at both schools. Detailed quantitative methods are available in Appendix S4 (see Supplementary materials). During the ten-month monitoring period, nine fecal vault samples and nine urine samples were collected and analyzed. Results were compared to World Health Organization (WHO) recommendations to determine whether facilities were being operated effectively.

Institutional Review Board (IRB) approval for this study was obtained from the Uganda Virus Research Institute's Research and Ethics Committee, and the Uganda National Council for Science and Technology registered the study. The research proposal was granted an exemption by the University of South Florida IRB. All participants were provided with information about the study, and written informed consent and assent were provided before participation.

RESULTS

Phase 1

A summary of themes expressed during both qualitative phases is provided in Table 2. Prior to the introduction of demonstration facilities in Schools 1 and 2, the UDDT knowledge level was low, especially among students. None of the 40 student participants demonstrated correct understanding. Many had never seen or heard of UDDTs, while, in 23 cases, descriptions of those who thought they had encountered them revealed that they had mistaken other facilities (usually flush toilets) for UDDTs: 'I used it. There is water where you defecate, and, after [defecation], you pull a metal lever, water flows over, and the waste is carried away' (male student). A related misconception involved the cost of emptying UDDTs. Many participants believed 'you have to hire a truck to empty it' (male student). Again, water-based systems, with septic tanks requiring pumping, were likely mistaken for UDDTs.

After receiving basic information about UDDTs, participants noted only two distinct benefits: permanence and agricultural value. Regarding permanence: 'Once you have built an Eco-San toilet, you get relieved from digging toilets all the time … For [pit latrines], after three years it gets full and you dig another' (female parent). Permanence is especially valuable in small towns: 'In the town council, we stay on small plots that have limited space, and thus this toilet helps us not to dig pit latrines' (female parent). Some participants were enthusiastic about toilets that reuse resources: 'It does not serve only one purpose…We use our wastes on our crops and get nutritious food. I think we even need to clap for this' (female parent). However, others expressed aversions to reuse: 'Handling a person's feces…naturally you feel disgusted…You don't feel good using feces or urine as fertilizers' (female parent).

Overall, as Table 2 shows, negative perceptions outweighed positive ones during Phase 1. Ten different

Table 2 | Incidence of themes expressed by participants at Kalisizo schools

Thematic categories	Specific themes	Phase 1 Focus groups (58 participants)	Phase 2 Focus groups (59 participants)	Phase 2 Interviews (6 participants)
Level of knowledge	UDDTs incorrectly identified	xxx		
	Desiccant use		xxx	xxx
	Periodic emptying		xxx	xxx
	Urine diversion		xx	xxx
	Knowledge of structural characteristics		xx	x
	Incorporation of local knowledge		xx	x
Attitudes–disadvantages, challenges, and barriers	Expensive to maintain/empty	xxx		
	Lack of a feeling of ownership	xx		
	Not ideal for public places	xx		
	Not sufficiently large for school setting	x	x	
	Expensive to construct	xx		
	Not convenient for disabled/elderly	xx		
	Significant risk of infection	x		
	Mismanagement leads to problems	xx	xx	x
	Resistance to agricultural reuse	xx		
	Difficult to empty	x		
	Urine piping becomes clogged		xx	
	Fecal pile requires manual leveling		xxx	
	Heavy and odorous urine containers		xx	
Attitudes–advantages, benefits, and motivators	Durability/permanence	xx	xxx	
	Value of agricultural reuse	xx	xxx	x
	Absence of flies and odors		xxx	xx
	Easy to empty		xxx	
	Safer/less accidents		x	
	Long-term economic value		xxx	
	Urine diversion enhances hygiene		xxx	xxx
	Other hygiene facilities put in place		xx	

Symbols represent how often each theme was mentioned by those in a given group. For focus groups: x = 1 to 4 occurrences, xx = 5 to 14, xxx = 15 or more; for interviews: x = 1 to 2, xx = 3 to 4, xxx = 5 or more.

disadvantages were identified. For example, UDDTs were seen as expensive: 'For local latrines, you just dig a deep hole and that is all, but, with the Eco-San toilet, you require a lot of things to build this toilet' (female student). Participants also recognized possibilities for misuse: 'They may defecate where you are supposed to urinate and vice versa' (male student). This student explained that misuse could cause an objectionable atmosphere. These concerns led to skepticism regarding UDDTs in public places, since monitoring would be difficult: 'In public places…these toilets cannot work…but will instead spread diseases. These toilets can only work well if they are installed in people's homes' (female parent).

Phase 2

After six months of operation, levels of knowledge and attitudes had changed considerably. In Phase 2, among 59 students, including non-users of the demonstration facilities,

none exhibited incorrect understanding of UDDTs. Rather, 64 occurrences of correct knowledge occurred, showing that some students exhibited understanding of multiple points. For example, ash addition and vault emptying were each mentioned more than 20 times during focus groups. One user described the importance of adding desiccant as follows: 'After you are done, you put ash on the excreta so that [they] do not produce germs' (female user). Similarly, another user mentioned that ash controls odors: 'If you do not put ash, the excreta will stay wet; there is going to be a lot of smell in the process, like these [pit] latrines' (female user). A non-user, who had not received training, astutely described overall operation: 'The reason ash is poured there is to have the human excreta dry; thereafter, that chamber is closed after getting filled…By the time you are about to have the other chamber filled, the first one…should have already dried and turned into manure. So, you can now remove it and use it for agriculture' (male non-user).

Using local knowledge to improve the system was also mentioned seven times. For example, when storing urine, supplemental materials were added for odor control: 'Before we put fertilizers in the gardens, we mix collected urine with an herb called 'kawunyira' that controls or stops the bad odor. Later, we put it [on] banana trees without stench' (male non-user). Other materials, including tobacco leaves and red pepper, were also mentioned (female user).

Regarding attitudes, negative perceptions were less prevalent in Phase 2. Five distinct disadvantages were noted, significantly fewer than the ten from Phase 1. One disadvantage concerned facility mismanagement. Occasionally, ash was not added or was added incorrectly: 'When you pour ash and it mistakenly goes in the hole for urine, it…gets stuck there' (female user). Teachers occasionally needed to close facilities for a few days, until blockages could be removed. Similar clogging issues have been reported in other countries in sub-Saharan Africa (Müllegger & Freiberger 2010) and also resulted in temporary closures (Pynnönen *et al.* 2012). A possible solution might involve sieving ash before use to reduce particle size, as suggested by one participant from Kasensero (see Appendix S3).

Other operational issues concerned the 20-liter jerry cans used for urine collection. After being filled at the toilet, carrying these heavy, odorous containers to another location was difficult: 'Girls complain about having to carry filled jerry cans…They smell a lot' (female non-user). During monitoring visits, jerry cans were sometimes found to be overflowing, a problem also observed in Kenya (Pynnönen *et al.* 2012). Additionally, many containers were needed, since they often filled in under one week and the recommended storage period prior to reuse is six months for multiple-household systems (WHO 2006). Designing the system to accommodate larger (e.g., 200-liter) plastic collection tanks might reduce these problems. Cylindrical tanks of this size are sold in towns throughout Uganda (Thayil-Blanchard & Mihelcic 2015). Tanks could be fitted with overflow pipes and taps, allowing periodic filling of smaller containers.

Despite these challenges, overall perspectives were positive, especially regarding permanence, agricultural reuse, and hygienic conditions. Eight different advantages were mentioned in Phase 2 focus groups, far more than the two from Phase 1, and positive attitudes were expressed 86 times, significantly higher than the 43 Phase 1 occurrences. With respect to permanence, long-term economic advantages were emphasized in Phase 2. Participants recognized that periodic emptying is relatively inexpensive and precludes the need for additional construction: 'It lasts longer than ordinary pit latrines, as you have to empty human excreta regularly…We do not spend a lot of money because Eco-San is permanent' (female non-user).

Economic value was enhanced through agricultural products: 'You get manure, which you may use on crops, and in the end you get money' (female non-user). Although, during Phase 1, some negative views were expressed regarding agricultural reuse, these were not reported in Phase 2: 'We cannot detest these crops because…manure is applied to soil, and crops sprout out of the soil. The manure remains under the ground, and maize has to be cooked before it is eaten' (female non-user). The schools had not yet emptied fecal vaults when Phase 2 occurred, so these attitudes were likely informed by the educational sessions that had taken place when UDDTs were introduced. However, the schools had begun applying urine in their gardens to fertilize maize and banana plants. The improved crop quality and yields that students observed may have also played a role in their attitudes toward agricultural reuse: 'Students in the boarding section were very happy because the maize was so big and good' (male non-user). Similarly: 'Such bananas

always produce big bunches and…soft fruit. Food from such plants is always tasteful' (female non-user). Schools were also providing urine to students' families and hoping to sell it: 'The teacher told us that whoever wants fertilizers can get some to take home…If we get people who want to buy the fertilizer, we should bring them to her' (female user).

Participants also noted an absence of flies and odors: 'Eco-San toilets do not spread diseases because they do not produce insects or maggots like…ordinary latrines' (female user). This benefit was attributed to ash addition and urine diversion: 'A student may go to the pit latrine and urinate all over the toilet…You may pick up some germs or infections. But with the Eco-San toilet, you cannot urinate over the toilet. The hole for urine was well-designed, and it is big enough' (female user). Other studies (Müllegger & Freiberger 2010; Pynnönen *et al.* 2012) have noted similar positive attitudes toward UDDTs' hygienic conditions when the facilities are operated effectively.

One reported benefit transcends specific UDDT characteristics, involving broader sanitation concerns. After UDDT introduction, students reported the installation of other hygiene-related facilities (hand-washing stations and buckets for menstrual pad disposal) in and around the UDDTs: 'Eco-San toilets help to prevent infections like cholera and dysentery because there is a hand-washing facility' (female non-user). The schools added hand-washing stations to complement the UDDTs, with no prompting from the implementing organization. Similarly: 'It helps girls to keep themselves clean. When a girl is in her menstruation period, when the pad is used up, you can go to the Eco-San toilet and remove it, because they put for us a bucket where we dump used-up pads…I don't see provision of a bucket in these other ordinary latrines' (female user). These girls now had a private place to wash and dispose of menstrual pads. Hand-washing and menstrual hygiene facilities could be incorporated into pit latrines, but the presence of sanitation systems seen as more hygienic seems to have prompted the schools to consider other hygienic improvements.

Facility monitoring

Monitoring visits confirmed many of Phase 2's qualitative results. Demonstration UDDTs were being kept in good condition, with the exception of occasional, minor deficiencies related to ash addition, inadequate mixing within vaults, and odorous urine containers. Low levels of flies and odors were observed, likely due to effective urine diversion systems and sufficient desiccant use.

A summary of pH, moisture content, and temperature measurements taken during monitoring visits is provided in Table 3. Conditions within fecal material varied considerably, likely a result of inadequate mixing. However, they still satisfied WHO recommendations, with pH levels from 9.0 to 10.5 and moisture contents from 8% to 19%. These values were superior to vault measurements from multiple previous studies. In China, for example, moisture contents between 15% and 66% were observed in dry toilets that had been operating for three months (Peasey 2000). In Panama, ash-amended vault material from composting toilets exhibited moisture contents between 29% and 47%, while pH levels averaged 8.3 (Mehl *et al.* 2011). Still, whether or not treatment recommendations are achieved, it is important to note that resistant pathogens (e.g., *Ascaris lumbricoides*) may remain after at least one year of storage (Hawksworth *et al.* 2010). As a result, secondary treatment or burial is often suggested (Mehl *et al.* 2011; Manser *et al.* 2015). A companion study, conducted using urine and fecal

Table 3 | Treatment conditions in fecal material and stored urine in school UDDTs

Material	Measurement	Range	Average ± std. dev.	WHO (2006) recommendation
Fecal material	Temperature (°C)	22.3–34.3	25.6 ± 4.4	20.0–35.0 for one year
	pH	9.0–10.5	10.2 ± 0.6	>9.0 for one year
	Moisture content (%)	8–19	15 ± 4	<25 for one year
Stored urine	Temperature (°C)	20.0–23.6	21.8 ± 1.1	>20.0 for six months
	pH	8.5–9.0	8.9 ± 0.2	>8.8 for six months
Ambient storage temperature (°C)		19.7–23.9	21.8 ± 1.3	–

materials from the demonstration UDDTs, investigated a possible secondary treatment strategy for inactivating *Ascaris* eggs (Trimmer *et al.* in press).

DISCUSSION

Improved knowledge and attitudes through demonstration facilities

Prior to this project, students and parents at both schools knew little about UDDTs, with participants incorrectly identifying these facilities. At that point, spontaneous promotion and adoption of UDDTs would have been unlikely. Even if they were to advocate for UDDTs, participants' lack of knowledge and the prevalence of key misconceptions would have weakened their effectiveness. During Phase 2 (after community-aided design, installation, training, and six months of operation), improvements in knowledge were observed. Occurrences of correct understanding among students increased from zero in Phase 1 to 64 in Phase 2. Even though non-users of the facilities had not been trained, they also displayed improved understanding. In Phase 2, no non-users exhibited inaccurate knowledge, while UDDTs were mistakenly identified 23 times during Phase 1. The fact that non-users showed understanding of UDDT principles suggests that students were teaching their peers and/or that observation of the facilities was improving knowledge.

Similarly, positive attitudes regarding UDDTs improved after the introduction of demonstrations. During Phase 1, less than half of all attitude-related comments were positive. In Phase 2, some negative opinions remained, but positive attitudes predominated. Of all attitude-related comments in this phase, 68% were positive. A significant shift toward long-term advantages was observed. For example, during Phase 1, UDDTs were seen as being expensive, but Phase 2 responses emphasized economic benefits over time, with a focus on UDDTs' permanence and agricultural value. Similarly, Pynnönen *et al.* (2012) reported that, while installation costs of school UDDTs are often higher than those of pit latrines, long-term costs may be lower.

The introduction of these facilities also brought about other hygienic benefits not directly related to UDDTs' specific characteristics. After installation, the schools established hand-washing and menstrual hygiene facilities. Hand-washing is a key concern in Uganda, where only 27% of schools are reported to have hand-washing facilities (UNICEF 2012). Likewise, sensitively handling menstruation is particularly important, but many Ugandan schools do not adequately address female students' menstrual needs (UNICEF 2012). Menstruation has been linked with feelings of shame among female students due to stigmatization, feelings that are further complicated by inadequate access to sanitation facilities (Sommer 2010; McMahon *et al.* 2011). As a result, girls may be absent during menstrual periods and may drop out of school (UNICEF 2012). The establishment of private UDDTs equipped with school-provided wash water and disposal buckets, has empowered female students to manage these times without humiliation and to continue their education. Although facilities to manage menstruation could be provided in pit latrines, the introduction of a system perceived as more hygienic has encouraged a greater focus on these issues.

An important caveat involves agricultural reuse of fecal material. The schools had not yet emptied fecal vaults when Phase 2 occurred. Among Kasensero residents who emptied vaults, perceptions of this task were predominantly negative, especially if their facilities were operated ineffectively (see Appendix S3). Similar negative perceptions have been observed in Zimbabwe (Manyanhaire & Mutangadura-Mangeya 2009) and Panama (Wilbur 2014). It is possible that reuse of feces could also create problems in the Kalisizo schools; however, monitoring visits showed that demonstration UDDTs were being operated effectively, and vault conditions were satisfying WHO (2006) recommendations. If the schools continue to operate the facilities effectively, feces should be relatively inoffensive when emptied, minimizing the likelihood of negative perceptions. Alternatively, if perceptions of agricultural reuse were to worsen, collected feces could be used to restore eroded soil, in tree-planting efforts (Gacheiya & Mutua 2010), or to support flower production (Müllegger & Freiberger 2010). Both soil erosion and deforestation have been identified as serious environmental concerns in Uganda (NEMA 2010), and flowers are a major cash crop (UBOS 2011). If possible, the addition of a third phase of data collection is recommended after schools have emptied fecal vaults at least once to assess whether attitudes toward agricultural reuse have changed.

Advantages of demonstration facilities in school settings

Findings show that the promotion strategy described in this study positively affected students' knowledge and opinions, and that students could act as valuable advocates for UDDTs. As such, this study provides evidence supporting the introduction of demonstration facilities in primary schools. The issue of ownership is often a concern in institutional settings, but Schools 1 and 2 showed a strong sense of ownership through their willingness to adapt the facilities to meet their needs. For example, to address the issue of odorous urine containers, users added local herbs. The odor reduction mechanism of these materials is unknown; they may decrease pH or impart a masking scent. Regardless, this willingness to innovate suggests that the schools did not simply wait for the implementing organization to address issues. The question of ownership is important, but these schools have shown responsibility for the facilities, increasing the possibility that effective operation will continue.

Additionally, since children from many different households benefit, school-based demonstration facilities are more likely to be viewed as a service provided to the general community, one that can lead to further hygiene improvements (e.g., hand-washing and menstrual hygiene facilities) for the community's children and youth. In contrast, household demonstrations may limit future uptake by creating resentment or false expectations of similar services among surrounding households (Jenkins & Sugden 2006). Finally, information regarding school facilities seems more likely to spread through the community at a faster rate. Given the comprehension exhibited by non-users in Phase 2, it is likely that students have already been teaching their peers informally, and those students hail from various households in and around Kalisizo, where they can further disseminate knowledge.

Limitations

Despite the encouraging results obtained using this study's methodology, it is important to recognize certain limitations. First, while qualitative data collection prior to UDDT introduction helped to reveal key changes in attitudes and knowledge, it may have also influenced later results by encouraging students to begin thinking about the facilities. Without the base knowledge established in some students during Phase 1, the overall strategy may have been less effective. Alternatively, Phase 1 could also be seen as a valuable component of the promotion strategy, encouraging students to become effective UDDT advocates. Similarly, Ayi *et al.* (2010) studied a school-based, participatory malaria education program in Ghana using interviews before and after the intervention, finding that students successfully spread health messages to classmates and adults.

Second, as stated previously, the schools have not yet emptied fecal vaults, meaning that results related to agricultural reuse are incomplete. Positive attitudes may change once schools face the reality of fecal reuse. For future work, then, a three-phase data collection approach is recommended, in which Phase 3 takes place after emptying fecal vaults. Data collection phases (1) before introduction, (2) after operation has commenced but before vault emptying, and (3) after vault emptying could provide a comprehensive picture of how knowledge and attitudes change with time.

Finally, it is important to remember that different school communities are not equivalent to one another. UDDTs introduced in schools are not automatically successful (Austin 2003). Effective school sanitation programs require careful consideration of context and user preferences. As in the project evaluated here, administrators and parents should be involved in planning, opportunities for them to shape designs should be provided, and appropriate training and monitoring should occur. Perhaps most critically, implementing organizations should develop strong relationships with school communities, engendering an atmosphere of respect and trust, before facility introduction.

CONCLUSIONS

The effects of a UDDT promotion strategy, involving community-influenced design, installation, training, and monitoring focused around school-based demonstration facilities, were assessed using methods that included qualitative data collection before and after facility introduction and quantitative monitoring of facility operation. This approach revealed that both users and non-users of demonstration facilities exhibited improved knowledge and attitudes, suggesting that student users were educating

their peers. Attitudes shifted to emphasize long-term economic benefits, and UDDT introduction inspired the installation of other hygiene-related infrastructure (handwashing and menstrual hygiene facilities). These advances could have long-term benefits for student health and retention, and students appear likely to become compelling representatives for UDDTs within their communities.

Behavior change is complex, especially with regard to UDDTs' extra user responsibilities, which can act as barriers to continued and correct use. Additional considerations, including community involvement, education, monitoring, and an atmosphere of respect and trust, are critical components of UDDT projects. The strategy and assessment methodology presented here may not be appropriate everywhere, but they could be valuable in many contexts, especially in areas of water scarcity, nutritional insecurity, adverse soil conditions, and/or limited space.

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