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TRANSFORMATION TOWARDS SUSTAINABLE
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Finding sustainable funding for WASH facility monitoring through nutrient recovery in southwest Uganda

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The benefits of access to safe water supplies can be jeopardized by poor system functionality, often a result of inadequate financing for ongoing monitoring, operation, and maintenance. This study assessed the level of ongoing monitoring among water supply systems in Rukungiri District, southwest Uganda, and examined local stakeholder perspectives through household, institutional, and organizational surveys. System functionality was generally found to be inadequate. Furthermore, this study explored the possibility of financing ongoing water system costs by more closely linking water supply provision with resource recovery from sanitation. Certain sanitation technologies can recover nutrients from human excreta. The economic value of these nutrients may provide a sustainable source of funds sufficient to support a water system's ongoing operation and monitoring. Coupling water supply and sanitation through nutrient recovery may provide opportunities to develop innovative financing strategies, simultaneously promoting greater water and sanitation access, sustainable resource flows, and continued water system functionality.

Introduction

Access to water, sanitation, and hygiene (WASH) facilities is a key factor in improving the health and well-being of households and communities in resource-limited settings around the world (UN, 2016). However, system functionality is a significant issue in numerous locations. For example, a survey conducted in 11 countries in sub-Saharan Africa found percentages of functioning rural water systems as low as 35% (Montgomery et al., 2009). A study in Madagascar found that only 13-50% of populations served by rural water systems actually used them on a daily basis (McConville & Mihelcic, 2007). Along with continuing to increase access to WASH facilities, efforts must also ensure that systems remain functional, an effort contingent upon finding sustainable sources of continuous funding to meet ongoing operation, maintenance, and monitoring costs.

Nutrient recovery from sanitation systems could provide one potential funding source for water system monitoring and ongoing operation. The nutrient quantities embedded in human excreta have the potential to replace globally significant fractions of current and future synthetic fertilizer use, and to improve farmers' access to agricultural nutrients where availability is currently limited, particularly in sub-Saharan Africa (Mihelcic et al., 2011; Trimmer et al., 2017). Ecological Sanitation (Eco-San) systems such as Urine-Diverting Dry Toilets (UDDTs) are able to recover nutrients in liquid and solid forms (Esrey et al., 2001), although successful recovery is dependent upon user acceptance and understanding of the system's operating principles (Kamuteera et al., 2013). The economic value of recovered nutrients, which could either be sold to local farmers or enhance users' own crop production, may offer an innovative mechanism to generate funding for ongoing monitoring and operating costs of water systems, while simultaneously providing an incentive to accept and adequately maintain sanitation systems. Nutrient recovery can more directly link sustainable water supply and sanitation.

To illuminate possibilities for improving WASH outcomes and long-term functionality in a local context, this study focused on these issues in Rukungiri District, located in southwest Uganda. Access to improved

water sources is relatively high (84%) in the district (MWE, 2017), while sanitation and hygiene lag behind with little data available to estimate local access, use, or functionality. A fairly high number of UDDTs have been installed in this area, due to rocky soils and high water tables that hinder excavation for pit latrines. However, limited knowledge is present regarding how to operate and hygienically maintain UDDTs, especially in institutional settings (i.e., schools, markets), due to a lack of follow-up monitoring and training (Kamuteera et al., 2013). Therefore, an evaluation of training and monitoring practices in this area may reveal current gaps or useful approaches that could be applied in other contexts, and the prevalence of UDDTs provides a setting in which users could generate significant funds from nutrient recovery.

With these issues in mind, the objectives of this study were to assess the roles that training and monitoring have played in WASH projects in Rukungiri District, and to examine the theoretical possibility of selling nutrients recovered from sanitation to support the ongoing monitoring and operating needs of local water systems. As beneficial health outcomes from improved access to WASH facilities can only be assured when access is combined with users' safe hygiene behaviours (Mihelcic et al., 2009), local hygiene practices were also explored. The experiences and practices of households, institutions, non-governmental organizations (NGOs), and local government officials were used to identify specific recommendations for improving the functionality and outcomes of WASH projects through better training and monitoring. Although this study is focused on conditions in Uganda, its findings and ideas may be applicable to other countries in sub-Saharan Africa and around the world.

Methodology

To assess functionality and monitoring practices associated with local water systems, site visits were conducted by the lead author in 2016 and 2017. Data collection occurred through direct visual observation, onsite dialogue with individuals and groups, telephone and electronic correspondence with stakeholders, and structured questionnaires. Three types of questionnaires were developed to cater to various stakeholders, including: (i) households; (ii) institutions such as schools, churches, and police and prison barracks; and (iii) local government officials and NGOs. Generally, each questionnaire focused on the types of WASH infrastructure put in place, training and monitoring activities performed initially and during operation, and typical sanitation and hygiene behaviours practiced within the community.

In total, 138 protected springs and ten gravity-flow schemes (GFSs) were surveyed. Household-level data were collected from 150 households, and four NGOs provided insight into their experiences and practices. Several local institutions and government officials also provided their perspectives. It should be noted that these findings do not represent specific evaluations or recommendations regarding individual projects, sites, or organizations. Rather, they provide a narrative describing general impressions of typical WASH practices, training, and monitoring activities within Rukungiri District.

Finally, the potential of financing ongoing operation, maintenance, and monitoring of water systems through nutrient recovery from sanitation was evaluated using theoretical calculations. Through a procedure similar to that described by Richert et al. (2009), single-nutrient fertilizers that are available in Uganda were used to estimate the value of the three major agricultural nutrients (nitrogen, phosphate, potash). Average national fertilizer prices from 2013 to 2017 (AfricaFertilizer.org, 2017) were combined with the nutrient content of each fertilizer (FAO, 2016), estimating value per kilogram of nutrient. Then, these unit nutrient values were multiplied by potential per capita quantities of nutrients that could be recovered from sanitation in Uganda (Trimmer et al., 2017). Summing the results from all three nutrients, these calculations provided a theoretical total economic value associated with nutrients recovered from a single person in Uganda. This value can be compared with per capita estimates of water system monitoring and operating costs to determine whether nutrient recovery might theoretically function as a sustainable financing mechanism.

Results and findings

Water system assessments

Protected springs

Of the 138 protected springs surveyed, 26 included storage tanks to accommodate the springs' low flow rates. In general, these storage tanks were in poor condition, with only four having fully functioning taps. The remaining 112 springs without taps ("ordinary springs") tended to be of excellent workmanship but had been poorly maintained over time. For 109 of these 112 ordinary springs, a marked lack of ownership was

apparent, with caretakers abandoning their efforts due to inadequate oversight and motivation. The remaining three did have active caretakers, but no springs were reported to have functioning community management committees. If they had been formed initially, they ceased functioning immediately or soon after construction. Certain issues associated with these springs might have been addressed after construction (e.g., insufficient monitoring and/or maintenance; in Photograph 1, poor operation and maintenance led to blockage of the water outlet, creating a health hazard). However, the nonexistence of management committees resulted in a lack of post-implementation monitoring observed across the springs surveyed.

Gravity-flow schemes

Of the ten GFSs surveyed, six were implemented by the local government, while four were installed by NGOs. The construction, quality, and functionality of these systems varied considerably (see Photograph 2 for a well-functioning example). One GFS was noted to have been particularly well-maintained and regularly monitored, with functioning committees at each tap stand overseen by a general operation and maintenance committee. While this system has encountered problems over the years, the committees are able to address issues due to regular collection and accounting of funds from beneficiaries. Among other GFSs with more limited functionality, local actors reported efforts to implement monitoring plans and improve long-term sustainability, but these endeavours do not yet appear to be yielding better results. In some cases, scheduled monitoring visits were not being carried out. When visits did occur, identified concerns could not be addressed due to insufficient funds. Even so, it is encouraging that actors are recognizing sustainability and functionality issues and are beginning to work toward addressing them.



Photograph 1. A poorly maintained protected spring visited during this study



Photograph 2. A well-maintained tap stand functioning as part of a GFS

Household and institutional assessments

Among the 150 households visited, sanitation facilities were typically traditional pit latrines, often constructed using low-cost materials (Photograph 3). The latrine environment was often unpleasant and unhygienic, because the facilities were odorous, wet, and filled with flies. Some households reported using Eco-San systems, which have the potential to reduce unpleasant smells and insects (Kamuteera et al., 2013). With regard to hygiene facilities, most households had dish drying racks, but hand-washing facilities were extremely uncommon, with only four households having basic facilities (tippy taps). At critical times (e.g., before eating, before handling food, after using the latrine), most households did not report washing hands either “all of the time” or “most of the time”. One third of respondents stated that they used soap when washing hands. However, among the four households with tippy taps, no soap was observed, and the jerry cans had not been filled with water for a long time (Photograph 4), suggesting that adequate hand-washing after latrine use may be uncommon.

Household satisfaction with current sanitation and hygiene facilities is substantially lower than satisfaction levels with respect to water supply, with a more pronounced difference among households where NGOs or the local government had installed water infrastructure. These respondents often reported being satisfied with their water source, while sanitation and hygiene satisfaction levels were low. Sanitation and hygiene at institutions were especially concerning, as no institutions reported being satisfied with their sanitation and hygiene facilities, and an absence of safe hygiene practices was observed. These results agree with the fact

that NGOs and government officials reported installing more water supply systems than sanitation or hygiene facilities, an unsurprising finding given that, historically, donors have been more likely to fund water supply projects. A possible cause for this imbalance may relate to the fact that water supply systems can often be installed at the community level (e.g., GFSs), while sanitation and hygiene facilities are typically required at each household. As such, one water supply installation can impact a larger number of people. However, the health and economic gains created by a safer and more convenient water supply may be jeopardized if adequate sanitation and hygiene are not present.

Finally, a disparity existed between households' perceptions of monitoring and training and the reports from local government officials and NGOs. As stated previously, local organizations and governments often reported that monitoring visits had occurred and were regularly scheduled, but the household beneficiaries of these systems typically described a situation in which systems were installed, some initial training may have taken place, and then no follow-up activities occurred. It is possible that the beneficiaries were not aware of monitoring activities that had occurred. However, if this is the case, then government officials and organizations are missing potential opportunities for education and additional training. In addition to checking the status and functionality of the infrastructure, monitoring visits could be used to educate beneficiaries regarding appropriate hygiene practices and the correct use of facilities, enabling them to realize the greatest potential health and economic benefits from the systems that have been put in place.



Photograph 3. A traditional pit latrine constructed using low-cost materials



Photograph 4. An empty tippy tap outside of a pit latrine

Economic Value of nutrient recovery from sanitation in Uganda

The preceding results show that, in many cases, ongoing operation of WASH facilities may be hindered by insufficient monitoring due at least in part to a lack of sustainable financing mechanisms. This section explores the theoretical potential of nutrient recovery from sanitation to act as a continuing source of funds, using Uganda as a case study. While practical issues including the safety of recovered products, farmers' acceptance and willingness to pay for recovered nutrients, volatility of international and local fertilizer markets, and the need for widespread buy-in from WASH facility users would be key concerns if this strategy were put into practice, they are outside the scope of this analysis. Rather, the findings presented here indicate whether the approach represents a potentially viable mechanism for supporting most or all of a WASH facility's ongoing financial requirements, if those practical issues could be overcome. As such, these results represent the start of a conversation, rather than the end. Future work and discussion would be needed to develop this theoretical possibility into a feasible real-world strategy.

Using data on national fertilizer prices in Uganda from 2013 to 2017 (AfricaFertilizer.org, 2017) and the nutrient content of fertilizers (FAO, 2016), economic values of one kilogram of nitrogen (N), phosphate (P₂O₅), and potash (K₂O) were estimated (Table 1). These unit values were combined with estimates of per capita nutrient recovery potentials in Uganda (Trimmer et al., 2017) to calculate the total value of nutrients that could be recovered from one person in Uganda. Summing all three nutrients, the total value was estimated to be US \$5.60 per person per year (Table 1). This value is similar to estimates of operating and post-construction support expenses for water services throughout Africa (US \$1.50 to US \$9.50 per person per year, as reported by Pezon et al., 2015), suggesting that recovered nutrients could theoretically cover most or all of a water system's ongoing costs if all system users participated in the endeavour. However,

sanitation systems themselves also incur operation and maintenance costs (Hutton and Varughese, 2016), potentially reducing the financial benefits of nutrient recovery for water system sustainability.

Nutrient	Single-nutrient fertilizer for comparison (nutrient content) ^a	Average national fertilizer price (USD tonne ⁻¹) ^b	Economic value of N, P ₂ O ₅ , and K ₂ O (USD·kg ⁻¹) ^c	Average recoverable nutrients from sanitation (kg·cap ⁻¹ ·yr ⁻¹) ^d	Value of recoverable nutrients from one person (USD·cap ⁻¹ ·yr ⁻¹) ^e
Nitrogen (N)	Urea (46% N)	\$722	\$1.57	2.2	\$3.45
Phosphate (P ₂ O ₅)	Triple superphosphate (46% P ₂ O ₅)	\$707	\$1.54	0.8	\$1.23
Potash (K ₂ O)	Potassium chloride (60% K ₂ O)	\$607	\$1.01	0.9	\$0.91
Total annual value of nutrients recoverable from one person in Uganda					\$5.60

^a Nutrient content taken from documentation provided by the Food and Agricultural Organization (FAO, 2016)

^b Average of Uganda's annual national fertilizer prices from 2013 to 2017 (obtained from AfricaFertilizer.org, 2017)

^c Nutrient economic value = (fertilizer price per tonne) / (nutrient content) / (1000 kg·tonne⁻¹)

^d Average of Uganda's per capita recovery potentials from 2013 to 2017 (estimated in Trimmer et al., 2017)

^e Per capita value of recoverable nutrients from sanitation = (recoverable nutrients) × (nutrient value)

Recommendations and lessons learnt

Explore practical strategies to connect nutrient recovery with water system monitoring

This study's results suggest that water system operation and monitoring could be improved with a sustainable source of locally-derived funding, and nutrient recovery from sanitation is a potential mechanism for generating those funds. However, the analysis of nutrient recovery presented here represents a theoretical economic exploration of the concept and does not consider practical matters that would need to be addressed before the strategy is implemented. Future work and discussion surrounding nutrient recovery as a way to fund water system operation and monitoring should consider issues related to product safety, designing low-cost recovery technologies, developing local nutrient markets, promoting local buy-in, creating affordable pricing structures so that farmers are willing to pay for recovered products, and designing efficient mechanisms for collecting and tracking funds. A key question may involve whether water system users should be individually responsible for recovering and selling nutrients, or whether they should pull together all recovered nutrients to sell collectively. The logistics of each possibility will need to be examined.

Focus on institutions to address needs, simplify connections, and increase reach

This study also found that significant needs exist in institutional settings (e.g., schools, churches), especially with respect to sanitation and hygiene. Placing greater focus on institutions would help to address at least some of these issues, and institutional projects could simplify the connection between nutrient recovery and ongoing water system costs. Rather than requiring individual users to be responsible for selling nutrients and then contributing the proceeds, the institution could implement a more centralized approach in which it collects large nutrient quantities from its own onsite sanitation systems. As a potential centre of community activity, the institution could also promote household nutrient recovery, sensitize farmers to increase acceptance of recovered products, and conduct hygiene training sessions.

Conclusions

This study combined results from household, institutional, and government/NGO surveys, direct observation of WASH infrastructure functionality, and a theoretical economic exploration of nutrient recovery as a means to fund ongoing water system costs. These pieces suggest that, in Rukungiri District, a lack of monitoring (often due to limited funding) has historically hindered WASH infrastructure functionality and the possibility of improving local outcomes. Sanitation and hygiene in institutional settings appear to be of

particular concern. These issues must have the prominence they deserve. Improvements in health and hygiene would be possible through increased monitoring, sensitization, and hygiene campaigns among local beneficiaries. Nutrient recovery could contribute towards these goals, acting as an innovative mechanism to finance continued monitoring and operation of WASH infrastructure. This strategy could offset the need for user fees greater than what would be generated through nutrient recovery, but a number of practical issues will need to be considered before implementing such an approach. Nevertheless, the analysis presented here suggests nutrient recovery could act as a nexus point, more closely connecting water and sanitation systems, helping to finance a historically neglected component of WASH infrastructure (ongoing operation and management), and simultaneously improving local access to agricultural nutrient inputs.

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