http://dx.doi.org/10.1016/j.exis.2017.01.014

Admiraal, R., Sequeira, A.R., McHenry, M.P. and Doepel, D. (2017) Maximizing the impact of mining investment in water infrastructure for local communities. The Extractive Industries and Society, 4 (2). pp. 240-250.

Title:

Maximizing the impact of mining investment in water infrastructure for local communities.

Abstract

Mining activities requiring the development of new or expansion of existing water infrastructure provide an opportunity to benefit local communities with limited access to clean water. Mining companies have commonly assisted water service provision to communities as part of their mining concession or through corporate social responsibility programs. In addition to the water infrastructure provided to local communities, the accompanying capacity building, infrastructure governance, and the consultation process all have notable impacts not only on the sustainability of the water infrastructure, but also the level of benefit to communities. Using recent Australian Government funded water and sanitation interventions along the Nacala Economic Corridor (Mozambique) as a case study, we provide an examination of how mining companies can most effectively ensure the delivery of sustainable water infrastructure to local communities.

Keywords: *water supply, service delivery, sustainability, guidelines*

1. Introduction

A recent publication by the World Health Organization (WHO) emphasized the importance of a renewed focus on increasing access to safe water and improving sanitation and hygiene practices to combat a number of tropical diseases. The publication noted that prioritizing access to improved water supply, sanitation, and hygiene (WaSH) would be expected to not only have significant positive effects for health but also be instrumental in reducing poverty (WHO, 2015). The health impacts of access to improved WaSH are well understood with diarrheal diseases being the third leading cause of death in the WHO Africa Region and fifth leading cause of death in the WHO South-East Asia

Region, regions that are generally characterized by the lowest levels of access to improved WaSH (WHO, 2014). Mortality rates for children are disproportionately higher for such diseases, which rarely result in death in developed countries. The economic benefits of improved WaSH are also substantial with savings in terms of health costs alone making investment in WaSH cost-effective, particularly in those regions where diarrheal diseases are a leading cause of death (Evans et al., 2004). Additionally, less time missed from work, greater educational opportunities, and other indirect benefits from access to improved WaSH increase earning potential for individuals (Bartram et al., 2005).

1.1. The health impacts of access to clean water

The WHO / UNICEF Joint Monitoring Programme estimated that, as of 2012, "more than 700 million people still lack ready access to improved sources of drinking water; nearly half are in sub-Saharan Africa" (Joint Monitoring Programme, 2014). For the sub-Saharan Africa region, it was estimated that 36% of households rely on unimproved water sources for water supply with this being broken down between surface water sources (such as rivers, streams, and lakes) at 12% of households and other unimproved sources (such as unprotected wells or springs) at 24%. Only an estimated 16% of households have water piped to the premises. The small percentage of households with water piped to the premises is important, as Pickering and Davis (2012) claim that water infrastructure improvements that do not deliver water near the home will be unlikely to engender health and sanitation benefits to children under five years of age. Schmidt et al. (2009) found that use of soap or ash increases with use of water points in closer proximity to households as well as with targeted media messages, and piped water at the household has been found to lead to an increase in washing hands at key moments (e.g. after defecating, before preparing food, before eating or serving food) for young mothers (Curtis et al., 1995). Cairncross and Valdmanis (2006) argue that provision of a public water point has little if any impact on health, regardless of the water quality of the water point it is replacing. However, simply by moving the water point within close proximity to the house (and particularly within the yard confines or the home), significant health benefits occur with a substantial reduction in incidence of diarrhea, which is commonly caused by Salmonella or E. coli. The explanation for this improvement in health is the relationship between water consumption and time spent collecting water. Pickering and Davis report that approximately 44% of the global population (mostly women and children) must travel to fetch water for drinking and domestic use, causing a massive physical and time burden. The time burden has indirect implications for health, as long travel times are associated with decreased water consumption (White et al., 1972; Feachem et al., 1978; Thompson et al., 2002; Wang and Hunter, 2010; Subaiya and Cairncross, 2011). Cairncross and Valdmanis (2006) found that, as water consumption increases, much of the additional water being consumed goes toward hygiene purposes (such as handwashing, cleaning, or bathing), and Moe and Rheingans (2006) argue that increased water consumption is more important than improved water quality in achieving effective hygiene and leading to greater prevention of many diseases (including shigellosis, trachoma, and scabies). In general, the closer and more convenient the water source is to the home, the more likely that effective sanitation and hygiene will be the norm. In particular, using data from the Demographic and Health Survey for 26 sub-Saharan African countries, Pickering and Davis (2012) found that a 15 minute reduction in one-way walk time is associated with a 41% average relative reduction in incidence of diarrhea prevalence, improved nutritional status, and an 11% relative reduction in mortality for children under the age of five; a benefit comparable to water disinfection and hygiene promotion programs.

1.2. Mining activity and resulting pressures on water supply

For mining companies operating in developing countries, mining activity frequently occurs in rural areas where nearby communities tend to have lower socio-economic status and poorer health conditions, in part due to insufficient access to clean water (and particularly piped water to the home). Even in areas where access to clean water is sufficient, mining and associated economic activity can lead to rapid population growth (Australian Bureau of Statistics, 2007; Petkova et al., 2009; Carrington and Pereira, 2011), placing significant pressure on existing water infrastructure. This population growth oftentimes extends well beyond the general vicinity of the mine site due to infrastructure projects (such as roads or rail) accompanying mining. For example, in Mozambique the shallow water port of Beira has limited capacity for increasing mineral outputs, especially coal, from mining activity in Tete Province. To address this limited capacity, Mozambique developed the Nacala Corridor and the deep-water port of Nacala, which can better accommodate large vessels for bulk cargo. Road and rail construction along this corridor to facilitate the transport of mineral resources to the port has generated economic opportunities in small towns along the corridor, and accompanying this economic opportunity has been significant population growth. In the town of Ribáuè (pop. 26,000), which falls along this corridor and has seen significant rail and road works in recent years, roughly 8% of households surveyed in November 2014 reported having moved to Ribáuè within the past three years specifically for work, and it is estimated that Ribáuè will grow by 140% over the next 25 years, a rate significantly higher than the estimated growth rate of 63% over the same period of time for the province as a whole (Instituto Nacional de Estatística, 2010).

At the same time, because mining is often a water-intensive endeavour (Szyplinska, 2011), particularly for lower grade ores (Business Monitor International, 2011; Global Water Intelligence, 2011), it has the potential to affect water availability (through reduction of surface water availability or lowering groundwater levels) and quality (through contamination of water supply). In addition, mining may lead to involuntary resettlement of communities, in which case the site selection of resettlements has been crucial in relation to water availability. Oxfam has identified a number of critical factors that should be considered when examining the suitability of any candidate resettlement location, and, as would be expected, one of the key factors is the availability of clean water. In the Mozambican context, these factors have not always been appropriately considered, however, as evidenced in reports by the Human Rights Watch (Varia, 2013) and Southern Africa Resource Watch (Kabemba, 2012). One of the cases highlighted in these reports is the Benga Coal Mine and resettlement of families to Mualadzi. In fieldwork carried out by Oxfam Australia in Mualadzi in November 2014, households noted that water availability from the nearby river is seasonal, and only four of eleven electric pumps used to supply water to the town were functional, leading to water shortages for not only livestock but also households (Lillywhite et al., 2015).

1.3. The role of mining companies in delivery of water supply to communities

Investment in water infrastructure for local and other impacted communities is an important consideration for mining companies. This should be the case when clean water is scarce in close proximity to mining operations and mining operations may be anticipated to lead to rapid population growth, placing an increased strain on water infrastructure and potentially impacting on available local water capacity. It is also an important consideration when mining activities lead to resettlements. Investment in water infrastructure can occur directly from mining companies as part of corporate social responsibility projects integrated in local social and economic planning or through negotiations with the government where a portion of mining royalties is earmarked for investment in water infrastructure for local communities or communities affected by associated infrastructure projects. Although the private sector may consider investing if it is possible to supply water profitably, securing private investment may still require some form of investment on the part of mining companies or the government. Budds and McGranahan (2003) suggest that rural and peri-urban areas (which are the areas most significantly impacted by mining operations) tend to be unattractive investment destinations for private WASH projects unless they are bundled with other utility services, as the rate of return otherwise would be anticipated to be too low to make investment worthwhile.

Mining companies may view such investments as an additional financial burden that should not be their responsibility given the substantial royalties or taxes they already may pay. However, in many cases existing water infrastructure in local communities is insufficient for mining needs, meaning that mining projects increasingly must invest in water infrastructure to meet their own needs. Over the period of 2011 to 2014 it is estimated that global spending on water infrastructure for mining will have doubled from $7.7 billion USD per annum to $13.6 billion USD (Thomas, 2012). This spending on water infrastructure accompanying mining activity during the development and production phases can be a catalyst for improving water situations for local communities, and Toledano and Roorda (2014) explore the opportunities that exist when mining companies share this water infrastructure with local communities. Thus, investment in water infrastructure by mining companies can lead to substantial benefit for local communities for an incremental increase in spending on the part of the mining company, government, or private investors, and it would be practically and politically prudent to explore such opportunities. While the mining company may secure the water that it requires, the local community may fail to receive clean water in sufficient quantities or through infrastructure appropriate for the area; and blame for this failure is frequently misplaced on the mining company. Both as a means of preserving reputation and as a recognition of access to clean water being a basic human right (as formally recognized in 2010 resolutions by the United Nations General Assembly [2010] and the United Nations Human Rights Council [2010]), mining companies should have a vested interest that clean water is effectively delivered to communities they impact, and it would be anticipated that investments in potable water supply delivery would engender goodwill with these communities.

Indeed, since colonial times, private water supplies provided by mining companies to many communities in regions of Africa evolved in the early days from bulk water for general requirements to a basic level at a centralised level (ensuring the mine water supply/operations were prioritised), towards entrusting and encouraging local authorities with expansion, geographical distribution, and development of a greater water supply system (Kazimbaya-Senkwe and Guy, 2007). Research by Kazimbaya-Senkwe and Guy (2007) noted the historical involvement of mining in water supplies in the Zambian Copperbelt, where early underground mining company dewatering infrastructure became de facto private water companies serving domestic water supplies in mining towns, and where mining pumps, tanks, and dams provide additional water supply capacity. The authors describe how these early Zambian Copperbelt mining companies chose to limit the town water service provision at a certain level yet remain engaged to ensure the local authorities and communities all understood their differentiated responsibilities to sustain, expand, and improve the service above and beyond the mining company service provision.

The long-term sustainability of provided water supply is vital, and Improve International (2015) maintains a partial list of statistics related to non-functional water points or frequent water point breakdown in developing areas. These statistics paint a sobering picture of a developing world landscape littered with unreliable and derelict water points; testaments to decades of well-intentioned but failed attempts to provide water to communities that are desperately in need. These failures may imply that the water sector is an unreliable destination for investment in the developing world (Ryan, 2014), but more often they reflect an overly simplistic approach in addressing the complexities of water delivery in the developing context. In particular, simply delivering infrastructure is not sufficient, and it is essential to understand the factors that influence sustainability of water supply for communities.

Cobbing et al. (2014) provide an in depth examination of issues with the management of groundwater supply in South Africa, and they note that "poor understanding of the resource and a failure to translate groundwater data into management actions can result in groundwater sources failing and continuity of water supplies being put into doubt. The situation is often exacerbated by poor communication and misunderstanding between the various interlocking organisations tasked with water supply management." Further, a failure to adequately understand the financing required for ongoing operations and maintenance (O&M) sometimes means that the balance between capital expenditure and O&M is not sufficient to guarantee the long-term viability of provided water infrastructure. They ultimately concluded that both inadequate funding and capacity for O&M were largely responsible for the lack of sustainability of groundwater supply in South Africa.

In this paper we present a series of considerations when delivering water supply to local communities. These considerations aspire to guarantee a sustainable service delivery and include:

- Compile available water sources, existing supply, and local capacity;
- Understand local preferences for water supply and management;
- Enhance governance, ongoing local capacity, and adaptive management;
- Ensure the water market is stimulated; and
- Ensure future planning for appropriate water supply, expansion, and repair.

We do not presume that this is an exhaustive list of guidelines but rather treat this as a minimal checklist that can be applied to almost any case of water delivery. Note that, while we do not make any assumptions about who ultimately delivers water to local communities, we do assume that the mining company is an integral stakeholder in the process, either taking on the responsibility for delivery or ensuring that a consensual agreement was reached between local government, communities, private operators, and other stakeholders in regard to water service delivery. We further assume that local governments or local regulation entities are considered as the mandated water service authority. The administration of the water delivery system falls under the responsibility of the government, which generally allows the participation of other stakeholders in the service delivery through the establishment of public-private partnership contracts and concessions to private operators. Regardless of the level of devolution of the water delivery responsibilities, the central and local governments usually have supervisory responsibilities on the safety (water analysis) and quality of services provided.

On the other hand, rural and urban water committees still play an important role in the consultation stage, advocating for the community interests in regard to the location of the water points, prices, and regulations. In some places, it is also common for the water committee to be responsible for creating mechanisms that ensure the maintenance of the infrastructure and daily operation. Finally, although these directives can be generalized to almost any form of water supply delivery and world region, we will frequently refer to work carried out in the town of Ribáuè, Mozambique, as part of the Small Towns Water, Sanitation and Hygiene Programme in Nampula to help illustrate the various points.

2. The Small Towns Water, Sanitation and Hygiene Programme in Nampula

The Small Towns Water, Sanitation and Hygiene Programme in Nampula (NAMWASH) was jointly funded by the Australian Government, UNICEF Mozambique, and the Government of Mozambique, 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 specifically considered five towns (Ribáuè, Rapale, Mecubúri, Namialo, and Monapo) along the Nacala Corridor in Nampula Province, Mozambique. The Nacala Corridor has benefitted from significant infrastructure projects in road and rail over recent years, and the towns considered as part of NAMWASH are anticipated to grow rapidly over the next

25 years, in part due to increasing urbanization worldwide (Recent projections by the United Nations Department of Economic and Social Affairs [2014] suggest that the percentage of people living in areas classified as "urban" will increase from 54% to 66% by 2050 with 90% of that growth occurring in Asia and Africa) but also potentially due to the economic opportunities associated with the development of the Nacala Corridor. The goal of NAMWASH was to implement Mozambique's delegated management framework (DMF) for water supply and sanitation in these towns and establish a model for best practice that could be used in similar towns (UNICEF Mozambique, 2014).

As part of NAMWASH, the town of Ribáuè benefited from the rehabilitation of a piped water system from colonial times. After considering various options for the specific type of piped water system to introduce to Ribáuè, it was ultimately decided to use a low-cost gravity-fed system to reduce O&M costs. The piped water system delivered to the town of Ribáuè consisted of construction works in the way of:

- rehabilitation of a dam in nearby mountains to supply water to the town,
- rehabilitation of a water tower in the town centre with a capacity of 100 m^3,
- the laying of 5,000 m of large diameter (250 mm) pipe for the main pipeline,
- the laying of 11,000 m of small to medium diameter (50-200 mm) high quality PVC pipe for the distribution network, and
- construction of a rapid filtration water treatment plant, along with chlorine dosing equipment.

Using Mozambique's DMF, water infrastructure is owned by AIAS, operated by a private partner under a leasing arrangement, and regulated by the Water Regulatory Council (CRA). Ultimately, piped water was delivered to Ribáuè in the form of 10 public water points (in the form of water kiosks) and 170 yard taps. Additionally, water was delivered to 45 local businesses and public institutions (including the local school and hospital) through direct connections. To assess the impact of this new water supply infrastructure in terms of not only increase in the use of improved water supply (defined as boreholes or piped water) and decrease in diarrhea incidence but also economic opportunities and a variety of other factors, researchers from Murdoch University (MU) and Eduardo Mondlane University, with support from AIAS and the Provincial Directorate of Health of Nampula, carried out fieldwork in Ribáuè in November 2014 consisting of household surveys, surveys of water points, surveys of public sanitation facilities (including schools, health centers, and public markets), semi-structured interviews of key informants in Ribáuè and Nampula city, and follow-up interviews in June and July 2015. Prior to commencing fieldwork, human ethics approval for research was obtained from both MU (2013/184) and the Mozambican Ministry of Health Bioethics for Health National Committee (307/CNBS/14).

3. Context for Ensuring the Effective and Sustainable Water Supply

Although NAMWASH produced improvements in towns that were not directly adjacent to mining operations, the towns considered represent communities that are being indirectly affected by mining, as road and rail projects to transport coal from Tete Province to the Port of Nacala are in close proximity to these towns. They are also similar to towns in close proximity to mining activity in terms of their projected growth trajectories. One key area of difference, however, is that the presence of mining activity may lead to a real or perceived competition between industry and communities for limited water resources. Mining companies can be advised to remain engaged locally when there is a perception of a conflict of interest or competition between communities and private companies for water access (Atschuller and Chen, 2010). Considering this, a first important consideration is the impact of mining operations on available water sources.

3.1. Compile available water sources, existing supply, and local capacity

As a precursor to the development and production phases of mining, it would be expected that a mining company will carry out a census of local water sources to determine the types of water sources available, capacity, and costs associated with obtaining water supply from these sources. At the same time, it would be anticipated that detailed water studies must be carried out in applying for a water use license or in a standard environmental impact assessment, where impacts of mining activity on water supply in terms of both quality and abundance are an important consideration (e.g. Environmental Law Alliance Worldwide, 2010). Consequently, as part of their standard operations, mining companies should have a detailed understanding of local water sources, existing water supply infrastructure, and capacity. In addition to understanding the types and capacities of water sources available, it is important to assess groundwater recharge rates and annual rainfall to gauge water sustainability for intended levels of use for freshwater sources.

If we consider the town of Ribáuè, prior to NAMWASH there was strong reliance on groundwater with 94.05% (91.12%, 96.97%) of households using boreholes or wells. (Numbers shown in brackets represent the 95% confidence interval.) Rivers on the outskirts of the town only provide seasonal supply. However, surface water from nearby mountains could be utilized, and an existing dam was rehabilitated to provide the water that is ultimately being used by the piped system. Additional surface water can be sourced from a lagoon in nearby Namiconha. We are not aware of in-depth analysis of groundwater levels or reservoir capacity, but the choice of a piped system using surface water from the mountains has helped alleviate some of the pressure on groundwater with a nearly 50% reduction in the use of wells post-NAMWASH, and the diversification of water supply would have positive effects on sustainability of water supply to the town.

In terms of rainfall, from 2007 to 2013, Nampula Province recorded annual rainfall ranging from 740 mm to 1,130 mm. There is considerable seasonal variation with little or no rain during the dry season (typically May to October) and significant rainfall during the rainy season (typically December to March) (Food and Agriculture Organization of the United Nations, 2015). Rainfall in Ribáuè district tends to be higher than the provincial average with the most recent local estimates available reporting annual rainfall above 1,500 mm (Ministério da Administração Estatal, 2005), suggesting greater recharge rates and levels of replenishment of surface water supply than what would be anticipated in other parts of the province.

3.2. Understand local preferences for water supply and management

Local understandings of water (including cultural or religious importance of water [e.g. Strang (2016)]) and preferences for water supply can be ascertained through consultation with the local council / leaders, water regulator, households, businesses, and public institutions (including schools and hospitals or health centers). In the case of households, it is important not only to determine households' stated preferences for various forms of water supply, but also their capacity to pay and willingness-to-pay (WTP) for forms of water supply that incur ongoing costs. This is a necessary step in ensuring that the form of water supply that is ultimately delivered and associated tariff structure produces a system that is economically viable for the community. To illustrate this, Ampadu-Boakye and Hebert (2014) describe the Atebubu Water System in Ghana, which supplied piped water to eight communities and roughly 32,000 people beginning in 2001. For three of four years for which revenue and expenditure data were available, the system produced a deficit, in part due to illegal tapping, which resulted in 27% non-revenue water as well as government institutions being in arrears with the amount owing representing 35% of revenue. At the same time, per capita consumption was 7.5L per day when projections were based on 20L. Although the illegal tapping and lack of payment from government institutions may indicate more substantial problems, the low per capita consumption would suggest either low capacity to pay or WTP for piped water and continued reliance on other forms of water supply. (Even the illegal tapping may be symptomatic of unwillingness to pay for piped water.) Compounding this, the system that was delivered used cheap PVC pipes that frequently ruptured, producing high maintenance costs, and it had high operation costs from diesel-powered generators used to pump groundwater. Based on the revenue that it could produce and the high cost of O&M for the system, the piped system that was delivered was largely inappropriate for those communities, and it is not surprising that the system ultimately shut down in 2010 and remains non-operational.

The failure of the Atebubu Water System in Ghana illustrates the importance of understanding what people are able and willing to pay, as well as forms of water supply that can ensure cost recovery. Large-scale household surveys are an effective means for understanding household preferences, WTP, capacity to pay, and can generally be carried out cheaply. While WTP surveys should typically be designed by those with expertise in the area, a set of clear and accessible guidelines for WTP surveys in the context of water supply are presented by Wedgwood and Sansom (2003) and Gunatilake et al. (2007). These sources provide a template for the structure of such surveys and describe appropriate sampling procedures of households. They also emphasize in-person interviews, clear descriptions of the form of water supply and level of service (which includes hours of operation, water pressure, etc.), explaining effects on household income, and trying to ascertain reasons for willingness or unwillingness to pay.

To understand the importance of WTP in the context of NAMWASH, Figure 1 shows the primary water point usage reported by households in the towns of Ribáuè and Liúpo (the latter which is characterized mainly as a poor and remote town with slow economic growth), Mozambique, in 2012, as estimated by baseline data collected prior to implementation of NAMWASH. (See WE Consult [2012], Admiraal and Doepel [2014], and Barrington and Admiraal [2014] for further information on this baseline survey and key results. Note that the reported use of piped water in Ribáuè in the form of yard taps and standpipes is in contradiction to reports from locals, who said that the piped system was not operational in 2012.) Figure 1 indicates a greater use of improved water supply in Liúpo than Ribáuè in 2012, which is commonly indicative of higher socio-economic status and greater WTP for even further improved water supply (i.e. piped water in this case). However, this is not the case for these two towns, as households in Ribáuè report higher monthly incomes and WTP than households in Liúpo on average. Table 1 shows reported household income for the two towns, suggesting a much higher capacity to pay for households in Ribáuè. Additionally, households in Ribáuè report higher monthly WTP for water from both standpipes and yard taps, as shown in Table 2. If we examine WTP for yard taps, in the town of Ribáuè the mean WTP of 109.71 MZN (USD 3.75, based on the informal in-country rate for 2014 of 1 USD = 30 MZN) constitutes slightly more than 4% of the median household income and would support a consumption of 109.05 L of water per day, or roughly 20 L per capita per day according to the specified tariff structure. (A number of sources, including Fankhauser and Tepic [2007], suggest that water payments of less than 5% of household income would be considered affordable in developing countries.) This quantity of water is almost identical to reported mean household consumption for the town of 107.36 L, so the amount that households are willing to pay is sufficient to cover household water needs. By comparison, mean WTP in the town of Liúpo constitutes a similarly reasonable percentage of household income but would only support 45.40 L per household per day, or roughly 8 L per capita per day, for a similar tariff structure. This falls well below the Sphere Handbook's (2011) recommended minimum of 15 L per capita per day, so other sources of water would be required to meet household needs.

Town	Mean Income	Median Income
Ribáuè	3,894.47 (3,231.64, 4,557.31) MZN	2,500 MZN
	USD 129.81 (107.71, 151.91)	USD 83.33
Liúpo	3,088.34 (2,428.65, 3,748.03) MZN	1,510 MZN
	USD 102.94 (80.95, 124.93)	USD50.33

Table 1: Mean and median monthly incomes (along with 95% confidence intervals for the mean) reported by households in the towns of Ribáuè and Liúpo in November 2014

Town	Standpipe	Yard tap
Ribáuè	46.93 (42.47, 51.38) MZN	109.71 (105.39, 114.03) MZN
	USD 1.56 (1.41, 1.71)	USD 3.75 (3.51, 3.80)
Liúpo	40.89 (32.10, 49.68) MZN	74.86 (65.46, 84.25) MZN
	USD 1.36 (1.07, 1.65)	USD 2.49 (2.18, 2.80)

Table 2: Mean monthly WTP (along with 95% confidence intervals) for water from standpipes and yard taps for the towns of Ribáuè and Liúpo in November 2014.

Ultimately, Ribáuè received a piped system, whereas Liúpo did not, and the WTP data would back up the viability of piped water in Ribáuè through a mix of yard taps and standpipes. Looking at the disparity in WTP for yard taps and standpipes in Ribáuè, as well as the level of water consumption that can be supported by mean WTP, it is not surprising to find that uptake of yard taps has nearly doubled since completion of NAMWASH with an average of 17 new connections per month, and yard taps have comprised 63% of water revenue. Additionally, only 7.67% of households (and no businesses or public institutions) were in arrears as of July 2015, whereas a feasibility study assumed a default rate of 20%.

While yard taps are a significant source of revenue for the piped system in Ribáuè, water kiosks have comprised only 2.5% of water revenue, and the system would not be solvent if dependent solely on the water kiosks. Part of the reason for this may be that water kiosks in Ribáuè tend to be in relatively close proximity to boreholes, which have a fixed low monthly fee (5-25 MZN/USD 0.11-0.56). Even for the average family in Ribáuè using 'The Sphere Handbook's' minimum standard of 15 L of water per capita per day, families using a standpipe would on average at least double their monthly water bill while having similar travel distances for water. For households in Liúpo, this disparity in cost would be a factor of 5, suggesting that households may ultimately opt for cheaper boreholes in spite of a potential sacrifice in water quality. Although it is not certain that the level of use of standpipes would be similarly low in Liúpo, the inability of household WTP to support widespread use of yard taps would call into question the economic sustainability of such a system for Liúpo if similar tariff structures are required to recover costs. The piped system delivered to Ribáuè emphasized low O&M, so high grade PVC pipe was used for the distribution network, and a gravity-fed system was installed to avoid the high costs associated with pumping. All of these have led to the system having a reported average profit of 11% per month over the first year of operation, with this profitability expected to increase to roughly 40% from August 2015 when new cost structures are introduced.

In addition to the local preferences and WTP for water supply, it is also critical to consult communities about the service delivery management model, including form of payment, which can also influence the economic sustainability of a water system. For example, Hope's (2015) study on community preference for hand pump maintenance service provision in Kenya showed that community management was the least preferred option due to lack of sufficient funds, access to spare parts, and a competent local mechanic. At the same time, in contrast to the success of M-PESA and LIFELINK in other contexts, alternative payment methods such as prepaid mobile water payments did not resonate with the community (Haas and Nagarajan, 2011; Hope et al., 2011). In the town of Ribáuè, water kiosk operators charged 0.50 MZN (USD 0.01) per 20L bucket at the time the water was obtained, and the level of use was relatively low (as noted previously). It is not certain whether this was because of the kiosk location, payment method, tariff, or lack of community consultation. Regardless, it is important to consider the model used in delivery and payment of water, and it is important that the end beneficiaries / customers are consulted so that the ultimate delivery model and payment method properly account for local preferences and realities.

3.3. Enhance governance, ongoing local capacity, and adaptive management

The governance and management of a water system has implications for roles and responsibilities, O&M, cost recovery, and appropriate expansion. The general structure of institutional arrangements is usually pre-determined, and, in the African context where decentralization is a point of emphasis, many water systems are run by private operators with local regulators and government oversight and ownership of the infrastructure. However, the specific roles and responsibilities of each of the players can vary, and Ampadu-Boakye and Hebert (2014) suggest that key success factors include sufficient local capacity, transparency, and clarity of roles and responsibilities. Where gaps are identified, capacity building must take place to address deficiencies.

In the Atebubu Water System example in Ghana, Ampadu-Boakye and Hebert (2014) noted incompetency at both local and district levels in the management of the water operator which resulted in inflexible low tariff structures that continued to be enforced despite evidence from the private operator that these were resulting in regular losses. (Incidentally, the one year where a profit was recorded for the water system was when water regulators allowed for an increase in tariffs.) Ampadu-Boakye and Hebert (2014) suggest that it is important to have regulators that include local community representation, and Ryan (2014) insists that gender balance is crucial to the success of such regulatory committees. Ampadu-Boakye and Hebert (2014) suggest that it is important that all partners have a vested interest in the success of the water system, and one way of ensuring this is paid regulatory committees. Additionally, pricing decisions should be made through a consultative process with broad community representation.

In the case of the piped water system in Ribáuè, AIAS owns the piped system and has oversight, CRA established a local regulatory council (CORAL) consisting of two men and one woman to regulate the piped system, and a private operator runs the system under a five-year lease. Capacity building was provided to all three players (AIAS, CORAL, private operator) as part of NAMWASH so that roles and obligations were delineated and clear to all parties. CORAL was trained in performance review, and it provides monthly reports to AIAS and CRA on the performance of the operator and provides recommendations. The private operator is responsible for the day-to-day operation of the system, maintenance, and limited expansion of the network. To ensure that technical skills existed locally, the local council has hired a focal person with appropriate expertise to assist with issues related to the water system. A supply chain was established to ensure that repair parts could be easily sourced with parts needed for basic repairs and expansion of the system available locally. Other parts can be sourced from the district capital of Nampula, which is roughly 1.5 hours away by car. To date, there have been a total of three major repairs (two of which were due to road works damaging the water network), all of which were addressed in three days or less.

The contractual agreement with the operator spells out key terms such as responsibilities of the operator and AIAS (e.g. AIAS is responsible for rehabilitation or construction of new standpipes, whereas the private operator is responsible for construction of new yard taps; AIAS carries the financial burden for major maintenance or expansion costs [such as generators, pumps, new water towers]; the operator is meant to achieve certain benchmarks in terms of water quality, repair times, and coverage of the system; etc.), water tariffs (which have been set at similar levels to those in the nearby city of Nampula), required expansion of the network, and monthly payments to both CORAL (6,000 MZN [USD 134]) and AIAS (2% of water revenue). This revenue structure is in line with the recommendations of Ampadu-Boakye and Hebert (2014), helping to ensure that all parties have a stake in the economic viability and success of the piped system. Water tariffs and yard tap installation costs can be renegotiated on an annual basis, allowing for some degree of flexibility in regard to both consumer demand and operator costs. For example, after the first year of operation, it was agreed to increase the cost of yard tap installations, as the cost to the consumer turned out to be less than the actual cost to the operator. (The operator has reported that demand for new yard taps remains steady in spite of an increase in cost.)

We note it is important for clarity between parties involved in water service provision, including regulatory structures, commercial incentives, international and national agencies, and where the roles and responsibilities of each public and private entity begin, end, and interface/co-operate. These practical elements of defining responsibility, improving governance, and implementing regulatory approaches are important determinants in water utility performance and are a major challenge in the least developed regions due to their complexity and high risk of WASH system failure (Budds and McGranahan, 2003; Davis, 2005; Kirkpatrick et al., 2006). Economically developing regions with inadequate resources and capacity to construct and maintain water infrastructure (in particular the distribution system) commonly endure ongoing water quality issues (Moe and Rheingans, 2006). The water supply distribution is a uniquely important element for an essential service, as pumping water along pipes is a higher component of water costs than comparable essential services such as electricity and telecommunications (Kirkpatrick et al., 2006). While small-scale independent water providers include a variety of practical and flexible means to bring water to consumers (standpipe, carts, trucks, bottles, on-selling piped water, etc.), and will play a major role in meeting the WASH needs of the poor for the foreseeable future (Davis, 2005), they will need assistance to ensure the appropriate technology and cost structures are delivered over time. For example, short contracts without clear directives of how the network should be expanded may lead to decisions producing high short-term profits but at the expense of long-term sustainability or profitability. Such ill-advised decisions may include using inadequate cheap repair or replacement parts, ignoring the need to diversify water sources or regulate the level of consumption from current water sources, over-saturating a distribution network without providing additional pumps or water towers to increase water pressure, and failing to expand main water supply pipelines to areas that may have lower levels of profitability. While unserved people represent a large untapped market to private operators in theory, in practice there is little commercial incentive and interest in supplying WASH services to extremely low income groups (Budds and McGranahan, 2003).

In terms of provision of capacity building to address gaps, it is common to focus on the technical elements of O&M and putting in place a supply chain for parts, but one skill that may be overlooked (but is vitally important in the developing world context) is the fundamentals of running a business. In the case of Ribáuè, given that the system only supplies one town, limited local capacity for and interest in operating the piped system existed. As mentioned previously, the current system operator reports turning roughly an 11% profit, and this should increase under new cost structures, but we have identified gaps in terms of basic bookkeeping, identifying efficiencies and exploiting economies of scale, setting up a business model, etc. Providing capacity building in the fundamentals of running a business and maintaining proper accounting will ensure maintenance of transparency in the level of profitability of a system, areas where costs must be reigned in, where necessary costs are being avoided, and opportunities for increased revenue. All of these can impact on the economic sustainability of the system. Furthermore, it is important that ongoing capital maintenance is included in budgeting, as emphasized by Cobbing et al. (2014). Under its contractual agreement, the private operator is to pay AIAS 2% of water revenue. Based on projected costs by Fonseca et al. (2011) for maintaining infrastructure, the ratio of revenue to cost for the system in Ribáuè would have to be at least 13-to-1. Because the system presently is strictly gravity-fed and does not use any pumps, maintenance costs are likely to be significantly lower than typical piped systems considered by Fonseca et al. (2011), but a 2% allocation of revenue would still appear to be low. When the system expands and requires pumps to maintain water pressure, capital maintenance costs will almost surely increase, so the contractual agreement would need to specify increased payment to AIAS if the system is to be self-sufficient.

Grounded in our fieldwork, capacity building and ongoing supervision and training should also be extended to water point operators (e.g. water kiosk operators, in the case of Ribáuè) and local water regulators. In both cases we found that, although there is strong entrepreneurial drive and goodwill to support the community, issues arise when people with low education and no previous experience in small or informal businesses are left to manage water infrastructure. The professionalisation of community management suggested by Lockwood and Smits (2011) is an attempt to move from voluntary and non-technical, non-accountable ways of management to a more professional, technical, and formally contracted system where water infrastructure and level of service is continually evaluated, proper accounting practices are followed, and maintenance and repair are delivered with minimum cost to users. To illustrate the issue in the context of Ribáuè, interviews carried out with water committees revealed that 16 out of 20 committees for boreholes had an accounts book for daily management, but only 5 actually knew the current balance. This is in spite of 15 of the 20 reportedly knowing how many families paid their fee the month before the survey was carried out.

Data collection and analysis, clear accounting, and ongoing coordination between water stakeholders and local institutions and communities is essential to implement sound empirically-based decisions in a volatile environment where the price for spare parts and piped expansion materials can rise suddenly, staff may be relocated, water supply and quality and/or its perception may change, etc. Providing sufficient capacity to adapt to these challenges and maintain effective communicate across institutions and with local authorities will ensure the institutional resilience needed for reliable water supply delivery. These software expenditures on direct and indirect support are important considerations for any water investment (Fonseca et al., 2011).

3.4. Ensure the water market is stimulated

Cost recovery for water supply is essential, and appropriate tariff structures can be important in achieving this. Boland and Whittington (2000) suggest that increasing block tariffs, which are commonly used for piped water in the African context, actually can be a hindrance to the uptake of yard taps, whereas other tariff structures such as uniform pricing coupled with rebates can promote uptake. Additionally, the typically high initial cost of obtaining a yard tap or household connection can prevent families from securing water to the home. Small loan schemes, rotating savings, and credit associations, could be used to make the cost for the infrastructure less prohibitive for families (Montgomery et al., 2009). Wedgwood and Sansom (2003) recommend that water providers try to keep the connection charge low to encourage greater market participation from households.

When introducing forms of water supply with which communities have limited or no previous experience or for which household expenditure on water would likely increase, marketing campaigns that explain the benefits of the particular form of water supply and why it is worth the increased cost are important in effecting uptake. Simanis (2009) provides the example of Procter & Gamble’s PUR water treatment packets as an example of marketing messages failing to effect change when the technology should have been hugely successful in the African context. In part, this appears to be because marketing approaches failed to fully understand the cultural contexts of those it was marketing to. Market research by PATH (2015) in the area of water treatment found that messages focusing on water bacteria had little effect on households deciding to treat water, whereas messages emphasizing health impacts or touting an improved technology were much more effective. In Mozambique, “Certeza”, a branded and socially marketed point-of-use water treatment, was launched in 2004 by Population Service International, and results from two surveys implemented in 2007 and 2012 concluded that ever-use of Certeza increased from 17% to 30% and current use increased from 10% to 25% as a result of behavior change communication activities to promote healthy behaviors related to water treatment (Wheeler and Agha, 2013). These examples help illustrate the importance of having an appropriate understanding of the target market and the types of messages that will influence individuals.

In the case of NAMWASH, discussions were held among program partners in Ribáuè to decide on appropriate culturally relevant marketing messages, and these appear to have been effective in at least generating a steady uptake of yard taps. The number of yard taps has almost doubled within the first year after NAMWASH with continued steady uptake projected to continue based on both WTP and ongoing demand reported by the private operator. Importantly, this is not a shift between revenue-generating water points, but rather there has been a substantial increase in people using revenue-generating forms of water supply. Figure 2 shows primary water point usage in September 2012 before piped water was introduced to Ribáuè, and again in November 2014, roughly four months after the completion of NAMWASH. It shows an almost 50% reduction in the use of unprotected wells with a slight increase in the usage of boreholes and significant uptake of piped water. The use of revenue-generating water points is estimated to have increased from 39.22% (33.20%, 45.25%) to 63.64% (59.40%, 67.88%), suggesting that the community attaches greater value to improved water supply, possibly because it has a better understanding of the benefits.

When considering marketing messages for piped water, one means of increasing uptake is by normalizing the affiliation between clean water and piped water. For instance, in the provincial capital city of Nampula where piped water points are more commonly used than in Ribáuȅ, 46.49% (42.26%, 50.72%) of respondents said that they knew that water was safe to drink if it came out of a tap. Only 18.83% (15.39%, 22.27%) of respondents in Ribáuȅ responded similarly. At the same time, while residents of Ribáuȅ were twice as likely to report choosing a water point based on water quality than price, residents in Nampula were nearly eight times more likely to report choosing a water point based on quality. Continued messages equating piped water to clean water and emphasizing the importance of clean water can help bring Ribáuè in line with Nampula and help maintain a steady uptake piped water.

3.5. Ensure future planning for appropriate water supply, expansion, and repair

Decisions about water supply must be forward-looking in terms of the form of water supply provided, clear water supply expansion plans, and appropriate savings plans for significant maintenance costs. It is possible that this may conflict with stated preferences of the community or impact on short-term profitability. In these cases, clear communication with the local community and regulator becomes increasingly important in discussing why a different form of water supply or expansion plan may be more appropriate, and marketing messages may take greater prominence. To illustrate this issue, an initial WTP study carried out by UNICEF in the town of Ribáuè in early 2012 found an overwhelming preference for standpipes with 48% of households stating a preference for standpipes and 25.1% stating a preference for yard taps (UNICEF and Administração de Infra-estruturas de Água e Saneamento, 2012). Rather than prioritize standpipes, UNICEF and its implementation partners had the foresight to recognize that standpipes would not be a sufficient level of service for a growing peri-urban community and so designed the piped system with yard taps in mind and included a small number of standpipes. Indeed, Davis (2005) insists that standpipes are not a level of service that municipalities should be satisfied with in the long term, and significant health benefits are achieved by moving a household’s primary water point from a public water point to the yard. Additionally, revenue data provided by the operator suggest a piped network would face severe financial distress if it was primarily reliant on revenue from standpipes.

Appropriate expansion can be aided by having concrete plans included in contractual agreements. These contractual agreements would also clearly spell out the infrastructure to be provided by the system owner to ensure that water quality and pressure are preserved and in a manner where costs are transparent to the operator. This is an important consideration in the African context where many major cities have intermittent water availability. The lack of regularity of water can be due to poor water pressure from outdated leaky distribution networks, but it can also be the result of operators shutting down pumps periodically because of high energy costs (Lee and Schwab, 2005). Expansion plans that provide a high level of detail can help safeguard both the owner and the operator from poor decisions by the other party, thereby ensuring that all parties do what is in the best interest for the system as a whole. Changes to these plans in response to new technologies, variances in town planning, etc., can be enacted through joint agreement between the two parties.

In the case of Ribáuè, the contractual agreement between AIAS and the water operator allocates 2% of revenue to AIAS, who assume responsibility for major maintenance and expansion costs. The private operator is responsible for operational and minor maintenance costs and is obligated to expand the main pipeline by 500 m and the distribution (secondary) network by 1000 m. However, these contractual agreements do not clearly spell out where expansion should occur or provide clear timelines, technical specifications, or cost implications, and decisions in regard to this appear to be largely driven by impromptu discussions among the operator, AIAS, and the local council. It is important to ensure that expansion is not done strictly based on profitability but takes into consideration social equality. At present, the piped network primarily serves the town center of Ribáuè, and ensuring that the piped network is extended to the town outskirts is important in guaranteeing that those areas that typically have the lowest level of access to clean water see a substantial improvement in their water situation, even if this reduces the overall profitability of the system. The clear articulation between all parties in the expansion planning process will provide future safeguards that improve the likelihood of an effective water supply system for the majority of citizens of Ribáuè that is also in the best interest for all parties over time.

4. Conclusion

We have presented a series of guidelines for helping to secure the long-term viability of water supply for the types of communities typically impacted (both directly and indirectly) by mining activity, doing so in the African context with specific supporting examples from the NAMWASH program implemented in Mozambique. Although emphases may change as technologies improve and become more cost-effective and, simultaneously, clean water in sufficient quantities becomes a more pressing global problem, the considerations presented are malleable for this changing landscape, and we would argue that they be part and parcel of water supply delivery accompanying mining activity. In developing regions where mining is all too frequently portrayed as a competitor to the interests of the local community, taking a more active role in ensuring the effective delivery of sustainable water supply provides opportunities for mining companies to change this perception, and instead be seen as communities' strongest advocates for access to clean water and guarantors of one of the most basic human rights.

References

Admiraal, R., Doepel, D., 2014. Using baseline surveys to inform interventions and follow-up surveys: A case-study using the Nampula Province Water, Sanitation, and Hygiene Program. Journal of Water, Sanitation and Hygiene for Development 4(3), 410–421. doi:10.2166/washdev.2014.145

Ampadu-Boakye, J., Hebert, R. 2014. Cluster Management in Ghana: The Promise and Pitfalls for Managing Water Services for Multiple Communities. Safe Water Network, Accra. URL: http://www.safewaternetwork.org/sites/default/files/FIS_Cluster%20Management%20in%20Ghana_Rebrand_v1_0.pdf. Accessed on 17 October 2015.

Appiah, D. O., 2006. Environmental Impact Assessment Regulations: The Level of Compliance by Mining Companies in the Western Mining Enclave, Ghana. TRITA-LWR Master Thesis, ISSN 1651-064, Stockholm, Sweden.

Atschuller, S. and Chen E., 2010. Corporate accountability and human rights in the age of global water scarcity. Natural Resources & Environment. 24(3): p. 9-14.

Australian Bureau of Statistics, 2007. Population: Mining areas boom, drought-affected areas decline. URL: http://www.abs.gov.au/ausstats/abs@.nsf/mediareleasesbytitle/985827DA3B32F8A5CA257321001FD34E?OpenDocument. Accessed on 30 August 2015.

Barrington, D.J., Admiraal, R., 2014. Learning by design: Lessons from a baseline study in the NAMWASH Small Towns Programme, Mozambique. Waterlines 33(1), 13–25. doi:10.3362/1756-3488.2014.003

Bartram, J., Lewis, K., Lenton, R., Wright, A., 2005. Focusing on improved water and sanitation for health, Lancet, 365, 810-812.

Boland, J., Whittington, D., 2000. The political economy of water tariff design in developing countries: Increasing block tariffs vs. uniform price with rebate designs, in: Dinar, A. (Ed.), The Political Economy of Water Pricing Reforms. Oxford University Press, New York.

Budds, J., McGranahan, G., 2003. Are the debates on water privatization missing the point? Experiences from Africa, Asia and Latin America. Environment and Urbanization 15(2), 87–114.

Business Monitor International, 2013. Water scarcity the next big challenges for miners. URL: http://www.bmiresearch.com/news-and-views/water-scarcity-the-next-big-challenge-for-miners. Accessed on 30 August 2015

Cairncross, S., Valdmanis, V., 2006. Water supply, sanitation, and hygiene promotion, in Mills, A., Measham, A.R., Musgrove, P., Breman, J.G., Jamison, D.T., Evans, D.B., Jha, P., Claeson, M., Alleyne, G., (Eds.), Disease Control Priorities in Developing Countries, second ed. The World Bank, Washington D.C., pp. 771–792.

Carrington, K., Pereira, M., 2011. Social Impact of Mining Survey: Aggregate Results Queensland Communities. Technical Report, Queensland University of Technology.

Cobbing, J., Eales, K., Gibson, J., Lenkoe, K., Rossouw, T., 2014. An appraisal of diverse factors influencing long-term success of groundwater schemes for domestic water supplies, focusing on priority areas in South Africa. Water Research Commission Report No. 2158/1/14, Pretoria.

Curtis, V., Kanki, B., Mertens, T., Traore, E., Diallo, I., Tall, F., Cousens. S., 1995. Potties, pits and pipes: Explaining hygiene behaviour in Burkina Faso. Soc. Sci. Med. 41(3), 383–393.

Davis, J., 2005. Private-sector participation in the water and sanitation sector. Annual Review of Environment and Resources, 30, 145–183.

Environmental Law Alliance Worldwide, 2010. Guidebook for Evaluating Mining Project EIAs. Environmental Law Alliance Worldwide, Eugene.

Evans, B., Hutton, G., Haller, L., 2004. Closing the sanitation gap: The case for better public funding of sanitation and hygiene behaviour change. Organization for Economic Co-operation and Development Roundtable on Sustainable Development, Paris.

Fankhauser, S., Tepic, S., 2007. Can poor consumers pay for energy and water? an affordability analysis for transition countries. Energy Policy, 35, 1038–1049.

Feachem, R., Burns, E., Cairncross, S., Cronin, A., Cross, P., Curtis, D., Khan, M.K., Lamb, D., Southall, H., 1978. Water, Health and Development: An Interdisciplinary Evaluation. Tri-Med Books, London.

Fonseca, C., Franceys, R., Batchelor, C., McIntyre, P., Klutse, A., Komives, K., Moriarty, P., Naafs, A., Nyarko, K., Pezon, C., Potter, A., Reddy, R. and Snehalatha, M. 2011. Life-cycle costs approach: Costing sustainable services. WASHCost Briefing Note 1a., IRC International Water and Sanitation Centre, The Hague, Netherlands.

Food and Agriculture Organization of the United Nations, 2015. Global Information and Early Warning System—on Food and Agriculture: Interpolated Estimated Dekadal Rainfall—By Region/Province, Mozambique. URL: http://www.fao.org/giews/english/ierf/list.asp?code=170. Accessed on 18 October 2015.

Global Water Intelligence, 2011. Mining a rich seam for water companies. Global Water Intelligence, Oxford.

Gunatilake, H., Yang, J.C., Pattanayak, S., Choe, K.A.. 2007. Good Practices for Estimating Reliable Willingness-to-Pay Values in the Water Supply and Sanitation Sector. Asian Development Bank, Economic and Research Department Technical Note No. 23, Manila, Philippines.

Haas, S., Nagarajan, G., 2011. Water Delivery through Payment Platform--M-PESA Pushes the Rural Frontier. IRIS and Microfinance Opportunities, College Park.

Hope, R., 2015. Is community water management the community's choice? Implications for water and development policy in Africa, Water Policy 17, 664–678.

Hope, R., Foster, T., Krolikowski, A., Cohen, I., 2011 Mobile Water Payment Innovations in Urban Africa. School of Geography and the Environment and Skoll Centre for Social Entrepreneurship at Saïd Business School, Oxford University, UK.

Improve International, 2015. Statistics on Water Point Failures. URL: https://improveinternational.wordpress.com/handy-resources/sad-stats/. Accessed on 30 August 2015.

Instituto Nacional de Estatística, 2010. Projecçoes anuais da população total, urbana e rural, dos distritos da Província de Nampula 2007–2040. URL http://www.ine.gov.mz/operacoes-estatisticas/inqueritos/inquerito-sobre-orcamento-familiar/relatorio-final-do-inquerito-ao-orcamento-familiar-iof-200809.pdf. Accessed on 30 August 2015.

Joint Monitoring Programme, 2014. Progress on Drinking Water and Sanitation, 2014 Update. WHO / UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP), ISBN 978 92 4 150724 0.

Kabemba, C., 2012. Coal v. Communities: Exposing Poor Practices by Vale and Rio Tinto in Mozambique. Southern Africa Resource Watch.
URL: http://www.sarwatch.org/resource-insights/mozambique/coal-versus-communities-mozambique-exposing-poor-practices-vale-and-rio. Accessed on 30 August 2015.

Kazimbaya-Senkwe, B. and Guy S., 2007. Back to the future? privatisation and the domestication of water in the Copperbelt Province of Zambia, 1900–2000. Geoforum. 38: p. 869-885.

Kirkpatrick, C., Parker, D., Zhang, Y.-F., 2006. State versus private sector provision of water services in Africa: an empirical analysis. The World Bank Economic Review 20, 143-163.

Lee, E.J., Schwab, K.J., 2005. Deficiencies in drinking water distribution systems in developing countries, Journal of Water and Health 3(2), 109-127.

Lillywhite, S., Kemp, D., Sturman, K., 2015. Mining, Resettlement and Lost Livelihoods: Listening to the Voices of Resettled Communities in Mualadzi, Mozambique. Oxfam, Melbourne.

Lockwood, H., Smits, S., 2011. Supporting rural water supply: Moving towards a service delivery approach. Practical Action Publishing, Rugby.

Ministério da Administração Estatal, 2005. Perfil do Distrito do Ribáuè, província de Nampula. Ministério da Administração Estatal, Maputo

Moe, C.L., Rheingans, R.D., 2006. Global challenges in water, sanitation and health. Journal of Water and Health 4(Supplement), 41–57.

Montgomery, M., Bartram, J., Elimelech, M., 2009. Increasing functional sustainability of water and sanitation supplies in rural sub-Saharan Africa, Environmental Engineering Science 26 (5), 1017–1023.

Onder, H., Yilmaz, M., 2005. Underground dams: A tool of sustainable development and management of groundwater resources, European Water 11(12), 35-45.

PATH, 2015. Market segmentation: PATH’s segmentation research provides insights into low-income HWTS market, Seattle, USA.

Petkova, V., Lockie, S., Rolfe, J., Ivanova, G., 2009. Mining developments and social impacts on communities: Bowen Basin case studies, Rural Society. 19(3), 211-228.

Pickering, A.J., Davis, J., 2012. Fresh-water availability and water fetching distance affect child health in sub-Saharan Africa. Environmental Science and Technology. 46, 2391–2397.

Ryan, P., 2014. Madagascar WASH Sector Sustainability Check. Peter Ryan Consulting, Antananarivo.

Schmidt, W.-P., Aunger, R., Coombes, Y., Maina, P.M., Matiko, C.N., Biran, A., Curtis, V., 2009. Determinants of handwashing practices in Kenya: The role of media exposure, poverty and infrastructure. Tropical Medicine and International Health 14(12), 1534–1541.

Simanis, E., 2009. At the Base of the Pyramid, The Wall Street Journal, 26 October 2009.

The Sphere Project, 2011. Humanitarian Charter and Minimum Standards in Humanitarian Response, 3rd Edition, The Sphere Project, Geneva, Switzerland.

Strang, V., 2016. Infrastructure relations: Water, political power and the rise of a new 'despotic regime', Water Alternatives 9(2), 292-318.

Subaiya, S., Cairncross, S., 2011. Response to Wang and Hunter: A systematic review and meta-analysis of the association between self-reported diarrheal disease and distance from home to water source. American Journal of Tropical Medicine and Hygiene 84(3), 504.

Szyplinska, P., 2013. CEO 360 Degree Perspective on the Global Membrane-based Water and Wastewater Treatment Market. Frost & Sullivan, San Antonio.

Thomas, S., 2012. Water and mining: a love/hate relationship? Water World 27(3). URL: http://www.waterworld.com/articles/wwi/print/volume-27/issue-3/regional-spotlight/latin-america/water-and-mining-a-love-hate.html. Accessed on 30 August 2015

Thompson, J., Porras, I.T., Tumwine, J.K., Mujwahuzi, M.R., Katui-Katua, M., Johnstone, N., Wood, L., 2002. Drawers of Water: 30 Years of Change in Domestic Water Use and Environmental Health. International Institute for Environment and Development, London.

Toledano, P., Roorda, C., 2014. Leveraging Mining Investments in Water Infrastructure for Broad Economic Development: Models, Opportunities and Challenges. Columbia University Academic Commons. doi:10.7916/D8PZ57K9

UNICEF and Administração de Infra-estruturas de Água e Saneamento, 2012. Willingness to Pay for an Improved Water Service: Ribáuȅ Municipality, Ribáuȅ

District, Nampula Province, Mozambique. UNICEF and Administração de Infra-estruturas de Água e Saneamento, Maputo.

UNICEF Mozambique, 2014. NAMWASH Programme Final Report, January 2012 – June 2014. UNICEF Mozambique, Maputo.

United Nations Department of Economic and Social Affairs, 2014. World Urbanization Prospects: The 2014 Revision. United Nations, New York.

United Nations General Assembly, 2010. Resolution on the human right to water and sanitation. UN doc. A/RES/64/292

United Nations Human Rights Council, 2010. Resolution on Human rights and access to safe drinking water and sanitation. UN doc. A/HRC/RES/15/9

Varia, N., 2013. ‘‘What is a House without Food?’’ Mozambique’s Coal Mining Boom and Resettle. Human Rights Watch, New York, USA.

Wang, X., Hunter, P.R., 2010. Short report: A systematic review and meta-analysis of the association between self-reported diarrheal disease and distance from home to water source. American Journal of Tropical Medicine and Hygiene 83, 582–584.

Wedgwood, A., Sansom, K., 2003. Willingness-to-pay surveys: A streamlined approach. Water Engineering and Development Centre, Loughborough University.

WE Consult, 2012. Baseline Study 2012: NAMWASH Programme Data Collection, Final Report December 2012. WE Consult, Maputo.

Wheeler, J., Agha, S., 2013. Use of Certeza point-of-use water treatment product in Mozambique, Journal of Water, Sanitation and Hygiene for Development (In Press).

White, G.F., Bradley, D.J., White, A.U., 1972. Drawers of Water: Domestic Water Use in East Africa. University of Chicago Press, Chicago.

World Health Organization, 2014. Global Health Estimates 2014 Summary Tables: Deaths by Cause, Age and Sex, by WHO Region, 2000-2012. World Health Organization, Geneva. URL: http://www.who.int/entity/healthinfo/global_burden_disease/GHE_DthWHOReg6_2000_2012.xls. Accessed on 30 August 2015.

World Health Organization, 2015. WHO strengthens focus on water, sanitation and hygiene to accelerate elimination of neglected tropical diseases. World Health Organization, Geneva. URL: http://www.who.int/water_sanitation_health/events/wash-and-ntd-strategy/en/. Accessed on 30 August 2015.

Figures and Figure captions

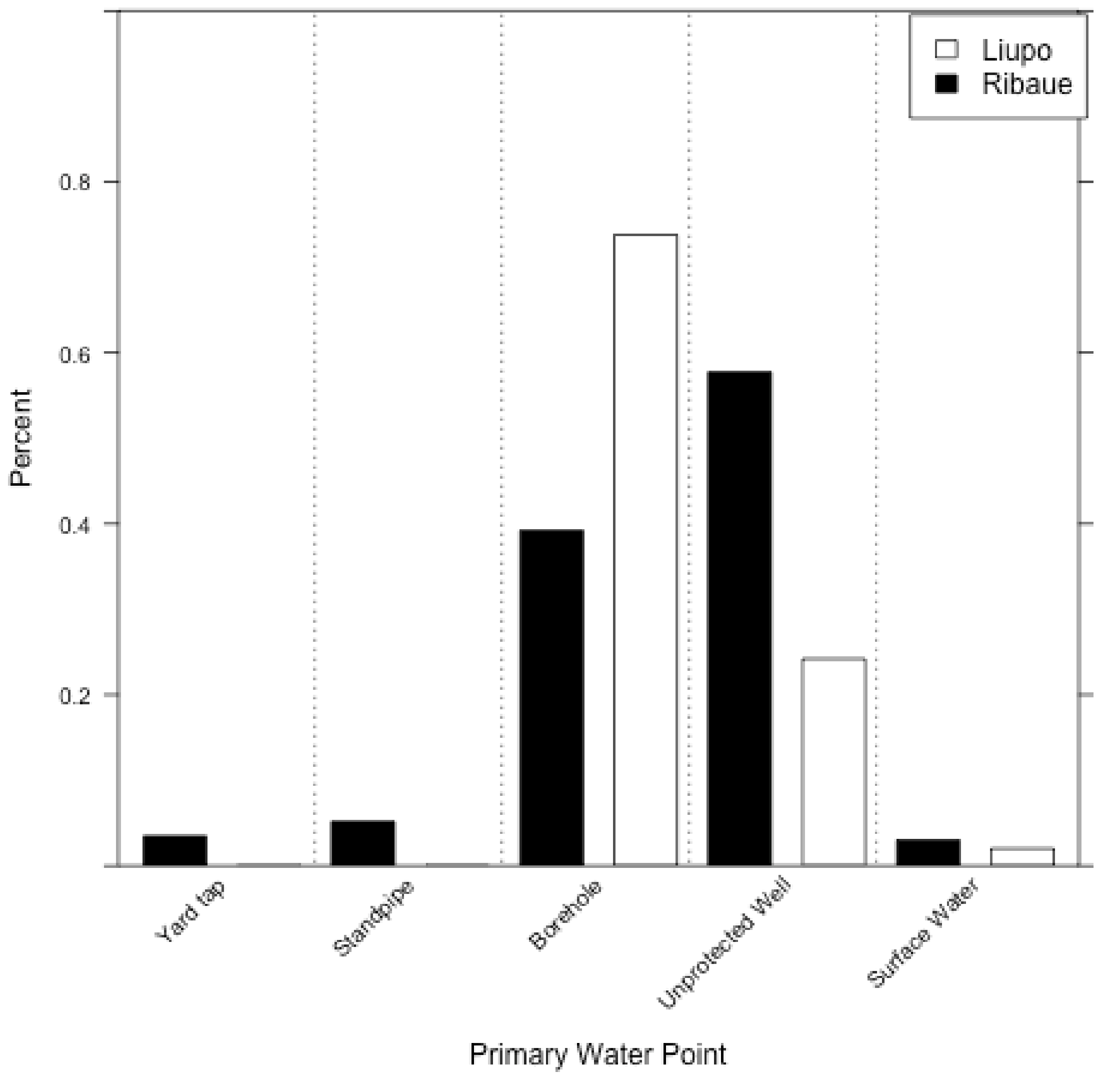

Figure 1: Primary water point usage for the towns of Liúpo and Ribáuè in Nampula Province, Mozambique, as estimated in September 2012.

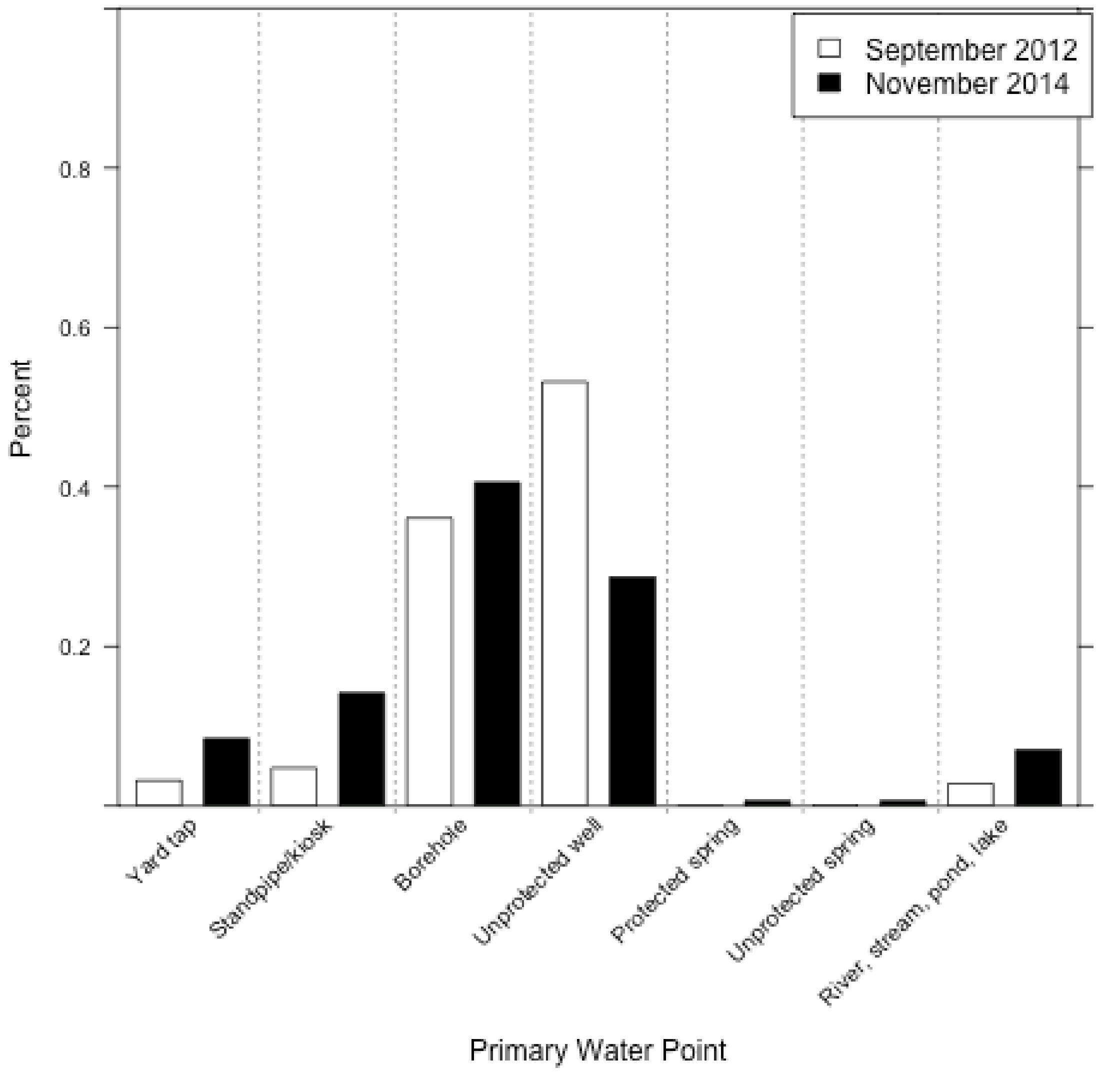

Figure 2: Primary water point usage in Ribáuè in September 2012 (pre-NAMWASH) and November 2014 (post-NAMWASH).