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Households' Assessment of the Water Quality and Services of Multi-model Urban Water Supply System in the Informal Settlements of Dar es Salaam, Tanzania

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Abstract: In the global south wide range of studies highlight the limitations of the single-modelled public urban water system to meeting the endogenous water preferences of the urban population. Studies also touched on the complementary roles of private water actors to the single-modelled public water supply system in the urban water supply network. Multiple of urban water supply systems (multi-model) co-exist in the urban landscape of global south. However, it is unclear and largely inconclusive on the suitable and satisfactory urban water supply model that meets the water consumption needs of informal settlement dwellers in the global south. This study draws the experiences of households in the informal settlements using a case-study with cross-sectional survey strategy to assess the suitability of the multi-model urban water supply system for sustainable urban water supply in the informal settlements. A total of 292 households were randomly sampled alongside 35 purposively sampled private water actors and public water departments. The data were collected through face to face interviews. Findings show that water supply services of the multi-model water supply system are inevitably suitable for the water consumption needs of informal settlements's dwellers. The operation of the multi-model water supply system is flexible and able to accommodate the diverse water consumption preferences and choices of the different socio-economic groups in the informal settlements. We observed that multiplicity of urban water supply system increases households' access to water but does not necessarily improve the quality of water serve in the informal settlements. The paper recommended for the formalisation and adoption of the multi-model urban water supply system to meet the growing demand for improved water supply and services in the informal settlements.

Key words: water quality, multi-model water supply, informal settlements, urban water supply, urban poor.

1. Introduction

Even though the world is surrounded by water, there is still inadequacy in the availability of safe drinking water [1]. Again, though the world met some of the targets of the Millennium Development Goal of having half the proportion of people with access to safe drinking water in the year 2015, access to improved water in sufficient quality remains a major challenge in the global south [2]. There is still a gap between urban population with access and that of population without access to improved water, especially in urban areas in the global south [3-7]. The low capacities of public water supply agencies have been largely blamed for the existing gap [8, 9]. Again, unlike the global north where the capacity of a single water supply model robustly supply water to the satisfaction of households' water consumption needs, a complementary role of multiple urban water actors serves the water needs of households in the global south. More than half of the urban population in global south countries depend on multi-model (multi-source water supply system): either served by private water actors or varied small-scale water actors [8-15]. However, how a multi-model urban water supply system satisfies the water consumption needs

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of households on aspects of water quality and services provision in the informal settlements requires keen assessment.

In Sub-Saharan Africa, limited public water infrastructure and services, insufficient improved water in most urban areas coupled with low capacity of public water services providers compound the issue of quality water availability and provision to the urban population [8, 10, 16, 17]. Rapid urban population growth has led to an increased demand for the limited municipal water supply. Only 64% of the population in Sub-Saharan African countries have access to improved water sources [6]. Even where quality water exists, variation is seen in supply mostly favoring the formally planned areas to the detriment of the informally planned areas. Owing to these deficiencies, multiple private water actors specifically small-scale private water actors have emerged to complement the municipal water supply system to salvage the growing water demand in cities in Sub-Saharan Africa [4, 18, 19], serving more than half of the urban population. For instance, multiple private water actors serve as much as 95% of the population in the city of Onitsha (Nigeria), 60% in the case of Nairobi (Kenya), and 66% in Conakry, Guinea [10]. In Tanzania, 44% of the urban population in Dar es Salaam, are served water by the small-scale private operators.

The access variation in the distribution of the already limited public improved water in the urban areas has been the reason for many calls to acknowledge the roles of private water providers, to formalise and support the operations of multiple private water actors involved in the urban water distribution network [10, 13, 14, 17-23]. This unavoidable recognition is implicit of the limited capacity of public water actors to supply water services to peri-urban and most especially informal settlements. Though the call to formalise their operations in all scale is relevant for minimizing the widening water access gap in developing countries, there is the need to understand the quality of water and services provided by multi-model water supply system to peri-urban and informal settlements in the global south.

The significant of this study is deduced from the fact that water consumption represents both as a source of good health and a source of ill health, yet a suitable and satisfactory urban water supply model is barely found to serve domestic urban water demand of households in the global south given the limitations of the single-modelled public water supply system [8, 24]. Therefore, it is relevant to assess the quality of water and the services offered by the multi-modelled private water supply system that commonly operate as an alternative urban water supply model in the global south. Most studies on small-scale private water supply devoted to understanding the roles of small-scale private water supply in the urban water distribution network [10, 17, 25-27], others delved on the general accessibility of the water supply by the small-scale water actors [12, 28, 29]. Others observed the high bills associated with informal water supply in the urban areas [1, 30, 31], whilst others look at the potentials of small-scale private water operators in the water and sanitation market [8, 25, 32]. Though the above studies contributed to the broader view on private urban water supply, there is also the need to understand the quality of water and the services served by a multi-model urban water supply system, where a network of small-scale actors constitute the major water supply model in the informal settlements. The value consumers attached to the different water supply systems, how it differs by income status, as well as the differential uses of the water from the various water supply systems are earnest for the formalisation and subsequent support for multi-model urban water supply system in the global south.

2. Theoretical and Conceptual Perspectives on Multi-model Urban Water Supply System

2.1 Theoretical Review

The paper draws largely on the neo-liberal theory as a guide to understand the water quality and services of

the multiple private water actors largely led by small-scale water actors in urban water services provisions in urbanising cities. The earlier usage of the term "neo-liberalism" has its history date back to Walter Lippmann in 1938, who used it to describe a set of economic beliefs [33]. Neo-liberal theory later emerged as a potential remedy to capitalism's ills in the 1970's, through the work of the *Mont Pelerin Society* including Ludvug Von Mises, Milton Friedman, Karl Popper etc. [34]. Though the theory is applied to diverse subjects of study [35], the fundamental assumptions underpinning the arguments relate to market economics; the institution of multiple services providers in a freely functioning market, private property rights and privatization with state as the moderator [34, 36].

Following the neo-liberal theory, two major arguments can be deduced in relation to this study; argument supporting the multiple private urban water supply models and argument against the involvement of multiple private water actors in urban water services provision. The thinking on private water operation argues that free market gives flexibility to consumers, allowing consumers to switch from one service provider to another when dissatisfied with the quality of water, the services as well as the prices (Table 1). They argue that market is structured to accommodate consumer preferences and choices [34, 37].

Public service providers do not create or face any competition, but are often motivated primarily by the desire to expand their agencies' budgets and workforces. The theory posits that marketplace competition through private water operations can lead to higher quality of services as it drives out underperforming companies through market forces. Public water actors often desire to either satisfy needs of the consumers by lowering cost of production and costs of the services resulting to lower quality of services provision [37]. Further views indicate that, unlike the private service providers, public service providers do not seek out mutually beneficial exchanges with consumers but often act to be motivated by elected officials who supposedly take public interest for their own interest [37].

That apart, the effectiveness and efficiency of private water actors can be seen in the prudent services distribution whilst the inefficiency and ineffectiveness of the public infrastructure services' providers boils down to the non-discriminatory services they provide to society [36, 37, 39]. For instance, the proponents of

Table 1 Basic tenets of the neo-liberal theory.

For state's water supply	For private water supply
Water as public good argument: Water is a public good where benefits are collective, for which there are no means to consumers (Non-payers are non-excludable for which consumers do not have to compete for to enjoy).	*The competitive allocation arguments:* Under non-competitive provision, water services are not economically utilised to produce and given out. It may not maximize returns, but may result to abuses and misuses of water services.
The market failure argument: Private enterprise may fail because of: (a) monopoly of water supply services; (b) the necessary investment is so long and returns so uncertain that the private sector might not undertake; (c) negative externalities may reach persons who are unwilling or unable to pay for the cost of water tariffs; (d) consumers in low-income areas may have little knowledge and information to make informed decisions.	*State's failure arguments:* State's water provision often does not reflect consumers' preferences and may lead to charges that do not reflect producers' real cost making further investment on water unsustainable. Water enterprises and households can find their own market solutions to water problem.
The equity or "merits good" argument: Everyone should have access to improved water supply regardless of their willingness and ability to pay for the service, access to water is a basic human right and the right of the poor might be curtailed if left to the market.	*The poor pay the most anyway:* State is incapacitated to provide water services for everyone. Only the few affluent who can even pay rather enjoy free and low charges because of low coverage. The urban poor is made to buy water because of lack of state's extended water supply to their settlements.

Source: Adapted from Refs. [30, 37, 38].

user fees as a form of private operations, argue that government provides infrastructure services at lower cost even to persons who can out-rightly pay higher cost for infrastructure services. This accordingly is the reason for public resources overuse, misallocation and abuse of the commons [37, 40, 41].

Other arguments show that state allocation of services to individuals who can afford higher fees also limits the coverage of such water services supply to the very disadvantaged group of persons who dearly need such services but cannot afford them [41]. Owing to this, the engagement of private operators in water supply services delivery can potentially free up and help government to focus its resources on policy development and analysis to cater for the poor in society because private sector participation has possible impact on water coverage [37, 42]. Overall, the neo-liberal view is relevant for this study as it holds water suppliers and consumers as the key components in water privatisation debates.

3. Conceptual Definition: Water Quality

Most water sources in the global south do not provide water of adequate quality for domestic consumption [43]. Water quality is assessed through the analysis of the turbidity of the water, the color and the odor. According to Harris [44], these variables fall within the physical, chemical and bacteriological characteristics that define water quality for public acceptance and for the day-to-day control of water quality particularly for domestic consumption. Given the fact that, microbiological quality of drinking water is an increased concern especially for domestic water consumers, water regulatory departments and public health authorities, the experiences of households depending on the various water supply services are important for assessing the quality of the water they depend on [9]. Though the scientific method of testing for quality is relevant for water quality analysis, consumers' opinions and acceptability of the quality of an existing water source they depend on also count in water quality and standards for measuring water access [9]. Globally prescribed water standards and principles may be fundamental in influencing the operations of formal water supply companies but might not influence water consumption preferences of people particularly in areas and times of water scarcity [9].

Furthermore, the WHO (World Health Organization) considers safe or quality water as water that is accessed from an improved water source [45]. WHO thus classifies improved water sources to include: tube-well or borehole, bottled water, rainwater collection, protected spring, protected dug-well, public tape or standpipe, piped water in yard and piped water within dwellings. The unimproved water sources also include: cart with small tank or drum, unprotected spring, tanker trucks water and unprotected dug-well [45]. However, what is considered quality water or service is individually determined largely influenced by the environment in which water consumers find themselves, the income levels of households, gender as well as the water required activities. Depending on the kind of existing water supply model in a particular locality, water consumers may redefine what constitute water quality or an improved source of water for domestic consumption. As a result, UNICEF [43], indicates that the quality of water is better assessed subjectively by the water users or consumers. For others, water is considered good in quality when it is suitable to sustain the various uses and processes of the users, which implies that the suitability of the water may vary from person to person, by the required water uses, cost and quantity [46]. The differential use of water also determines quality either physically, chemically, and biologically. Though many water users have some common variables, each water use has its own demand and influences on water quality [46]. The quantity and quality demands of different water users are not always compatible with one another. For instance, the water use activities of one water source may restrict the activities of another also largely shaped by the households' income levels, educational

background, gender, the water use activities and the values attached to differential water sources [46]. Again, a given water is considered poor in quality when a range of variables within the water limits its use [46].

In many instances, a significant proportion of water diseases outbreak result from the consumption of water with poor quality or quality deteriorated through the collection and handling process. Common among the water-borne diseases or outbreaks that emanate from the drinking of contaminated water range amongst others to include diarrhoea, cholera and dysentery killing millions of people within the globe [46]. Households in the informal settlements in the developing world suffer most, the burden of poor quality water due to the wide varieties of informal water sources they depend on for water supply services. Evidence also shows that change in the water quality in many circumstances is driven by the degree of water handling and the water collection practices and in the distribution process [47].

4. Methodology

4.1 Study Location, Sampling and Key Variables

The study was conducted in *Goba* Ward—a peripheral informal settlement of the Dar es Salaam city. *Goba* Ward had a total population of 42,669 with eight (8) sub-wards. The sub-wards are served by the multi-model water supply system [48]. Considering the homogeneity of the water supply systems, the study was conducted in three (3) purposively selected sub-wards (*Goba-Chaurembo*, *Goba-Kunguru* and *Goba-Kibululu*) within *Goba* which had a total of 1,078 households. Though DAWASCO water standpipes exist, the water barely flows to serve the water demand of the inhabitants.

Due to the public water supply deficiency in the area, a proportion of the urban population in both formal and informal settlements in all municipal councils depend on multiple water supply systems for water [8, 9, 35, 48]. The paper focused on the informal settlements because most of such settlements depend on multiple water supply actors for water. The study targeted households, particularly persons directly involved in households' water collection, either financing, fetching or a consumer of both private and public supplied water. The study adopted a case study with cross-sectional survey design. This design was found suitable for an in-depth examination of water users' perceptions of services they have enjoyed and experienced overtime. We tap on the experiences and insight of households who act as primary consumers of the water [49]. The selection of the case study area (*Goba*) was done in four sequential levels using a multi-stage sampling technique.

Firstly, the city of Dar es Salaam was purposively selected because of its rapidly urbanizing rate of 5.6% with widespread informal settlements [48].

Secondly, due to lack of data on the number of informal water suppliers in the various municipalities, a fair representative of the five municipalities in the sample was done by categorizing the municipal councils according to their *levels of urbanization* and the *number of planned vs. unplanned settlements* drawing inputs from the 2012 Tanzania National Census report and from the Town planners. Through this, *Ubungo* municipal council was purposively selected as a moderately urbanising municipality with the highest number of informal settlements.

Thirdly, a fair representative of all wards within the selected municipality was done listing all the wards within the Ubungo municipal council. The listed Wards were then categorized according to their population and the planning status. At this stage, all unplanned settlements were purposively selected as potential case study areas. All the unplanned settlements were again categorized according to their levels of urbanization, level of water supply services received from the public water supply company (DAWASCO), drawing information for the 2012 Tanzania National Census report and from DAWASCO. Through this, *Goba* ward was purposively selected as a rapidly urbanising ward,

lowly served with improved water by DAWASCO.

Fourthly, the eight (8) suburbs within the selected Ward were categorized according to their population, number of households and housing density. Based on these, three (3) sub-wards *Goba-Chaurembo*, *Goba-Kunguru*and *Goba-Kibululu* with 1,078 inhabitants were purposively selected as information rich cases dominated by multiple water suppliers [48] as shown in Fig. 1.

The study draws on qualitative and quantitative data to assess households' perception of the services and water quality and services of multiple private water suppliers in the informal settlements. The qualitative insight was drawn from the study of 35 purposively selected water actors and formal stated-led water departments in the city of Dar es Salaam, whilst the quantitative data were drawn from the study of 292 households out of 1,078 households in the informal settlements. The purposively selected in-depth interviewees comprised of the pushcarts water supply operators, mechanized borehole operators, tanker trucks operators, well water and water kiosks operators, health officers, water engineers from the water departments and *Mtaa* (Ward) leaders in the selected wards. The representativeness of the 292 households were determined using Yemane's [50] mathematical formula as follows:

$$n = \frac{N}{1+N(\alpha)^2} \quad (1)$$

where:

n—desired sample size;

α—stands for the margin of errors (0.05) at 95% level of confidence;

1—is constant;

N—total population.

$$n = \frac{1{,}078}{1+1{,}078(0.05)^2} \quad (2)$$

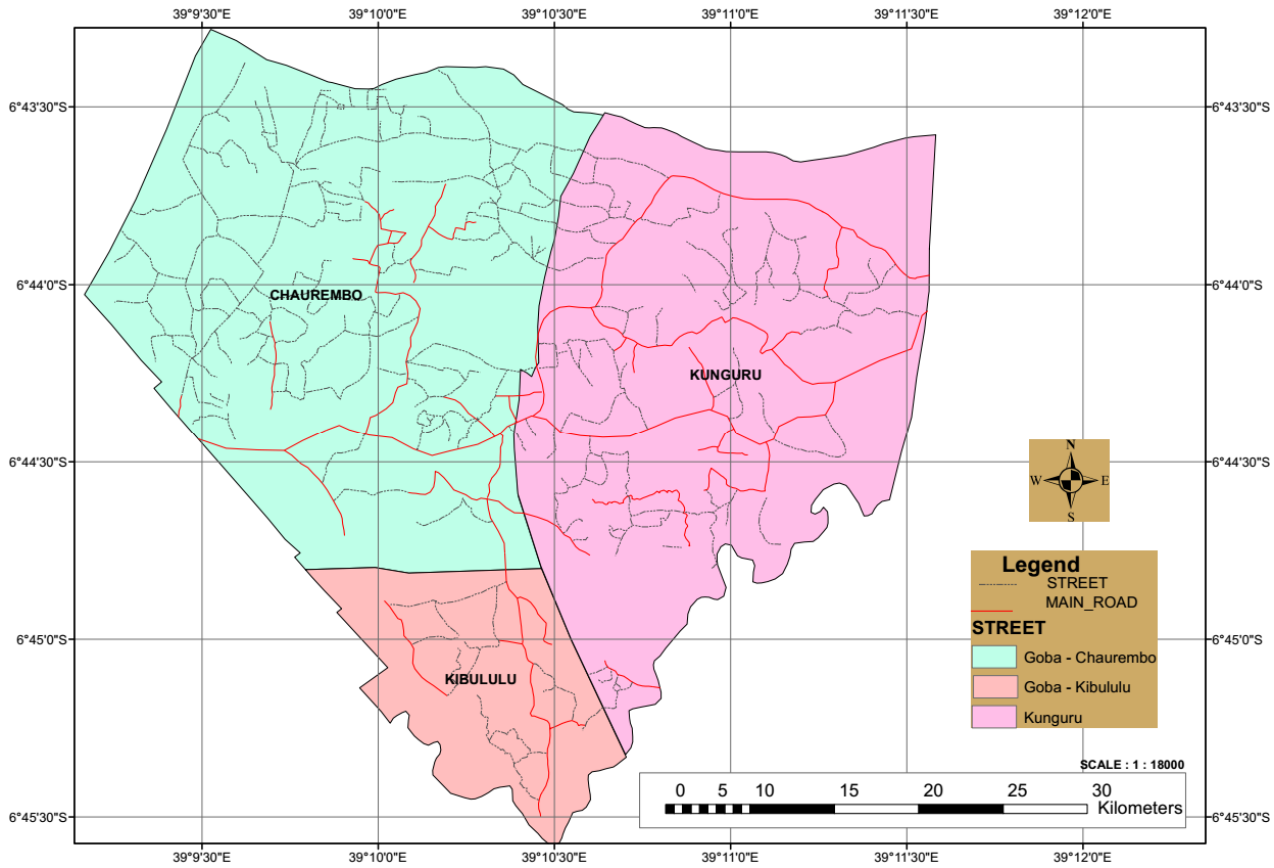

Fig. 1 Map showing the sub-wards selected for the study.

Source: Ardhi University, GIS Laboratory, Dar es Salaam, Tanzania.

$n = 292$ households.

The sampled households were selected using simple random sampling, data were collected through face-to-face interview. In-depth interviews were conducted through face-to-face interaction with private operators, DAWASCO water officials, the *Ubungo* municipal water officials, the *Mtaa* leaders in the three sub-wards. Data collected from in-depth interviews were recorded, noted and transcribed. The quantitative data were analysed using SPSS version 21. Validity of the data was ensured through triangulation of the data collected.

5. Results and Discussion

5.1 Socio-economic Status of Households and Urban Water Supply Systems

A relationship is drawn analysing the socio-economic status of the various households interviewed and the type of water supply system they depend on. Following the analysis, all households surveyed access water supply from two or more water supply systems which confirms the hypothesis of the neo-liberal theorist that open market water services system serves as gateway to freedom of choice and flexibility among consumers [34, 36, 39]. This can be deduced from the fact that none of the water supply systems is reliable to satisfy the water consumption needs of the households. Few water supply models were observed to provide water services in all year around. The complementarity of the multiple water operation markets was observed to be more flexible to accommodate water consumers' preferences and choices. Households depend on water models based on the existing situation surrounding them at the time. Results from cross-tabulation analysis of the socio-economic background characteristics of the sampled surveyed households show that occupations, income levels as well as the household size influence the type of the water systems households most often depend on for water supply.

As shown in Table 2, most households who earn their primary income through medium/large scale business operations (58.3%) and government work (57.1%) rely mostly on the tanker trucks water supply as their major source of water. Households that earn their income from small-scale business activities also rely on the tanker trucks as their main water supply system whereas households who earn their primary income from farming depend mostly on well water (28.1%). Though a higher proportion of all the households depend on the tanker truck water as their primary water supply system, there exist variations in the distribution of the various households among the existing water supply systems. The diversity among the various households is either shaped by the primary source of income. Whereas the distribution of respondents whose income is from government works, and medium and larger business operators is more skewed towards tanker trucks water source, mechanized boreholes, and water kiosks, the distribution of households that earn their primary income through petty trading, farming are more dispersed across all the existing water supply system in the study (Table 2).

In other words, households that engage in low income earning sources depend on more water supply systems to satisfy their domestic water consumption needs due to their inability to afford bulk purchase from one water supply source and vice versa. The association of the sources of income with the source of water does not only point to income levels, but also by the contractual mutual relationships that exist between tankers trucks water operators and owners of large-scale businessmen and women as well as public sector bureaucrats.They act as business partners, and as administrators managing the operation of these small-scale water businesses.

Table 2 Socio-economic statuses of households and their water supply systems.

Socio-economic statuses	Water supply systems (private)						
	Mechanize borehole water (%)	Tanker trucks (%)	Private tap water (%)	Pushcart water (%)	Well water (%)	Water kiosks (%)	None (%)
Income sources							
Small-scale business	21.7	48.1	4.7	9.3	0.0	12.4	3.9
Farming	19.3	24.6	10.5	0.0	28.1	8.8	8.8
Government work	12.3	57.1	8.2	10.2	0.0	12.2	0.0
Medium/large business	25.0	58.3	0.0	0.0	0.0	16.7	0.0
Others*	18.2	15.5	66.7	0.0	0.0	0.0	0.0
Household's income							
High-income	9.9	52.1	22.5	0.0	8.5	0.0	7.0
Middle-income	25.4	65.7	0.0	7.5	0.0	1.5	0.0
Low-income	21.4	38.3	3.9	7.1	6.5	19.5	3.2
Household's sizes							
1-2 people	37.9	20.7	0.0	0.0	20.7	20.7	0.0
3-4 people	15.2	64.6	7.6	0.0	0.0	12.7	0.0
5-6 people	9.4	54.7	7.7	10.3	0.0	9.4	8.5
7-8 people	33.3	27.8	11.1	9.3	11.1	7.4	0.0
9-10 people	19.5	47.7	7.2	5.8	5.5	10.6	3.4
Education							
Primary	21.0	56.2	3.7	3.7	0.0	12.3	3.1
Secondary/Voc./Tec.	25.0	42.6	0.0	16.2	8.8	2.4	0.0
Tertiary	9.7	32.3	24.2	0.0	9.7	16.1	8.1

Source: The authors.

Aside the influence of the households' primary income earning sources, the sizes of households were observed to influence the kind of water supply models' households depend on for water supply services. Though all households were found to rely on two or more water supply systems. Results from cross-tabulation analysis of households' sizes and main water supply models show that, many medium sizes families (3-4 people) rely on tanker trucks for water supply than other water supply systems within the study area. Larger sized households are more likely to depend on multiple and a reliable private water sources to satisfy their water consumption demand with or without consideration of the quality level of the water source.

Ironically, the income levels of the various households were found to minimally vary with various private water systems that households depend on in a multi-model water supply system. Results from cross-tabulation analysis show that middle-income households mostly rely on very limited water sources. Majority of the middle-income households rely more on either tanker truck (65.7%) or mechanized borehole water (25.4%), whereas the sources of the water of the lower income households are more distributed across all water supply systems in the informal settlements. Nevertheless, a higher proportion (38.3%) of lower income households depend on tanker trucks for water supply. This finding justifies the social good component of water as observed by Kjellén [30] and Bacho [38], in that households indiscriminately switch to any water supply services available in the midst of water scarcity particularly in the informal neighbourhoods justifying the fact that a multi-model

water supply is inevitably suitable for informal settlements.

5.2 Urban Water Systems and Hours of Water Supply Services in the Informal Settlements

As part of understanding the diversity of services available within the multi-model urban water supply system in the informal settlements, this section looks at the duration of time water supply services are available for households' access. Using a 24 hours duration of time as water availability assessment indicator [45], each household was asked to state the duration of time water is supplied for access. From the findings gathered, the duration of hours varies from one service operator to another. On average, all the water supply services of the private water operators are available between the period of 7 hours per day. Specifically, the water services of mechanized boreholes, protected wells, and pushcarts water services are more available between 10-24 hours per day, whereas that of the tanker trucks and water kiosk are more available from 6-10 hours per day (Table 3).

The variation of the hours of water services availability of the various water supply models is influenced by the locations of the various households and the nature of operations of the subscribed water models. Private water sources with longer hours of water supply services have implications on the kind of

Table 3 Water supply system and hours of services availability.

Water supply systems	Time of water services availability per day			
	24 hours	10 hours	6 hours	4 hours
Mechanized borehole	47.4	31.6	10.5	10.5
Tanker trucks	20.0	38.6	35.7	5.7
Private tap water	0.0	0.0	52.4	47.6
Pushcart water	64.7	35.3	0.0	0.0
Well water	62.5	37.5	0.0	0.0
Water kiosk	18.4	48.4	20.4	0.0

Source: The authors.

Fig. 2 Pushcart water actor.
Source: The authors.

Fig. 3 Private water tap.
Source: The authors.

Fig. 4 Water transport by bicycle.
Source: The authors.

services arrangements they provide. For instance, mechanized borehole water services are more available for the duration of 10-24 hours because such water services are often connected directly to households through distributed water pipes.

Subscribed households make payments monthly and fetch water within their yards. The long duration of services hours of the pushcarts water service was observed to be as a result of their mobile nature, the kind of management operation (mostly family or individual) and business ownership.

Operators of pushcart do not require to render account or seek consent from anyone prior to delivery services at late hours as in the case of the tanker truck operators. As a result, they are often willing to supply water in return for payment at any time on the bases of expression of interest for water. As a 30-year-old woman remarked:

"…for the pushcart water sellers, you only need to call them, wherever you are, they will bring you the water, all they want is their money, so they will come anytime you need the water."

Households in the informal settlements rely on this water supply model not habitually as a primary water source but as a coping measure in times of inability to access water from other equally existing water models in the informal settlements. In the case of operators of protected well water, the availability hours are

influenced by the individual ownerships of their water source. Most protected wells water is owned by households primarily not for sale, as part of self-help [24, 29], but only sold on days of water scarcity. As such, depending on their locations, neighbours enjoy user right of water access from the wells at all times as needed.

5.3 Multi-model Water Supply vs. Single-Model Public Water Supply System Services

This section draws largely on qualitative insight from households to understand the difference in the services between the multi-model urban water services and that of a single-model public water supply service. The assessment leans on the neo-liberal argument of efficiency and reliability of services delivery of the plurality of water actors as theoretical foundation. Per the neo-liberalist view, multiple water services operators are perceived with high capacity and efficiency. This supposed efficiency of the multiple water supply services is often generically presented without due regard to the sizes of the operators. As such, this aspect of the study looks at the experiences of households in the informal settlements who have both experiences of a multi-private water supply and a single-model public urban water supply system. The guiding criteria for the assessment were the issues of services reliability, information provision on water quality and water availability and general satisfaction with the services.

A high proportion (32.2%) of the households interviewed described the multi-private water supply services as more reliable but not the most reliable water service. For other households (25%), the multi-private urban water supply services are never the best, however, they complement one another, and are suitable to their conditions given the limited services of the single modelled public water supply system in the informal settlements (Table 4). The third highest group of households described the services as more flexible in terms of their arrangements which confirm Kyessi's [8] earlier observation of the flexibility that usually surrounds multiplicity of water services operations particularly in an informal neighbourhoods where everyone is a neighbor or a perceived relative to other. The associated reliability of multi-private water services is influenced by the inefficiency and the equally unreliable nature of the public water supply services (DAWASCO water supply services in the area which evolved through attempt to formalizing the settlement).

Public water supply services are optimal in quality but generally periodic in terms of supply. Further views supporting the efficiency and reliability of the multi-private water supply services as against that of the single modelled public water supply (DAWASCO) were justified in an in-depth interview as remarked by clients:

Table 4 Private verses public water services models.

Multiple water supply models	Type of supplier	No. of days water flows per week	Households sources of water information	Services quality
Water kiosks actors	Private	7 days per week	Verbal communication from colleagues	Services not reliable but suitable to our situations
Private tap water actors	Private	7 days per week	Personal observation	Services not reliable however arrangements for water supply services are more flexible
Mechanized borehole actors	Private	7 days per week	Verbal communication from colleagues	Services are not the most reliable services we anticipate but suitable to our situations
Well-water actors	private	7 days per week	Personal observation	Services are reliable, water available always and all days
DAWASCO	Public	2 days per week	Personal observation	Services unreliable
Tanker trucks actors	Private	7 days per week	Personal observation	Services are more reliable but not the most reliable services expected

Source: The authors.

"In this location, there is a big problem of water, if you depend on DAWASCO water you will lack water. I have been here for four years, but the water situation has not changed. There are DAWASCO water supply pipelines here, but DAWASCO water supply is periodic when it flows one day there is no water again. Cars selling water here is most common and buying of water from private operators is common. The tanker water suppliers have rather increased but not DAWASCO water supply."

In the informal settlements, households rely on the multi-private suppliers because of services reliability. Due to erratic flow of water, the few public water standpipes (DAWASCO standpipes) are often not monitored and maintained for safe water supply. Though this neglect partially correlates with Hardin's [40] concept of the tragedy of the commons where citizens abused public resources through the habits of non-maintenances of the facilities. To some extent, public inefficiencies often contribute to the tragedy of the commons, where citizens show little regard towards the maintenance of existing public services particularly in this case.

Comparatively, services of multi-private water supply systems are considered better than that of the water services supplied by the public agency (single model). The major weakness of the multi-private water supply systems in the services delivery concurs on information flow on water availability and quality of the source' water. This is equally common in a municipal/public driven water supply service provisions in many urban areas. Multi-private water operators are unable to provide information about the availability and quality of the water supply to their clients, 56.2% of the households surveyed attested to this. For most households (32.2%), information about water availability and quality is often sought through personal observation or through communication with colleagues (20.2%).

Though services of the multi-model private water actors are comparatively better than the public water supply (single model) service in the informal settlement, 40.8% of the surveyed households expressed less satisfaction with the water supply systems involved whilst 30.5% of the households expressed their satisfaction with the services. The levels of satisfaction also vary among the different categories of households (high-income, middle and low-income) surveyed, whereas the middle-income households expressed more satisfaction with the services quality of the multiple private water supply systems, the low and the high-income households expressed less satisfaction with the services. This difference is either influenced by the individual households' expectations and definition of quality services per their income levels. For instance, whilst low-income households are unable to purchase water from tanker trucks operators in bulk to escape the incremental charges of water kiosks, and private taps operators, middle and high-income households are able to purchase water in bulk.

5.4 Socio-economic Background of Households and Perception on the Quality of Water

The surveyed households were asked to rate the quality of water of their subscribed water supply systems, a high proportion (41.4%) of the water consumers (households) disclosed that the quality of the water is moderately good for consumption, adding that not all the water accessed from the various private water sources are usually satisfactorily for all households' water required activities. The major challenge has been the issue of the salinity of the water due to geogenic contaminants, turbidity; presence of particles in the water through long-term storage of the water either in poly-tanks. As shown in Table 5, households' perceptions of water supply systems with acceptable quality vary by age, sex, educational levels, marital status and households' income levels. Almost all the age groups studied rated water supplied by the tanker trucks water system as one with the most acceptable quality. Also, majority of the studied groups

rated water supplied by the tanker trucks as the one with the most acceptable in quality. In case of sex groups, 51% of the males rated water supplied by tanker trucks water system as the one with the most acceptable quality followed by water supplied by private taps 45.5%. Again, 39.2% of the females rated water supplied by the tanker trucks system as the most acceptable followed by water supplied by the private tankers (28.1%) (Table 5). The less acceptability of water supplied by private taps has been due to salinity of the water. According to the respondents, except for water supplied by tanker trucks, water sourced from the other water supply systems required further purification either by boiling and filtering.

In most cases, households operate a dual-purpose water access and storage system, where water with high salinity is accessed for bathing, cooking and for cleaning their rooms, and purchase tanker truck water, or DAWASCO (public water) and bottled water for drinking. A 34-year woman shared her opinion on the quality of water as follows:

"…some of them are of good quality, the tankers and poly-tanks carry water for a long period, so sometimes you get water with particles, there are only few good ones, some by looking you can tell whether the water is of good quality or not. In the dry season water quality issue is often compounded because of water scarcity so the water you get is not often in good quality either dusty, but water is water and we usually have no option than to use it…" (*Goba-kibululu*, Maraaba[1])

The experience of *Maraaba* is not in isolation, the Water Engineer of the Ubungo Municipal Council also shared similar opinions:

"Relying on the private water providers for water has a high cost than good. Quality is an issue with the small-scale private water sources, the small-scale private operators cannot control water quality because they are suffering for money only and not anything, for you to control the quality of water you have to check always for the turbidity (salinity, sodium etc), you also have to control the physical quality of the water the colour, the smell and also the chemical quality the conductivity of the water, salinity, sodium and also the bacteriological factors like faecal matter …" (Ubungo Municipal Council, Dar es Salaam, 15:30)

This view highlights the financial and the health cost involve in relying on the multiple private water supply systems. Again, water management processes of the multiple private water suppliers are usually not consistent with the conventional management processes for safe drinking water of the WHO (World Health Organization).

Per the WHO drinking water quality guidelines, the removal of microbial contaminations must be done through water sources protection, appropriate treatment processes as well as the disinfection of the water to prevent or remove microbial contaminants from the water. Ironically, the major capacities of private water actors are seen in cleaning around the water services centers as remarked by a 43 years' old water-kiosk's operator (woman) on the question of water quality regulation:

"…I always clean around the poly-tank, I source water from tankers trucks and DAWASCO taps and put into the poly-tanks for sale. I do not test the quality of the water in the poly-tank, so I cannot tell the quality of the water, but the business is good when tanker trucks water supply is reliable…" (Goba-Chaurembo, Dar es Salaam 14:34)

Continuous disinfection at least every six month reduces the health-risk associated with the in-take of such water. Ironically, actors of multiple private water providers do not have capacity to disinfect water against microbial contaminants.

5.5 Households' Assessment of the Water Supply Systems vs. Global Classifications of Quality Water

The surveyed households were asked to describe the quality of the systems they depend on for their domestic water required activities. Households' views of the quality of water from the multiple water supply

[1] Maraaba is an assigned name not actual name of the interviewee.

systems vary from one supplier to another. Despite the variations, 30.1% of the households described the general quality of the water as considerable good whereas 11% of the households described the quality as generally poor for domestic consumption. In water supply system specific cases, a high proportion of the surveyed households (76.2%) described the quality of the tanker trucks water as the one with the most acceptable quality, followed by water supplied by the mechanized borehole water (49.1%) and the private tap 49.1% (Table 6). Though not all are in line with the WHO definition of an improved water supply system, respondents' classification of the various water supply systems is shaped by the existing situation surrounding water access in their neighbourhoods, this confirms McGranahan et al.'s [9] observation that conventional (global) water and sanitation criteria or standards are either suitable or unsuitable to local beneficiaries given their locational contexts (Table 6).

Though the tanker trucks water supply system is globally considered as an unimproved source of water [45], in the midst of improved water scarcity, the tanker trucks water supply system is considered as the source with the most acceptable water quality. This is deduced from the fact that tanker trucks' operators have an alignment with the public water supply agency

Table 5 Socio-economic background of households and perception of improved water source.

Socio-economic background	Water supply systems with acceptable quality (cases*)						
	Mechanize borehole water (%)	Tanker trucks (%)	Private tap water (%)	Pushcart water (%)	Well water (%)	Water kiosks (%)	I don't know (%)
Age							
20-25	10 (28.6)	20 (51.1)	10 (28.6)	0 (0.0)	0 (0.0)	0 (0.0)	5 (14.3)
26-31	20 (35.6)	25 (35.7)	20 (28.6)	0 (0.0)	5 (7.1)	5 (7.1)	10 (14.3)
32-37	0 (0.0)	16 (50.0)	22 (68.8)	0 (0.0)	0 (0.0)	0 (0.0)	5 (15.6)
38-43	5 (11.4)	17 (38.6)	12 (27.3)	0 (0.0)	5 (11.4)	3 (6.8)	12 (27.3)
44-49	3 (23.1)	15 (83.3)	9 (50.0)	0(0.0)	0 (0.0)	0 (0.0)	0 (0.0)
50-55	0 (0.0)	3 (23.1)	9 (69.3)	0 (0.0)	0 (0.0)	3(23.1)	3 (23.1)
56-61	0 (0.0)	4 (100)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sex							
Male	15 (10.5)	73 (51.0)	65 (45.5)	0 (0.0)	10 (7.0)	10 (7.0)	21(14.7)
Female	48 (33.6)	56 (39.2)	41 (28.7)	0 (0.0)	5 (3.5)	5 (3.5)	27 (18.9)
Marital status							
Single	12 (19.0)	29 (46.0)	17 (27.0)	0 (0.0)	5 (7.9)	5 (7.9)	12 (19.0)
Married	47 (23.5)	92 (46.0)	76 (38.0)	0 (0.0)	10 (5.0)	10 (5.0)	30 (15.0)
Divorced	0 (0.0)	0 (0.0)	4 (100)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Widowed	4 (21.1)	8 (42.1)	9 (47.4)	0 (0.0)	0 (0.0)	0 (0.0)	6 (31.6)
Educational level							
Primary	24 (14.9)	62 (38.3)	57 (35.2)	0 (0.0)	4 (2.5)	4 (2.5)	27 (22.8)
Secondary	21 (30.9)	42 (61.8)	31 (45.6)	0 (0.0)	11(16.2)	11(16.2)	0 (0.0)
Tertiary	12 (21.4)	25 (44.6)	24 (42.9)	0 (0.0)	0 (0.0)	0 (0.0)	11 (19.6)
HH income levels							
High-income	20 (30.8)	36 (55.4)	31 (47.7)	0 (0.0)	0 (0.0)	0 (0.0)	6 (9.2)
Middle-income	0 (0.0)	37 (55.2)	24 (35.8)	0 (0.0)	6 (9.0)	6 (9.0)	6 (9.0)
Low-income	43 (27.9)	56 (36.4)	51 (33.1)	0 (0.0)	9 (5.8)	9 (5.8)	36 (23.4)

Source: The authors.

Table 6 Households' assessment of the water quality of urban water systems.

Urban water supply systems	Households' assessment of the water quality				WHO's water quality classification
	Most acceptable quality	More acceptable quality	Less acceptable quality	I do not know	
	(%)	(%)	(%)	(%)	
Mechanized borehole	49.1	8.8	31.6	10.5	Improved water source
Tanker trucks	76.2	0.0	0.0	23.8	Unimproved water source
Private taps	36.3	29.4	34.3	0.0	Improved water source
Protected well water	23.6	9.3	42.9	24.2	Improved water source
Pushcart water	0.0	0.0	62.5	37.5	Unimproved water source
Water kiosks	16.1	29.0	54.8	0.0	Unimproved water source
Public standpipes	64.1	30.9	0.0	5.0	Improved water source
DAWASCO	76.1	20.9	0.0	3.0	Improved water source

Source: The authors.

(DAWASCO) through which they source water for sale.

However, all other water supply systems meet the WHO's improved water source classification. The surveyed households equally rated public standpipes water source as most acceptable in quality (64.1%), the water kiosk water source as less acceptable in quality (54.85%), the private pipe water source as also most acceptable in terms of quality (36.3%), the pushcart water source as less acceptable in terms of quality (62.5%) and the mechanized-borehole water source as most acceptable in terms of quality.

However, the widely known low water quality associated with private water often compel depending households to treat such water prior to domestic consumption. Among the surveyed households, 71.9% of them asserted to have treated water hauled prior to consumption. From observation, the commonest method of treatment has been by boiling (88.3%) coupled with filtration (6.8%) as prescribed by WHO [45]. Groundwater in Dar es Salaam is already poor in quality, compounded by high salinity hence most urban households either treat the water by boiling and filtering prior to domestic consumption [9].

5.6 Water Access, Storage, Distributions and Risk of Water Contamination

Excessive water handling is known to be associated with increased risk of clean water contamination through storage and water distribution [45]. Basing on this hypothesis, we analysed the possibility of contaminating improved water accessed drawing on the views of water consumers in the informal settlements and the concept of water handling. The analysis centered on how water is accessed, stored and distributed to households in the informal settlements. From the study, each water operator hauls, stores and distribute water differently. But in general, three major methods of water storage were realised, the first and the commonest method of storing water prior to distribution is through poly-tanks (common among water kiosks operators, private water taps operators); the second method discovered is through the tanks of tankers trucks (usually by the trucks operators); the third method observed method is that stored in *yellow Jerry-cans* (common among pushcarts operators). Though regular cleaning of the storage containers is part of ensuring and maintaining the quality of water for domestic consumption, routine cleaning is barely done by water operators. The major cleanliness is either done by sweeping around the water site or washing the outer part of the water poly-tanks. Water stored in poly-tanks is not routinely disinfected in given times. The implication of the water storage and distributions methods on the water quality varies from one storage method to the other (Table 7). However, in general, the implication of all water storage and distribution methods are the exposure of the water to

Table 7 Water storage, distributions systems and the risk of water contamination.

Urban water supply systems	Water storage system	Mode of water distribution	Risk of water quality deterioration
Pushcarts water	Jerry-cans	Direct system of distribution	Water is transported directly to consumers or randomly in search for potentials buyers. Using the maximum degree of water handling and risk principle, the processes in water access points, transport either randomly or directly by pushcarts often lead to an increased inhuman contact (excessive handling of the water). The risk of introducing microbial substances is high. However, long-term storage often results to the growth of bacteria, algae in the water jerry-cans as jerry-cans are not frequently washed by operators. The contaminates that often arise through this type of storage and distribution system are negligible and less likely to result to outbreak of diseases.
Tanker trucks	Tankers	Direct system of distribution	Quality water is sourced from DAWASCO water supply point, and transported to households. The transport processes often result to the ingress of particles, washing of rusted surfaces within the tank into the water through shaking in untarred roads particularly in the informal areas and when the tank is rusted. Using the maximum degree of water handling, the risk of contaminating the water is low when directly delivered to households without due delay but high risk when delayed, due to the excessive handling, less frequent washing of the tank and water disinfection may affect quality of the water.
Well-water	Underground (natural)	Indirect system of distribution	Wells water sources are in specified areas, households fetch water from wells and transport directly to their homes. Depending on the nature of the water source, the water collection container and the distance of the house from the water point, the risk of deteriorating the quality of the water is lower given the low degree of water handling from the water point to the house as compared to that of the pushcarts and tanker trucks. But biologically, the risk is higher and may result to outbreak due to lack of protection of the main water source.
Water-kiosk	Poly-tanks	Indirect system of distribution	Water kiosks are located within the informal neighbourhoods and households' fetch and carry water from the water kiosks to their various houses. Water kiosks either draw groundwater or source water from tankers for supply. Depending on the source of the water draw by kiosks operators, the risk of contamination is either low or high basing on the maximum degree of water handling. Water kiosks that source water from tanker trucks operators and resell as in the case of the pushcart, exert high degree of water handling implying high risk of water quality deterioration, and low risk of water quality deterioration among water kiosks that source groundwater directly and supply to households. But in both cases, the risk of algae formation in the poly-tank is high due to low frequent monitory and washing of the poly-tanks.
Mechanized borehole	Poly-tanks and pipelines extension	Direct distributions system	Most mechanized boreholes in the study area draw groundwater directly for supply. The water is usually delivered directly to households through pipelines extension and standpipe in place for manual water access. Direct delivery through pipelines to consumers' yards presents low risk of water deterioration, however operators of mechanized borehole could not tell whether their pipelines were disinfested prior to water distribution or not. But on a circumstance of disinfections, the level of water handling is low implying low risk of quality deterioration. However, over-head poly-tanks are not frequently washed and disinfected.
Private stand taps	Poly-tanks or pipelines extension	Indirect distribution system	Water is distributed through PVC pipes to specified locations in a form of pipes, and households fetch and transport water home. The maximum degree of water handling is considerably lower compared to other sources of private water. However monitory and disinfections are not usually done, only detected leakages are patched for continuous water supply.

Source: The authors.

contaminates either through excessive manual handling or the storage system.

Despite these implications, interviews with experts in the Municipal Water Department show that water quality surveillance particularly targeting small-scale private water operators is only done upon suspicion of outbreak of diseases in the informal settlements but not on routine basis. This further implies that informal urban settlers who haul drinking water from multiple private water providers usually fulfill their daily water access right and at the same time place their health at risk owning to undefined quality of the private water.

On the aspect of water distributions, two major systems of water distribution were realized: direct distributions to households and indirect water distribution to households. With the direct system of water distribution, water is transported to households either by pushcarts, tanker trucks or through the extension of pipelines (PVC pipes) connected to the major water source to interested households. This system of distribution is common among the mechanized boreholes, pushcarts and the tanker truck operation systems. Households depending on mechanized boreholes for water supply are often given meters as basis for regulating consumption and payments in every month. In the indirect distribution system, the water source is located within the neighbourhoods of catchment/accessible distance indirectly to attract customers (households). Interested households fetch water from the water sources using their own containers. Depending on the distance, different modes of transport are used to carry or transport water to consumers. The commonly associated water system to the indirect water distribution system are the standpipes, the water kiosks, well-water etc. Transportation of water is invariably a universal means of water access in the informal settlements where water scarcity abounds. However, findings gathered from households (49.1%) indicate that water transportation has a likelihood of deteriorating the quality of already clean water fetched for domestic consumption, but findings to justifying water quality changes between water accessed and transported require further studies.

6. Conclusion and Recommendation

Even though water access has gained global recognition as a basic human right without regard of rural or urban, states' incapacity has contributed to the emergence of multiple private water actors. Their operations contributed to an increased in water coverage but with low capacity to serve quality water in planned and unplanned urban areas. This however has a serious health implication on the population served. The social good component of water is missing when individuals take the mantle in water provision in the informal settlements. The implications of such water supply are enormous and revolve around the issue of poor water quality, deterioration of the quality of water with already good quality due to lack of regular disinfection of the water sources, and low reliability and acceptability of the water. Nevertheless, multi-private water supply system has potentials for promoting water supply coverage than the public water supply system. Unfortunately, multiple private water supply systems are constrained in purifying water in larger scale to serve the water needs of their clients.

Given the existing socio-economic inequalities in the informal settlements (income levels, educational status, etc.), the promotion of a multi-model water supply system will adequately serve the water needs of both the low-income groups as well as the high-income households. Households will choose a water supply system based on their income level, the value for the water and the required water uses. Prior to their promotion, there is the need to first of all, recognise the operations of the multi-model water supply system through registration of the water supply actors involved, formation of associations to provide an avenue for regular monitoring of their activities. Key partners such as DAWASCO and DAWASA are

required to strengthen partnership with informal water actors to sustain and formalise their operations. Secondly, the integration of the informal water actors should be backed by legal recognition. Legislations should spell out guidelines and measures required for actors to operate in the urban water distribution network. A legal recognition will position actors in adequate position to seek financial assistance to expand their operations and increase water supply to the unserved urban population. Thirdly, mainstreaming the informal water actors requires the development of cooperation between utilities agencies, and that of the informal water providers and government authorities. The cooperation will sustain the actors in the water operation and polish up their weaknesses. Fourthly, given the fact that water consumption represents good health and ill-health, regulatory measures are required to control the quality of the water supply. Finally, multi-model water supply actors should be incorporated in city water support policy issues, to contribute to the implementation of water related programmes to make them more effective and efficient in the urban water supply.

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