Smart Water

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Do prepaid water meters improve the quality of water service delivery? The case of Nakuru, Kenya

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Abstract

Conventional water metering has a tendency of being unreliable, inaccurate, and a source of dispute and disquiet among customers, and hence it is considered to be one primary reason why water service providers perform poorly and have very low revenue collection figures. The result of this poor performance spirals into poor management, ineffective maintenance, inaccurate billing and high non-revenue water. This study explored what a prepaid metering project in Nakuru, Kenya achieved, and to see whether or not prepayment can be considered to be an innovative way of addressing these concerns, especially how to provide better service, when providing water to the urban poor. In addition, the study investigated micro financing as tools for supporting efforts by water service providers serving the poor and whether they are an effective way of financing projects. Communal prepaid meters were installed in an existing conventional network and data on commonly used performance evaluation parameters collected through interviews, field visits, and existing literature. The results portrayed prepaid metering with positive improvements to the conventional metering. It was found that there is an opportunity in microfinance for win-win partnerships among financial institutions, water service providers and low-income customers to help them in increasing access to water services. Communal prepaid meters are now bankable and viable options for serving urban poor communities.

Keywords: Communal prepaid metering, Metafinance, Urban poor, Water service providers

Background

Water service providers (WSP) often face many challenges in their service especially among the urban poor customers (Easterly 2009). Some of these challenges are management challenges that can be resolved by the WSPs themselves. Chief among them is the non-revenue water, which is reported to be as high as 50% in developing countries (Trémolet and Hunt 2016). Non-revenue water (NRW) is the difference between the volume of water supplied into a distribution network and the authorized billed consumption (Kamani et al. 2012). It's a financial loss to WSPs and also an avenue for degradation of water quality through the leakages and vandalized pipelines. The water infrastructure worldwide is riddled with leaks, which contribute to a variety of losses within the water network. Losses can be in the form of direct water dissipation,

production energy losses, and losses in treatment costs (Samer et al. 2017). Another challenge to water service providers expanding their services has been their lack of sufficient assets to obtain traditional financing from a bank (Heymans et al. 2014). Technology with water metering is one of the reported ways to overcome some of the challenges in service provision (Tsitsifli et al. 2017). In the study country, Kenya, investments in water supply needed to rise more rapidly to expand services to a growing urban population if the country was to achieve its National Water Services Strategy target for access to safe water of 80% in urban areas and 75% in rural areas by 2015. (Acolor and Adams 2013). In 2002, the Kenyan Government adopted the Water Act and instituted reforms to commercialize the water sector (Ward 2012). The Water Act has been observed as being the driving force to improve sector efficiency and performance in the last decade (Collignon and Vezina 2016).

According to the Africa Water Task Force conference proceedings, (Africa Water Task Force 2012), after more than a decade of implementing the Water Act, there have been visible improvements in the sector, including increased consumer and stakeholder participation in the decision making processes; increased pro-poor orientation evidenced by the establishment of a pro poor basket fund called the Water Services Trust Fund (WSTF); socially responsible commercialization of water services and increased funding to the sector. However, Kenya's water sector remains heavily donor dependent with approximately 40% (USD 140 million) of the annual capital spending coming from the donor community with the government providing the bulk of the balance and the private sector playing a negligible role (Collignon and Vezina 2016).

To address the challenges above and build on the existing sector reforms, microfinance banks started linking with the strategic plans of water service providers to increase access to water services among the urban poor in Kenya (Foster et al. 2014). Family Bank, a microfinance institution, which had nearly 1 million customers, and was interested to leverage its mobile banking platform and experience with pre-paid electricity payments to the water sector selected and partnered with Nakuru Water and Sanitation Services Company, Ltd. (NAWASSCO) to find a commercially viable way to improve the quality of service delivery to the urban poor through smart technology, i.e., communal prepaid meters. This was in realization that as observed by (Hoon 2018), "the water sector is a domain with the greatest potential and most room for improvement through the application of smart technologies."

This study installed and tested communal prepaid metering for its suitability to improve water service provision among urban poor communities. Water metering is a management tool in water supply. It is used by the service providers to quantify water bills, for leak detection, monitoring water demand and plan for supply, among others (Maddaus 2001). Many water metering technologies and models have been reported in literature. Van Zyl (2011) described different types of water meters and where they are often used. These meters also have some impact on the type of water meter management in terms of meter reading and water billing. As such, there are now meters that allow automatic reading and telemetric submissions to a central location and those that require a meter reader to periodically walk to the meter and collect the readings (Marais et al. 2016). There also those that are pre-loaded to allow water-use up to the loaded limit (Gambe 2015). Flat rate billing is another approach that is often used in places with multiple metering problems (Bakker 2001). Each of these water metering models

have own potential and challenges especially when applied to urban poor areas. For the challenges, there is a lot of literature on issues like non-revenue water, high cost of water per unit volume, frequent outages in water supply, billing inaccuracies, among others (Chepyegon and Kamiya 2018).

Nakuru is the fourth largest city in Kenya and has the fastest growth rate in East Africa at 13.3% per annum. (WASREB 2010) The growth was leading to a population boom in the poor settlements and straining NAWASSCO's service delivery mechanisms and capacity. With grant support from the government, NAWASSCO had made small pipe investments in poor settlements and had high water coverage of 79%. A survey was conducted to inform the demand for paid-for water, and discussions were held with the service provider to define their challenges in urban poor areas, financial position and debt service capacity. From this information, it was determined that prepaid metering combined with metafinance products could address the needs and affordability of the low-income urban populations in these areas. Metafinance pools individual cash flows to secure previously inaccessible high-value loans for communal benefit, e.g. extending water infrastructure into a low-income community so that households can get connected (Castro 2009). For the bank, this also made economic sense as making one large loan to a single WSP is preferable to making hundreds or thousands of individual loans to the end consumer. After all the elements of market research and the business analysis, and community education and outreach and been done, individual connections were provided to some customers, but in the low income areas, the introduction of communal prepaid meters gave opportunity to many customers to have access to water services, giving them access to affordable, clean, potable and reliable water (Gambe 2015). The difference between traditional microfinance and metafinance is shown in Fig. 1.

Methods

Study area

This study was carried out in Nakuru, Kenya (Fig. 2). By the end of the year 2017, the projected population was 760,000 in Nakuru. About 80% of Nakuru population live below the global poverty line and are largely concentrated in the densely populated peri-urban areas (UN-DESA 2017).

In terms of water supply, 70% of the population in Nakuru is served by the Nakuru Water and Sanitation Services Company (NAWASSCO) with over 40,900 metered connections (WASREB 2011) (Table 1).

Communal prepaid metering model

Communal prepaid meters (CPM) were installed in Nakuru. In this model, water meters are activated using tokens that are bought from the water service provider. The tokens are uploaded with credit at designated pay-points and water users can draw water up to the amount credited in the token (Fig. 3). There were 91 communal prepaid meters installed in the network in Nakuru between January 2011 and January 2012. The development and installation of the water meters were carried out in accordance with the Government of Kenya guidelines (WASPA 2018). The prepaid meters were installed to improve the quality of water service delivery to 15,000 people in the six low-income settlements in Nakuru (Fig. 2).

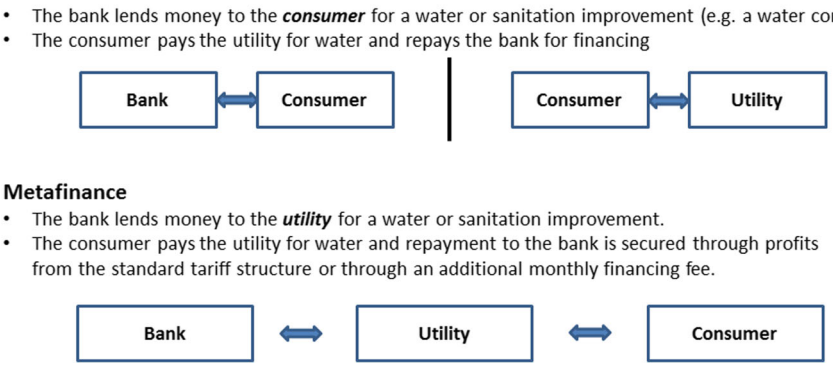

Fig. 1 Traditional Microfinance vs. Metafinance. By definition, in traditional microfinance, the bank lends to an individual consumer for water improvements, such as a new water connection, pays the utility for water consumed and repays the bank the loan. In metafinance, the bank lends the money to the utility for water improvements, and the consumer pays the utility both for water consumed and the loan repayment through an agreed tariff structure. The figure provides a graphical description of the two financing models

For this study, 260 household surveys were conducted and analysed to evaluate sources of income; monthly expenditures; potential savings; critical challenges relating to access to water services; sources of finance to meet water demand.

Data collection

This study was designed such that the study site in Nakuru was divided into two: areas with and areas without the communal prepaid meter (CPM) but which are served by the same water service provider (WSP). The areas without the study metering models had the old conventional metering models installed by the WSP. The old conventional model consists of a distribution network with mechanical meters at the consumer premises and from which meter readers collect the readings at the end of every month for billing water consumed.

During this study, equal number of samples were randomly selected from the two groups (with and without CPM) in each study site. Data was collected through field visits, interviews, and focused group discussions. Interviews targeted water-user households, water vendors/meter operators, and staff members of the WSP. Focus group discussions were done with members of water user associations, association of WSPs, association of water vendors, and association of landlords.

Data collection was carried out during the first dry seasons of the year between January and March 2012 and repeated during the second dry season between July and September 2012. Dry seasons were selected because these are the times for high household water demand in the study area and in the country in general (WASREB 2011). Data was collected on the following parameters: sources of income; monthly expenditures; potential savings; critical challenges (and opportunities) relating to access to water services; sources of finance to meet water demand; volume of money transfers made over the last 12 months, potable water, water coverage, and non-revenue water. These parameters are also often used in determining the impact of service delivery for urban poor dwellers in Kenya (WASREB 2011).

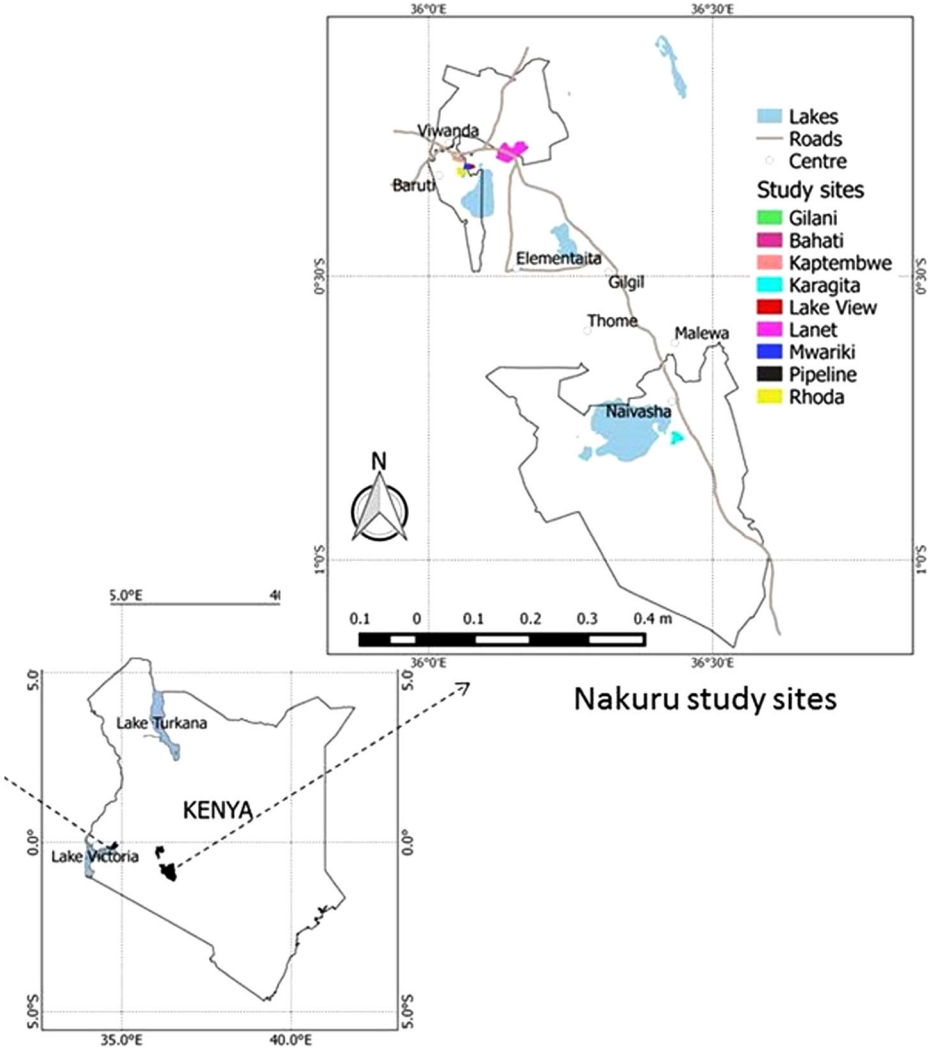

Fig. 2 Location of study Area. This study was carried out in Nakuru in Kenya. Nakuru is the fourth largest city in the country. By the end of the year 2017, the projected population was 760,000 in Nakuru. About 80% of Nakuru populations live below the global poverty line and are largely concentrated in the densely populated peri-urban areas. The high density areas studied in this research are Gilani, Bahati, Kaptembwe, Karagita, Lake View, Larnet, Mwariki, Pipeline and Rhoda

Table 1 General water provision information in the study area (WASREB 2011)

Parameter	Nakuru Town
Total population in service area	674,789
Population served	472,352
Percentage of population served	70.0%
Number of metered connections	40,910
Non-Revenue Water (NRW)	47%
Average time to fetch water from nearest water point	1 h

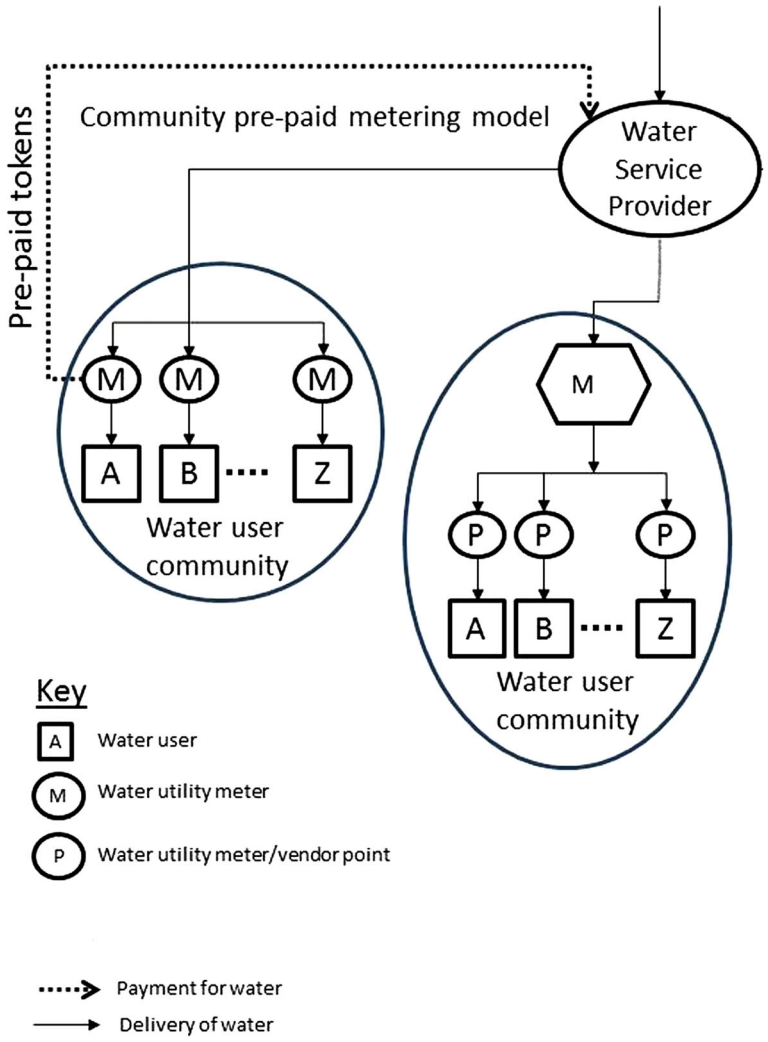

Fig. 3 Conceptual Prepaid Metering Model. The communal prepaid meters are activated using tokens that are bought from the water service provider. The tokens are uploaded with credit at designated pay-points and water users can draw water up to the amount credited in the token. There were 91 communal prepaid meters installed in the network in Nakuru. The prepaid meters were installed to improve the quality of water service delivery to 15,000 people in the nine low-income settlements in Nakuru

The samples for interviews included 260 households in Nakuru and 84 employees of the WSP, NAWASSCO. These samples were uniformly allocated throughout the 9 target slum areas. The interviews were administered using predesigned questionnaires. The questionnaires for household/water-vendor interviews targeted the following parameters: sources of income; monthly expenditures; potential savings; critical challenges (and opportunities) relating to access to water services. The questionnaires for interviews with WSPs focused on potable water, water coverage, and non-revenue water. Field visits targeted the frequency of outages in water supply and leakages in the distribution network. A market assessment was also designed and conducted to assess the urban poor's current water usage and consumption practices and the amount currently paid for those services, demand and willingness to pay for improved services, and the ability to take on financing for those services.

All together there were 7 field visits during the study. Focus group discussions (FGD) targeted overall community views on the study parameters with regard to water service provision. There were 6 FGDs.

Data analysis

Statistical analysis of the study parameters was done between with and without installed study metering models. One-way analysis of variance (ANOVA) was used to compare the means for each study parameter in an attempt to determine the impact of the communal prepaid meter in the study areas. Analysis was done at 5% level of significance.

Results

Perspective of the water users

60% of the Nakuru population lives in low-income settlements. Households paid an average of USD 0.08 per 20-l jerry can versus a connected household which pays USD 0.01 for 20 l. 16% of people obtained water from rain water, rivers, boreholes and other sources. 25% of respondents also purchased water from water vendors where the source and quality of the water was unknown. This suggests that the urban poor residents in Nakuru prior to the introduction of prepaid metering, preferred to access water from alternative sources of water, that were not of acceptable quality and when they did buy water from vendors, they were buying expensive water, for which there was a strong demand. Further to that, people paid more than five times as much for 20-l of water from vendors than consumers who were connected to NAWASSCO, and that the unknown source and quality of water had significant impact on people's general health and well-being. It was also observed that one key reason that people opted for alternative sources was because they found the water from NAWASSCO to be expensive, especially the start-up fees for new connections. Also, other identified reasons for using alternative sources were that at NAWASSCO, there was a high incidence of malfunctioning meters, inaccurate meter readings, and frequent outages that forced water users to seek the services of the expensive water vendors.

After the communal prepaid meters had been installed, 115 beneficiary households were surveyed to assess the project effect. The study focused on improvements in the ease of access, reliability and affordability of water, and provided a critical analysis of the benefits and challenges of the pre-paid meter system and customer satisfaction levels. A few of the key finding include that before the communal prepaid meters were installed, 67% of beneficiaries spent 1 h or more daily collecting water. The main reasons for the time spent to fetch water included long queues at the watering points, relatively long distances to the nearest cheap alternative source of water, and frequent outages at the nearest water point. After the installation, 92% spend less than 15 min collecting water (Table 3). This was because water was always available at the communal prepaid meters and that there were many well-managed prepaid meters in the area.

Perspective of NAWASSCO

NAWASSCO had high water coverage of 79% in the low income areas of the city (versus the national average of 45%). NRW at 45–49% was also considerably high in the low income areas. NAWASSCO had collections challenges with a collection ratio

of just 74%. However, critically looking at the finances of the water service provider, with annual sales of nearly USD 7,317,073 and annual profits of USD 303,537, (Table 2), they would be considered attractive to commercial banks who wanted to invest in financing water. This information suggests that the service provider was capable of taking on financing and had good pipe infrastructure coverage in low-income areas but had problems with collections, and needed to address the high NRW.

Household interviews with water users established that the cost of water was erratic and relatively high prior to the installation of the prepaid meters. After the installation of the meters, instead of paying an average of USD 0.08, consumers now pay USD 0.01 per jerry can (Table 3). For most households, this means a total monthly water bill of USD 3.23 (Trémolet and Hunt 2016). In addition, the consumer save time spent fetching water due to close proximity to water points and because NAWASSCO manages the number of tokens per meter to ensure minimal waiting time. To use the system, consumers first upload credit at NAWASSCO zone offices in the low-income settlements (Acolor and Adams 2013). The pre-paid meter system presents strong potential for commercially viability in delivery to the low-income settlements. Collections are 100%, with no provisioning for bad debts and no write-offs. A technology platform minimizes cash handling and fraudulent activities in the field. Paperless transactions also eliminate the need to print and post water bills, thus resulting in cost savings. Furthermore, existing staff manage the meters, and no meter reading and collections follow-up is needed. The investment allows NAWASSCO to recoup its costs in a timely and secure manner, thus presenting a sound investment opportunity to financial institutions.

Consequentially, NAWASSCO partnered with Family Bank, a local financial institution, and adopted the metafinance approach to finance the intervention in the low income areas. Individual cash flows are now pooled together to secure previously inaccessible high-value loans for communal benefit. As such, individual connections were provided to some customers, but in the low income areas, the introduction of communal prepaid meters gave opportunity to many customers to have access to water services, giving them access to affordable, clean, potable and reliable water. But for the larger part, the finances were used to install the communal prepaid meters. Finance Bank was selected partly because of their customer friendly mobile banking platform, in which Family Bank had integrated for paying electricity bills and was interested in doing the same for water. NAWASSCO now takes mobile payments from regular customers through the mobile platform.

Table 2 Summary performance indicators from NAWASSCO

	Nakuru	
	With CPM	Without CPM
Non-revenue water	14%	45–49%
Proportion of water outage	11%(± 2.1)	61%(± 3.3)
Incidences of network leakage	17% (± 1.1)	75%(± 2.4)
Compliance with KEBS standards	98%	95%
Annual Sales	USD 7,317,073	No records

Table 3 Summary mean performance parameters for water service provision

	Nakuru	
Performance parameter	Without CPM	With CPM
Non-revenue water	47%	14%
Cost of Water	KES 6.3 (USD 0.08) per 20 l	KES 1.2 (USD 0.01 per 20 l
Incidence of waterborne diseases	21% compliance (KEBS standards)	91% compliance (KEBS standards)
Time for fetching water	1 h	15 min
Potable water	95% compliance (KEBS standards)	100% compliance (KEBS and WHO standards)
Coverage	79%	92%

Performance evaluation of NAWASSCO

Mean non-revenue water (%) was higher in areas without the communal prepaid meter than in areas where the metering models were installed (Table 3). Non-revenue water (NRW) is the amount of water produced for which revenue is not received (Liemberger and Wyatt 2018). NRW is usually caused by factors such as water losses from leaky pipes, malfunctioning meters that charge too little, vandalism of water distribution network, or due to illegal connections to the water network. Water coverage is the proportion of a population that has been served with potable water for more than 20 h a day. 75% coverage in an area is generally considered to be an indication of high performance (Collignon and Vezina 2016). In this study, the areas without the communal prepaid meter, the CPM surpassed the 75% water coverage mark and could be considered to have had high performance in terms of water coverage.

In Nakuru, CPM areas had NRW which was 70% lower than in areas without CPM and 80% lower in cost of water per 20 l than in areas without CPM. These comparative results suggest better management of water supply in the areas with installed CPM. Since the water users improved their stake in the water supply management through prepayment, they more or less shared the management responsibilities by protecting the distribution network. Perhaps this also contributed to the low NRW and eventual improved network management in the CPM model. Furthermore, the water distribution network seemed better than areas without CPM going by the reduced time for fetching water by 75% (Table 3). Overall, the low NRW and time for fetching water in CPM areas gave the impression of improved coverage and efficiency in water supply.

An analysis of variation between the cases with- and without-installed communal prepaid metering at 5% level of significance showed that communal prepaid meters had significant positive difference on the water service provision performance when compared to areas that did not have the meters. It was also established that while there was some positive impact on water coverage, the CPM seemed to have had more positive impact on the cost of water, financing options and time for fetching water from the nearest water point.

Discussions

The results from this study showed that although communal prepaid metering can potentially improve the quality of water service provision, much improvement can be realized if financial options are supporting such interventions. The CPM enforces a sense of water use efficiency on the part of consumers because the water user must settle

their water bills in advance. Water meters also help water service providers to quantify the amount of supplied water to the consumer, which is eventually useful in planning water budgets (Van Zyl 2011). However, the water meter alone is not enough in managing water provision. Water users need to be content that the bills from the water meter readings truly represent the actual water used. They must also be able to afford what they are being billed. Prepaid water metering is one way of building trust with the water users on water billing. The water users not only ensure commensurate water bill with consumption, they are also ingeniously incorporated in the water management through their active involvement in monitoring the water use and billing (Heymans et al. 2014). In this study, the communal prepaid metering model came out as a viable tool for managing the cost of water. Although there have been discussions for and against the use of prepaid meters in the literature (von Schnitzler 2008), the management of communal prepaid meters in particular, seem to have some positive impacts on water cost and water-user trustworthiness of the water bills.

One of the goals of WSPs as business entities is to attain adequate customer satisfaction. This can be assessed through sufficient water coverage in demand localities, and reduced time for getting water access (Gallego-Ayala et al. 2014). Comparing the performance of the CPM with areas where conventional metering is used, this study has demonstrated remarkable improvements in water coverage and reduced time for fetching water.

Non-revenue water in water supply is caused by a number of contributors. They include unmetered consumption, inaccuracies in registration of water meters, illegal consumption, and water tariffs, among others (Liemberger and Wyatt 2018). These are brought about by vandalism, illegal connections, poor meter management, or lack of metering. Vandalism/and or physical loss of supply network also occasion intermittent water supply and water rationing especially during network shutdown for repair works. There could be chances of contamination entering the network during shutdown or through leakages. The endeavor of WSPs is to minimize non-revenue water in order to make profit. Lowering NRW also has the potential of increasing water quality since the avenues of contamination are reduced (Van Zyl 2011). The high improvement in lowering NRW (Table 3), shows that the network management factors driving NRW can be partially addressed using communal prepaid metering.

It was observed that the metafinance approach made economic sense for those who wanted individual connections and couldn't afford the new connection costs. For the bank, issuing out one loan to NAWASSCO proved to be more effective than to making multiple individual loans to the end consumers. After all the elements of market research and the business analysis, and community education and outreach and been done, individual connections were provided to some customers, but in the low income areas, the metafinance option was not relevant and the introduction of communal prepaid meters gave opportunity to many customers to have access to water services, giving them access to affordable, clean, potable and reliable water.

Conclusions

This study analyzed community prepaid water metering (CPM) in which water meters are preloaded with tokens that are used up to the loaded amount in comparison the conventional water metering where meter readers visit the meters once a month to

collect the readings for post-billing. Prior to the installation of the CPM, there were many service provision challenges such as low water coverage, high non-revenue water, time to fetch water and high and erratic water bills. In effect, the water users and water service providers were not well served. The CPM was portrayed with positive improvements in water provision focusing on the water users and water service providers. The CPM had positive impacts on the cost of water, NRW, coverage and time to fetching water from the nearest water point. This transformation has the potential to dramatically improve the quality of water service delivery and to improve the financial performance of water service providers.

It's recommended that the CPM model used in this study be tested further and more individual strengths drawn. They can also be widely tested in situations where the main water provision challenges are similar to those that are portrayed in this study as model strong points.

This metafinance approach demonstrates the possibility of win-win partnerships among financial institutions, water service providers and consumers who want individual connections, but for low-income consumers, the CPM is more effective in helping the urban poor access water services.

Abbreviations

ANOVA: Analysis of Variance; AWTF: Africa Water Task Force; CPM: Communal Prepaid Meter; FGD: Focus Group Discussions; NAWASSCO: Nakuru Water and Sanitation Services Company; NRW: Non-Revenue Water; SUWASA: Sustainable Water and Sanitation in Africa; UN-DESA: United Nations Department of Economic and Social Affairs; USAID: United States Agency for International Development; USD: United States Dollar; WASPA: Water Service Provider Association; WASREB: Water Services Regulatory Board; WSP: Water Service Provider; WSTF: Water Services Trust Fund

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Availability of data and materials

Whereas data sharing not applicable to this article as no datasets were generated or analyzed during the current study, more information can be found on https://www.usaid.gov/news-information/frontlines/water-neglected-tropical-diseases/can-water-meters-ease-kenyas-supply, http://www.tetratech.com and http://www.developinnovations.com/Programs/Financial-Services-for-the-Poor.aspx#KenyaII

Authors' contributions

This research article had two authors, and their individual contributions are described as follows: RH conceptualized the study, was key in fund acquisition, participated in the design of the study and performed the statistical analysis, wrote the original draft manuscript and is responsible for submission. CO helped in designing the study, validated the data, helped in data cleaning, write reviewing and editing the draft manuscript as well as supervising the whole study. Both authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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