Advancing rainwater harvesting as a strategy to improve water access in Kinondoni municipality, Tanzania
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ABSTRACT

The Sustainable Development Goals concept advocates affordable, safe and clean water supply. The water shortage in Dar es Salaam city affects communities in different wards of Kinondoni municipality. As a strategy to improve water access, this study assessed opportunities for application of rainwater harvesting (RWH) technologies, communities’ knowledge of this and their willingness to adopt RWH technologies, and challenges for installation and maintenance of RWH technologies in areas of Makongo, Mbezi, Msasani and Kimara wards of Kinondoni municipality. Data collection involved interviews, questionnaires and observation while the SPSS tool was used for data analysis. Also, laboratory tests for water quality parameters were conducted. Results showed that rooftop RWH systems with proper components and proper maintenance were found to provide better quality water for domestic use than other sources. Laboratory tests revealed that rainwater was better than other water sources. Lack of knowledge was the main factor that hindered adoption of RWH technology. Also, initial investment cost was among the reasons deterring its adoption. Therefore, to improve the adoption rate of RWH technologies there should be an integrated participation of different stakeholders to educate and support communities to address RWH technologies’ challenges. This can be supported by a proposed institutional framework.

Key words | adoption of rainwater harvesting, Dar es Salaam, Kinondoni municipality, participatory institutions, rainwater harvesting technology, water access

INTRODUCTION

The source of water for piped supply water systems in most of Tanzania’s cities is rivers. Urban areas also use groundwater as a supplemental source. In rural areas, domestic water comes from surface water (rivers and springs) and from groundwater accessed through public and private wells. Although there has been an upward trend since 2005, access to improved sources of drinking water has actually declined over the last decade due to rapid urbanization. Stacey (2005) indicated that about 56% of Tanzanians have access to an improved source (i.e. protected sources) of drinking water. In dealing with water scarcity for urban and rural water supply, population growth and urbanization rates complicate adaptations for climate variability and change in Tanzania’s water supply sector. Currently, total demand for water in Dar es Salaam city is 450,000 m³ per day while the production capacity from Dar es Salaam Water Sewerage Corporation (DAWASCO) is only 300,000 m³ per day.

Recently, application of rainwater harvesting (RWH) technology has been welcomed in various nations due to growing water shortage as a result of massive population increase and uncertainties of water resources. Urban and rural communities are struggling to get water for domestic and economic use. RWH is now receiving increased recognition as a source of water supply in many parts of the world. Pandey et al. (2003) hypothesize that this relates to climate change. Among the targets of the 6th Sustainable
Development Goals (SDGs) are by 2030 to achieve universal and equitable access to safe and affordable drinking water for all, and address water scarcity and substantially reduce the number of people suffering from water scarcity. For achievement of this target the need to consider effective (the effective consideration of) RWH in planning and implementation is essential, as some places lack sustainable water resources. As most villages and some urban places in Tanzania lack central water supply, the strengthening of communities’ capability for adoption of RWH in terms of skills and capital can be an important approach toward improving water accessibility. The Ministry of Water (MoW) has attempted to provide effective support to RWH under several programmes such as the Health through Sanitation and Water (HESAWA) programme since 1985 (UNESCO 2015). However, the support was mostly donor-dependent, not countrywide, lacked continued awareness raising, and thus was not sustainable.

In Dar es Salaam city, RWH is crucial due to lack of sustainable alternatives such as groundwater, which has been found to be not feasible for domestic use following concentrations of chloride ranging between 998 and 5,096 mg/l (United Republic of Tanzania (URT) 2013a), which exceeds the limit of 800 mg/l required by the Tanzania Bureau of Standards (TBS). Also, Ndomba & Wambura (2010), studying parts of Dar es Salaam city in the Changanyikeni area in Kinondoni municipality, found that only 10% of households had complete RWH systems (with functioning collection, diversion components and a storage tank), out of which 60% were not reliable. Most systems were not performing well due to poor designs. Therefore, this study has surveyed areas in Makongo, Mbezi, Msasani and Kimara wards of Kinondoni municipality to assess opportunities and challenges of using RWH as a crucial alternative water source in Dar es Salaam city. The study highlights available opportunities for RWH technology, design challenges and user requirements. The MoW has departments of rural water supply and water resources, which handle all issues of water resources including RWH. However, due to departments’ weaknesses on financial capability and adequate staffing, RWH technology and its management is not well understood by many people. This study proposes a framework for management of RWH technology because currently in Tanzania there is no effective RWH institution that supports and addresses its opportunities and challenges.

**METHODS**

**Study area**

Kinondoni municipality (Figure 1) is among the three municipal councils of Dar es Salaam city; it covers an area of 531 km² and has a population of 1,775,049 people with an average household size of four (URT 2013b). The Kinondoni municipality is bordered by the Indian Ocean to the north-east, Ilala municipality to the south, Bagamoyo district to the north, Kibaha district to the west and Kisarawe district to the south-west. Administratively, Kinondoni has a total of 34 wards and 171 sub-wards. Only 25% of Dar es Salaam city’s residents have access to Dar es Salaam Water Supply and Sewerage Corporation (DAWASCO) water; the remaining 75% live in unplanned and unserviced settlements (UN-HABITAT 2009). This indicates the importance of decentralized water supplies such as RWH. The study was carried in four wards: Makongo, Mbezi, Msasani and Kimara of Kinondoni municipality, which were randomly selected considering the convenience of carrying out the study.

**Sampling technique and sample size**

A formula (Equation (1)) by Yamane (1967) was used to determine that samples were required from 102 households in Kinondoni municipality for the purposes of this study. Out of these, 68 samples were from rainwater harvesters in areas without adequate or with non-DAWASCO water supply areas and 34 samples were non-rainwater harvesters in areas with adequate access to DAWASCO water supply.

\[
n = \frac{N}{1 + Ne^2}
\]

where \(n\) is sample size, \(N\) is the total number of households in Kinondoni municipality and \(e\) is the confidence interval (level of precision) of 10%. Equation (1) is valid for a 95% confidence level.

Other bodies such as the Ministry of Water and some education institutions that harvest rainwater, i.e. Ebonite College of Education, Makongo and Changanyikeni primary schools and Sierra high school, were also selected.
purposively for the research. Moreover, five farmers and two brick-makers who are adopters of RWH technologies, together with ten water vendors were selected for the study. Further, seven rainwater samples and five samples of water supplied by vendors were collected for laboratory tests. Four rainwater samples were collected from concrete storage and three were collected from plastic storage.

Data collection and analysis

An interview method was used to obtain data from the Ministry of Water as RWH experts, and from education institutions, farmers, water vendors and brick-makers as water users and RWH beneficiaries. A questionnaire method was mainly applied to households because of its ability to accommodate large numbers of samples. Observation was used to assess design-standard adherence and the type of RWH system used. Water samples were collected for laboratory tests so as to assess quality of rainwater and its compliance with Tanzanian domestic water standard guidelines.

Qualitative data was coded into numerical values and installed in the Statistical Package for the Social Sciences (SPSS) version 16 to provide information on RWH aspects. Also, SPSS helped to analyze relationships between variables such as level of education and type of RWH used, population size of household and size of RWH storage.

RESULTS AND DISCUSSION

Assessment of the community’s knowledge and their willingness to adopt RWH

This aspect was tackled by assessing various aspects of RWH such as (a) type of RWH technologies known and used by respondents, (b) knowledge on handling first-flush rainfall, (c) timing of adoption of RWH, (d) sources of...
RWH knowledge, (e) views on quality of rain water and (f) uses of rainwater. Additionally the study looked at their willingness to adopt technology in the scenario of a loan being provided and install a RWH technology.

Source of RWH knowledge

The study results for sources of RWH knowledge are shown in Table 1.

Results showed that the main respondents’ source of knowledge and the catalyst for adoption of RWH was learning from neighbor’s RWH systems. This accounted for 47.1% of all sources of RWH knowledge, followed by 27.9% from educational institutions. This explains why many educated respondents have little knowledge of RWH. Moreover, adoption of RWH was found to originate from indigenous knowledge of harvesting rainwater practiced by respondents’ parents when they were children. Therefore, since high adoption is influenced by learning from seeing examples of RWH systems, there is a need to promote exhibitions at institutions and mass media.

Type of RWH technologies known and used by respondents

Among households, 97% use only rooftop RWH while 1.5% use both rooftop RWH and catchment runoff and the remaining 1.5% use only lined storage ponds which capture direct rainfall. RWH by runoff catchment is seldom known by many respondents despite being a good way of harvesting rainwater. However, the issue of managing sedimentation and the high risk of pollution is of great concern.

Table 1 | Sources of RWH knowledge

<table>
<thead>
<tr>
<th>Source of knowledge</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seminars</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Education institutions</td>
<td>19</td>
<td>27.9</td>
</tr>
<tr>
<td>Neighbours</td>
<td>32</td>
<td>47.1</td>
</tr>
<tr>
<td>Advice from constructor</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Local/indigenous knowledge</td>
<td>14</td>
<td>20.6</td>
</tr>
<tr>
<td>Sabasaba exhibition</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Total</td>
<td>68</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Knowledge of handling first flush of rainfall

Figure 2 shows the distribution of techniques used to handle the first flush of rainfall. This is important to guarantee good quality harvested rainwater.

The study was not able to identify any automatic first-flush diverter which is highly recommended (Australian Government 2004; Worm & Hattum 2006) in rooftop RWH. Due to lack of sufficient knowledge of RWH it was clear that 50% of respondents were not attempting to get rid of the polluted first flush. Other methods used, such as diversion chambers, detachment of downpipes and covering of cisterns are effective but they have some weaknesses, such as someone having to be there to close or open cisterns to allow water to enter the tank when rain occurs.

Uses of rainwater and views on its quality

The uses of rainwater helped to determine the level of awareness of RWH technology. The survey results showed that the major use of rainwater (69%) is for domestic purposes. Other uses such as cleaning and feeding animals accounted for less than 12%. However, rainwater quality has been perceived differently by various adopters of RWH; 33.8% considered it as very good, 16.2% good and 50% moderate. With different perceptions, some communities do not believe rainwater can be safe water for cooking and drinking which is why they do not use it for these purposes. This indicates that a lack of knowledge is a significant factor that hinders adoption rates.

Timing of adoption

Households that had the idea of installing RWH systems prior to the construction stage of their homes were
considered to be more knowledgeable than those who installed RWH later as an addition after establishment of settlements. Most who installed RWH systems prior to building had a clear knowledge of the importance of the technology and decided to prioritize it. Results show that 29.4% of respondents had the idea prior, 66.2% installed RWH later, and 4.2% had no knowledge of RWH. Based on these results, more education is needed to familiarize people about RWH technology.

**Opportunities for the development of RWH technologies**

In the study area, there are various opportunities for development of RWH technology.

**Government’s legal framework on RWH**

According to the Tanzania Water Resources Management Act (2009), ‘The owner/occupier of any land may construct any works for RWH for domestic purposes without a water permit issued under this act.’ The National Water Policy (2002) encourages research and adoption of RWH technology. Moreover, currently the Government of Tanzania has made RWH adoption mandatory for new buildings by introducing bylaws that empower district authorities to issue building permits for drawings only with inclusion of a RWH plan. There are many authorities that have started to implement this bylaw (e.g. Tanga city, Iringa municipal, Arusha, Tabora, municipalities of Monduli, Meru, Moshi, Mtwara, Newala, Nanyumbu, Tandahimba, Rombo, Hai and Siha). In Kinondoni, the climate is also conducive: an average annual rainfall of 1,300 mm (Kassenga & Mbulugwe 2012) is quite adequate for any RWH project with reference to the minimum threshold of 200 mm recommended by UNEP (2006).

**Quality of rainwater**

Table 2 indicates that except for plastic storage, rainwater in storage was found to be good quality water adhering to TBS and WHO standards for domestic use, and to be better than other sources of water available in the study area (e.g. water supplied by vendors and groundwater). The problem with rainwater in plastic storage is that it was observed to have a low pH level in the range 5.8–6.4 that does not meet the standard for domestic use (i.e. pH in the range 6.5–8.5). A reason that has been advanced is that, unlike in plastic storage, in concrete storage there is calcium that dilutes the acidity of rainwater (Texas Water Development Board (TWDB) 2005; Mechell et al. 2009). Acidic water is not desirable as it is aggressive to water works, and can contribute to the introduction of trace metals to the water. Laboratory analysis of fecal coliforms from samples of rainwater indicates that harvested rainwater was free from these except for two water samples supplied by a vendor where 12nos /2 ml and 32nos /2 ml fecal coliform were observed. Presence of fecal coliform is an indication of fecal contamination from human faeces, which indicates high chances of the presence of pathogenic microorganisms such as typhoid and diarrhea (gastrointestinal distress).

**Table 2** Water quality analysis

<table>
<thead>
<tr>
<th></th>
<th>Rainwater from concrete storages</th>
<th>Rainwater from plastic storages</th>
<th>Water from vendor (bowser)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>S₁</td>
<td>S₂</td>
<td>S₃</td>
</tr>
<tr>
<td>pH</td>
<td>6.5</td>
<td>7.1</td>
<td>8.3</td>
</tr>
<tr>
<td>TDS (ml/L)</td>
<td>27</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>EC (μs/cm)</td>
<td>54</td>
<td>119</td>
<td>149</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>28</td>
<td>27.6</td>
<td>28.3</td>
</tr>
</tbody>
</table>
Hammer 2009). These are not directly related to health risks but the presence of high concentrations beyond standards is an indication of pollution as TDS can harbor or act as attachment sites for other pollutants. Most of the pollutants that are dissolved in water become attached to the TDS. The palatability of water with a TDS level of less than about 600 mg/l is generally considered to be good. Drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1,000 mg/l (WHO 2014). Accordingly, the water supplied by vendors has potential pollution risks (Table 2).

Creation of financial and technical institutions for development of RWH technologies

Creation of an institution that supports communities financially and technically on issues of RWH would assist those communities and institutions that have invested or are willing to invest in RWH technology. Most adopters of RWH technologies lack adequate skills and enough capital to invest in reliable and sustainable RWH systems. The available financial institutions or banks were reported by most respondents to be exploitative as they levy high interest rates with unfavorable conditions. Respondents expressed their interest in obtaining a loan to invest in RWH at a reasonable interest rate. About 91% of adopters of RWH technology wished to receive such loans while 64.7% of non-adopters of technology in areas with daily water supply by DAWASCO accepted and are ready to install RWH technology with support from a loan. These results showed that there is high willingness for adoption of technology but the problem is the initial investment cost, which could be supported by mainstreamed or tailor-made financial institutions.

On the other hand, various economic activities were found operating under support of RWH. This includes livestock keeping, water for sale, brick-making and commercial public toilets, for example, at Mbezi bus station. However, at the bus station, the RWH system is not fully exploited as only one roof catchment was connected to a downpipe to harvest rainwater despite the availability of large storage (size 25 m³) and well-connected gutters. This is causing much dependency on water supplied by vendors.

Challenges for the adoption of RWH

Poor design and management problems

Problems at the design stage together with a low level of knowledge on management of rainwater at the collection, storage and treatment stages were among detrimental factors for RWH implementation. Due to poor design, 16.2% of cisterns were not reliable due to leakage problems. For example, a cistern at Makongo primary school was found to be non-functional due to a leakage problem. Other systems in Makongo, Kimara and Mbezi areas suffered from poor design and leakage of gutters that affects collection efficiency.

Problems of worms

About 23% of adopters of RWH technology reported worms as their main problem in utilization of technology. The said worms were commonly the larval stage for mosquito growth, which prefers uncovered still water (Australian Government 2004). Most of the adopters and non-adopters of technology consider that rainwater is delicate water that is easily attacked by worms. This problem of worms was only reported by communities with little knowledge of proper management of rainwater to an extent that even storage systems were not designed according to required standards. About 26.5% of adopters of RWH who overcame worm problems suggested that with proper covering of cisterns, the possibility of having worms is minimal. Therefore, proper management of water in storage systems has a significant role in minimization of organisms in water.

Minimal distances between cisterns and septic tanks

The study observed a trend of close distances between underground cisterns and septic tanks in Makongo ward (Figure 3). This situation is not recommended, due to health and sanitation issues such as the risk of contracting diarrheal, nausea, dysentery or water-borne diseases. According to Tanzania water standards for domestic use, water storage should be located 50 metres away from a septic tank. The possibility of pollution is higher when leakage occurs in water storage. Therefore, since many plot sizes
in low income settlements of Dar es Salaam are small, the least distance for the location of storage as specified in TBS standards should be considered. Education on management of RWH is needed as only a few knowledgeable persons considered the locations of water storage and septic tanks.

Rainwater storage as breeding sites and locations for dangerous organisms

Rainwater storage can provide breeding sites for mosquitoes and dangerous organisms unless well designed and managed. For example, in Mbezi, where bricks were produced a live snake was noted inside the rainwater storage and respondents were amazed as to how it had entered. Therefore, openings in storage should be covered so as to exclude pollutants and to deter organisms’ access.

Acidity of rainwater

The three samples of rainwater from plastic storage exceeded the TBS standards (Table 2). The pH levels in concrete storage were within the required standard. Various references indicate that pure rainwater is slightly acidic in nature as normally rainwater’s pH ranges from 5 to 6.5 (UNESCO 2006; Mechell et al. 2009). As raindrops fall and come into contact with the atmosphere the water combines naturally with carbon dioxide to form a weak acid. In plastic storage, the acidity of rainwater is not diluted as in concrete storage where the presence of limestone (calcium) affects water pH, raising it closer to neutral (TWDB 2005; Mechell et al. 2009). Acidic water is a problem for copper materials such as pipes and taps as it has a corrosion effect. To solve the acidity problem, experts have recommended methods for increasing pH in polyethylene and plastic storage materials. Apart from using concrete storage, 1 tablespoon (15 millilitres) of baking soda will neutralize acidity in 100 gallons of water (TWDB 2005) while Mechell et al. (2009) proposed that if the pH is less than 7.0, add 2 pounds (0.8 kg) of baking soda per 10,000 gallons to raise the pH.

Proposed framework for a participatory RWH institution

This study indicates that technical (Ndomba & Wambura 2010) and financial support is needed for the improvement of RWH technology in Tanzania. In order to explain the importance of a participatory approach towards development of RWH technology, an institutional framework was developed (Figure 4). This participatory approach enables
sustainability in development of RWH technology due to the involvement of different stakeholders. These include consulting experts on issues of RWH, to be located in ward offices. These experts can solve some issues on RWH and channel some issues, e.g. financial issues, to a central RWH institution for more assistance. This central RWH institution is to direct technical and financial boards to solve burning issues for RWH stakeholders. Stakeholders could also propose loans from ward offices for investment in RWH technologies. The central authority could analyze the proposed project and direct the financial support board to facilitate the project. Use of the local authority provides a knowledge of the stakeholders who plan to take loans for RWH.

Since finances are needed for the institutional development, a budget from the Ministry of Water should fund this entity. Cost recovery without or with low interest should be the basis of the institution in which installation of RWH from stakeholders’ requests will be done with a loan (in terms of construction expertise and materials). With experience from the HESAWA project, through money contributions at installments, it enabled installation of RWH systems to households who wanted to have RWH systems. The households were required to make their installment contributions before construction of the RWH systems until the cost of installation of the RWH is met. Similar experiences can be used but for up-scaling, starting installation of RWH first as a loan to known workers or institutions and then recovering the loan later.

**CONCLUSIONS**

Generally, RWH is not developing sufficiently due to a lack of awareness of essential technology for social economic development, together with wrong perceptions by the majority of persons that rainwater cannot be stored long term without losing quality and being invaded by organisms. This kind of mentality affects adoption of RWH as a solution to water scarcity problems. Most adopters of RWH technology lack proper skills in management of RWH from collection to storage. The essence of diverting first-flush rainfall and protecting well rainwater in their storage is not realized. The main challenge hindering adoption of RWH was reported to be initial investment cost. Another challenge affecting utilization of RWH was reported to be leakages.
The study has proved that harvested rainwater in concrete storage is a good source of water compared with water supplied by vendors in the study area. Water supplied by vendors was found to have higher TDS, electrical conductivity and fecal coliform than the guidelines for Tanzania domestic water standards. The Government of Tanzania through the MoW has been supporting adoption of RWH through good policies, favourable legal aspects and awareness-raising to households and institutions. However, the ministry should create a standalone department on RWH and decentralize it to the local level to enable people in each ward to implement the technology. RWH technology with relatively free rainwater could be a solution to schools with accumulations of unpaid water bills.

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