

Perceptions of water services and innovations to improve water services in
Tanzania

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Abstract

Lack of access to safe drinking water is a crisis of great proportion. An estimated 1.8 billion people rely on unsafe drinking water. This study focuses on the case of Tanzania, in which an estimated 29 million people, or 44% of the population, lack access to safe drinking water. This study investigates the use of two innovations, solar power and mobile prepayment, to improve water services in Tanzania. User perceptions of innovations are valuable for gauging the potential benefits and barriers to incorporating innovations in the water sector. There are currently no data on user perceptions of these innovations in Tanzania. This study fills this data gap through the analysis of focus group discussions (n=6) and key informant interviews (n=14) collected during summer 2016 in three urban communities in the city of Dar es Salaam, and three rural communities scattered throughout Tanzania. While perceptions varied between urban and rural study settings and within study sites, most people perceived major challenges with the current water system. Research participants generally perceive mobile prepayment as a modern solution to water service challenges, but perceive that cost may be a barrier for the poor. Generally, people in the rural setting perceive that solar power will reduce costs and increase water service reliability, while those in Dar es Salaam were less familiar with the technology. While perceptions indicate that solar and mobile phone innovations have great potential in both urban and rural settings, they also indicate that there exist significant challenges to implementing the innovations.

General audience abstract

Lack of access to safe drinking water is a crisis of great proportion. An estimated 1.8 billion people rely on unsafe drinking water. This study focuses on the case of Tanzania, in which an estimated 29 million people, or 44% of the population, lack access to safe drinking water. Furthermore, the Tanzanian Ministry of Water estimates that approximately 38% of all water access points in the country are nonfunctional. As the Government of Tanzania and other actors work to improve water access, they employ innovations to facilitate water service delivery that is both high quality and sustainable over time. These innovations must be field-tested prior to large-scale implementation to ensure they are appropriate and effective in varying contexts. User perceptions of innovations are valuable for gauging the potential benefits and barriers to incorporating new innovations in the water sector. This study investigates the use of solar power and mobile prepayment to improve water services in Tanzania. There are currently no data on user perceptions of these innovations in Tanzania. Thus, this study fills this data gap through the analysis of focus group discussions (n=6) and key informant interviews (n=14) collected during summer 2016 in three urban and three rural communities in Tanzania. Urban sites are located in the city of Dar es Salaam, and rural sites are scattered throughout Tanzania. Using qualitative methods, this study identifies themes related to user perceptions of water services, solar power, and mobile prepayment. While perceptions varied between urban and rural study settings and within study sites, most people perceived major challenges with the current water system. These perceived challenges included the poor reputation of the water service provider, health problems related to water, and the general lack of consistent high-quality water provision. Research participants perceive that mobile prepayment is a modern solution to water service challenges, but perceive that cost, particularly for the poor, may be a barrier. Generally, people in the rural setting perceive that solar power will reduce costs and increase water service reliability, while those in Dar es Salaam were less familiar with the technology. While perceptions indicate that solar and mobile phone innovations have great potential in both urban and rural settings, they also indicate that there exist significant challenges to implementing the innovations. User perceptions ultimately manifest in real behaviors related to water services, and thus must be incorporated before these innovations are scaled-up across Tanzania.

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List of abbreviations

COWSO: Community Owned Water Supply Organization

DAWASA: Dar es Salaam Water and Sewage Authority

DAWASCO: Dar es Salaam Water and Sewage Corporation

GoT: Government of Tanzania

HDI: Human Development Index

HBM: Health Belief Model

IMF: International Monetary Fund

SWD: Smart Water Dispenser

TPB: Theory of Planned Behavior

TTM: Trans-Theoretical Model

WASH: Water, Sanitation, and Hygiene

WM-T: Water Mission-Tanzania

1. Introduction

1. Introduction

Lack of sustained access to safe drinking water¹ is a problem of pressing global importance. Approximately 663 million people around the world do not have access to improved drinking water sources and must rely on water that is not protected from outside contamination, such as surface water, unprotected springs, and unprotected hand dug wells, (WHO & UNICEF, 2015). Lack of access to safe drinking water is associated with myriad negative outcomes at the community level, including poor health and high burden of disease; economic costs associated with disease; increased mortality; substantial burden of time for water collection; social impacts that disproportionately impact women and children; and ultimately a protraction of cyclical poverty. Through a host of actors--including governments, non-governmental humanitarian organizations, international aid agencies, and communities themselves--access to safe water has increased significantly in recent decades. Between 1990 and 2010, more than two billion people gained access to an improved source of safe drinking water for the first time (WHO & UNICEF, 2015). Although significant capital and resources have been invested to augment water services around the world, these investments are not always successful nor sustainable². Juxtaposing the many narratives of success and improvement to water services delivery around the globe, there are also widespread reports of failure of water projects, poor service quality, and systems prematurely out of commission due to technical failures or lack of long-term maintenance, all representing a loss of between \$1.2-1.5 billion USD invested in water supply over the last two decades (Lee & Schwab, 2005; Rietveld, Haarhoff, & Jagals, 2009; Rural Water Supply Network, 2009).

¹ The United Nations defines safe drinking water coverage as the “proportion of population with access to an adequate amount of safe drinking water located within a convenient distance from the user’s dwelling,” (WHO & UNICEF, 2015, p. 33). For the purpose of this paper, ‘safe’ is defined as water that is free from contaminants (biological, chemical, etc.) that pose a risk to human health based on WHO and national standards.

² While definitions of ‘sustainability’ of water services vary, this paper adopts the definition of sustainability of community water supply and sanitation programs in developing countries as the “constancy in water supply and sanitation services- which may be achieved through evolving and adaptive delivery mechanisms,” (Carter, Tyrrel, & Howsam, 1999, p. 294). For the purpose of this paper, ‘sustainable’ or ‘sustainability’ of water services refers not only to water services working over time, but also, to a host of factors that enable the water services to adapt over time (e.g., cost recovery that funds proper maintenance and upgrades over time, sense of community ownership over the water system).

In response to these challenges, there has been an increased push towards the establishment of best practices for sustainable water service delivery, particularly in developing countries. Many studies published in recent years explore and identify factors related to the acceptance and sustainability of water, sanitation, and hygiene-related interventions (Montgomery, Bartram, & Elimelech, 2009; Francis et al., 2015). These studies also indicate that user perceptions regarding their water services, are related to the long-term sustainability of water services (Herbst, Benedikter, & Koester, 2009; Ramos da Silva, Heller, de Campos Valadares, & Cairncross, 2010; Francis et al., 2015). Research has shed light on the individual, cultural, and contextual factors that influence the formation of these perceptions, and also demonstrate the many ways that perceptions manifest in behaviors, choices, and habits that impact water services sustainability. As new technologies, financial management systems, and other innovations³ are implemented to improve water services, these innovations must be established as appropriate, effective, and sustainable for each specific context. User perceptions of these innovations are valuable in assessing the potential benefits and barriers to incorporating new innovations in efforts to improve water services.

This study illuminates the various user and stakeholder perceptions related to water services and innovations to improve water services in Tanzania. The research exploits data from focus group discussions and key informant interviews, utilizing qualitative methods to investigate relevant perceptions in three urban and three rural communities in Tanzania. Urban sites are located within the city of Dar es Salaam, and rural sites are scattered throughout Tanzania. The Government of Tanzania (GoT) plans to invest significantly in the improvement water services in coming years, and hopes to employ innovations to ensure water service delivery is both high quality and sustainable. These innovations must be field-tested prior to large-scale implementation to ensure they are appropriate and effective in varying contexts. This study focuses on the following specific innovations: 1) the use of solar power and 2) mobile prepayment in water services. Themes and narratives rising from qualitative analysis are useful in assessing benefits and barriers to the incorporation of the selected innovations.

³ This paper adopts the definition of ‘innovation’ presented by Everett Rogers and utilized in his Diffusion of Innovations theory. By this definition, an innovation is “an idea, practice, or object that is perceived as new by an individual or other unit of adoption,” (Rogers, 2003, p. 12).

2. Human geography

Geographers have studied the interactions between water resources and society in many contexts (Wescoat, 1987; White, 1998; Swyngedouw, 2009; Sultana & Loftus, 2012). As human geographers study the interactions between society and the environment, the proposed study will fit into this sub-field and contribute to knowledge on the human ecology of water. More specifically, factors that impact how people interact with water will be better understood. Furthermore, geographers have historically studied the diffusion of innovations. From Roger's Diffusion of Innovations theory to Torsten Hagerstränd's notion of innovation as a spatial process, geographers, as well as sociologists, have made significant contributions to explain the processes by which innovations spread throughout a population (Hagerstrand, 1968; Rogers, 2003). This research builds on the theoretical frameworks related to diffusion of innovations developed by these and other geographers.

3. Research objectives and implications

The first research question sheds light on the factors that influence community perceptions of water, while the second question aims to leverage knowledge of these factors to inform future efforts to expand sustainable safe water services in Tanzania. This research project also addresses gaps in the literature in its investigation of the applicability of mobile prepayment and solar power in the context of water services, and the perceptions of users and relevant stakeholders regarding these innovations. In particular, this project will address the following:

- *Research Question 1:* In the case of three urban and three rural communities in Tanzania, what are people's perceptions of water services and innovations to improve water services?
 - *Objective 1.1:* Identify users' and relevant stakeholders' perceptions of current water services.
 - *Objective 1.2:* Identify users' and relevant stakeholders' perceptions of the use of mobile prepayment systems and solar power in water service delivery.
- *Research Question 2:* How can the Government of Tanzania improve water services in a way that incorporates users' perceptions of water services and innovations to improve water services?

- *Objective 2:* Identify potential opportunities and barriers to the incorporation mobile prepayment systems and solar power in water service delivery.

In response to challenging water issues in Tanzania (e.g. poor service delivery, service sustainability), it is important to investigate strategies for ameliorative interventions that are most effective and that simultaneously exhibit scalability in Tanzania and potentially beyond. The proposed research seeks to improve effectiveness and sustainability outcomes in water interventions in Tanzania by studying perceptions of water services and innovations to improve water services.

This research is part of a larger World Bank grant that was jointly carried out by GoT and the nonprofit humanitarian organization Water Mission-Tanzania (WM-T). The purpose of the initiative is to determine, in a timely manner and variety of settings (urban and rural), whether water projects incorporating specific technologies (mobile prepayment and solar power) are effective and can be appropriately scaled. This thesis will focus specifically on the role that user perception plays in the scalability and sustainability of these two specific innovations to improve water services in Tanzania. Water Mission is an international non-profit/non-governmental organization (NGO) that provides safe water solutions to people in developing countries and disaster areas. Since 2001, Water Mission has provided sustainable access to safe water for more than 2.5 million people in 50 countries on five continents. Water Missions-Tanzania (WM-T) is a registered NGO in Tanzania and as such oversees research activities in the country. WM-T will design and undertake operational research (field trials) in 3 representative rural districts of Tanzania as well as 3 urban water kiosk units in Dar es Salaam. WM-T will install the proposed water service technology and continuously and systematically evaluate its effectiveness, user satisfaction, and scale-up potential in Tanzania over a 6-month period.

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2. Literature review

1. Global access to safe drinking water

Sustained access to safe drinking water and proper sanitation is a critical prerequisite to a healthy and productive life. According to a recent WHO and UNICEF report, roughly 1.8 billion people in the world consume water that is faecally contaminated (Onda, LoBuglio, & Bartram, 2012; United Nations Water, 2013). Among those who consume faecally contaminated water, 663 million lack access to improved drinking water sources and must obtain drinking water from untreated and/or unregulated sources such as rivers, lakes, unprotected dug wells, and tanker trucks (WHO & UNICEF, 2015). Consumption of unsafe water in conjunction with inadequate sanitation and poor hygiene practices results in increased waterborne disease and premature mortality (Clasen, Schmidt, Rabie, Roberts, & Cairncross, 2007). Estimates suggest more than 500,000 people die every year from diarrheal illness related to unsafe water consumption, poor sanitation, and lack of hygienic practices (WHO, 2015). To that end, a recent WHO report estimated that improvements in water, sanitation, hygiene, and water resource management could reduce the global burden of disease by close to 10% (Prüss-Üstün, Bos, Gore, & Bartram, 2008).

The global magnitude of inadequate water and sanitation services has been referred to as a world water crisis. This crisis is not simply one of health, but is also inextricably connected to poverty, level of development, education, nutrition, and gender equality (Jasper, Le, & Bartram, 2012). Issues related to drinking water impact both individual and community health, and such issues disproportionately impact women and children (Jasper et al., 2012). Consumption of water with pathogens and other contaminants renders consumers susceptible to illness and accounts for approximately 88% of deaths attributed to diarrheal illness (Black, Morris, & Bryce, 2003). Unfortunately, most of these deaths occur in children under the age of five (WHO, 2007; Prüss-Üstün et al., 2008).

2. Innovations in the WASH sector of developing countries

Through the efforts of a variety of actors, global access to safe water has increased significantly in recent years. In fact, more than two billion people gained access to an improved source of safe drinking water for the first time between 1990 and 2010 (WHO & UNICEF,

2015). Governments, water utilities, nongovernmental organizations, international aid organizations, and other entities involved in the provision of water services rely on a suite of technological and managerial solutions to facilitate water extraction, treatment, and delivery. In recent decades, innovations in the water sector have not only advanced water treatment and delivery systems, but also changed the way people pay for water services, report water service problems, and even interact with water service providers. While a large number of technological innovations have been implemented in the WASH sector, this analysis will focus on the use of solar power and mobile prepayment systems as they relate to water services.

Mobile phones and mobile prepayment systems

Opportunities for utilizing mobile and web-based technologies as tools in the WASH sector have skyrocketed in recent years. The market for mobile phones has expanded rapidly, resulting in lower costs for service connection, increased mobile phone ownership, and increased mobile service coverage. In Africa, mobile phone subscriptions rose from 16 million in 2000 to 376 million in 2008 (Aker & Mbiti, 2010), and another report notes a 79% mobile phone subscription rate in the developing world (Hutchings et al., 2012). It is estimated that by 2012, more people in Sub-Saharan Africa were connected to mobile phone services than were receiving improved water services (Hope, Foster, Money, & Rouse, 2012). Mobile phones provide significant opportunities in the WASH sector as they are convenient, readily accessible, function remotely, provide access to mobile banking networks, and facilitate opportunities for instantaneous data generation and dissemination. In the WASH sector, mobile phones are currently utilized in many ways, both formally and informally, for data collection, mobile banking, and information dissemination on service repairs and disruptions (Hutchings et al., 2012).

With greater connectivity through mobile phone and Internet networks, the WASH sector has seen increased adoption of Information and Communication Technology (ICTs). WaterAid defines ICTs as the “hardware, software, networks, and media for the collection, storage, processing, transmission and presentation of information (voice, data, text, images)” (Welle, Williams, Pearce, & Befani, 2015, p. 5). ICTs are being utilized as instruments for remote data generation, transmission, and dissemination in many sectors, including banking, agriculture, health, disaster relief, economic development, and natural resource management (Fjeldsoe,

Marshall, & Miller, 2009; Cole-Lewis & Kershaw, 2010; Hutchings et al., 2012). In terms of the WASH sector, ICTs are being deployed for many purposes, including data collection through mobile surveys; using mobile phones to crowd-source data about a water point; mapping water points; disseminating water service information to relevant stakeholders; water quality monitoring; and smart water metering (Foster et al., 2012; Hope et al., 2012; Hutchings et al., 2012; Thomson, Hope, & Foster, 2012).

The smart water dispenser (SWD) is one such ICT with water service applications in developing countries. These dispensers remotely transmit water flow data from water points to relevant stakeholders. This remote monitoring technology is designed to “provide universal, low-cost and immediate data [regarding water point functionality] to guide timely maintenance responses and planning decisions, as well as drive greater accountability and transparency in donor and government behavior” (Thomson et al., 2012, p. 1). Data from these SWDs can be used to monitor and improve the functionality of water service infrastructure by enhancing system performance, decreasing time for system repair through closing the information gap, and detecting leaks and water theft. Examples of SWDs include, but are not limited to, Grundfos LIFELINK, Grundfos AQtap, Water for People Handpump Water Meter, and Welldone Momo (Rural Water Supply Network, 2015).

Mobile banking is a growing market around the world, and the market has penetrated the WASH sector. Services provided through mobile banking markets, which are not limited to developed countries, involve prepayments, cash transfers, and traditional bill payments for water services via mobile phones. Poor financial management and lack of sustainability have been identified as common problems in the WASH sector. Contributing factors to this problem include, but are not limited to, lack of formal banking services, lack of financial transparency and financial management training, high rates of bill nonpayment, problems (or perceived problems) of affordability, high rate of non-revenue water (water lost through leaks or theft), and high cost of capital maintenance (Montgomery, Bartram, & Elimelech, 2009). One study noted that as many as one in six water bills in Kenya go unpaid (Hope et al., 2012).

As a result of mobile phone proliferation and innovations in the mobile banking sector, some of these SWDs have been linked to mobile payment platforms. In the absence of formal banking services, mobile banking can promote more effective water payment systems. Mobile payments can reduce transaction costs for consumers, including the opportunity costs of time and

travel, which tend to be higher in physical payment systems. Other benefits include reduced risks associated with paying in cash and the ability to pay bills and add credits outside of normal business hours. Mobile banking and smart metering systems can also contribute to improvements in billing accuracy, transparency, and efficiency while also providing real-time data on system leaks and water theft detection (Hope et al., 2012; Schaub-Jones, 2013). Thus, the coupled use of SWDs and mobile water billing may lead to greater operational efficiency, a decrease in unaccounted-for-water, reduced costs for water providers and consumers, and enhanced system performance and user satisfaction. As argued by Hope et al., “mobile water payments represent a secure, low-cost and increasingly accessible mechanism to support the financial and operational sustainability of urban water services,” (Hope, Foster, Krolkowski, & Cohen, 2011, p. 6).

There are significant opportunities in Tanzania for mobile banking. In Tanzania, mobile phone penetration increased from 59.2% in 2013 to 67% in 2014 (Mongi, Mvuma, Kucel, Tenge, & Gabriel, 2015). Furthermore, 10% of Tanzania’s GDP is already transacted via mobile commerce (Wesselink, Hoppe, & Lemmens, 2015). Urban water providers, including Dar es Salaam Water and Sewage Corporation (DAWASCO), are currently experimenting with the deployment of mobile banking to improve water services (Hope et al., 2011). DAWASCO has partnered with Vodacom and Airtel to provide bill payment via mobile money, but only 1% of their customers pay using this service (Hope et al., 2011).

Solar power

Significant energy is required to extract, transport, treat, and distribute water to its end users. In the past (and in many communities to this day), water transportation was done by hand, with users physically carrying water from the source to their homes. From Roman aqueducts to the India Mark II hand pump, innovations through the centuries have made the conveyance of water faster, easier, and less labor intensive. In recent years, solar power has emerged as a potential source of sustainable power to convey water, particularly in rural areas that lack access to an electricity grid or to adequate quantities of electricity. These systems have the potential to decrease the amount time and energy required for people to fetch water, which in turn carries potential to improve the quality of life for many. Solar power could replace diesel fuel as the predominant energy source for water pumping and distribution in developing markets, thus

saving communities time and money while also expanding the use of sustainable, renewable, and less polluting sources of energy. While there are many advantages and opportunities associated with the introduction of solar photovoltaic water pumping, many challenges also exist, such as: high/cost prohibitive initial capital costs, lack of supply chains/local availability of spare parts/affordability of spare parts, lack of skilled technicians for maintenance, and theft and vandalism (Meah, Ula, & Barrett, 2008).

Informally, Tanzania is no stranger to harnessing solar energy, but the market for formal solar photovoltaic energy generation is still nascent. Due to its position between the latitudes of 1°S and 12°S, Tanzania receives intense solar radiation throughout the year and thus has great potential for solar energy development. In Tanzania, energy from the sun has been harnessed for beneficial uses such as drying grain, wood, and salt. The market for solar energy began with the oil crisis of 1973, and while it expanded in the following decades, the market for solar energy in Tanzania is still relatively undeveloped. Tanzania lacks a national solar manufacturer and is thus forced to import solar systems and parts from countries like Kenya and South Africa (Ondraczek, 2013). Most current solar energy development in Tanzania is focused on rural electrification projects, such as the major World Bank initiative “Lighting Africa,” which launched in 2011 (Krebs, Nielsen, Fyenbo, Wadstrøm, & Pedersen, 2010).

Solar water pumping in Tanzania has typically taken place at a small scale and/or as proof-of-concept interventions. For example, two solar water pumping projects in Dar es Salaam were implemented as a proof-of-concept by the United Nations Energy Project (Kassenga, 2008). However, applications and project size will increase as technical and manufacturing developments increase the efficiency and decrease the cost of solar power. Furthermore, expansion will increase as spare parts become available and affordable at the local scale and as the solar technology continues to prove itself as a strategic, alternative source of energy for the conveyance of water. As a case in point, in 2015, Tanzania’s Rural Energy Agency, the Ministry of Water, and the World Bank initiated an ambitious project to install hundreds of rural water points powered by solar energy (The World Bank, 2015).

3. Barriers to incorporating innovations in developing countries

The presence of a water supply intervention (e.g., a public or private well, piped supply, or rainwater harvesting and treatment system) does not necessarily guarantee long-term access to safe drinking water, even when new and improved innovations are implemented. As one study

states, “simply supplying communities with improved infrastructure does not guarantee there will be the necessary desire to adopt it” (Whaley & Webster, 2011, p. 20). While new technologies have potential to improve the functionality and sustainability of a water system, there are many challenges associated with innovations in the WASH sector, particularly in developing countries. These challenges include, but are not limited to: consistent operation and maintenance, availability and affordability of replacement parts, community capacity to properly use and look after the water system, and financial management issues such as poor billing and cost recovery. Thus, it is no surprise that an estimated 30-50% of water supply interventions worldwide fail within five years of implementation, representing a loss of between \$1.2-1.5 billion USD invested in water supply over the last two decades (Rural Water Supply Network, 2009). One widely used tool called Akvo Flow was developed to monitor the functionality of water points. Of the 126,251 water points monitored by Akvo Flow across the globe, only around 70% were fully functional, with 20% nonfunctional and 10% partially functional but in need of maintenance (Akvo.org, 2015).

Previous studies have uncovered a host of factors that influence the sustainability of water interventions, particularly in developing countries. These studies have identified determinants related to the failure or success of interventions in delivering long-term, high quality water service. The success and impact of a water intervention cannot be assured simply through the use of the newest and best technical components. For example, a water supply technology (e.g., a hand-pump) that works well in one place may neither be effective nor appropriate in another area as communities vary greatly not only in their physical resources (e.g., existing water resources, terrain, size, population), but also in their human, financial, and technical resources. Furthermore, each location is a composite of historical approaches to water management, indigenous approaches to water tenure, and culturally-dependent epistemologies on the meaning(s) of water, the environment, and society. Murphy argues that an appropriate technology for use in water and sanitation is one that, “incorporates both ‘hard’ and ‘soft’ aspects of technology, meaning not only the physical tools, but the knowledge transfer mechanisms, capacity building and communication methods as well as social, cultural, and gender implications of technology implementation” (Murphy, McBean, & Farahbakhsh, 2009, p. 159).

Research demonstrates that in addition to technological factors, there are significant institutional, environmental, geographical, financial, and societal factors associated with

sustainability outcomes of water projects (Montgomery et al., 2009; Marks & Davis, 2012; Mandara, Butijn, & Niehof, 2013). Water supply management strategies and institutional capacity are shown to have significant impacts on water service endurance (Marks & Davis, 2012). Without the capacity to manage a water system, villages and households who are assigned to technical and managerial roles without the proper training are unable to maintain their water systems (Mandara et al., 2013). In fact, a 2011 study of water point functionality in rural Tanzania concluded that “the investment to create community social capital for management is as important as the technology itself for the sake of sustainability” (Jiménez & Pérez-Foguet, 2011, p. 8). Additionally, a community’s willingness to pay up-front capital costs associated with improved water supply as well as their long-term willingness to pay for water services are associated with positive water service sustainability outcomes (Prokopy, 2005; Marks & Davis, 2012). Furthermore, community ‘sense of ownership,’ participation in the planning of their water system, and direct involvement in decision making processes that guide water service provision are similarly associated with a higher likelihood of long-term service sustainability (Prokopy, 2005; Marks & Davis, 2012).

4. User perceptions in the WASH sector

Multiple studies indicate that the acceptance and long-term sustainability of water quality interventions are intricately linked to attitudes, beliefs, and perceptions held by water users regarding their water services (Herbst, Benedikter, & Koester, 2009; Francis et al., 2015). A water user’s perceptions, attitudes, and beliefs surrounding their water significantly impacted the ability of participants to recognize health benefits from the intervention, their willingness to pay for interventions, and ultimately acceptance of the water supply intervention (Francis et al., 2015). However, perception is particularly challenging to study. All people have perceptions, which are shaped by lived experience, level of education, under facts and myths, and micro- and macro-cultural attributes. Thus, perceptions are highly subjective, and whether they do or do not match reality, they must be considered because perceptions ultimately manifest in real behaviors that impact the applicability, receptiveness, sustainability, and scalability of water solutions. Ultimately, solutions in the water sector must be subjected to locally-held perceptions so there exists congruency among the project, the population it serves, and the beliefs they hold. Given its importance, scholars have studied perceptions from the perspective of behavioral economics, behavioral psychology, industrial design, and many other fields (Lynne, Franklin Casey, Hodges,

& Rahmani, 1995; Nazarea, Rhoades, Bontoyan, & Flora, 1998; Lam, 1999; McKenzie-Mohr, 2000; Alessa, Bennett, & Kliskey, 2003; Gregory & Leo, 2003).

Many factors influence how a water user thinks about their water services. These factors in turn impact user behaviors surrounding water, such as decisions about how and where to source water; whether water quality is assumed ‘safe’ or ‘unsafe;’ willingness to pay for services; willingness to adopt new WASH-related technologies; and more. The confluence of these behaviors influences the sustainability of water interventions, and ultimately household and community health (Herbst et al., 2009; Francis et al., 2015). User perceptions of physical attributes of water (e.g., taste, color, and odor) are associated with and have a strong influence on user perceptions of their water services, and several studies indicate that perceptions of physical attributes go on to shape user behavior, choices, and preferences surrounding water supply services (Doria, Pidgeon, & Hunter, 2009; Ramos da Silva, Heller, de Campos Valadares, & Cairncross, 2010; Wright, Yang, Rivett, & Gundry, 2012; Rojas & Megerle, 2013). These physical water quality parameters are easily seen, tasted, and felt (i.e., ‘tangible’). Thus, it is somewhat intuitive and understandable that the detectable nature of such parameters results in their disproportionately higher role in affecting user perceptions and assessments of water quality. It should be noted that objectionable taste, color, and odor can be related to many contaminants, some of which pose health risks and some of which merely impact water aesthetics. In developing countries, the adoption and acceptance of water interventions can be hindered by people’s resistance to changes in water taste or odor, even though users understand that the presence and taste of chlorine indicate the disinfection of water and removal of many health risks (Francis et al., 2015). For example, the presence of chlorine taste is shown to elicit varying responses from users depending on idiosyncratic preferences, background, habits, and ideas about what constitutes good water, revealing part of the complex web of factors that determine how users perceive their water, and therefore the decisions users make regarding the water they drink.

Perception of health risk is another important factor that impacts user choices and behaviors related to how water is retrieved, stored, and used. Perceptions of water-related risks vary significantly across space and season and are weakly correlated with a variety of factors (Doria et al., 2009; Rojas & Megerle, 2013). People often perceive a health risk in drinking untreated water there is a high incidence of disease that is known locally to be linked to

water. In a study in Medellin, Colombia, for example, surveys indicated that people associate diarrhea with consuming contaminated water, and that people likewise perceived a health risk associated with the consumption of contaminated water (Rojas & Megerle, 2013).

On the other hand, a study in the Mekong Delta in Vietnam found that while communities may acknowledge their water quality as poor, a lack of perceived health risk combined with a lack of understanding of relationships among water, hygiene, and infectious disease theory can serve as a barrier to behavior change in the WASH domain (Herbst et al., 2009). Ultimately, widely held beliefs that ‘if water is clear and tastes normal, then it must be safe to drink and does not pose health risks’ are difficult to overcome (Rojas & Megerle, 2013). Water that looks, smells, and tastes ‘normal’ may pose health risks if it harbors contaminants such as bacteria, viruses, parasites, heavy metals, and other contaminants. Therefore, perceptions that a water source is safe based solely on physical properties may lead users to consume water of poor quality and expose them to health hazards. Interviews and focus group discussions across multiple studies revealed that water consumers feel little incentive to change drinking water source or invest in water treatment technologies if they are not experiencing health problems that they associate with poor quality water (Doria, 2010; Juran & MacDonald, 2014). For example, a study in rural South India on boiling as a treatment method supports the notion that if no one in a household is sick, people generally perceive that the water they are drinking is safe. In response to being informed that her water was in fact contaminated with fecal coliform, one interviewee claimed, “You do not know what you are talking about. Piped water is good, very good. It’s super. If there are *krimi* [‘bacteria’ or ‘germs’ in Tamil] then I would be sick right now. I’m not sick, so the water is safe” (Juran & MacDonald, 2014, p. 795). This interview quote provides insight on both the perceptions of water consumers and how such perceptions serve to influence water consumption behaviors.

Interestingly, health events directly linked to poor quality water may not impact a user perceptions of the safety of their water. A study by Wright et al. (2012), for example, used South Africa’s annual and nationally representative General Household Surveys from 2002-09 and focused on the perceived safety of drinking water across the country. The study period encompassed a large-scale cholera outbreak that affected multiple regions of South Africa. The outbreak was related to contamination of the water supply, yet analyses determined that

perceived water safety remained relatively consistent and was not affected by the cholera outbreak.

The relationship and communication between water providers and users also impacts the attitudes users hold regarding the quality of their water supply. Multiple studies evidence that the communication between users and water service providers can either generate trust or mistrust, and this relationship impacts perceptions of water quality (Ramos da Silva et al., 2010; Wright et al., 2012). In some regions, water users perceive the water supplier as authoritative and trustworthy, as evidenced by a study in South India in which conventional wisdom dictated that water supplied by the government was automatically safe for the simple fact that the government provided it (Juran & MacDonald, 2014). However, water quality tests demonstrated that the supposed safe water was chemically and bacteriologically unsafe. In a case of distrust, water users in Brazil lacked confidence in the quality of water provided by a private company due to issues of taste, appearance (turbidity), and absence of consistent and transparent communication by the water utility. This lack of trust and information exchange between providers and consumers led many to believe they were receiving poor quality water, and many of these users went on to implement household water treatment practices as a precautionary method (Ramos da Silva et al., 2010). These cases bring to light a significant gap between perceptions of water quality and reality, which sometimes manifests in user behaviors founded on inaccurate perceptions.

While demographic characteristics likely influence attitudes and beliefs regarding water quality, studies thus far reveal only weak relationships. In a 2012 study in South Africa, analyses showed that perceived drinking water safety was only weakly associated with socioeconomic and demographic characteristics, and was impacted much more significantly by taste, odor, and color (Wright et al., 2012). Further, a 2011 study of women in Pakistan revealed weak relationships between level of education and the ability to perceive risk factors in water (Yasar et al., 2011). Gender, however, is widely acknowledged to be a significant factor in determining the responsibilities one has in managing water resources. Generally, women are responsible for the collection, transportation, storage, treatment, use (i.e., cooking, cleaning, and serving), and overall management of water in the household. Francis et al. (2015) found that women are generally more concerned about household water quality and that female

participation in water quality interventions positively affected program success and uptake of hygienic behaviors.

As previously discussed, the sustainability of water interventions is related to the beliefs, attitudes, and perceptions users have regarding their water services, which serve to impact their use and acceptance of the water intervention. As Francis et al. conclude, “faulty perceptions on water treatment, lack of knowledge about health hazards associated with drinking unsafe water, false sense of protection from locally available water, resistance to change in taste or odor of water . . . were [are] important factors impeding acceptance and long term use of the intervention” (2015, p. 1). Thus, it is crucial to identify, acknowledge, and consider such factors when designing and operationalizing a water service intervention. Stated shortly, if you want to help people, then you must listen to the people. A deeper understanding of factors influencing user perceptions of water quality and service delivery is a prerequisite for gauging intervention acceptance both before and after an intervention.

5. Behavior change theory and the WASH sector

Behavior change is an important factor in determining the long-term success of a WASH intervention, as interventions depend on people adopting and maintaining, for example, a treated drinking-water service or a hand-washing station. Thus, behavior change theories play a significant role in the WASH sector. Behavior change theories attempt to explain and analyze why people behave the way they do, and even go so far as to analyze the role of user perceptions as they influence behaviors. Some theories focus explicitly on altering individuals’ perceptions and, thus, impacting their behaviors. The theoretical constructs attempt to disentangle factors that influence how perceptions are formed, explaining both how perceptions impact real behaviors related to water, sanitation, and hygiene, and how these perceptions can be changed. Behavior change theories can be leveraged as frameworks for designing interventions focused on encouraging WASH-related behavior change, and they also provide a systematic lens for explaining and evaluating the role of behaviors. Below are some of the prominent behavior change theories that relate to the WASH sector.

Health Belief Model

The Health Belief Model (HBM) is an expectancy value theory that focuses on perceptions of susceptibility to and the severity of a specific health concern, as well as on the

belief that specific actions can prevent the likelihood of manifestation of the health concern. Essentially, the HBM model posits that perceptions of a threat and the benefit of engaging in a recommended action can explain the likelihood of preventative health behavior. The model has been used for decades, was applied to personal health behavior by Becker (1974), Rosenstock (1974), and later by Janz and Becker (1984), and is now one of the most well-known health behavior theories. The major constructs of this theory include the following: perceived threat (a person's perception of the severity of a threat, their susceptibility, and their likelihood of being impacted); cues to action (information about the threat and recommended actions to prevent the threat); expected utility (made up of perceived benefits and barriers, which involves a person's evaluation of the recommended preventative action); and self-efficacy (a person's confidence in their ability to take a specific action) (Janz & Becker, 1984; Simons-Morton, McLeroy, & Wendel, 2011, p. 115). The HBM model has been applied successfully in both developed and developing countries and to investigate a wide range of health behaviors (Addington, 1979; Volk & Koopman, 2001).

Theory of Planned Behavior

Theory of Planned Behavior (TPB) asserts that behavior is the result of a person's attitudes regarding an action, their perceived behavioral control, and subjective norms (Ajzen, 1985, 1991). TPB presents many constructs. This theory suggests that attitude towards an action, is rational, and arises from a person's beliefs about the consequences of a behavior and the expected outcomes of this behavior. It suggests the importance of subjective, or injunctive, norms, made up of normative beliefs about the prevalence of and acceptability of an action by relevant others around them. An additional construct presented by TPB is motivation to comply, defined as the valuing of the perceived behavioral preference of their significant others. Finally, this theory suggests the importance of perceived behavioral control, which is made up of a person's perception of barriers and opportunities to carrying out an action, and the perceived power, or valuing of these constraining and facilitating factors (Ajzen, 1985, 1991; Simons-Morton et al., 2011, p. 104). TPB has been widely used to understand health behaviors (Godin & Kok, 1996; Graf, Meierhofer, Wegelin, & Mosler, 2008; Inauen & Mosler, 2016). Other than the addition of the perceived behavioral control construct, TPB is very similar to the Theory of

Reasoned Action, which states that behavior is influenced by a person's intentions, their intentions influenced by attitudes, and their attitudes informed by their beliefs (Fishbein, 1979).

Trans-Theoretical Model

Trans-Theoretical Model (TTM), also known as the Stages of Change Theory, explains how people naturally progress through stages of change. While it does not have specific constructs, TTM provides a way to conceptualize the steps a person takes during the change process, and argues that moving individuals from one stage of change to the next is the primary goal of behavior change interventions (Prochaska & DiClemente, 1986; Prochaska, DiClemente, & Norcross, 1992). TTM assumes that behavior change is a process, and specific strategies should be employed at each stage to motivate individuals to move to the next desired stage (Prochaska et al., 1992; Simons-Morton et al., 2011, p. 260). Stages of the TTM change process include: pre-contemplation, in which a person is not interested in changing their behavior; contemplation, in which a person is considering changing their behavior; preparation for action, in which a person plans to take action in the near future; action, in which a person adopts a substantial behavior change; and finally maintenance, in which a person works to maintain the changed behavior (Simons-Morton et al., 2011, p. 260). TTM also calls for 'stage-tailoring' an intervention, or implementing specific change strategies based on the stage of the change process an individual is in. These change strategies, or change processes, are adopted from many theories, including consciousness raising, self-reevaluation, stimulus control, self-liberation, helping relationships, and others. Though it was first developed to make sense of stages of change specific to addictive behaviors, TTM is also widely cited in the literature for its use in conceptualizing stages of change for many types of behaviors, both in developed and developing countries (Velicer, Prochaska, Fava, Norman, & Redding, 1998; Thevos, Kaona, Siajunza, & Quick, 2000).

Other behavior change theories in the WASH sector

The aforementioned theories, while comprising the most commonly applied in the WASH sector, are not the only health behavior theories used in the field. New behavior change theories specific to the WASH sector have been developed in recent years, including the "three-level model" created by Robert Aunger (2010), and the Risk, Attitudes, Norms, Abilities, and

Self-regulation (RANAS) model of behavioral change created by Hans-Joachim Mosler (2012), and the Integrated Behavioral Model for Water, Sanitation, and Hygiene created by Robert Dreibelbis and others (2013). RANAS has been deployed by several in the WASH sector, and early uses of the theory indicate valuable applications (Mosler, 2012; Lilje, Kessely, & Mosler, 2015).

Application of behavior change theories in the WASH sector

The use of behavior change theories is significant, yet limited, in its applications to the WASH sector. While many interventions are designed with the goal of facilitating behavioral change related to water, sanitation, and hygiene, a recent publication on health communication in the WASH sector states, “the field of water, sanitation and hygiene lacks a theory-based approach to the design and evaluation of interventions” (Figueroa & Kincaid, 2010, p. 3). While most studies and interventions utilize health promotion strategies of some sort, the majority of studies associated with WASH-related behavior changes are not fully grounded in theory. A solar water disinfection behavior study, for example, referenced Diffusion of Innovations and the Elaboration Likelihood Model, but did not actually use the constructs to affect study design or better understand how the intervention played out, and thus, did not demonstrate fidelity to either theory (Tamas, Tobias, & Mosler, 2009). On the other hand, a study by Rainey and Harding used the constructs from HBM to provide a useful analysis and explanation of WASH-related health behaviors and to evaluate intervention efficacy. The authors state that one of the goals of the study is to “use the constructs from the Health Belief Model as a framework to examine the acceptability of solar disinfection . . . as a household water treatment method . . . and investigate the local understandings of the links between water quality, sanitation, and health” (Rainey & Harding, 2005, p. 362). Thus, their survey asked questions that shed light on components of the HBM (e.g., modifying factors, perceived risk, perceived barriers, perceived benefits, self-efficacy, cues to action, and likelihood of adoption). As a result, Rainey and Harding harnessed HBM to critique and understand their intervention, which helped them to explain why subjects behaved the way they did, how such behaviors related to safe water consumption, and the role that perceptions played in shaping such behaviors.

Studying behavior change through a theoretical lens provides a framework for studying and understanding how perceptions do or do not impact behaviors. A study by Graf et al. 2008,

for example, applies the HBM and TPB to water disinfection and hygiene behavior in a slum in Kenya. The goal was to explain why people behave the way they do in reference to solar water disinfection techniques, and to identify factors associated with behavior change within that sphere. Thus, in order to “gain an understanding of how beliefs . . . influence health-improving behavior” such as water disinfection and hygiene behaviors, Graf et al. developed variables founded on the HBM and TPB (Graf et al., 2008, p. 339). In terms of HBM, while Graf et al. set up measurable indicators for perceived risk (perceived risk that young children get diarrhea), perceived severity (perceived severity of young children’s diarrhea), and cues to action (called “lay ideas of the causes of young children’s diarrhea” in their study), they did not address self-efficacy or perception of susceptibility, both of which are trademark constructs of HBM. Similarly, the study addressed the role of social norms and beliefs, borrowing constructs from TPB, but did not address constructs such as perceived behavioral control or attitudes. That being said, the questionnaire was included with the study, and prompts that addressed each construct posed were comprehensive and well-thought out. For example, in addressing perceived risk, the surveyors asked participants, “are your young children at risk of getting diarrhea?” using a Likert Scale from 1 to 5. Based on survey results, Graf et al. determined that “there was a positive correlation between hygiene behavior and . . . stronger beliefs in the important role played by water in causing diarrhea and a stronger social pressure felt by the respondents for water treatment” (Graf et al., 2008, p. 351).

As discussed, while behavior change is central to most interventions in the WASH sector, the use of theory to affect study design, the selection of interventions based on theory, and the post-hoc evaluation of interventions based on theory is limited. Further, even when theories are used, they are typically used only to explain why subjects behave the way they do rather than to leverage such theories in a proactive manner (i.e., to influence the actual intervention). The application of theory in the WASH sector is particularly challenging because resources are typically limited (especially in humanitarian interventions); monitoring and evaluation is challenging (intervening entities may not be based locally, may not have funds for follow-up studies, and have likely moved on to the next project); and interventions rarely focus on examining behaviors. Further still, even when investigating behaviors, interventions often encompass multiple related behaviors (i.e. hand-washing, use of sanitation facilities, and boiling water), which makes studying the behaviors, isolating contributions of each individual behavior

to health, and disentangling how each behavior affects the others extremely complex. While encouraging WASH-related behavior change is important, it is also important to explore the theoretical backing of techniques that are utilized, which helps one understand *why* the techniques work and how interventions can better promote long-term healthy behaviors.

Interventions in the WASH sector frequently involve the introduction of new technologies and innovations, which in turn often affect behavior as people use, consume, and incorporate the innovations into their daily lives. Unfortunately, while interventions in the WASH sector often introduce innovations, the current literature fails to fully account for theories on adoption of these innovations. Diffusion of Innovations theory, proposed by Rogers in 1962, is perhaps the most widely-used theory in the WASH sector related to the deployment of innovations and new technologies. This theory explains how innovations spread throughout a population, and defines diffusion as “the process in which an innovation is communicated through certain channels over time among the members of a social system” (Rogers, 2003, p. 5). Rogers identified variables and constructs that help explain the rate of adoption of innovations, including relative advantage, compatibility, complexity, trialability, and observability. Rogers also discusses how variance in communication channels as well as personal characteristics and perceptions impact the rate of adoption of innovations. Diffusion of Innovations theory has been applied to a few WASH specific innovations, including studies on the adoption of household water treatment technologies and a behavioral study on solar water disinfection (Murcott, 2006; Tamas et al., 2009).

The Technology Applicability Model is another theory related to the introduction of innovations in the WASH sector. This model was proposed by Davis (1989) and subsequently expanded by Venkatesh and Davis (2000). The theory asserts that both internal and external variables influence the perceived usefulness of a technology, as does perceived ease-of-use, which is "the degree to which a person believes that using a particular system would be free from effort" (Davis, 1989, p. 320). Though the Technology Applicability Model is generally applied in the context of information systems technologies and has not yet been applied to WASH interventions, it has been applied in developing countries (Ahlan & Ahmad, 2014), specifically to mobile banking in developing countries (Tobbin, 2012), and in Tanzania (Musa, Meso, & Mbarika, 2005). Thus, this theory may prove useful for explaining behaviors and planning interventions related to implementing WASH-related innovations in Tanzania.

6. The case of Tanzania

Geography of Tanzania

Tanzania is a coastal country located in the Great Lakes region of East Africa (see Figure 1 and Figure 2). With a population of 51.8 million, the nation is ethnically, religiously, and linguistically diverse, comprising Christians, Muslims, and other religions across more than 100 tribal groups speaking various languages (although Swahili is the most common language). Tanzania's physical geography is also diverse. Mountains, including the tallest peak in Africa, Mount Kilimanjaro, and forests are predominant in the northeast. Large open plains and arable land characterize the large plateau of central Tanzania. Further, the country is situated on the coast of the Indian Ocean and borders Lake Victoria and Lake Tanganyika to the north and west, with Lake Nyasa to the southwest. Approximately 38% of land in Tanzania is set aside in conservation areas and national parks, including Serengeti National Park. The climate differs greatly across Tanzania, with rainfall and temperature highly variable across the different regions of the country.

Development and the water sector of Tanzania

As argued by Jiménez and Pérez-Foguet (2010), “Water provision is indisputably the most politicized of public services, and developing countries have been greatly affected by the consequences of the ideological and



Figure 1. Map of Africa highlighting Tanzania

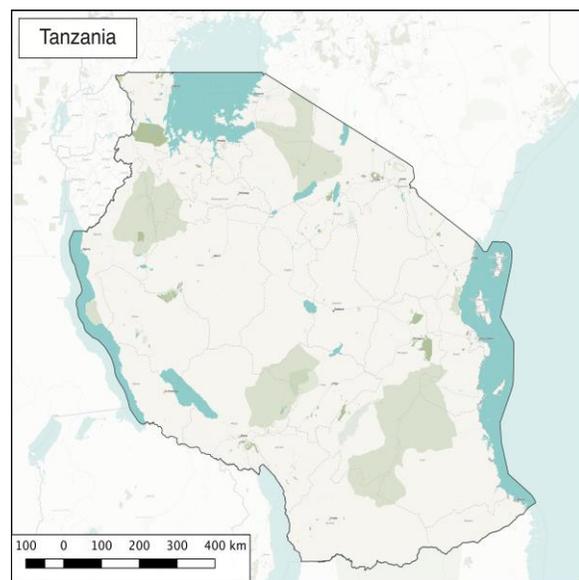


Figure 2. Map of Tanzania

political tendencies surrounding it” (Jiménez & Pérez-Foguet, 2010, p. 93). Thus, in order to understand current challenges to the water sector of Tanzania, it is first important to understand the history and development of the unique nation.

Similar to many East African countries, Tanzania has a history of colonization. At different times, Zanzibar and mainland Tanzania were claimed by Omani Arabs, Portugal, Germany, and Great Britain. The economy of Tanzania (known as Tanganyika at the time, before it was united with Zanzibar in 1964), was built predominantly on the export of raw materials and agricultural products, with manufactured goods primarily imported (Ngowi, 2009). During this period, many water services were constructed and funded via cost sharing between the central government and local authorities.

Tanzania received independence from the British under the leadership of Julius K. Nyerere in 1961. Nyerere was the leader of the Tanganyika African National Union (TANU) and eventually became the president of Tanzania in 1962. In 1967, Nyerere implemented the Ujamaa policy, which instituted economic and political policies oriented towards socialism, through the Arusha Declaration (Ngowi, 2009). Ujamaa, which means ‘brotherhood,’ centers around the goal of self-reliance and explicitly states that it is the “responsibility of the State to intervene actively in the economic life of the Nation so as to ensure the well-being of all citizens and so as to prevent the exploitation of one person by another or one group by another, and so as to prevent the accumulation of wealth to an extent which is inconsistent with a classless society” (Nyerere, 1968, p. 1). Thus, the market economy was replaced by a “state-owned, centrally planned and controlled economy” in which the means of production were nationalized (Ngowi, 2009, p. 262). With Ujamaa came ‘villagization’ schemes, in which citizens were relocated into ‘Ujamaa villages,’ to create a self-sustaining rural agrarian society. During this period, the central government paid for 100% of capital investment in the water sector and, as a result, access to improved water increased from 12% to 46% by 1985 (Mandara et al., 2013).

The period during which private enterprise was essentially nonexistent is now seen as a failed socialist experiment, with the “nationalization of the productive sectors of the economy . . . among the major reasons for poor economic development in Tanzania” (Ngowi, 2009, p. 263). Although Ujamaa did not deliver as Nyerere had hoped in economic terms, it did produce a sense of unity in Tanzania, resulting in a “legacy of stability” which has left Tanzania “one of the most stable countries in Africa” (Ibhawoh & Dibua, 2003, p. 71).

The time period since 1985 is characterized by various phases of massive economic reforms, liberalization, and privatization. Nyerere stepped down in 1985, and “the government was forced to formally abandon its commitment to socialism and adopt neoliberal, market-oriented policies of structural adjustment and IMF/World Bank-sponsored reform” (Jennings, 2008, p. 37). In order to accept last-resort loans from the IMF, Tanzania had to accept “as a condition for further loans, liberalization of the national economy, devaluation of national currency, lifting of price control, and cuts in government expenditure” (Ibhawoh & Dibua, 2003, p. 72). Thus, policies instituted under Ujamaa were largely discarded and “structural adjustment led, inevitably, to the shrinking of the state, and loss of control over economic policies” (Jennings, 2008, pp. 197-198). In this era, authority and responsibility to provide water services was decentralized, with villages and communities taking a more central role in the planning and management of their water services, as articulated by the 2002 National Water Policy.

Under the current National Water Policy of 2002, the stated role of the national government in the supply of safe water is to “change its role from being an implementer to a regulator, facilitator, and co-coordinator” and to strengthen “institutional linkages between key sector actors including central government, local government, external support agencies, private sector, NGOs . . .” (United Republic of Tanzania, June, 2002, pp. 34, 37). In 2006, the central government published the National Water Sector Development Strategy, which further decentralized the water sector. Under the new policy, authority for water provision was decentralized and delegated to 20 utilities in urban areas and 100 District Councils in rural areas, each of which supervise Community Owned Water Supply Organizations (COWSO) within their district. These rural COSWOs act as implementers who are ultimately responsible for water provision in their community (United Republic of Tanzania, 2006). Under this policy, the responsibility of providing water to the population is decentralized and does not belong solely to government of Tanzania, which often results in inadequate and intermittent water services.

Tanzania has yet to “develop in the way desired by the nation’s father [Nyerere]” (UNDP & United Republic of Tanzania, 2014, p. xi). With a Human Development Index (HDI) score of 0.488 and an HDI ranking of 159 out of 187 countries, Tanzania is in the lowest quartile and is classified as a ‘low’ human development country (UNDP & United Republic of Tanzania, 2014). Though its average annual GDP growth rate is an impressive 7%, this “high growth rate did not result in commensurate poverty reduction” and has “failed to expand the ability of the majority

of Tanzanians to lead the kind of lives they value” (UNDP & United Republic of Tanzania, 2014, p. xi). Poverty is still the reality for many; as of 2012, the poverty rate was 28.2%, only 21% had electricity for lighting, 67% lived in dwellings with floors made of earth or sand, educational attainment and quality were relatively low, and rapid population growth was occurring at a rate of about 1.2 million people annually (UNDP & United Republic of Tanzania, 2014). Unfortunately, based on 2004 data, 98% of donor monies and the Tanzanian government’s tax revenues were spent on the richest 20% of the population (Greenhill & Weklya, 2004).

Of the 663 million people who currently lack access to an improved drinking water source globally, nearly half (319 million) live in Sub-Saharan Africa. In Tanzania, approximately 29 million, or 44% of the population, lack access to an improved drinking source (WHO & UNICEF, 2015). Rural access to improved drinking water is even lower, with around 54% of rural populations lacking access (WHO & UNICEF, 2015). These rates are significantly lower than the global average, as all but 9% of the global population currently enjoy access to improved drinking water (WHO & UNICEF, 2015). According to a 2015 WHO and UNICEF report that monitored progress towards the United Nations Millennium Development Goal (MDG) for improving access to safe drinking water, “limited or no progress” was made between 1990 and 2015 in Tanzania. Untreated surface water is the primary drinking source for the 20% of Tanzanians that live in rural areas, and such water is typically contaminated with *E. coli*, among other contaminants that are hazardous to health. The combination of a lack of infrastructure in rural areas, informal and unplanned settlements in urban areas, a historic lack of investment in the water sector, and poor quality of infrastructure in related sectors (e.g., wastewater and drainage), Tanzania has many large challenges to overcome in providing safe water to its residents.

In response to the lack of access to improved water sources, the Government of Tanzania (GoT) and funding agencies such as the World Bank and others have poured hundreds of thousands of dollars into water supply infrastructure over the past three decades (Mandara et al., 2013). However, investments in the water sector have not necessarily been successful or sustainable. A 2014 study conducted by the Ministry of Water in Tanzania revealed that of the 74,331 water points surveyed, 38% were nonfunctional and another 7% were in need of repair (Tanzania Ministry of Water, 2015). Therefore, not only is the goal of universal access to safe

drinking water far from reality (particularly in rural settings where infrastructure is often nonexistent), but much of the existing supply infrastructure is nonfunctional and unused due to issues of poor water service sustainability outcomes. As GoT and other development and humanitarian organizations seek to expand water services across the country, prioritizing sustainable water service delivery is vital for long-term success of the investments.

The case of Dar es Salaam

Tanzania's largest city of Dar es Salaam demonstrates the tumultuous history of water provision in the country. Dar es Salaam exhibits a history of antiquated and overstressed water infrastructure that "dates to the colonial era and has seen few improvements or expansions since that time" (Smiley, 2013, p. 132). Thus, water infrastructure has not only aged well past its design horizon, but it also serves many more people than was intended. These factors, along with poor administration and maintenance, have led to issues of poor water quality, intermittent supplies, poor physical access to water points, and a general dissatisfaction in the level and quality of services. In 2000, under the IMF Poverty Reduction and Growth Facility, the government was required to "assign the assets of Dar es Salaam Water and Sewage Authority (DAWASA) to private management companies" in order to improve water services in the city (Grusky, 2001, p. 17). As a result, in 2003 a consortium called City Water Services Ltd. (which is part of Biwater International Ltd., a transnational corporation with water and wastewater operations in dozens of countries) took over the provision of water and sewage services (Castro, 2008; Dill, 2010). However, the contract was canceled eight years early in 2005 following a drastic increase in water prices with little to no increase in the quality of water or extent of services, and multiple Biwater executives were quickly deported (Dill, 2010). Following this failed privatization of Dar es Salaam's water services, "this private sector enterprise was quickly replaced with the newly formed Dar es Salaam Water and Sewerage Corporation (DAWASCO), a publicly-owned company" (Dill, 2010, p. 612).

As a result of the failure of both the public and private entities to provide safe water in Dar es Salaam, the majority of its more than 4 million residents still "struggle to meet their basic daily needs for water" (Dill, 2010, p. 613). As of 2009, only approximately 16% of residents had household water connections, only 26% of water was being billed, and roughly 60% of water was lost through leaks and 13% was lost to illegal connections (Dill, 2010). Many residents of

Dar es Salaam are slum-dwellers, living in informal settlements between arterial roads and on marginal lands. These communities often utilize “more than one regular source of water, switching between public standpipes, unprotected wells and water vendors” depending on seasonal availability, cost, convenience, and because often several sources are required in order to make ends meet (Dagdeviren & Robertson, 2011, p. 487). As a result, water infrastructure in Dar es Salaam is fragmented and inadequate, and the “reality of everyday life is poor or even nonexistent access to water” for a majority of residents (Smiley, 2013, p. 132).

7. References

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3. Perceptions of water services and innovations to improve water services in Tanzania

1. Abstract

Lack of access to safe drinking water is a crisis of great proportion. An estimated 1.8 billion people rely on unsafe drinking water. This study focuses on the case of Tanzania, in which an estimated 29 million people, or 44% of the population, lack access to safe drinking water. Furthermore, the Tanzanian Ministry of Water estimates that approximately 38% of all water access points in the country are nonfunctional. As the Government of Tanzania and other actors work to improve water access, they employ innovations to facilitate water service delivery that is both high quality and sustainable over time. These innovations must be field-tested prior to large-scale implementation to ensure they are appropriate and effective in varying contexts. User perceptions of innovations are valuable for gauging the potential benefits and barriers to incorporating new innovations in the water sector. This study investigates the use of solar power and mobile prepayment to improve water services in Tanzania. There are currently no data on user perceptions of these innovations in Tanzania. Thus, this study fills this data gap through the analysis of focus group discussions (n=6) and key informant interviews (n=15) collected during summer 2016 in three urban and three rural communities in Tanzania. Urban sites are located in the city of Dar es Salaam, and rural sites are scattered throughout Tanzania. Using qualitative methods, this study identifies themes related to user perceptions of water services, solar power, and mobile prepayment. While perceptions varied between urban and rural study settings and within study sites, most people perceived major challenges with the current water system. These perceived challenges included the poor reputation of the water service provider, health problems related to water, and the general lack of consistent high-quality water provision. Research participants perceive that mobile prepayment is a modern solution to water service challenges, but perceive that cost, particularly for the poor, may be a barrier. Generally, people in the rural setting perceive that solar power will reduce costs and increase water service reliability, while those in Dar es Salaam were less familiar with the technology. While perceptions indicate that solar and mobile phone innovations have great potential in both urban and rural settings, they also indicate that there exist significant challenges to implementing the innovations. User

perceptions ultimately manifest in real behaviors related to water services, and thus must be incorporated before these innovations are scaled-up across Tanzania.

2. Introduction

Water is one of the most basic needs for human life, yet access to safe drinking water remains one of the world's most critical challenges. Approximately 663 million people lack access to 'improved' sources of drinking water, and more than 500,000 people die each year from diarrheal illnesses related to unsafe water consumption, poor sanitation, and lack of hygienic practices (WHO & UNICEF, 2015). Around 99% of this excess morbidity and mortality occurs in the developing world (Prüss-Üstün, Bos, Gore, & Bartram, 2008).

In response to widespread accounts of premature water service failure and poor service quality (particularly in low-income countries), many studies have attempted to discern and explain why some water supply interventions provide high quality service in the long-term, while others either provide low quality service and/or fail prematurely (Montgomery, Bartram, & Elimelech, 2009; Jiménez & Pérez-Foguet, 2011; Marks & Davis, 2012; Mandara, Butijn, & Niehof, 2013). These studies identify a host of financial, technical, social, economic, environmental, and institutional factors associated with the sustainability outcomes of safe drinking water solutions, including water supply management strategies, institutional capacity, technical solution appropriateness, and user perception of the water service. Moreover, past studies also reveal that the confluence of attitudes, beliefs, and perceptions one has regarding their water services is intricately related to the acceptance and long-term sustainability of water services (Herbst, Benedikter, & Koester, 2009; Ramos da Silva, Heller, de Campos Valadares, & Cairncross, 2010; Francis et al., 2015). As a result, there is a clear identified need to disentangle the complex factors that influence how perceptions are formed, and ultimately to explain how perceptions manifest in real behaviors that serve to impact the sustainability and acceptability of safe drinking water solutions. This shift in the focus of ongoing reports indicates that innovations in the water sector should be subjected to place-based variables and locally-held perceptions to facilitate compatibility among the project, the population it serves, and societal beliefs. Therefore, the investigation of user perceptions and their necessary impact on service sustainability forms the crux of this study.

Using qualitative methods, this study examines individual and community perceptions of water services and the introduction of innovations to improve water services in rural and urban Tanzania. At present, 29 million people, or 44% of the country's population, lack access to an improved drinking source (WHO & UNICEF, 2015). A 2015 study determined that 38% of water access points in the country are nonfunctional, indicating that efforts to increase safe water access in Tanzania have not been sustained over time (Tanzania Ministry of Water, 2015). As the Government of Tanzania (GoT) invests in the improvement of water services, it is essential that user perceptions are considered and that newly introduced innovations to improve water services are acceptable and effective before large-scale implementation is pursued. This study is part of a larger World Bank grant that was jointly carried out by GoT and the nonprofit humanitarian organization Water Mission-Tanzania (WM-T). While the greater research project involves the rehabilitation of water infrastructure and the use of solar power and mobile prepayment systems for enhanced water delivery, the present effort presents baseline perceptions before the outset of such improvements to assist in the evaluation of broader project success. This study uses focus group discussions (FGDs) and key informant interviews (KIIs) to investigate perceptions of water services in three urban and three rural communities in Tanzania, specifically including perceptions of innovations to improve water services, e.g. the use of solar power and mobile prepayment systems. These perceptions are useful for gauging the appropriateness, scalability, and efficacy of water sector innovations.

The overarching research question is: *in the case of three urban and three rural communities in Tanzania, what are user perceptions of water services and user perceptions of innovations to improve water services?* The objective is to identify user and relevant stakeholders' perceptions of current water services as well as perceptions on the implementation of mobile prepayment systems and solar power in water service delivery. Additionally, this study seeks to identify potential opportunities and barriers to the incorporation of mobile prepayment systems and solar power in water service delivery and, in doing so, inform how GoT can improve the delivery of water services in a way that better incorporates user perceptions of water services and innovations to improve water services. A clearer understanding of perceptions related to water services and innovations to improve water services is essential for ensuring the long-term sustainability of water services in Tanzania.

3. Background

Past research has explored the relationship among perceptions, behavior, and the long-term sustainability and effectiveness of water services (Herbst et al., 2009; Doria, 2010; Francis et al., 2015). By raw definition, perceptions are variable, subjective, and are often based on lived experiences that cannot be objectively verified or measured. However, perceptions--whether they align with actual or 'imagined' realities--must be considered in WASH interventions because they ultimately manifest in the form of real actions and behaviors. For example, scholarly research demonstrates that aesthetic qualities such as taste, color, and odor significantly impact how consumers perceive their quality of water, perception of water safety, and related health risks—all of which affect the choices consumers make regarding their water sources and services (Doria, Pidgeon, & Hunter, 2009; Ramos da Silva et al., 2010; Francis et al., 2015). Research also indicates that perceptions of water service are influenced by demographic characteristics of the individual or community, negative health and disease events related to water, and WASH education campaigns (Herbst et al., 2009; Doria, 2010; Francis et al., 2015).

A recent study conducted by Francis et al. (2015) in southern India indicates that attitudes, beliefs, and perceptions held by water users regarding drinking water not only impact their short-term choices and acceptance of interventions, but also the long-term sustainability of water service interventions. This qualitative study demonstrated that user perceptions related to water services significantly impact the ability of participants to recognize health benefits from interventions, willingness to pay for interventions, and ultimately acceptance of the water supply interventions themselves. Francis et al (2015), also identified several barriers to long-term acceptance and use of water interventions, including a basic lack of perceived relationship between drinking unsafe water and negative health impacts, as well as resistance to changes in water aesthetics, especially taste and odor, following water treatment. Interviews and focus group discussions across multiple studies also revealed that water consumers feel little incentive to change drinking water source or invest in water treatment technologies if they are not experiencing health problems that they associate with poor quality water and thus perceive as a health risk (Doria, 2010; Ramos da Silva et al., 2010; Juran & MacDonald, 2014). For example, Marks and Davis (2012) found that a perceived 'sense of ownership,' or the perception that the water system in some way belongs to the community and is in their control, is associated with a higher likelihood of long-term service sustainability. Further, this sense of ownership may be

fostered through community participation in water system planning and direct involvement in decision making processes that guide water service provision (Marks & Davis, 2012).

Multiple studies also demonstrate that perception of trustworthiness of a water service provider—whether based on fact or not—impacts actual behaviors (Ramos da Silva et al., 2010; Wright, Yang, Rivett, & Gundry, 2012). In one case in southern India, for example, users assumed water was safe simply because it was supplied by the government and came out of a pipe, even though water quality tests indicated that the water was bacteriologically contaminated (Juran & MacDonald, 2014). In a case of mistrust, water consumers in Brazil lacked trust and confidence in their service provider due to issues of taste, appearance (turbidity), and the absence of consistent and transparent communication on behalf of the water utility. Perceptions that the provider could not be trusted to provide safe water triggered users to activate specific behaviors in response, such as boiling water as a precautionary treatment (Ramos da Silva et al., 2010). These cases reveal a significant gap between perceptions of water service quality on one hand and reality on the other, the result of which sometimes manifests in behaviors founded on inaccurate perceptions.

Previous studies also describe user perceptions of technologies and innovations in the water sector, which serve to impact the effectiveness and sustainability such interventions over time. As indicated by Jiménez and Perez (2011) in Tanzania, there exists a relationship between the type of technology used at water access points and the functionality of the water points over time. Murphy et al. argue for the use of “appropriate technology” in the water sector that is suitable for the context in “both ‘hard’ and ‘soft’ aspects of technology, meaning not only the physical tools, but the knowledge transfer mechanisms, capacity building and communication methods as well as social, cultural, and gender implications of technology implementation” (Murphy, McBean, & Farahbakhsh, 2009, p. 159). In Tanzania, Mandara et al. (2013) uphold the importance of context-sensitive technology in rural water facilities, arguing that even ‘good’ technologies and innovations have the propensity to fail if users do not have the technical, managerial, or community capacity to manage the system over time. As argued by Juran et al. (2016), the local context must be considered if one seeks to accurately identify a problem, formulate a culturally-sensitive solution to the problem, and ultimately operationalize an appropriate intervention to solve the problem.

Several theories shed light on factors that influence the acceptability and diffusion innovations, although their use in the water sector is limited. The Technology Applicability Model, for example, asserts that both internal and external variables influence the perceived usefulness of a technology or innovation, as does perceived ease-of-use (Davis, 1989). The Technology Applicability Model is generally applied in the information systems technologies domain and has not yet been employed in the water sector, although it has been applied in low-income countries (Ahlan & Ahmad, 2014), in the context of mobile banking (Tobbin, 2012), and in Tanzania (Musa, Meso, & Mbarika, 2005). Diffusion of Innovations Theory, developed by Rogers, conceptualizes diffusion as “the process in which an innovation is communicated through certain channels over time among the members of a social system” (Rogers, 2003, p. 5) and identifies specific variables and constructs to explain the rate of adoption and diffusion of innovations, including relative advantage, compatibility, complexity, trialability, and observability. Diffusion of Innovations Theory also contends that technological adoption and diffusion is subject to attributes situated in place, such as local communication channels, social structures, demographics, and perceptions. Acknowledging the role that perceptions play, Rogers claims that “subjective evaluations of an innovation, derived from individual’s personal experiences and perceptions and conveyed by interpersonal networks, drives the diffusion process and thus determines an innovation’s rate of adoption” (2003, p. 223). Diffusion of Innovations Theory has been applied to WASH innovations, including studies on the adoption of household water treatment technologies in Nepal (Murcott, 2006) and a behavioral study on solar water disinfection in Bolivia (Tamas, Tobias, & Mosler, 2009).

This study focuses on two innovations to improve water services in Tanzania: mobile prepayment for water services, and solar power. The mobile prepayment system involves the linkage of mobile banking services with water meters, thereby creating a system in which users prepay for water services. In this system, individuals can either load their individualized ‘water card’ with prepaid funds through a mobile transaction or pay a mobile agent with cash in exchange for money on their water card. Literature demonstrates that mobile payment systems exhibit several benefits, including reduced transaction costs for consumers, reduced risks associated with paying in cash (e.g., generation of a receipt/confirmation of payment), improvements in billing accuracy—although there also exist legitimate challenges in terms of technical unreliability and accessibility among the poor (Hope, Foster, Money, & Rouse, 2012;

Schaub-Jones, 2013; Heymans, Eales, & Franceys, 2014). In Tanzania, mobile phone penetration increased from 59.2% in 2013 to 67% in 2014 (Mongi, Mvuma, Kucel, Tenge, & Gabriel, 2015), and 10% of Tanzania's GDP is already transacted via mobile commerce (Wesselink, Hoppe, & Lemmens, 2015). The urban water service provider Dar es Salaam Water and Sewage Corporation (DAWASCO) has partnered with Vodacom and Airtel (two large mobile service providers) to offer bill payment via mobile funds; however, only 1% of customers currently use the service (Hope, Foster, Krolkowski, & Cohen, 2011).

This study also focuses on solar power as a replacement for diesel generators and grid-based sources of energy for water pumping and conveyance in developing markets. The literature indicates great opportunity for solar power in the water sector, with potential benefits of money savings, time savings (and other opportunity costs), increased power reliability (relative to diesel), and other advantages stemming from the expanded use of a sustainable, renewable, and less polluting source of energy (Short & Thompson, 2003; Kassenga, 2008; Meah, Ula, & Barrett, 2008; The World Bank, 2015). However, significant barriers are also recognized, such as: high and sometimes cost prohibitive initial capital costs; incongruences in supply chains or the local availability and affordability of spare parts; lack of skilled technicians for maintenance; and theft and vandalism (Short & Thompson, 2003; Kassenga, 2008; Meah et al., 2008; The World Bank, 2015). In Tanzania, there are small-scale examples of solar water pumping projects as well as data that project the increased use of solar energy in the water sector in the future (Kassenga, 2008; The World Bank, 2015). This study is unique because it represents one of very few focused explicitly on perceptions related to either mobile prepayment or solar power innovations to augment water services, and it is the only study of its kind based in Tanzania. Thus, this study has the potential to provide valuable insight on the potential benefits and pitfalls of scaling up such innovations in rural and urban Tanzania and in similar social, physical, and built environments in the lesser developed world.

4. Study area

Tanzania is a coastal country located in the Great Lakes region of East Africa (Figure 3). With a population of 51.8 million, the nation is ethnically, religiously, and linguistically diverse, comprising Christians, Muslims, and other religions across more than 100 tribal groups speaking various languages (although Swahili is the most common language). Tanzania's physical geography is also diverse. Mountains, including the tallest peak in Africa, Mount Kilimanjaro, and forests are predominant in the northeast. Large open plains and arable land characterize the large plateau of central Tanzania. Further, the country is situated on the coast of the Indian Ocean and borders Lake Victoria and Lake Tanganyika to the north and west, with Lake Nyasa to the southwest. Approximately 38% of land in Tanzania is set aside in conservation areas and national parks, including Serengeti National Park. The climate differs greatly across Tanzania, with rainfall, temperature, and experience of seasons highly variable across the different regions of the country.

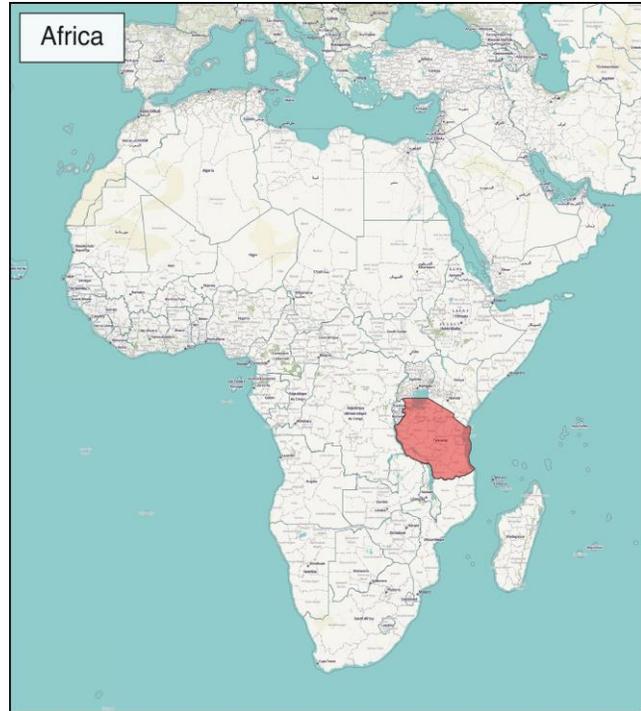


Figure 3. Map of Africa highlighting Tanzania

Six study sites were selected for this research project; three are in an urban setting and three are in a rural setting (Figures 4 and 5). Though differences exist between each study site within the rural and urban settings, differences between the urban and rural contexts are more significant. Thus, these two distinct settings facilitate an investigation that captures the diversity and breadth of perceptions among water users and relevant stakeholders.

The three urban sites are located in Dar es Salaam, Tanzania’s largest city (population over 4 million) that functions as the financial capital of the country. Dar es Salaam has a history of antiquated and overstressed water infrastructure that “dates to the colonial era and has seen few improvements or expansions since that time” (Smiley, 2013, p. 132). Much of the infrastructure has aged well past its design horizon and, due to rapid and unplanned growth of informal settlements, the systems service more people than intended. These factors, along with poor administration and maintenance, have led to issues of poor water quality, intermittent supplies, poor access to water points, and general dissatisfaction in the level and quality of services. As of 2009, only 16% of residents had household water connections, only 26% of water connections were billed, and 73% of water was lost through leaks or illegal connections (Dill, 2010). Many residents of Dar es Salaam inhabit informal settlements, which are often

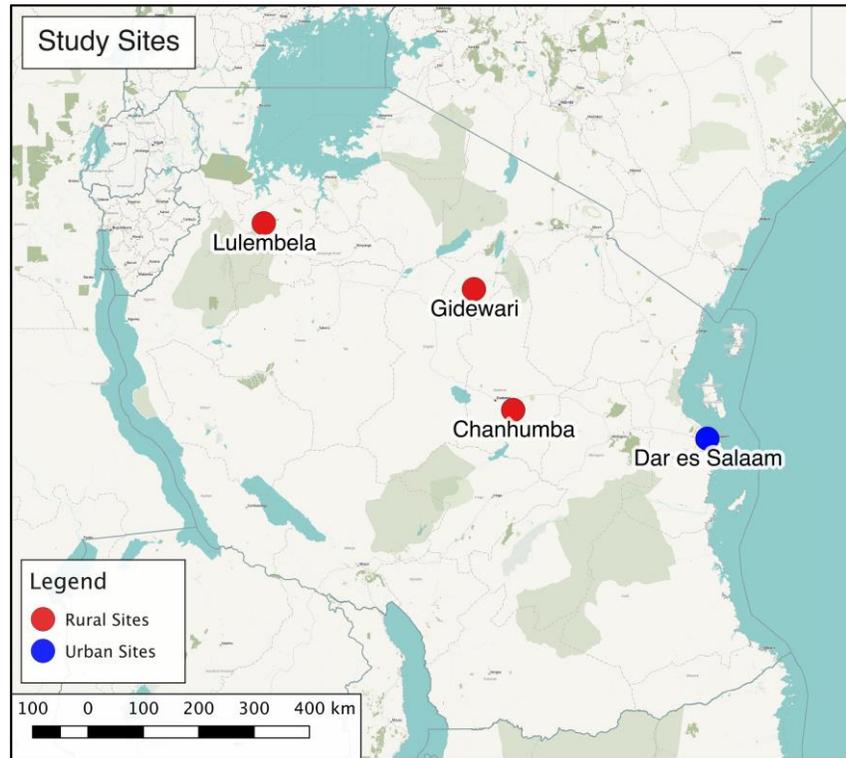


Figure 4. Map of study sites in Tanzania.

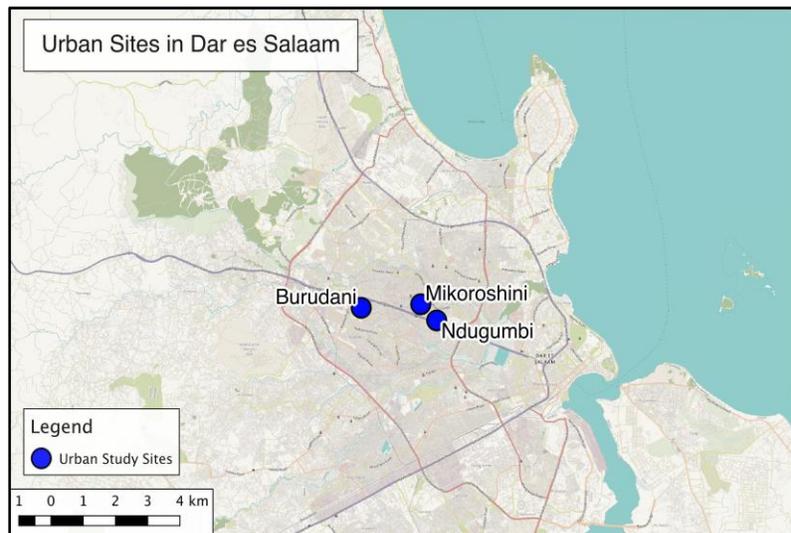


Figure 5. Map of urban study sites in Dar es Salaam.

located between arterial roads, near rivers, railroad tracks and other marginal lands, and in built environments that were developed in the absence of formal planning. As a result, water infrastructure is fragmented and inadequate, and the “reality of everyday life is poor or even nonexistent access to water” for a majority of residents (Smiley, 2013, p. 132). The three study sites in Dar es Salaam were selected with input from the Dar es Salaam Water and Sewerage Corporation (DAWASCO), the water authority that serves the city. The three urban sites (Burudani, Mikoroshini, and Ndugumbi) are all located in densely populated centers with narrow streets dominated by single story, cinder block buildings. Each study site has access to a water kiosk owned and operated by DAWASCO from where residents can purchase water in set increments (see Figure 6 for an example of a water kiosk operated by DAWASCO).

The three rural sites are scattered throughout the country. Many of the residents are farmers, pastoralists, or small business owners. Rural communities in Tanzania confront significant water-related challenges, and these challenges are apparent at the study sites. More than half of the rural population of Tanzania (which comprises 20% of the total population) lacks access to improved drinking water (WHO & UNICEF, 2015); untreated surface water is the primary drinking source for those who live in rural areas, and such water is typically contaminated with *E. coli* and other contaminants that hazardous to human health. Other challenges that impact water services and the ability to access



Figure 6. Users collect water from kiosk in Mikoroshini site. Image courtesy of Water Mission.

water include lack of basic transportation infrastructure, inconsistent or non-existent access to electricity, and greater vulnerability to seasonal variation and drought. The three rural sites, Chanhumba, Gidewari, and Lulembela, were selected in coordination with the Ministry of Water. The study sites are served by Community Owned Water Supply Organizations (COWSOs), which serve most villages in rural Tanzania. The three rural study sites vary significantly in

terms of type of water sources available, but are similar in terms of the challenges they face and the needs of their residents.

5. Data collection and analysis

Data were collected May-July 2016 utilizing qualitative methodologies, specifically focus group discussions (FGDs) and semi-structured key informant interviews (KIIs). This research is part of a larger study funded by a World Bank grant awarded to the nonprofit engineering organization Water Mission Tanzania (WM-T) in conjunction with the Government of Tanzania (GoT). Sampling included project beneficiaries at each site as well as key stakeholders, such as community leaders, government officials, water system operators, and other interlocutors who possess nuanced knowledge on water quality and supply in Tanzania. The data collection instruments were used to gather data on perceptions of water services, solar power, and mobile prepayment from individuals who live in, cope with, and manage the waterscape. While other portions of the project harnessed quantitative data, this component of the project employed qualitative methods in order to tease out the nuanced observations, lived experiences, and ultimately perceptions of beneficiaries and stakeholders, which are subjective by nature. FGDs and KIIs took place before the installation of solar power and mobile prepayment innovations, and thus the data reflect baseline perceptions.

KIIs ($n=14$) were conducted with stakeholders at each study site. Questions probed the perceptions of current water services; interests in and concerns with solar power; interests in and concerns with mobile prepayment innovations; and anticipated impacts of ensuing projects to improve water services through the use of innovations. At the three urban sites, one KII was conducted with the elected chairman of each site, and two additional KIIs were conducted with representatives from management and development of the DAWASCO system ($n=5$). Three KIIs were conducted at each rural study sites ($n=9$), which typically included the village chairman, Water Technician, and District Water Engineer. These informants were selected due to their awareness of the project, level of influence, and specific knowledge of village-level water concerns.

An FGD was organized at each study site ($n=6$). Convenience sampling was used to identify 8-12 female and male water consumers 18 years and above at each site. FGDs were used to probe and uncover: perceptions of current water services; issues that affect user behaviors; desired improvements to water services; community knowledge of and experience

with mobile prepaid metering; community knowledge of and experience with solar power; and perceived benefits and barriers of the mobile prepayment and solar power innovations. In the rural study sites, participants were recruited from community mobilization meetings in which communities were informed about the intervention, and purposive sampling of individuals who did not attend the meetings. In the urban study sites, local leaders assisted the research team in identifying and recruiting permanent residents of nearby communities. Participants were selected to be representative of the population in terms of gender, age distributions, and demographic characteristics (e.g., income and social location).

FGDs and KIIs were conducted in Swahili by a local researcher under the supervision of the research team. FGDs and KIIs were recorded and then translated and transcribed into English. Data were then organized and analyzed using Dedoose qualitative analysis software to identify dominant themes and patterns. Results were pooled according to study site and setting (rural and urban) and also by theme.

6. Results

FGDs and KIIs revealed common themes and narratives regarding perceptions of water services, mobile prepayment systems, and solar power to improve water services. Results demonstrate variation and nuances in perceptions within and across study settings (rural and urban), as well as among individuals. Results are organized thematically, and the prevailing themes, sub-themes, and quotes from interlocutors are used to construct dominant narratives. Major findings related to perceptions of water services are presented in Table 1. Users perceive that their water service provider lacks training and responsiveness, and state that they rely on multiple water sources for different end uses. Many people also perceive that water and health are related, and that their water may not be ‘safe.’ Table 2 presents major findings related to perceptions of innovations to improve water services. While perceptions of mobile prepayment and solar power varied, most users perceived both benefits and challenges to these innovations. Additional details related to these findings are found in Table 1 and 2, and are discussed in more detail below.

Table 1. Themes, sub-themes, and observations and perceptions of water services.

Theme	Sub-theme(s)	Observations and perceptions
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Water sources and water access	Multiplicity of sources Source characteristics Urban source changes	People rely on different sources for different end uses Cost, convenience, quality, availability Growth in household connections, illicit sources
‘Safe’ water	Water and health Water treatment	Bacteria, diarrhea, stomachache, malaria, contamination Waterguard (chlorine-based disinfectant), chlorine, impact of treatment on water taste and odor
Perception of water service provider	Changing reputation of DAWASCO Need for COWSO training	Poor reputation in past (ineffective, nonresponsive, corrupt), but noticeable improvements since 2016 COWSOs are not financially transparent or accountable
Training and education to promote change	Resistance to change Education and training	Members of community resistant to new technologies Education and training needed for people to accept innovations

Table 2. Themes, sub-themes, and observations and perceptions of innovations to improve water services.

Benefits of mobile prepayment system	Familiarity “Modern” and effective	Previous experience with mobile payment: Electricity, DART system, and bills Convenient and modern solution, better revenue collection, decreased water theft, fairer system
Challenges of mobile prepayment system	Network reliability Costs Effect on poor, elderly, and women Mobile money agents	Perceived risk of relying on unreliable network to access water services Cost of mobile phone, cost of water Water access challenges for poor, elderly, and women Not enough agents in rural study setting
Benefits of solar power	Reduced costs Increased reliability	Reduces operational costs, no diesel Perception in rural setting that solar is more reliable than diesel
Challenges of solar power	Seasonality	Varying perceptions regarding impact of rainy seasons

Water sources and water access

In both study settings, rural and urban, community members rely on a multiplicity of water sources to meet their needs. These sources vary greatly in terms of convenience, cost, quality, and availability. FGDs reveal multiple considerations that influence an individual’s preference for specific water sources over others. When selecting a source, users consider cost,

perceived quality, perceived safety of the water, simplicity of using the system, convenience/distance, and water source availability. These preferences are also influenced by users' intended use for the water. In the rural setting, for example, FGD participants generally prefer sources perceived as 'clean' or 'safe' for drinking, but prefer free and convenient sources, such as surface water and hand-dug wells, for their livestock and domestic non-consumptive uses (e.g., cleaning and laundry).

In the rural setting, users perceive many challenges in accessing water. Study participants in the three rural sites typically gather water from taps, shallow hand-dug wells, boreholes, surface water, and cattle troughs. Generally, users perceive their water sources to be insufficient in both quantity and quality. Water availability is inconsistent throughout the year as its abundance is affected seasonal factors; for example, some surface water sources diminish and/or disappear during the dry season. At a smaller timescale, users also acknowledge inconsistencies in water availability on a daily basis, as water demand often outstrips the quantity of water available. As a case in point, FGD participants noted that while the school in Giderwari pumps water for its students, other water taps in the area are not able to dispense water, as the school uses it all first. Users also cited financial barriers to water access. In Lulembela, the local water system technician noted in a KII that only 50% of people in the area had access to "safe and clean water," partially due to a lack of sufficient funds to improve and extend services. On an individual basis, those who cannot afford to pay for water rely on free sources, which are frequently of poor quality and/or far away. In an FGD, a participant noted that these sources present significant safety risks, citing the threat of wild animals to those who fetch water at night and danger to children playing at the wells, who are prone to fall in.

In the urban study setting, people typically obtain water from shallow and brackish hand-dug wells and from water supplied by DAWASCO. Most participants reported getting water at public water kiosks supplied by DAWASCO, though some individuals are able to afford household connections or are authorized as private vendors who have an agreement with DAWASCO. Public kiosks are owned by DAWASCO but operated by private system operators. FGD participants complained that such public taps provide water inconsistently, claiming that there is no specific routine for when water is available at these taps. FGD participants also acknowledged that many in Dar es Salaam rely on illicit water sources in which individuals either illegally tap into DAWASCO water pipes to access water or sell water from their private

household tap without the consent of DAWASCO. Participants noted that these illicit sources are often more convenient than public kiosks and are often available when public taps are turned off, as shared by an FGD participant in Ndugumbi:

We do not care to know if someone is a registered dealer or not. What we want is just service, and when water goes off [at the public kiosk] I have to go and get the service and I'm not interested in whether they are authorized or not.

FGD participants and key informants in each of the urban sites mentioned the growing number of household water connections. While few people currently have a private household connection, many believe that this is the way the water sector is heading in Dar es Salaam. In KIIs, both the chairman of Ndugumbi and a System Developer for DAWASCO stated their belief that household connections will take over within 2.5 years, and public water kiosks would eventually be phased out, although a key informant from DAWASCO management presented a more conservative estimate of 15 years. Thus, the perception of multiple key informants in the urban setting is that the model of public water tap services is reaching the end of its lifespan and will be replaced by household connections in the coming years.

'Safe' water

Water users in all study sites perceive a connection between water and health, though the characteristics of this perceived association varied. Participants frequently described their water using subjective descriptors such as 'safe' and 'clean.' Thus, many individuals implied that 'safe' water is simply water that comes out of a pipe, while others contended that water is only good to drink if it was free of bacteria. Key informants and FGD participants made connections between water and health, specifically attributing diarrhea, upset stomachs, and malaria to poor quality water. Perceptions that water quality is poor overall was a consistent theme throughout all study sites. In the urban setting, water users explained that water quality from public kiosks is generally poor and that they often must wait for the dirt and impurities in their water to settle to the bottom of the bucket before use. Some expressed a sense of resignation and powerlessness over their perceived lack of control over water quality, while others simply acknowledged the necessity to value water quantity over quality, as intimated below:

It's not exactly that the water is safe that we decide to use it, but it's mostly because we have no better alternative. The pump water has not been treated, it is water that comes straight from underground and we use it just like it is, what can we do? And you can't exactly say you will track the source of the water because it is right where you draw it from, so let's just say that we have no choice but to use it (FGD, Gidewari).

We do not have a culture of asking about water safety and hygienic things--what we need is water. We think of getting water and that's all (FGD, Mikoroshini).

In the urban setting, key informants and FGD participants perceive that water contamination is, in part, a result of illicit tapping of the pipes and the vulnerability of damaged water pipes to external contamination. DAWASCO managers pointed out that many water pipes run through or over contaminated trenches of open waste and sewage and that DAWASCO works to remove these vulnerabilities:

Contamination is firstly caused by illegal connections. Those water pipes have some holes and people who made illegal connections build connections through contaminated water pipeline, so this could be a source of contamination (KII, DAWASCO System Operator).

Ever since I came here, I have been one step ahead. I have been assisting my district commissioner in fighting against cholera. At least 70% get this disease from water, from water not being used properly. Most of the [water] lines cross rivers. Most of them are also leaking. I removed all those lines which are crossing trenches (KII, DAWASCO Manager).

There exists a significant variation in perceptions of water safety and quality among rural sites. In Lulembela, for example, FGD participants discussed the connection between water and health, and thus many people either used Waterguard, a chlorine-based water disinfectant, to treat their water or are familiar with this method of precautionary water treatment.

Perceptions of water service providers

In both rural and urban settings, participants commented on their water services provider, implying that the improved management of water services is a major priority. In rural settings, water services are managed by COWSOs, and in Dar es Salaam DAWASCO is in charge of water services—both entities were critiqued in terms of strategies for improvement.

An important theme uncovered during urban FGDs was the changing performance of DAWASCO. DAWASCO had developed a poor reputation over time for corruption and unresponsiveness to service problems. This perception was consistent across all urban study sites, and a key informant in management within DAWASCO even admitted that the image of DAWASCO has historically been “very bad.” While experiences with and attitudes toward DAWASCO varied among individuals, FGDs identified that many perceived that DAWASCO lacks receptiveness to its clientele, is corrupt, untrustworthy, and prioritizes connecting wealthy or powerful individuals with water services over relatively poor communities, as intimated by a Burudani Chairman:

Me, I know DAWASCO. I've done a lot of work with them and often they are reckless, so I don't know if they will change, or change the management. Because, at the moment, you can come across a leak and call them and after a week you'll see it's still dripping--they don't respond. If someone needs to connect their house to the water supply they can call them [DAWASCO] the whole month and it's the same.

An FGD participant in Ndugumbi also shared concerns over DAWASCO's reputation and trustworthiness:

Yes, there is no clear relationship between what we use and what we pay. We use little and pay much, and when you tell DAWASCO these complains they claim that is what they read from the meter, so there is mistrust with DAWASCO people and their services.

Though many perceive problems with DAWASCO, the general attitude among participants and key informants in Dar es Salaam is that DAWASCO is improving. Multiple

people noted that DAWASCO has been noticeably more responsive to complaints and comments, and that service quality has improved distinctly since the beginning of 2016. Some FGD participants credit this to the largescale push for greater accountability and transparency in the national government under the 50th president of Tanzania, Dr. John Magufuli, who was inaugurated in November of 2015. Management within DAWASCO has also transitioned recently, and a key informant within DAWASCO noted that the organization recently put a new water production facility online, increasing the quantity of water available throughout the city. These positive reforms were palatable among two FGD participants in Ndugumbi:

For now, there is a huge improvement as it [water service] does not go off like it used to in the past.

Since the new government has been in power we have seen some changes in this sector, so we can say these changes are noted right from the beginning of this year.

In the rural study setting, FGD participants reported challenges with water service management under the authority of their local COWSOs. In two of the three rural study sites, there were complaints on financial and operational mismanagement by COWSOs. Participants perceive that COWSOs do not keep track of finances and that they also misuse the funds. In Gidewari, water service management under the COWSO is more formal, and the COWSO provides regular reports on how much water is sold, how much money the COWSO has in the bank, etc. Each of the three rural sites noted that their local COWSO needs more training and education in order to manage water services more transparently and efficiently:

The problem is the current management. The problem is they [COWSO] don't bring the information monthly on how much was collected and how much was spent and on what. Ever since the program started, there have never been any renovations. People are complaining that ever since the program started we have never heard information, we just hear some rumors. On public meetings and agenda, they never talk of water expenditures. They have never told even a chairman that they want to call a meeting with villagers for water issues (FGD, Lulembela).

Maybe they [COWSO] should be given training in the form of seminars. The current committee has never had any training whatsoever. I'm the one that's telling them to do this, to do that (KII, Lulembela water system operator).

Benefits of mobile prepayment system

While perceptions of the mobile prepayment system varied between rural and urban settings, FGD participants in both settings noted significant advantages associated with the system. FGD participants in both settings had exposure to mobile banking services, though rural-urban development dichotomies held in which participants in Dar es Salaam had more experience with personally using mobile banking services. Rural and urban FGD participants noted that almost everyone has a mobile phone, and even if they do not have a phone they have access to one through a friend or relative, as stated by interlocutors:

Most of them use mobile money, because this is the new generation. Especially the youths, almost all know how to use mobile money, and even in the household maybe there is someone who can't use them at all but they could be helped out by their relatives (KII, Mikoroshini Chairman).

Globalization is everywhere now, people are educated . . . so it is impossible that the whole family doesn't have a phone. The grandparents may not have phones, but the father will have one or the firstborn son will have a phone--surely they can get water. It's not compulsory for everyone to have a phone. Maybe the children won't have one, the elderly, or anyone who cannot afford one, but one or two people [in every house] has a phone who will make it possible as long as they know how to use it or they have the education on it (FGD, Chanhumba).

Participants in rural and urban settings have varied experience with mobile banking. Individuals reported using mobile payment systems to pay school fees, transfer money to friends and relatives, and pay for electricity, although use to purchase water is not as common. Many participants in both study settings are personally familiar with using mobile prepayment to pay

for electricity and, with the integration of a mobile payment system in the Dar es Salaam Rapid Transit (DART) bus system in the summer of 2016, participants in Dar es Salaam now use mobile banking services to pay for transportation throughout the city. Thus, the Burudani Chairman believes that mobile prepayment for water services will be well received:

That's what we do with electricity. You pay for it via phone and then you use it, in every place. So, there is no challenge that I think will come out of this [introduction of mobile prepayment for water services] that will mean my people won't receive it well.

Multiple people identified other benefits of mobile banking and mobile payment systems. Many described the system as “modern” and appropriate in an increasingly globalized world, while others applauded the system for the convenience of being able to pay bills at any time, referring to the system as “easier” and “time saving” compared to the traditional method of paying by cash:

It is good to use, it saves time and is convenient as you can do all the transactions at any time, any point (FGD, Ndugumbi).

Furthermore, since the system involves paying only for what you use, people stated that mobile prepayment systems are fairer. FGD participants in the rural and urban settings also view the system as a mechanism to decrease corruption and increase financial accountability and transparency in the water sector.

Key informants reiterated these perceptions and generally anticipate even more potential benefits from the mobile prepayment system than the general public. A technician in the rural study site of Lulembela, for example, noted that he expected the system to help improve the “sustainability of the project” and facilitate water services to “reach a larger area of people.” Key informants in Dar es Salaam contend that DAWASCO will benefit greatly as they expect mobile prepayment systems to result in higher revenue collection, better monitoring of the water supply network, decreased water theft, and an overall improvement in quality and coverage of water services. A DAWASCO manager noted that, eventually, water users will get used to paying through mobile prepayment systems and that it will become “business as usual.” Many of these sentiments are provided below:

It's [mobile prepayment for water] a good thing, a good thing, it's very modern. It will help water from being lost, but at the same time people will be able to use the amount of water that they need and can afford (KII, Burudani chairman).

It's very positive! Actually, it's where the world is headed, and it's where DAWASCO should head. This is a cost/benefit idea. The system will operate by itself. I think that's a major advantage that we are going to get (KII, DAWASCO manager).

I like this system because it will help to stop those who were pocketing the water money. If someone's [DAWASCO kiosk attendant or authorized seller] child is sick and their pockets are empty they decide to take the water money and use it without replacing it, so this tampers with the collection. But with this system, it means the money will automatically go to the account. This system will do away with people's greed (KII, DAWASCO engineer).

Challenges of mobile prepayment system

FGD participants in both settings also identified challenges to incorporating a mobile prepayment system, although these challenges are perceived to be greater in the rural setting. Network reliability and security were recognized across all of the study sites as potential challenges to the mobile prepayment system. For example, stories were shared of funds disappearing from mobile money accounts and network service disruptions at critical times, leading an FGD participant in Burudani to claim that “I don't think mobile money is the safest way of keeping money.” These sentiments are not uncommon:

Sometimes we face difficulties with network operation. When it happens that you mis-send money or make a wrong payment in water bills, like maybe you enter a wrong meter number, it becomes difficult to recover it (FGD, Mikoroshini).

For what I have seen they [community members] mostly use the services to receive money but they don't use the services a lot as they have already believed them to be unreliable (KII, Gidewari water technician).

Another perceived challenge with mobile prepayment is with the practical and ideological act of paying for water, particularly in the rural setting. With a primarily agrarian economy, rural FGD participants expressed that they already do not carry much cash to purchase water through traditional methods. Thus, FGD participants articulated concerns with not having enough money to make the minimum deposit onto their mobile phone. Beyond the context of this cash-strapped economy, many argued that water should be either free or very inexpensive. Moreover, participants perceived that water not being provided at free of cost is a challenge to water provision and health, as people may elect to consume free but unsafe sources over relatively safer sources that must be paid for:

Wait before you go too far, for the water that is being sold in this community, let me be honest, here they [community members] find it as a nuisance. So, for the one who can afford water then it is annoying, but for those who cannot afford it will resolve to the open wells. I think that the price is too much for us because most of us depend on farming (FGD, Gidewari).

They [community members] are used to getting water from the traditional wells. So, people are stubborn even to contribute to these projects. For them, they feel 50 shillings to pay for water is a lot of money. So, often they want the cost to be reduced. But the maintenance cost of these projects is high, so you can't just reduce the price of the water (KII, Lulembela water technician).

In the rural setting, as well as one urban study site, participants also expressed concern that a full replacement of the cash-based system with a mobile prepayment system will result in suffering among the poor and elderly. People noted that, under the current system, the poor and elderly are entitled to free water every day and, generally, the poor and elderly cannot afford to purchase a mobile phone. Therefore, the mobile payment system may price out vulnerable members of society from crucial access water services, as acknowledged by a chairman in Burudani:

I think it [mobile prepayment for water] could be a problem for people who are very poor, and water is very important so they'll [COWSOs] have to think about how to help those poor people. Because water is so important for mankind, I don't think someone should be prevented from getting access to it just because of this new system. There are some old people I know who are unable to pay, so we are able to give them free water.

Participants, particularly in the rural setting, also acknowledged gendered dimensions of the mobile prepayment system. Some expressed concern that women will be further marginalized because phone ownership, financial decisions, and many everyday transactions tend to be the responsibility of men. The perception that women may be disenfranchised by the water prepayment system was especially apparent among interlocutors in Gidewari:

In the village, it is mostly men who have access to phones and men use their phones for many things like business and communication. Men also have a lot of exposure--they may have gone to another village, so they get to interact with different people and so they may get a better understanding of the service than the women who stay at home (FGD, Gidewari).

The culture here does not tend to involve women in things like that. For most of the villagers there is a perception that maybe if you have money in your mobile account it may get stolen somehow, but with most of the men who have businesses, such as with the salt, they just send and receive money through their phones (KII, Gidewari water technician).

Not only did participants articulate concerns of access among the poor, elderly, and women, but they also noted challenges arising from a government crackdown on “fake” phones, or counterfeit phones imported illegally. The government disconnected fake phones during the summer of 2016 in an attempt to reduce the importation and use of counterfeit and black market goods. News source estimates vary, but an estimated 1.2 million fake phones were disconnected from service (BBC, 2016; Robi, 2016). Participants in both study settings, rural and urban, discussed this mobile phone shutdown, and multiple people were affected as they had

unknowingly purchased a counterfeit phone that was shut off during the government crackdown. Although this is unlikely to impact mobile phone ownership in the long-term, events such as this have the potential to decrease access to mobile prepayment services in the short run and could affect the public's perception of and willingness to participate in such a service:

Another challenge is about these phones which have been put off by the government to get rid of all fake phones. This has caused trouble to us. Now some of the people are without mobile phones. I have decided not to possess a phone until when the government declares that now the phones in the country are all original (FGD, Burudani).

A final concern is the number of mobile money agents. To add credit to mobile accounts, people generally pay cash to a mobile money agent who then transfers the money to their account. In the urban setting, participants perceive this system as convenient; however, in the rural setting, this system was perceived to be a concern. In some rural communities, there are only a few mobile money agents. FGDs revealed that the agents are not always available when people need to add money to their mobile account, which was a perceived barrier to securing water services. This is complicated by the fact that agents already provide other services (e.g., payment for electrical utilities), so the expected combination of additional customers and increase in volume of transactions will render the agents even less accessible. Furthermore, some people live far from mobile money agents. Given the opportunity costs, water consumers may be incentivized to collect water from closer but relatively unsafe water sources rather than traveling first to the agent and next to the tap to physically secure the water. Research participants in Chanhumba explicitly voiced these apprehensions:

There will be a high demand for the [mobile money] service. They already provide mobile services and electricity services, so if there are more services to be provided by just those two [mobile money agents] they will be outnumbered because they will have to provide many services to many people because a person cannot get water without going to them, so they will need to increase to about 5 or 4 agents (FGD, Chanhumba).

It is the challenge of long distance to get to the agents. It might make them lazy to go to the neighboring village, so as a result they would end up going to the shallow wells (KII, Chanhumba district engineer).

Benefits of solar power

For the most part, perceptions on the implementation of solar power to convey water were overwhelmingly positive. While none of the key informants or FGD participants in the urban study setting had personal experience with solar power applications, some shared anecdotes from friends and family in rural areas where the technology is more widely used. In general, participants regard solar power as popular (based on anecdotal experience from others), effective, and a technology that has the potential to reduce costs and increase service reliability. As shared by a DAWASCO engineer in Dar es Salaam, “I was really happy, because if pumps are solar powered then the cost can be reduced, which means the cost of water for citizens will go down too.”

In the rural setting, on the other hand, nearly every participant had personal experience with harnessing solar energy to charge phones and radios and to power lights. Participants were enthusiastic about incorporating solar power into the water sector, in part due to the inconveniences of the current system. At present, rural communities distribute water using diesel-powered generators. Thus, operators, technicians, and COWSO members must ride a bus to a nearby city, purchase diesel, and carry it back on the bus in order to power the current system. Not only is diesel inconvenient, but it is also expensive. Compared to diesel-powered generators, rural participants perceive solar power as more reliable, less burdensome, less expensive, and a technology that can expand service coverage while permitting time to focus on other operation and maintenance issues, as intimated below:

One benefit of using solar is that it has no losses, once it gets sunlight throughout the day then you can use the power at night, there is no need of using matches or a torch. Also, it is not too costly, there's no maintenance needed--once you've bought it then that's it and you can expect power every day. It may need maintenance only once in maybe 1 or 2 years, but it's not like having to buy fuel every day (FGD, Chanhumba).

When we get solar then the project will run itself assuredly because we will have enough water and it can go to the consumers. The biggest thing is that getting solar will reduce all the operation costs, so then we can instead channel that money to get water to areas that weren't initially reached. Diesel won't be needed anymore, we will just be left with maintenance costs like a broken pipeline and to expand to areas that have not received this service (KII, Gidewari water technician).

Challenges of solar power

There were few perceived challenges regarding the use of solar power to improve water services. FGD participants in Lulembela perceived that solar panels may not last long and that they require expensive batteries to store energy. Others noted that people may be tempted to steal solar panels and that guards may need to be hired. The only perceived challenge vocalized by multiple sources was that the solar power system may not run during the rainy season. Participants perceive that rainy season cloudiness may present an issue, but went on to voice that rainwater could be substituted in such instances:

Another thing is that sunshine is about 99%. The other 1% is when there is cloud cover, so the sun is not shining to get solar power. For example, during the rainy season there's cloud cover from morning until around noon, and from what I know about solar is that with no sun you cannot get power from it (KII, Chanhumba chairman).

During the rainy season, since the solar panels cannot store the energy, there is a problem--but not too much of a problem because they [community members] have rainwater which they can harvest (KII, Gidewari water technician).

Training and education to promote change

A final dominant theme revealed is the resistance of communities to change. In both settings, key informants spoke about community members' hesitancy to change long-held methods of accessing water. Water consumers also mentioned that they harbor some resistance to change and suggested that training, education, and sensitization campaigns are the solution.

Key informants seem to agree, and many shared the common attitude that, if people understand the new system, they will use it:

It's just a question of education, if the systems [mobile prepayment and solar power] come to us then we will discuss them because we will have to call people together to educate people on them. But the world is changing, we can't just stick to the old-fashioned ways of doing things, so we have to participate in the change. But I feel that the people will understand (KII, Burudani chairman).

Our community needs education. It needs education, education, education. There is this habit of our community of stealing any valuable material that is sold at our kiosks (KII, DAWASCO manager).

Challenges will be there. As you know, when something new is introduced challenges are inevitable. Take an example of the new transport system in Dar Es Salaam. In its initial stage people used to complain, but now it is becoming popular and enjoyable to all, me included (KII, Mikoroshini chairman).

7. Discussion

Qualitative methods revealed themes in user and stakeholder perceptions related to water services as well as mobile prepayment and solar power to improve water services. While perceptions varied within and across study sites, the most significant differences were observed between the rural and urban settings.

In both settings, study participants discussed the multiplicity of sources used to meet daily water needs. Participants shed light on the complex set of competing priorities that influence a user's choice regarding their water source. Users weigh several factors, such as water source convenience, cost, availability, as well as safety and quality, and this valuation and assessment is ultimately based on user perceptions. This supports the conclusion of Juran and MacDonald (2014) and Francis et al.'s (2015) studies in rural south India, which argue that perceptions, attitudes, and beliefs significantly impact the behaviors and choices related to how users source their water. In fact, Francis et al. (2015) claim that these perceptions ultimately

impact the long-term acceptance and sustainability of water supply interventions. Therefore, perceptions of water services and innovations uncovered in this study have the potential to determine the acceptability of mobile prepayment and solar power to improve water services.

While perceptions of water service providers varied across space, FGD participants overwhelmingly called for increased communication and transparency from their respective water service providers (i.e., DAWASCO in Dar es Salaam and COWSOs in rural Tanzania). A study by Ramos de Silva et al. (2010) in Brazil similarly noted the importance of rapport between water service providers and consumers and especially stressed the need for good communication. On the side of water users, inadequate communication has the potential to generate perceptions that water quality is poor and the utility is untrustworthy. Though this study cannot demonstrate a causal relationship between inadequate communication on one hand and perceptions of poor water quality and inferior management on the other, it does demonstrate—as does the literature literature (Ramos da Silva et al., 2010)—that the two sides inform each other. On the side of water service providers, inadequate communication may result in misinformation and result in users unwilling or unable to alert providers of leaks or other system problems. Taking both sides together, Ramos de Silva et al. contend that “public institutions and the water supply services need to guarantee the quality of water and to invest in more efficient methods of information transfer in order to gain the confidence of the user” (Ramos da Silva et al., 2010, p. 776). This call to action should be taken seriously by DAWASCO and COWSOs in Tanzania as FGD participants frequently shared their fractious relationship with the water providers. However, participants also shared that negative perceptions of DAWASCO are changing due to efforts of the water provider to improve quality of service and communication with users. This result evidences the critical relationship between communication and user perceptions in Tanzania and elsewhere.

Water safety is another recurring theme. Participants in both the rural and urban settings acknowledged a relationship between water and health and often described water subjectively in terms of its ‘safety.’ Doria et al. suggest that perceptions of water quality and related risks are formed through the “complex interaction of diverse factors” (2009, p. 5455). This study concurs with Doria et al., as well as Rojas et al. (2013) and Juran and MacDonald (2014), in that user perceptions of water quality and safety in Tanzania were influenced by several factors, including physical properties of the water, previous experience with waterborne disease, and exposure to

education campaigns. Moreover, this study is consistent with that of by Rojas et al. (2013, p. 113), who argue that “consumers’ attitude towards their drinking water and towards their drinking water supply entities is strongly affected by the appearance of the delivered water.” Among study participants, subjective perceptions that water or the area around a water supply point looks dirty influenced perceptions of water quality, which went on to influence perceptions of the water service provider itself.

Experience with water-related diseases impacts perceptions of water services in Tanzania, and this affects perceptions of water providers. Nearly all FGD participants in Lulembela explicitly mentioned a connection between water and health and that they use the product Water Guard to treat their drinking water. There was a large cholera outbreak in Lulembela a few years ago, and it is possible that the outbreak contributed to the consensus perception that water provided by the COWSO is ‘unsafe’ and poses a risk to human health. While this connection between a health event and perceived water safety makes sense in terms of logic and syllogism, the finding is contrary to findings of Wright et al. (2012). Using data from South Africa’s nationally representative General Household Surveys, Wright et al. argue that a large-scale cholera outbreak between 2000-2002, which affected multiple regions of South Africa, did not significantly impact perceptions of water safety. In Chanhumba, FGD participants described their perceptions of treated water: even though ‘experts’ tell them that treated water is ‘safe, many participants do not like it and choose not to consume the water because it tastes bitter. Others complained about the odor of treated water, even though they acknowledge that treatment helps make the water safer. Literature provides evidence that taste and odor are some of the most important factors in determine people’s perceptions of water safety and choice of water source (Doria et al., 2009; Ramos da Silva et al., 2010; Wright et al., 2012; Rojas & Megerle, 2013). This is consistent with Francis et al. (2015), who indicate that the acceptance of water interventions may be hindered by people’s resistance to changes in water taste and/or odor, even when users understand that the presence and taste of chlorine indicate disinfection and elimination of many health risks.

Perceptions of the mobile prepayment system are generally positive, though more concerns arose in the rural study setting. Research informants perceived many benefits with mobile prepayment for water, including familiarity with the system, increased financial transparency, reduced corruption, and decreased water theft. While many participants perceived

the system as more convenient than the current cash-based system, perceived barriers to implementing the mobile prepayment system included unreliability of mobile networks, costs associated with mobile phone ownership, and scarcity of mobile money agents. In the rural setting, some feared that the system may inadvertently disenfranchise access among the poor, elderly, and women. The literature provides sufficient evidence to support the claim that mobile phone ownership is not homogenous within a given population. The first to adopt mobile phones are more likely to be “male, educated, young, wealthy, and urban populations” (Aker & Mbiti, 2010, p. 8). Technology use is widely studied and acknowledged to have gendered dynamics, as well as socioeconomic dynamics (Rathgeber, 2000; Bray, 2007; Blumenstock & Eagle, 2012). This gendered and socioeconomic dynamic helps to explain the grounded perception that poor, elderly, female, and rural cohorts may encounter formidable barriers in the transition to a mobile prepayment system for water services. Furthermore, a lack of mobile money agents combined with expectations of increased customer traffic presents a challenge in the rural context. An explicit goal of the intervention is to increase access to safe drinking water. However, if the payment process is complex, inconvenient, or perceived as inconvenient, then water users may incentivize alternative sources that are relatively unsafe, but free; this study hopes to avert such an outcome.

Perceptions of solar power are almost entirely positive. While people in the urban setting are less familiar with solar power, rural respondents—where the technology is more common--view the system extremely positively. General perceptions are that solar powered systems exhibit major advantages over the current approach of using diesel generators to distribute water: solar power will be less expensive, more convenient, and more reliable than diesel. However, it must be reiterated that some expressed concern that solar equipment is susceptible to theft and that the rainy season may present difficulties, the latter of which may result in consumers relying on rainwater sources opposed to treated water.

Diffusion of Innovations theory conceptualizes how innovations spread, which begins with identifying variables to explain the rate and patterns of innovation adoption within a population (Rogers, 2003). The theory couches innovation diffusion in terms of relative characteristics, meaning that the relative advantage, compatibility, complexity, trialability, and observability of the innovation is paramount. In the case of solar power, participants perceive a relative advantage over the current system. In the rural setting, participants have already used

solar power for other applications, so the method has been tested and consumers perceive solar power to be compatible and relatively advantageous for water distribution. According to Diffusion of Innovations theory, evidence presented in this study suggests that solar power is likely to be accepted, particularly in rural communities. Perceptions of the mobile prepayment system, on the other hand, were highly variable, suggesting that diffusion and adoption may be more arduous compared to solar power. Some perceive mobile prepayment as an improvement over the current cash-based system, while others suggest that paying in cash is better, particularly among the poor. Participants contend that the mobile system presents several barriers, including front-end costs, accessibility among subaltern groups, network coverage, and illegal mobile phones being shut down by the government. However, there a prototype exists in Tanzania in the form of mobile prepayment for electricity and transportation services. Given that these markets have been made more accessible through mobile prepayment services, the implementation of mobile prepayment for water is likely to succeed and diffuse in Tanzania.

This research indicates that while there are significant perceived advantages associated with mobile prepayment and solar power, significant barriers still remain. Perceptions of users and stakeholders are crucially important for determining the acceptance and ultimately efficacy, scalability, and sustainability of innovations to improve water services. This study suggests that users in Tanzania perceive water service management to be poor overall and, thus, that water services providers should make an effort to increase financial transparency and communication. Perceptions on mobile prepayment and solar power innovations suggest that GoT should consider how such innovations will impact poor, elderly, female, and rural populations, and GoT should address user concerns about mobile network reliability, whether through physical infrastructure or outreach on the reliability of network coverage. Furthermore, in the rural setting, the government should address the lack of mobile money agents prior to implementation. Similarly, they should ensure there is a reliable mobile network before implementing the mobile prepayment innovation, which requires reliable mobile network availability. Before scaling up these and other innovations, GoT and the Ministry of Water would be wise to continue to conduct timely research on user perceptions of innovations to improve water services, especially prior to implementation. User perceptions are a valuable for predicting the acceptance and impact of innovations. Simply put, if you would help the people, you must listen to the people. The case of safe water access is no exception to this rule.

8. Conclusions

This study employed qualitative methods to investigate perceptions of water services and perceptions of innovations to improve water services in rural and urban Tanzania. This study identified gaps in the knowledge of and perceptions of both mobile prepayment and solar power technologies to improve water services. Perceptions, attitudes, and beliefs of users and stakeholders were analyzed using Dedoose software, which identified consensus opportunities and barriers to integrating the innovations. As GoT seeks to improve water services across the country, this study suggests that satisfaction with current water services is low and that users perceive many problems with current water system (e.g., water quality, transparency, corruption). Furthermore, this study suggests that while users perceive solar power to be appropriate and acceptable, significant barriers exist before regarding mobile prepayment technologies. Perceptions imparted in this study have the potential to impact the acceptability and long-term sustainability of technology-based water interventions in Tanzania. Thorough and timely research on innovations to improve water services must be conducted before such innovations are scaled up, and post-intervention monitoring must follow to facilitate the incorporation of lessons learned. While this study does not claim to be generalizable across all rural and urban communities in Tanzania—let alone the Global South—the barriers identified indicate that more research should be conducted before innovations are introduced and scaled up in the water sector.

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Appendix A: Key informant interviews

PARTICIPANTS: Government/district officials, community organizations and leaders, urban Water Kiosk Operators.

OBJECTIVE: Identify initial motivations, concerns, and ongoing perceptions of government personnel, district officials, and community leaders in participating in the trials

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To be completed by the interviewer

Interviewee Name	Department/Community	Position Title	Mobile phone number(s)

QUESTIONS: General

- Tell me a little bit about yourself and your responsibilities with your position.
- What are the major water service issues in this area?
 - Is scarcity an issue? If so, could you tell me more about that?
 - How do people manage issues of scarcity?
- Do people have access to improved water sources?
 - Who provides the water?
 - How does this area compare with the rest of the country?
- What are your feelings about [NAME] community/urban site receiving a rehabilitated water system from World Bank and Water Mission?
 - What benefits do you foresee?
 - Do you have any concerns to raise?
- Do you believe there will there be some members of the community/service area who are unable to access the water? What barriers do you think they may face in accessing the water?
 - Distance, cost, time, etc.
- (for COWSOs and Water Kiosk Operators) where do community members/people who live near here get their water from now?
 - Where are the sources located?
 - How much do they cost?
 - Who supplies/manages these sources?
 - Frequency of use and for what purposes?--what do people tend to use the different sources for: drinking, washing, animals, etc.

QUESTIONS: Perceptions of the field trials

Solar

- One of the aspects of the water system Water Mission is installing is the use of solar to power the water pump instead of diesel generators or electricity.
 - How are water systems typically powered here?
 - How familiar are you with solar power? What are your experiences?

- How familiar do you think people are in this community/district/service area with using solar? Do you think it will affect their perceptions of the water service?
- Do you believe solar power will be effective in providing safe water to this/these community/communities?
- Do you have any concerns about the solar element of the trials? If so, what might they be?
 - *PROBES*: Unreliable, Not powerful enough, Will be stolen, Is not a modern solution to power supply issues in TZ, etc.

Smart Water Dispenser Technology

- Another element of these trials is using a prepaid water meter, rather than a traditional hand pump, at the water point.
 - Are you familiar with prepaid water meters?
 - What are your perceptions of this technology? What are your experiences?
 - Do you have any concerns about this aspect of the trials?
 - Do you think there might be problems with the community accepting this technology?
 - If they prefer the hand pump or other more traditional methods of water collection, what might be done to convince them of the usefulness of a prepaid water meter?

Mobile Prepayment

- Another element of these trials is using mobile prepayment to pay for water, rather than paying directly with cash
 - What are your thoughts about using mobile payment for basic services such as water?
 - Do you have any experience using mobile money? For what purposes? How often?
 - Do you think community members will accept this method of payment or will it be difficult for them?
 - If not, what do you think could be done to encourage people to feel comfortable using this payment method?

Project Sustainability

- Do you have any concerns about the ability of COWSOs/(DAWASCO/DAWASCA) to manage these projects themselves and support the financial and technical operations of the water system long-term?
- (*for rural sites*) Do you believe a community-managed model for water services is sustainable? If not, what would need to change for it to become sustainable?
- (*for DWEs, DAWASCO/DAWASA*) What challenges or rewards do you see as part of your working to implement/support this safe water system as part of your duties within your position?

questions to the group with the goal of having everyone respond and to have a group discussion. So please feel free to talk openly. I also ask that you make a pledge to each other, that we all can speak freely here today and the things that are discussed here are not repeated outside of this meeting. Do I have your commitment?

In addition, should you have anything you would like me to know after this meeting, you can contact me at the number on this card [hand out contact card].

Ongoing, I would like to follow up with you via phone in a few months, and also have another meeting like this one at the end of the monitoring period in 6 months, if that is agreeable to you all. I will be contacting you by phone to ask if you would like to participate again. I very much value your input and comments, and thank you very much for your time today.

ICE-BREAKER QUESTION

Before we begin, I would like to hear from everyone. What is your name, how long have you lived in this community, and what do you enjoy most about living here?

FOCUSING EXERCISE

- For you, what are the three most important things about water?

QUESTIONS

- What can you tell me about the current water situation in your community?

PROBES

- Where/from what source do you currently get your water?
 - Are you satisfied or dissatisfied with this source?
 - Why? (water quality, perceptions, convenience, etc.)
 - Do you have challenges in accessing this source?
 - Do you use different sources depending on what you are using the water for: for drinking, cooking, bathing, washing clothes, (animals)?
 - Do any of you own animals? Do you find it difficult to find safe water for them?
 - What do you like about the current water situation here?
- Tell me what you would like to see improved with the water here.

PROBES

- If you feel there is a need for an improved water system, what should it address first (cost, distance, quality)?
- What about the cost of water?

PROBES

- What is a fair price? What are you paying now?
- Do you think your community can support the cost of a solar water system?
- Is your COWSO able to responsibly manage a system such as this?
- Have there been other water projects here, what happened to them?

PROBES

- Have you had previous water projects in this community? If so, what did they involve?
 - Water source/design?
 - Project implementers/donors? Cost to community? Are they still in use, or have they failed? If so, why?
 - Do you think this community needs another/an improved water source? Why?
- What are your experiences with solar power?

PROBES

 - Have you used it before?
 - For what purposes? How often?
 - Did you like it? why/why not?
 - Do you think solar power can provide water to your community?
- Tell me about your experiences with mobile money.

PROBES

 - Have you used mobile money?
 - For what purpose? How often?
 - Did you like it? Why/why not?
 - Do you think this is an effective way to pay for water services? Or will this be difficult for you?