Research Paper

Assessing the short-term outcomes of a piped water supply intervention in peri-urban Mozambique

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ABSTRACT

We use data collected as part of a baseline survey in 2012 and a survey 5 months post-intervention in 2014 to assess the short-term outcomes of a water supply intervention in Ribáuè, Mozambique. This intervention included the rehabilitation and expansion of a piped water system, revitalization of water committees, and creation of and capacity building for small-scale private water enterprises. Quantitative results suggest that the intervention led to an immediate significant increase in the use of piped water supply at the expense of unprotected wells and other non-revenue generating forms of unimproved water supply with more than a 2.5-fold increase in the usage of yard taps and water kiosks/standpipes and a two-fold decrease in the use of unprotected wells. Family water consumption also increased by approximately 40 L/d, and the point-of-use treatment of water nearly tripled. Economic opportunities were generated for business and small enterprise owners due to the new water supply infrastructure, and piped water infrastructure had additional positive effects for both public and private sanitation facilities.

Key words | impact assessment, Mozambique, statistical survey methods, water supply

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INTRODUCTION

Water supply in Mozambique: a snapshot

Over the past 20 years, Mozambique has slowly but steadily improved its water supply with the Joint Monitoring Programme (JMP) estimating more than a two-fold increase in access to improved water supply from 2000 (26.8%) to 2015 (61.6%). As with many developing countries, however, the disparity between urban and rural areas in accessing improved water supply remains significant with the most recent JMP estimates (2015) placing access to improved water supply in Mozambique at 48.8% for rural areas as compared to 88.4% for urban areas (Joint Monitoring Programme 2017).

To address the chasm between rural and urban areas in terms of access to improved water supply and sanitation (WSS), in 2010 a joint partnership of the Government of Mozambique (GoM), aid partners, non-governmental organizations (NGOs), the private sector, and local, district, and provincial stakeholders established the National Rural Water Supply and Sanitation Program (PRONASAR) to operationalize the Strategic Plan for Rural Water Supply and Sanitation (2006–2015). PRONASAR aimed to increase access to improved water supply to 70% by 2015. At the time, the GoM estimated that it would require the rehabilitation or construction of 12,000 water points and 120 small-scale water supply systems to reach the target for rural water supply (Government of Mozambique 2010). This was indicative of the infrastructure deficiencies of the country as a whole at the time, with Domínguez-Torres & Briceño-Garmendia (2011) reporting Mozambique's infrastructure needs as being among the highest in Southern Africa.

Between 2008 and 2010, approximately 85% of sector investments came through official development assistance (World Bank 2012), while WSS investment by the GoM accounted for only 4.7% of the 2011 budget (Development Finance International & WaterAid 2014). Donor investment for WSS projects in Mozambique has favored the southern provinces, but the central and northern provinces have greater WSS deficiencies and more rural characteristics. With this in mind, UNICEF Mozambique approached the Government of Australia (GoA) to jointly fund the Small Towns Water, Sanitation and Hygiene Programme in Nampula (NAMWASH) with UNICEF and the GoM. Nampula Province is situated in the north and is the most populous province with an estimated 6.1 million inhabitants as of 2017 (Instituto Nacional de Estatística 2017). It rates poorly in access to the improved water supply with only 38.5% of households having accessed to improved forms of water supply (mainly public boreholes and standpipes) according to the most recent provincial estimates (Instituto Nacional de Estatística 2010b).

Nacala Corridor driving population growth

From 2010 to 2014, Mozambique had one of the fastest-growing economies in Africa with gross domestic product (GDP) growth of more than 7% every year, due, in part, to revenue from natural resources with associated rents comprising an average of 14.98% of GDP over the period (World Bank 2015). Natural resources, especially mineral resources, oil, and gas, have provided significant economic boosts to many countries in sub-Saharan Africa and are frequently associated with rapid population growth and pressures on basic social infrastructure in nearby communities (Australian Bureau of Statistics 2007; Petkova *et al.* 2009; Carrington & Pereira 2011).

Admiraal *et al.* (2017) note that population growth and pressures associated with mining activities extend well beyond the general vicinity of the mine site due to infrastructure development to support the mining operation and transportation of the minerals. A prime example of this is the town of Ribáuè in Nampula Province. Ribáuè is situated along the Nacala Economic Corridor, a region of significant growth in northern Mozambique due to its integration in an economic accelerated development zone (Kirk 2015). The Nacala Economic Corridor has aimed to create linkages between development hotspots and the city of Nacala, including road and rail projects to transport coal from Tete and Niassa Provinces in the east of the country to the deep-water port of Nacala as well as to satisfy the transportation demands of inland neighboring countries, particularly Zambia and Malawi. There have also been major agricultural projects along the Nacala Corridor, including the Triangular Co-operation Programme for Agricultural Development of the Tropical Savannah in Mozambique (PROSAVANA), and the Green Belt Initiative in Malawi (Africa Development Bank Group 2016). In 2014, the Nacala Corridor saw major railway expansion and road rehabilitation near Ribáuè, producing an influx of jobseekers. The Mozambican National Statistics Institute projects that Ribáuè will more than double in population size over the next 25 years (Instituto Nacional de Estatística 2010a), and this growth would be anticipated to present a major challenge for the town's water supply and water supply infrastructure.

Small Towns Water, Sanitation and Hygiene Programme in Nampula

Due to its anticipated rapid growth, Ribáuè was selected to benefit from WSS interventions through NAMWASH. NAMWASH was jointly funded by the GoA, UNICEF Mozambique, and the GoM, and implemented by UNICEF Mozambique, the Mozambican Administration of Water Supply and Sanitation Infrastructure (AIAS), and the Provincial Directorate of Public Works and Housing of Nampula. The program ran from January 2012 to June 2014 and specifically considered five towns (Ribáuè, Rapale, Mecubúri, Namialo, and Monapo) along the Nacala Corridor.

Planning for the piped water system to be delivered to Ribáuè began in June 2012. UNICEF Mozambique commissioned a baseline study of households, schools, and water points in the five towns to establish pre-intervention conditions in terms of WSS in order to better assess the impact of the interventions (Admiraal & Doepel 2014). The baseline survey of 1,610 households was carried out across these five towns as well as two 'control' towns (Liúpo and Namapa-Eráti) that were not to benefit from NAMWASH in order to understand their WSS profiles. This survey also measured households' preferences for various forms of water supply as well as willingness and capacity to pay for these forms of water supply.

Under NAMWASH, only Ribáuè received a significant upgrade in terms of water supply. Consequently, we restrict our focus to the outcomes of the interventions carried out in Ribáuè. To reduce operation and maintenance (O&M) costs for piped water supply infrastructure, the NAMWASH programme team opted to build a gravity-fed system, which involved the rehabilitation of a dam in nearby mountains, the rehabilitation of a water tower in the town center with a capacity of 100 m^3, the laying of 5,000 m of 250 mm diameter pipe for the main pipeline, and 11,000 m of 50–200 mm diameter PVC pipe for the distribution network, and the construction of a rapid filtration water treatment plant with chlorine dosing equipment. Implementation was concluded in June 2014 with the completion of the piped water system and turnover to the water regulator and the private operator.

In Ribáuè, the rehabilitation and improvement of the piped water supply system aimed to provide direct connections to households through yard taps and businesses and public services (hospital, local government and local council) through direct connections. Water kiosks were also constructed for small-scale private water enterprises. We present selected results on short-term outcomes of this intervention, focusing solely on piped water supply and associated economic opportunities.

METHODS

Study design, sampling, and research tools

To assess the outcomes of NAMWASH, in November 2014, researchers from Murdoch University and the University of Eduardo Mondlane carried out fieldwork in the towns of Ribáuè and Liúpo (control town in the baseline survey) and the city of Nampula in northern Mozambique. This research was funded by the GoA. For Ribáuè, our study included household surveys (495), surveys of water points (35) and public sanitation facilities (11), and key informant interviews (13). For a sampling of households, we used multi-stage cluster sampling based on enumerations areas (EAs), consistent with the NAMWASH baseline survey (WE Consult 2012). A random sample of EAs was obtained with 15 households per EA selected using systematic random sampling. The number of households to be sampled was calculated using sample size calculations specified in Barrington & Admiraal (2014), leading to a target of 495 household surveys to ensure location-specific inference. To guarantee comparability with the NAMWASH baseline survey, we excluded EAs that fell in regions further away from the Ribáuè town center than areas sampled under the 2012 baseline survey.

The household survey was composed of three sections. The first section aimed to collect the demographic and socioeconomic profile of the household. The second section focused on the water situation (access, use, quality, storage methods, waiting times, and costing), sanitation situation (access, use, quality, and cleaning practices), and hygiene knowledge and practice of the household. The last section assessed respondents' willingness to pay for piped water supply and fecal waste removal services. The household survey was translated into both Portuguese and Makhuwa (local dialect) and administered by 30 enumerators under the supervision of eight supervisors over 3 weeks in November 2014. Enumerators worked in male–female pairs that changed on a daily basis. Enumerator and supervisor training and piloting of the survey were carried out over a span of a week prior to the commencement of fieldwork.

Semi-structured interviews were conducted for key informants (e.g., kiosk operators, directors of health centers/hospital, and local entrepreneurs) and the private operator of the new small-scale piped water system in Ribáuè. All interviews were audio-recorded and partially transcribed and translated from Portuguese into English to conduct a thematic analysis. Follow-up interviews with the private operator of the piped water system were conducted in June and July 2015 in order to assess recent changes and solutions found to previous issues.

Data entry used CSPro (United States Census Bureau 2018) and was carried out by eight individuals with in-depth knowledge of the survey under the supervision of a dedicated supervisor, who carried out quality control on a random selection of at least 20% of surveys per individual. Data cleaning and analysis were carried out using R (R Core Team 2018).

Human ethics approval for research was obtained from both Murdoch University (2013/184) and the Mozambican Ministry of Health Bioethics for Health National Committee (307/CNBS/14).

RESULTS AND DISCUSSION

As part of NAMWASH, Ribáuè benefitted from the rehabilitation and expansion of its piped water system. This work was completed in June 2014, and as of December 2014, the piped network delivered water to households through approximately 170-yard taps, 10 water kiosks, two standpipes, direct connections to 14 businesses, and 31 connections to public services and the local council. Figure 1 provides a comparison of primary water point usage in September 2012 (NAMWASH baseline) and November 2014. It shows a 2.5-fold increase in usage of yard taps and a three-fold increase in usage of water kiosks/standpipes at the expense of unprotected wells, which saw a two-fold decrease in usage. Between December 2014 and July 2015, the private operator installed additional 220-yard taps (representing a 290% increase in yard tap customers from June 2014) and also rehabilitated two standpipes.

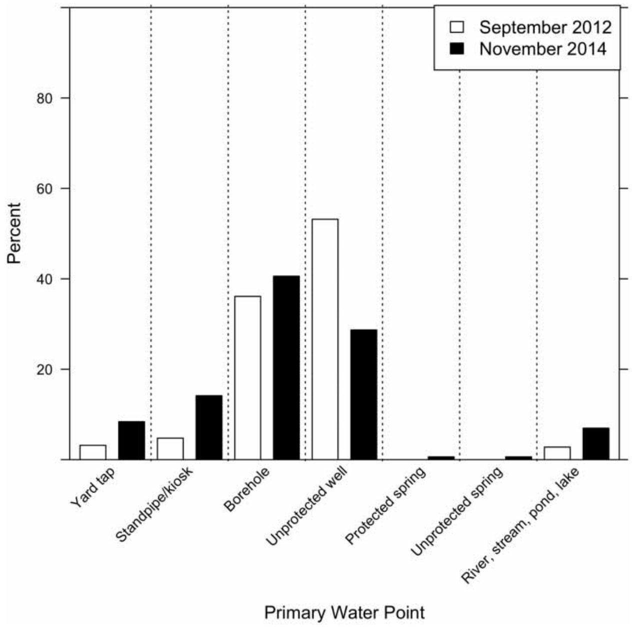

Figure 1 | Reported primary water point usage in Ribáuè in September 2012 and November 2014.

Accompanying the improvement to Ribáuè's water supply was a significant increase in household water consumption. In September 2012, households in Ribáuè reported consuming an average of 71.33 L/d (95% CI: 69.24, 73.42). In November 2014, households reported consuming an average of 111.07 L/d (106.79, 115.35), or 22.37 L/d (20.81, 23.93) per capita, an increase of roughly two 20 L jerrycans per household. By comparison, Liúpo saw household water consumption remain stagnant from 2012 to 2014 (approximately 75 L/d for households and

15 L/d per capita). This increase in water consumption in Ribáuè is important because studies have shown that, as water consumption increases, much of the additional water being consumed goes toward hygiene purposes, leading to improved health outcomes (Cairncross & Valdmanis 2006). Some of the improvements in water consumption do not supplant the fact that the reported water consumption still falls well below Howard & Bartram's (2003) recommendation of 50–100 L/d per capita.

Additionally, mean queue times for water kiosks (1.22 m [0.93, 1.53]) and boreholes (7.25 m [4.11, 10.38]) were manageable and more than five times shorter than what was observed for Liúpo (40.56 m [29.41, 51.70]). Queue times by location for boreholes and kiosks/standpipes in Ribáuè are presented in Supplementary Figure S1 (available with the online version of this paper).

The level of the point-of-use (POU) treatment of water in Ribáuè also increased from an estimated 10.71% (6.89%, 14.54%) of households in 2012 to 28.51% (24.53%, 32.49%) in 2014. The POU treatment of water has not only been shown to be substantially more effective than point-of-entry treatment in reducing incidence of diarrhea (Fewtrell *et al.* 2005; Clasen *et al.* 2006), but also by far the most cost-effective form of WaSH intervention (Varley *et al.* 2002; WHO 2002; Cairncross & Valdmanis 2006; Clasen *et al.* 2007; Haller *et al.* 2007; Hutton & Haller 2007).

For those using piped water in Ribáuè, a common initial complaint was the high cost. Households with yard taps, kiosk operators, and business owners alike commented on the high price of piped water, and part of this dissatisfaction may be residual effects from water not being charged for these users until August 2014. Because water was free until August, this resulted in unchecked water use during the preceding months and high bills for the first month that water was charged. Additionally, households only had, as a frame of reference, the low cost of drawing water from a borehole (MZN 5–25 per month). In spite of complaints about high water costs and struggles to pay initial bills, the water system operator reported that only 7.69% of households and one kiosk operator were in arrears as of July 2015, suggesting that households learned to adapt their monthly consumption of piped water to a volume they could afford. Furthermore, uptake of yard taps steadily increased between November 2014 and July 2015, suggesting that costs were within households' willingness and capacity to pay.

Another issue identified by households was poor water quality. This was noted as a significant issue for 21.21% of yard tap users and 16.22% of water kiosk users but only 6.64% of borehole users. Interviews with users of piped water suggested that the negative assessment was due to water color. Issues with water color are significant because the predominant criterion used by residents of Ribáuè to assess whether water is safe to drink was water clarity (86.44% of respondents). Despite these concerns, microbiological and chemical analyses of water at the source and the furthermost water point showed it to be safe to drink. However, some businesses went so far as to revert back to boreholes for drinking water. In response to issues with the water color, the water operator increased its cleaning of filters to twice a day, and follow-up interviews with kiosk operators and local businesses in July 2015 suggested a substantial improvement in water clarity since November 2014 and a higher degree of satisfaction with water quality. Businesses that had previously suspended their use of piped water reported having resumed using it as their primary water source.

Economic opportunities due to piped water

Economic development driven by the extractive industries led to significant construction-related activity near Ribáuè, placing pressure on local accommodation and hospitality whose infrastructure and quality standards had previously served only occasional travelers. Interviews conducted with local businesses indicated that important economic opportunities resulted from piped water availability. Many construction contractor agreements with owners of accommodation have stringent requirements for ensuring uninterrupted clean water piped to rooms, so water piped to local accommodation establishments opened the door for lucrative contracts. The presence of piped water also allowed for flush toilets in accommodation establishments, restaurants, and residences.

Water kiosks rather than standpipes were decided as components of NAMWASH largely based on the German Development Corporation's success in introducing them to neighboring Zambia. In Zambia, the implementation was facilitated through multi-donor basket funds that provided pro-poor funding to commercial utilities, implementation support, and post-implementation monitoring (Klawitter *et al.* 2009). NAMWASH had no post-intervention funding or support for water kiosk owners in Ribáuè, in contrast to the initial training and on-job supervision for kiosk operators in Zambia. Interviews with Ribáuè's kiosk operators suggested that profitability from water was low for most kiosks, and this was compounded during the wet season when demand decreases. Low profitability can be partially explained by many kiosks competing with functional boreholes in close proximity, as demonstrated in Supplementary Figure S1. The difference in price between kiosks and boreholes can be substantial, with households using a kiosk as their primary water point reporting a median monthly water expenditure of MZN 150 as opposed to MZN 20 for borehole users. Even using the minimum of 15 L/d per capita recommended for emergency situations (The Sphere Project 2011), for the average family in Ribáuè (approximately five people), using water sourced from a kiosk would more than double their monthly expenditure (MZN 57 per month for water sourced from kiosks versus MZN 5–25 per month for water sourced from boreholes). When comparing reported income and primary water source, the poorest use mainly unimproved water sources, as would be expected (Table 1).

Although kiosks are more expensive to construct than standpipes, they provide added protection for water infrastructure, and they provide the opportunity to generate income from both water and household goods. The ability to sell goods in kiosks can offset low-profit margins from water, helping to ensure that kiosks remain viable. In Ribáuè, the economic opportunity from water kiosk ownership faced several initial constraints. This included lacking the initial capital to stock kiosks with goods. Solutions such as small loan schemes with affordable repayment plans for new kiosk operators could potentially address this, as could rotating savings and credit associations, which have worked successfully in Kenya and Ghana (Montgomery *et al.* 2009). Those interviewed also demonstrated a range of kiosks operators' profiles and levels of management skills, highlighting the need for initial capacity building for business management and on-the-job training, as per the Zambian model.

Table 1 | Reported monthly family income (in MZN) by primary water source usage in Ribáuè in November 2014

	Median	Mean	Std. Dev.
Yard tap	3,000.00	4,653.44	4,306.58
Standpipe	2,500.00	3,127.60	2,874.86
Borehole	2,600.00	4,776.78	10,117.34
Unprotected well	1,500.00	2,382.18	2,307.21
River	1,520.83	2,933.93	2,800.88
Neighbor's tap	1,010.42	3,567.71	5,648.34

CONCLUSION: REACHING THE URBAN POOR AND ENHANCING SERVICE DELIVERY

The NAMWASH intervention produced important short-term outcomes in Ribáuè. Most notably, these included a roughly 50% reduction in the use of unprotected wells and a significant rise in the use of piped water supply with 8% of households using yard taps and 14% using water kiosks within the first 5 months of introducing new piped water supply. Water consumption increased by roughly 40 L/d per household, and POU water treatment also increased nearly three-fold. There were also new economic opportunities created for local accommodation and hospitality establishments and, to a lesser extent, water kiosk vendors.

Reintroduction of piped water did not come without its issues. Residents of Ribáuè complained that the cost for piped water was high relative to boreholes. It would be advisable that decisions of where water kiosks/standpipes are located be based on criteria such as borehole proximity, accessibility, willingness, and capacity to pay. As highlighted by those with yard taps, unchecked water usage due to water not being charged for the first several months led to bill shock when it finally was charged, and many believed the water to be unsafe to drink for a period when there were issues with water coloration. With the introduction of new water supply entities (small-scale piped water system operator and kiosk vendors), the mechanisms for effective communication and coordination between organizations and with users about water supply, quality, billing, and complaints/feedback must be considered in advance as a priority. Interventions should also seek to incorporate training in business management and budgeting (in this case, for both the water system operator and kiosk vendors) as well as provide mechanisms for securing start-up funds (in the case of kiosk vendors).

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