Using Natural Resource Wealth to Improve Access to Water and Sanitation in Mozambique:

A 2012 Australian Development Research Awards Scheme Project

Final Report, October 2015

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Disclaimer

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Executive Summary

The project "Using Natural Resource Wealth to Improve Access to Water and Sanitation in Mozambique" was funded by the Australian Government Department of Foreign Affairs and Trade through its 2012 Australian Development Research Awards Scheme programme. The project ran from May 2013 to October 2015 and sought to build the case for long-term investment in the water and sanitation sector in Mozambique. In particular, it considered the opportunities afforded by mining activity and associated revenue to address significant gaps in water supply and sanitation (WSS).

Mining as a Catalyst for Improvements in Water Supply and Sanitation

In 2012, cost estimates from Hutton [2012] suggested that Mozambique would need to spend roughly $1 billion USD annually to meet and sustain the Millennium Development Goal targets for WSS[1]. Given that gross domestic product (GDP) was estimated to be slightly over $16 billion USD in 2014[2], the cost to address deficiencies in WSS (as well as other pressing infrastructure needs) is significant, and a proactive approach needs to be considered in terms of finding potential sources of funds to address these needs.

Revenue from the mining sector may be one area worth exploring. In 2014, the contribution of mining to the Mozambican economy was estimated to be $500 million[3], and natural resource rents have comprised roughly 15% of GDP since 2010[4]. Although current uncertainty in commodity prices may undermine the importance of mining to the economy in the short term, it is anticipated that the mining and gas sectors will continue to be important for the economy of Mozambique in the long term. The contribution of mining and gas to GDP is expected to increase significantly when production begins to extract liquefied natural gas deposits in the Rovuma Basin. At the same time, mining companies may consider increased direct investment in community WSS through corporate social responsibility funds, and the mining investment in water infrastructure that commonly accompanies development and production phases can be potentially used to benefit local communities through shared use of infrastructure[5].

An evidence-based case of the types of impacts (including economic, health-related, and social) that can be anticipated for a com-

[1] G. Hutton. *Global Costs and Benefits of Drinking-Water Supply and Sanitation Interventions to Reach the MDG Target and Universal Coverage*. World Health Organization, Geneva, 2012

[2] World Bank. World Development Indicators, Mozambique, 2015. URL http://data.worldbank.org/country/mozambique/#cp_wdi

[3] A. Segura-Ubiergo, M. Poplawski-Ribeiro, and C. Richmond. Fiscal challenges of the natural resource boom. In D.C. Ross, editor, *Mozambique Rising: Building a New Tomorrow*, pages 122–140. International Monetary Fund, Washington, D.C., 2014

[4] World Bank.

[5] P. Toledano and C Roorda. *Leveraging Mining Investments in Water Infrastructure for Broad Economic Development: Models, Opportunities and Challenges*. Columbia Center on Sustainable International Investment Working Paper, 2014

munity as a result of WSS interventions can help motivate both the government and mining sector to consider how mining revenue, investment, and expertise can potentially be a catalyst for bringing about much-needed improvements in WSS.

NAMWASH and Improvements in Water Supply and Sanitation

To lay the case for investment in WSS, our research built on recent interventions carried out in Nampula Province, Mozambique as part of the Small Towns Water, Sanitation, and Hygiene Programme in Nampula (NAMWASH). NAMWASH was funded by the Australian Government, United Nations Children's Fund (UNICEF), and the Government of Mozambiqtue and implemented by UNICEF Mozambique along with the Mozambican Administration of Water Supply and Sanitation Infrastructure (AIAS) and Provincial Directorate of Public Works and Housing (DPOPH) in Nampula. It ran from January 2012 to June 2014 and included varied WSS interventions benefiting five towns along the Nacala Corridor. The most significant interventions were carried out in the town of Ribáuè and included the rehabilitation of a piped water system and sanitation and hygiene promotion programmes that resulted in (among other things) significant uptake of improved latrines.

Figure 1: Artisan and concrete latrine slab in the town of Ribáuè.

WSS interventions trialled in the town of Ribáuè as part of NAMWASH formed the basis for much of the research, and fieldwork was carried out not only in Ribáuè but also the city of Nampula and town of Liúpo in November 2014. These three locations differ in terms of a variety of characteristics, as shown in Table 1. Prior to NAMWASH, the WSS situation in Ribáuè lagged behind that of Liúpo, and, without intervention, the anticipated rapid growth for the town would be expected to exacerbate the problem.

Town/city	Population	Classification	Location	Projected Growth	Income
Nampula	≈ 500,000	Urban	Along Nacala Corridor	Moderate	Highest
Ribáuè	≈ 25,000-35,000	Peri-urban	Along Nacala Corridor	Rapid	Middle
Liúpo	≈ 10,000-15,000	Rural	Off Nacala Corridor	Slow	Lowest

Table 1: Profiles of the city of Nampula and towns of Ribáuè and Liúpo.

Researchers from Murdoch University and Eduardo Mondlane University carried out fieldwork in the towns of Ribáuè and Liúpo and the city of Nampula in November 2014. This fieldwork consisted of household surveys that were administered by university students fluent in local dialects to 1,255 households (495 households in Ribáuè, 225 households in Liúpo, and 535 households in Nampula) using a study design similar to the 2008 Multiple Indicator Cluster Survey (MICS)[6] and 2011 Demographic and Health Survey (DHS)[7], which used multi-stage cluster sampling. Additionally, water point surveys (90 in total, 35 for each of Ribáuè and Nampula and 20 for Liúpo) and public sanitation facility surveys (32 in total, 11 for Ribáuè, 7 for Liúpo, and 14 for Nampula) were administered to appropriate individuals with oversight of water points and sani-

[6] Instituto Nacional de Estatística. *Final Report of the Multiple Indicator Cluster Survey*. Instituto Nacional de Estatística, Republic of Mozambique, Maputo, 2009

[7] Instituto Nacional de Estatística. *Moçambique Inquérito Demográfico e de Saúde*. Instituto Nacional de Estatística (with technical assistance by MEASURE DHS/ICF International), Republic of Mozambique, Maputo, 2011

tation facilities, and key informant interviews were carried out with local health officials, businesses, non-government organisations, community based organisations, etc. Fieldwork was supported by AIAS and the Provincial Directorate of Health (DPS).

Observed WSS conditions in each of the three locations in November 2014, as represented through primary water points and sanitation facilities are shown in Figure 2 and largely follow what we would expect with the highest use of piped water and toilets in Nampula (the most urban location) and the greatest reliance on traditional latrines and practice of open defecation in Liúpo (the most rural location)[8]. Ribáuè largely fell in the middle. A mere two years before, it had higher use of unimproved forms of water supply and unimproved sanitation facilities than Liúpo.

[8] Even though the use of "improved" water points (*i.e.* boreholes and forms of piped water supply) was highest in Liúpo, this was due to heavy reliance on boreholes, which are lower on the water supply ladder.

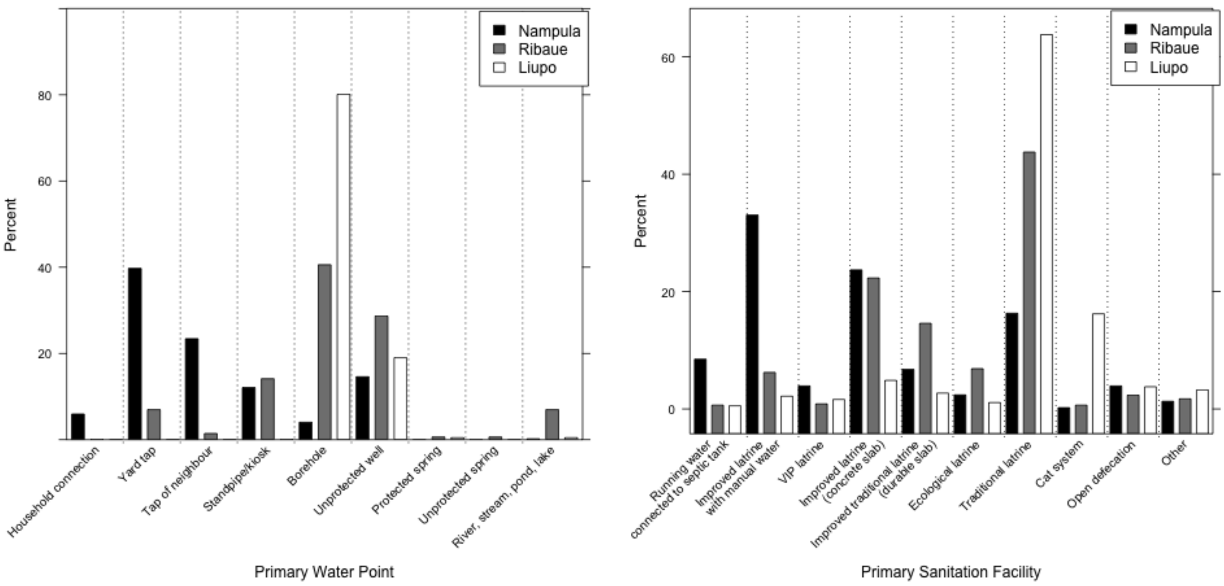


Figure 2: Reported primary water point usage (*left*) and sanitation facilities (*right*) in the city of Nampula and towns of Ribáuè and Liúpo in November 2014.

Water supply in Ribáuè

Looking more closely at Ribáuè and improvements as a result of NAMWASH, Figure 3 shows changes in primary water point and sanitation facility usage from immediately before NAMWASH to immediately after NAMWASH.

In terms of water supply, we note:

- a roughly 50% reduction in the use of unprotected wells,
- a 60% increase in the use of revenue-generating forms of water supply, and
- a significant increase in the use of piped water supply with 8% of households using yard taps and 14% using water kiosks. At the end of NAMWASH, 170 households had yard taps, and that

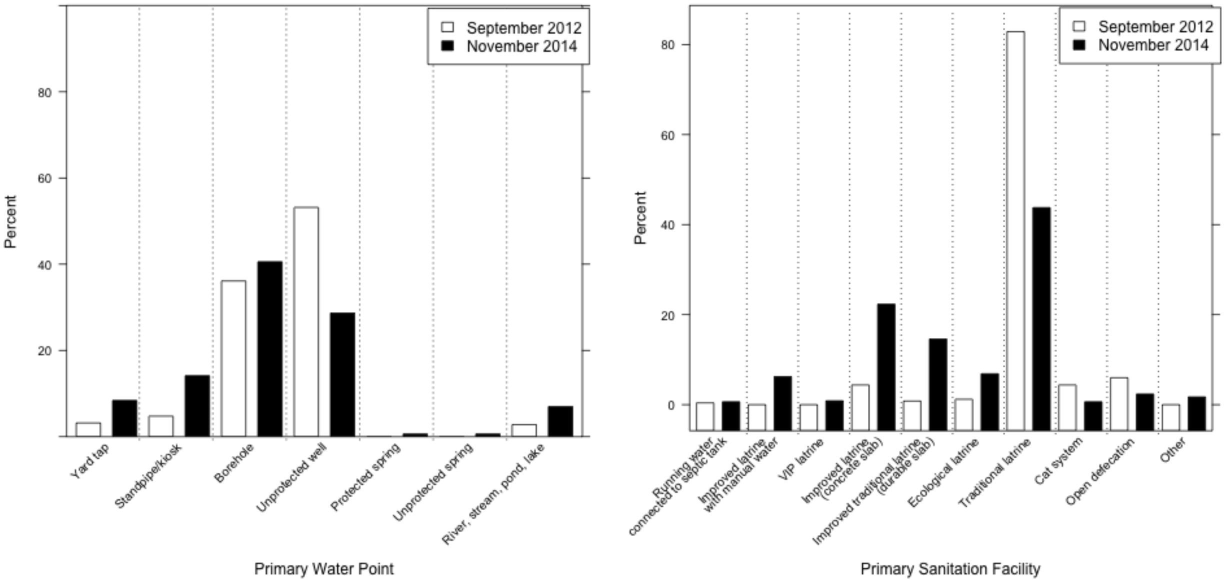


Figure 3: Reported primary water point usage (*left*) and sanitation facilities (*right*) for the town of Ribáuè in September 2012 (pre-NAMWASH) and November 2014 (post-NAMWASH).

number has doubled within the first year with steady continued uptake.

In contrast to the piped system in Nampula, which is plagued by frequent interruptions in supply, issues with water pressure, and an ageing distribution network, the piped system in Ribáuè has very reliably delivered water for 24 hours per day, 7 days per week. Importantly, the local council appears to recognise the value of the piped system to the community and has backed this up by investing financial resources[9]. Local accommodation owners have noted the importance of piped water and flush toilets in securing long-term contracts.

[9] This includes not only providing capital for an expansion of the network but also hiring a focal person to assist with technical issues related to WASH interventions held in the town, including the piped system.

Sanitation in Ribáuè

The intervention carried out in regard to sanitation in Ribáuè included a blend of community-led total sanitation (CLTS) and participatory hygiene and sanitation transformation (PHAST) approaches with sanitation marketing and multimedia communication techniques such as community radio and multimedia mobile units. This resulted in:

- a roughly 50% reduction in the use of traditional latrines[10] (unimproved sanitation facility),
- a reduction in the practice of open defecation from 10% to 3%, and
- a significant increase in the use of improved latrines[11] with more than 50% of households now having an improved sanitation facility[12].

[10] Traditional latrines are made of local materials. This includes the slab. The use of local material usually makes it more difficult to clean the facility.

[11] Improved latrine include a concrete slab with lid, along with a superstructure that secures privacy and a handwashing station.

[12] This was under 5% prior to NAMWASH, so there has been more than a ten-fold increase in the use of improved sanitation facilities.

At the same time, we noticed better latrine cleaning practices in Ribáuè than either Nampula or Liúpo and significant improvements in public sanitation facilities[13]. The training provided to local artisans has enabled them to diversify their services and produce appropriate durable concrete slabs, and one artisan reported plans to start an atelier fully dedicated to water and sanitation products.

[13] Local hospital and health center, schools, public markets.

As with any trial, some interventions will prove to be more effective than others. Although uptake of tippy tap handwashing stations as part of NAMWASH was high[14], we found few to be present at the time of fieldwork, suggesting low sustainability for this type of handwashing station. It would be prudent for future interventions to investigate the suitability of low-cost alternatives to implement in future sanitation and hygiene promotion programmes.

[14] Tippy taps are household handwashing stations made of locally available materials. They were built in conjunction with improved latrines.

In summary, in a brief period of time an integrated WSS intervention was able to transform (and visibly so) the WSS for a rapidly growing town, moving the town away from a WSS situation more in line with rural areas to what would more commonly be expected for a peri-urban setting. Importantly, if managed properly, the piped system provided to the town can expand with growing town needs.

Household Willingness-to-Pay, Capacity-to-Pay, and Implications for Sustainability of Piped Water to the Home

To understand the capability of the town of Ribáuè to support piped water supply in a manner that would guarantee the economic sustainability of the system, a rigorous willingness-to-pay study was carried out[15]. This focused primarily on water piped to the home[16] and followed the guidelines of Wedgwood and Sansom [2003] and Gunatilake and Tachiiri [2012] to produce an appropriate survey instrument[17]. Reported maximum willingness-to-pay (WTP) was validated through appropriate regression models[18], comparisons of actual uptake in Ribáuè versus what would be anticipated based on WTP[19], and a comparison of WTP and capacity-to-pay.

Stated WTP and maximum WTP for piped water to the home, capacity-to-pay, and per capita consumption corresponding to maximum WTP are shown in Table 2, and they show maximum WTP in line with what would be expected based on town/city profiles[20]. Mean maximum WTP for both Nampula and Ribáuè are able to support household water needs, whereas this is not true for Liúpo.

[15] This was necessary, given the timing of fieldwork so close to the end of NAMWASH.

[16] Numerous studies emphasise the significant benefits of water piped to the home over public water points, and others note that public water points are not a level of service that any town should aspire to. The goal should be water piped to the home.

[17] A. Wedgwood and K. Sansom. *Willingness-to-pay surveys: A streamlined approach*. Water Engineering and Development Centre, Loughborough University, 2003; and H. Gunatilake and M. Tachiiri. *Willingness to Pay and Inclusive Tariff Designs for Improved Water Supply Services in Khulna, Bangladesh*. Asian Development Bank, Manila, 2012

[18] This included examinations of the relationship between WTP and income, education level, reported incidence of diarrhoea, etc.

[19] These suggested that maximum WTP was conservative for Ribáuè.

[20] Per capita consumption is based on tariffs for yard taps in Ribáuè.

Town/City	Stated WTP	Maximum WTP	Median Income	Consumption
Nampula	68.50%	160 MZN ($5.33 USD)	3,040 MZN ($101.33 USD)	43 L
Ribáuè	66.80%	110 MZN ($3.67 USD)	2,500 MZN ($83.33 USD)	22 L
Liúpo	64.73%	62 MZN ($2.07 USD)	1,510 MZN ($50.33 USD)	4 L

Table 2: Stated willingness-to-pay and monthly maximum willingness-to-pay for piped water to the home, corresponding per capita daily water consumption supported by this willingness-to-pay value, and capacity-to-pay (as proxied by monthly income).

Looking specifically at the town of Ribáuè, estimated costs for sustainable delivery of water to the home based on projections by Hutton [2012] produce totals shown in Table 3. If considering only households that have stated WTP, total annual WTP is nearly identical to projected annual cost. If accounting for the investment made in water supply as part of NAMWASH, the annual cost that would need to be covered by households drops well below total WTP for households stating WTP, suggesting that the system should be economically sustainable[21].

[21] If extending to all households, then total WTP falls just shy of total cost, although we note that this scenario assumes that households not stating WTP would in fact pay nothing, an improbable scenario.

	Total WTP	Cost (HH stated WTP)	Cost (All HH)
Unadjusted	$200,000 USD	$200,000 USD	$300,000 USD
CapEx Adjusted		$113,000 USD	$210,000 USD

Table 3: Total willingness-to-pay for the town of Ribáuè, along with projected costs for piped connections to the home for only those stating willingness-to-pay and for all households. Totals adjusted for the capital expenditure on behalf as part of NAMWASH are also presented.

Benefits of Piped Water and Improved Latrines

Both piped water to the home and improved sanitation facilities have significant benefits, including:

- health benefits, particularly reductions in diarrhoea morbidity and mortality as well as a variety of other diseases related to poor water quality, sanitation, and hygiene;
- economic benefits, especially in healthcare costs avoided, increased earning potential due to reduced time spent collecting water or accessing locations to defecate, and increased earning potential due to increased life expectancy (or, equivalently, reduced premature loss of life); and
- social benefits, with women, children, and those of low socio-economic status (SES) receiving some of the greatest benefits.

To assess these benefits for the town of Ribáuè, we considered interventions consisting of:

1. Universal coverage of piped water to the home but no sanitation improvements.
2. Universal coverage of improved sanitation facilities (through provision of improved latrines to homes without sanitation facilities) but no water supply improvements.
3. Universal coverage of piped water and improved sanitation facilities through an integrated WSS programme.

Box 1: Intervention scenarios considered for the town of Ribáuè.

These are anticipated to have very different associated health and economic impacts.

Health Impacts

The health benefits of improved WSS are most significantly represented in reduction in risk of diarrhoeal diseases. Although we were unable to find evidence of a reduction in incidence of diarrhoea for the town of Ribáuè based on both survey data and clinic data, this may be due to fieldwork occurring shortly after the conclusion of NAMWASH. However, based on estimated risk reductions for transitions between various WSS situations, as based on a number of high quality studies and presented by Prüss et al. [2002] and Hutton [2012], we estimate the percentage reduction in diarrhoea morbidity and mortality associated with our intervention scenarios presented in Box 1 and for the town of Ribáuè to be as presented in Table 4[22].

[22] A. Prüss, D. Kay, L. Fewtrell, and J. Bartram. Estimating the global burden of disease from water, sanitation, and hygiene at the global level. *Environmental Health Perspectives*, 110(5): 537–542, 2002

Universal coverage of improved sanitation facilities would have a far more significant health impact than universal coverage by piped water to the home for Ribáuè. It is important to note that the health impacts of an integrated WSS intervention providing piped water and improved sanitation facilities to the home has a more significant health impact than the additive effects of an intervention targeting only water supply and an intervention targeting only sanitation.

	Health Impact	Economic Impact		
Intervention	Risk Reduction	Cost	Benefit	Benefit-Cost Ratio
Piped Water	11.5%	$297,851 USD	$467,550 USD	1.57
Sanitation	29.5%	$334,735 USD	$112,725 USD	0.34
Integrated WSS	53.3%	$632,585 USD	$607,490 USD	0.96

Table 4: Estimated health impacts (including risk reduction in diarrhoeal diseases) and economic impacts (including cost, benefit, and benfit-to-cost ratio) for universal coverage by piped water to homes (*top*), improved latrines to homes (*center*), and both piped water and improved latrines to homes (*bottom*) for the town of Ribáuè.

Economic Impacts

The economic benefits of improved WSS include

- healthcare costs avoided due to reduced diarrhoea morbidity (including those borne by the government and those borne by the individual),
- opportunity cost related to time missed from work or school or for caretaking for a sick individual,
- increased years of income earnings due to reduced premature loss of life, and
- opportunity cost related to time spent collecting water or accessing a location to defecate (for those practicing open defecation).

In the case of Ribáuè, the estimated total benefits are shown in Table 4 with universal coverage of piped water to the home producing significantly greater economic return than universal coverage of improved sanitation facilities. This is due to nearly all houses needing to collect water from some form of public water point prior to NAMWASH and reporting expending substantial time each day to do so, so there is significant opportunity cost corresponding to this time, comprising at least 95% of total economic benefit. Conversely, only 10% of households reported practicing open defecation prior to NAMWASH, so the opportunity cost related to time spent accessing a private location to defecate is low. At the same time, pre-NAMWASH incidence of diarrhoea for Ribáuè was reported to be relatively low, meaning that there were not significant gains to come in the way of savings from healthcare costs. When considering an integrated WSS intervention, the total benefit exceeds the sum of the marginal returns for investment only in piped water and only in improved latrines with this being attributable to the previously noted increased risk reduction obtained by an integrated WSS intervention.

Social Benefits

Piped water to the home and improved latrines provide significantly greater benefits to women, children, and those of low SES. In particular, women overwhelmingly assume water collection duties, so the significant opportunity cost associated with water collection means that they ultimately benefit most from piped water to the home. At the same time, children (particularly those under the age of 5) disproportionately suffer from diarrhoeal diseases, so the health benefits associated with improved WSS impact them most. Improved health for children (as well as eliminating travelling for water) has knock-on effects for school attendance and education, so we would anticipate increased educational attainment. This, in turn, is likely to lead to increased income. Using data from our survey, we found that a 1% increase in the percentage of head of households with some level of secondary schooling was associated with a 0.34% increase in income.

In addition to these social benefits, there are additional benefits in the way of greater safety (from both animals and humans) for not having to access locations for defecation or travel for water. This is particularly true for women and girls. There is also a prestige factor associated with having a latrine at the home. And the time saved by not needing to collect water can not only lead to income-generating opportunities but also provide leisure time.

Benefit-Cost Ratios

Using the previously presented costs for Ribáuè and following the approach of Hutton [2012] in estimating total benefit (related to the previously stated economic benefit components) for the town, we obtain the costs, benefits, and benefit-to-cost ratios (BCRs) shown in Table 4. These BCRs, along with both a conservative and more generous estimate, are presented for each of the three scenarios considered in Box 1, and we examine each scenario separately.

Piped water to the home

This has a BCR of 1.57, which is overwhelmingly attributable to the time households in Ribáuè reported collecting water with the

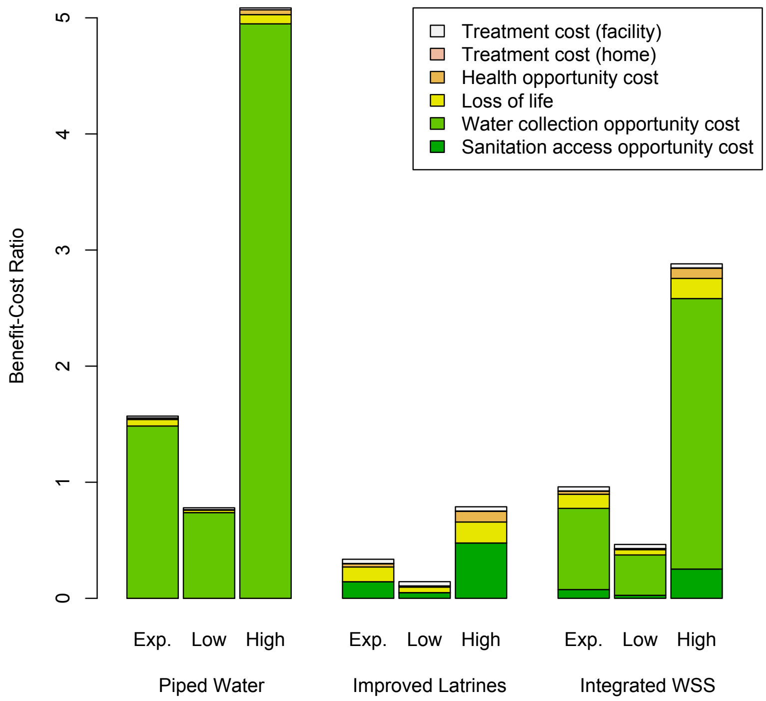


Figure 4: Component contributions (treatment cost, health opportunity cost, etc.) for the total economic benefit of interventions consisting of universal coverage by piped water to homes (*left*), improved latrines to homes (*middle*), and both piped water and improved latrines to homes (*right*) for the town of Ribáuè. Bar heights represent estimated benefit-to-cost ratio under the presented scenario, and estimates for a conservative ("Low") and generous ("High") scenario are presented as well.

opportunity cost associated with this accounting for roughly 95% of the benefit. Given the anticipated return on investment and fact that this aligns with an area in which mining companies excel (piped water infrastructure), this may provide a clear area of emphasis for directly engaging the extractive industries in WSS. We note that this does not negate the need for significant capacity building accompanying this infrastructure. For single-town systems like that found in Ribáuè, this capacity building is likely to need to be expanded to include greater attention to system operators and local regulators and include basic skills related to running a business, maintaining proper books, and carrying out audits.

As noted previously, if considering only households that state WTP, then cost and WTP are almost identical. Given that estimated benefit is more than 1.5 times estimated cost, though, this would suggest that either household WTP is undervaluing piped water to the home, or the estimated economic benefit is not reflecting the true value. Examinations of WTP against actual uptake of yard taps in Ribáuè suggest that WTP is conservative. Additionally, the timing of our survey in the immediate aftermath of NAMWASH may mean that households have not had time to appropriately calibrate the value of piped water, leading to an undervaluation as reflected by WTP.

Improved latrines

Although the BCR for investment in improved latrines (or other improved sanitation facilities) for the town of Ribáuè falls well below 1, this is not because of the NAMWASH intervention chosen but rather largely due to town characteristics that may be atypical for peri-urban or urban settings. In particular, pre-NAMWASH Ribáuè had:

- low use of improved latrines,
- low practice of open defecation, and
- low diarrhoea morbidity (except for young children).

This resulted in higher estimated costs (through more households obtaining an improved latrine) with lower associated benefits (due to minimal savings in terms of both health costs and time saved from accessing a private location to defecate), producing a low BCR. An estimate by Hutton [2012] for the BCR for investment in improved sanitation for Mozambique as a whole placed it at 1.71, suggesting that investment in improved latrines generally would produce a return at least equal to the investment. This further highlights that Ribáuè appears to be an anomaly.

Integrated water supply and sanitation

The BCR for investment in an integrated WSS intervention is nearly 1, with the significant anticipated returns from piped water to the home being offset by the losses from improved latrines. The time savings impacts of water piped to the home dominate total benefit, but the health impacts related to sanitation (especially in the way of reduced premature loss of life) are more pronounced than for an intervention only targeting water supply.

Implications for sectoral policies and definition of priorities in future interventions

From a government perspective, an investment should be worthwhile if revenue covers costs. For towns with a similar profile to Ribáuè, this would definitely be the case for water supply interventions emphasising piped water to the home and possibly be true for interventions considering an integrated WSS approach. Even though the BCR is lower and may be slightly under 1, the far more significant health impacts (some of which are not easily quantified economically) and social benefits of an integrated WSS intervention would lead us to believe that such an intervention would be preferable. Taking a broader approach is important, so weighing a BCR against anticipated health and social benefits as well as sustainability of the intervention is important.

We note that the methodological approach considered in this report provides a template for rigorously assessing both the sustainability and anticipated return on investment for interventions in the way of water supply and sanitation, much of which can be ascertained prior to implementation of any intervention if an appropriate survey is administered. Although the implementation and analysis of such a survey may constitute a significant up-front cost, the potential benefit in suggesting areas of greatest impact in terms of not only economic return but also health improvements can help shape the scope of intervention considered (water supply only, sanitation only, or integrated WSS) and messages to relay to produce greatest community response. For instance, if diarrhoea morbidity is high and avoided health-related costs constitute the most significant economic benefits, then being able to relay estimated savings to households can help increase WTP for improved water supply or latrines. Similarly, if significant time is being spent collecting water and households are better able to understand the opportunity cost associated with that lost time, they may have higher WTP for piped water to the home. Consequently, a clear understanding of costs and benefits can help shape interventions not only in terms of the WSS approaches considered but also the messages relayed to communities to spur change. Finally, if WTP is known, as are costs and associated benefits, the impacts of various levels of fundings on sustainability of interventions can be ascertained, ensuring greater efficiency in spending of funds.

List of Abbreviations

ADRAS	Australian Development Research Awards Scheme
AIAS	Administration of Water and Sanitation Infrastructure
ATPS	African Technology Policy Studies Network
BCR	Benefit-to-cost ratio
CBO	Community based organisation
CBA	Cost-benefit analysis
CapEx	Capital expenditure
CapManEx	Capital maintenance expenditure
CLTS	Community-led total sanitation
CNBS	Bioethics for Health National Committee
CoC	Cost of capital
CPI	Consumer Price Index
CRA	Water Regulatory Council
CSR	Corporate social responsibility
CV	Contingency valuation
DFAT	Australian Government Department of Foreign Affairs and Trade
DFID	Department for International Development
DHS	Demographic and Health Survey
DNA	National Directorate of Water
DPOPH	Provincial Directorate of Public Works and Housing
DPS	Provincial Directorate of Health
EA	Enumeration area
ExpDS	Expenditure on direct support
ExpIDS	Expenditure on indirect support
FIPAG	Fund for Investment and Ownership of Water Supply Assets
GAS	Water and Sanitation Group
GDP	Gross domestic product
IBT	Increasing block tariff
IMF	International Monetary Fund
INE	National Statistics Institute
IOF	Survey of Family Budgets
LCCA	Life-cycle costs approach
LNG	Liquefied natural gas
MDGs	Millennium Development Goal
MICS	Multiple Indicator Cluster Survey
MU	Murdoch University
MZN	New Mozambican metical

NAMWASH	Small Towns Water, Sanitation, and Hygiene Programme in Nampula
NGO	Non-government organization
NOAA	National Oceanic and Atmospheric Administration
NPV	Net present value
O&M	Operations and maintenance
OECD	Organisation for Economic Co-operation and Development
OLIPA-ODES	Organisation for the Sustainable Development
OLS	Ordinary least squares
OpEx	Operational expenses
PHAST	Participatory hygiene and sanitation transformation
PLM	Improved Latrine Programme
POU	Point of use
QGRL	Quantum Global Research Lab
SES	Socio-economic status
SNV	Foundation of Netherlands Volunteers
SSA	Sub-Saharan Africa
SSPWPs	Small-scale private water providers
STCC	Technical Society of Consulting and Construction
TotEx	Total expenditure
UEM	Eduardo Mondlane University
UNICEF	United Nations Children's Fund
UPR	Uniform price with rebate
USD	United States dollar
WASH	Water, sanitation, and hygiene
WHO	World Health Organization
WSS	Water supply and sanitation
WTP	Willingness to pay

Background to the Project

A recent report by the World Health Organization (WHO) emphasised the importance of a renewed focus on increasing access to safe water and improving sanitation and hygiene practices in combating a number of neglected tropical diseases. The report stressed that prioritising access to improved water, sanitation, and hygiene (WASH) was urgently needed if these diseases were to be controlled or eradicated by 2020, and it noted that this focus on improved WASH would be expected to not only have significant positive effects for health but also be instrumental in reducing poverty[23].

[23] World Health Organization. *Water, Sanitation, and Hygiene for Accelerating and Sustaining Progress on Neglected Tropical Diseases A Global Strategy 2015-2020*. World Health Organization, Geneva, 2015a

The health impacts of access to improved WASH are well understood, with incidence of diarrhoeal diseases[24] 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 characterised by the lowest levels of access to improved WASH[25]. Mortality rates for children are disproportionately higher for such diseases, which are closely linked to poor WASH and rarely result in death in developed countries.

[24] Diarrhoeal diseases include (among others) cholera, salmonellosis, shigellosis, and amoebiasis.

[25] World Health Organization. Global Health Estimates 2014 Summary Tables: Deaths by Cause, Age and Sex, by WHO Region, 2000-2012, 2014. URL http://www.who.int/entity/healthinfo/global_burden_disease/GHE_DthWHOReg6_2000_2012.xls

The economic benefits of improved WASH are not as well understood but are significant with savings in terms of health costs alone making investment in WASH cost-effective, particularly in those regions where incidence of diarrhoeal diseases are a leading cause of death[26]. Even under pessimistic data assumptions, the total socio-economic benefits of water supply and sanitation (WSS) interventions outweigh the costs in all developing world regions, and, for the sub-Saharan Africa (SSA) region, the benefit-to-cost ratio (BCR) under a variety of WSS intervention scenarios is estimated to range between 2.0 and 2.8[27]. In Mozambique, the country where our research was concentrated, Hutton [2012] estimates the BCRs for interventions required to reach the Millennium Development Goals (MDGs) for WSS to be 3.3 for water and 1.71 for sanitation, and the International Monetary Fund (IMF) estimates that at least 1.2% of gross domestic product (GDP) is lost per year due to inadequate sanitation[28]. Additionally, less time missed from work, greater educational opportunities, and other indirect benefits from access to improved WASH increase earning potential[29].

[26] B. Evans, G. Hutton, and L. Haller. *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, 2004

[27] G. Hutton. *Global Costs and Benefits of Drinking-Water Supply and Sanitation Interventions to Reach the MDG Target and Universal Coverage*. World Health Organization, Geneva, 2012

[28] E.B. Armas. Infrastructure and public investment. In D.C. Ross, editor, *Mozambique Rising: Building a New Tomorrow*, pages 37–49. International Monetary Fund, Washington, D.C., 2014

[29] J. Bartram, K. Lewis, R. Lenton, and A. Wright. Focusing on improved water and sanitation for health. *The Lancet*, 365:810–812, 2008

Pressures on Water and Sanitation Caused by Mining

For mining companies operating in developing countries, mining activity frequently occurs in regions where nearby communities have insufficient access to clean water and improved sanitation. Even in areas where access to clean water and improved sanitation is sufficient, mining and associated economic activity can lead to rapid population growth[30], putting pressure on existing water infrastructure and sanitation services. Because mining is a water-intensive endeavour[31], particularly for lower grade ores[32], it has the potential to affect water availability (through reduction of surface water availability or lowering groundwater levels) and quality (through contamination of surface water or groundwater) for these communities if not managed appropriately. In many cases, existing water infrastructure in local communities is insufficient for mining needs. Consequently, mining projects increasingly must invest in water infrastructure to meet their needs, and over the period of 2011 to 2014 it is estimated that global spending on water infrastructure by mining companies will have doubled from $7.7 billion USD to $13.6 billion USD[33].

In some cases, mining may lead to involuntary resettlement of communities, in which case the selection of suitable resettlement sites is critical. Oxfam has identified a number of critical factors that should be considered when examining the suitability of candidate resettlement locations, and, as would be expected, one of the key factors is the availability of clean water. In the Mozambican context, these critical factors have not always been appropriately considered, however, as evidenced in reports by The Human Rights Watch and Southern Africa Resource Watch[34]. One of the cases highlighted in these reports is that of 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[35].

The impacts of mining on communities can be further reaching, however, with economic activity due to mining leading to rapid population growth in regions far removed from mining activity. For instance, in the case of Mozambique the shallow water port of Beira faces massive pressures from the increasing mineral outputs from extractive activities in Tete Province, and this has stimulated the development of 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 of Nacala has generated economic opportunities in small towns along the corridor, and accompanying this economic opportunity has been significant population growth[36], placing strain on water infrastructure and negatively impacting sanitation.

[30] Australian Bureau of Statistics. Population: Mining areas boom, drought-affected areas decline., 2007. URL http://www.abs.gov.au/ausstats/abs@.nsf/mediareleasesbytitle/985827DA3B32F8A5CA257321001FD34E?OpenDocument; V. Petkova, S. Lockie, J. Rolfe, and G. Ivanova. Mining developments and social impacts on communities: Bowen Basin case studies. *Rural Society*, 19(3):211–228, 2009; and K. Carrington and M. Pereira. Social impact of mining survey: Aggregate results Queensland communities. Technical report, Queensland University of Technology, 2011

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

[32] Global Water Intelligence. *Mining a rich seam for water companies*. Global Water Intelligence, Oxford, 2011

[33] S. Thomas. Water and mining: A love/hate relationship? *WaterWorld*, 27(3), 2012. URL http://www.waterworld.com/articles/wwi/print/volume-27/issue-3/regional-spotlight/latin-america/water-and-mining-a-love-hate.html

[34] N. Varia. *What is a House Without Food? Mozambique's Coal Mining Boom and Resettlement*. Human Rights Watch, Washington, D.C., 2012. URL http://www.hrw.org/reports/2013/05/23/what-house-without-food; and C. Kabemba. *Coal v. Communities: Exposing Poor Practices by Vale and Rio Tinto in Mozambique*. Southern Africa Resource Watch, 2012. URL http://www.sarwatch.org/resource-insights/mozambique/coal-versus-communities-mozambique-exposing-poor

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

[36] For instance, in the town of Ribáuè, which falls along this corridor and has seen significant rail and road works, 8.08% 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 [Instituto Nacional de Estatística, 2010a].

Domínguez-Torres and Briceño-Garmendia [2011] note that Mozambique's infrastructure needs are among the highest in Southern Africa with a significant increase in spending needed to address deficiencies[37], and Montgomery et al. [2009] argue that Mozambique is in desperate need for an increase in WASH services and their sustainability[38]. Those most in need of this increase in WASH services are rural and peri-urban areas facing rapid growth, and 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 investments[39], leaving many of the areas most in need of WASH interventions without the improvements they desperately need. If the private sector and local, provincial, and national governments are not proactive in providing or sourcing the capital needed to fund water infrastructure and sanitation service needs accompanying significant growth in these areas, it is almost certain that continued growth will lead to adverse effects in terms of water availability and sanitation for these communities.

[37] C. Domínguez-Torres and C. Briceño-Garmendia. *Mozambique's Infrastructure—A Continental Perspective*. World Bank, Washington, D.C., 2011

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

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

Economic Growth and the Role of the Extractive Industries

Mozambique has seen steady economic growth over the last decade with an average growth in GDP of 6.85% per annum and a growth of more than 7% every year since 2010. Over that time period, natural resource rents have comprised an average of 14.98% of GDP[40], and over the period 2011-2014 it was anticipated that mining would roughly triple in value from 5,022 million MZN ($167.4 million USD) to 14,978 million MZN ($499.27 million USD)[41,42]. Massive reserves of liquefied natural gas (LNG) deposits in the offshore Rovuma Basin are anticipated to boost this significantly with production estimated to commence in 2019 with full-scale production being reached by 2036. Significant revenue to the government would be realised around 2023 when it is anticipated that all of four proposed LNG plants/trains would be operational[43].

[40] World Bank. World Development Indicators, Mozambique, 2015. URL `http://data.worldbank.org/country/mozambique/#cp_wdi`

[41] Totals in USD are based on the informal in-country exchange rate of $1 USD = 30 MZN commonly used in 2014.

[42] A. Segura-Ubiergo, M. Poplawski-Ribeiro, and C. Richmond. Fiscal challenges of the natural resource boom. In D.C. Ross, editor, *Mozambique Rising: Building a New Tomorrow*, pages 122–140. International Monetary Fund, Washington, D.C., 2014

[43] *Ibid.*

With Mozambique's growing resource wealth comes great opportunity, and investment, government, civil society and development partners all seek to see how extractive industry revenues can be used to address some of the most critical issues facing not only communities directly and indirectly affected by mining but also the country as a whole. Long-term investment strategies for social development have been missing from the growing debate for transparency, monitoring of mineral rent revenues, and corporate social responsibility (CSR) funds. Most noticeably, a discussion around investment in water and sanitation as a vehicle for not only improved health and wealth but also significant co-benefits (including increased educational prospects) has been missing, and it is within this context that this project was conceived.

Using Natural Resource Wealth to Improve Access to Water and Sanitation in Mozambique

In 2012, Murdoch University (MU) was successful in obtaining funding from the Australian Government Department of Foreign Affairs and Trade (DFAT) through its Australian Development Research Awards Scheme (ADRAS) programme to undertake research in Mozambique. The aim of the research was to amplify evidence-based advocacy at national and provincial levels by analysing current efforts to increase access to water and sanitation in Nampula Province with a focus along the Nacala Corridor. The research sought to build the case for long-term investment of mineral resource revenues into the water and sanitation sector by undertaking a rigorous impact assessment and cost-benefit analysis (CBA) of the Small Towns Water, Sanitation, and Hygiene Programme in Nampula. This analysis would include infrastructural, economic, environmental, health-related, and socio-cultural indicators to gauge the return on investment in water and sanitation to achieve greater socio-economic benefits for the target communities. This could be used to develop an evidence-based case to promote investment in WSS with a focus on growing rents from the extractive industries.

Figure 5: Reservoir supplying the piped system for the town of Ribáuè.

Figure 6: New pipeline from the reservoir into the town of Ribáuè.

The Small Towns Water, Sanitation, and Hygiene Programme in Nampula, January 2012–June 2014

The Small Towns Water, Sanitation, and Hygiene Programme in Nampula (NAMWASH) was formed through a joint partnership of the Australian Government, the United Nations Children's Fund (UNICEF) Mozambique, and the Government of Mozambique. It was implemented by UNICEF Mozambique in conjunction with the Administration of Water Supply and Sanitation Infrastructure (AIAS) and Provincial Directorate of Public Works and Housing (DPOPH) of Nampula. The programme ran from January 2012 to June 2014 and included varied interventions benefitting the towns of Ribáuè, Rapale, Mecubúri, Namialo, and Monapo. All five of these towns lie along the Nacala Corridor and are anticipated to experience significant growth over the next 25 years.

Figure 7: Rehabilitated uplifted water tank in the town centre.

Prior to carrying out interventions in these towns, UNICEF Mozambique commissioned a willingness to pay (WTP) survey to be carried out in Ribáuè in June 2012. This survey of 371 households was carried out to understand preferences for various forms of water supply as well as willingness and capacity to pay for these forms of water supply. In September and early October 2012, a baseline household survey was carried out to establish pre-intervention conditions in all five towns to be targeted by NAMWASH. This survey also included two "control" towns that would not benefit from NAMWASH—Liúpo and Namapa-Eráti. In total, 1,610 surveys were administered across seven towns with 252 households being sampled per town. The sampling design fol-

Figure 8: Water kiosk providing water to households in Ribáuè.

lowed that of the 2008 Multiple Indicator Cluster Survey (MICS)[44] and 2011 Demographic and Health Survey (DHS)[45] and used multi-stage cluster sampling based on enumeration areas (EAs) as specified by the National Statistics Institute (INE). Admiraal and Doepel [2014] provided an examination of key WASH indicators and comparisons across the sampled towns based on the baseline data[46].

The original intent had been for NAMWASH to be delivered in two phases with Phase I including comprehensive WASH interventions to be trialled in the town of Ribáuè. Phase II would then see the remaining four communities benefit from similar interventions. Funding for Phase II has yet to be secured, however, so, at present, only the town of Ribáuè has benefited from the full suite of benefits envisioned as part of NAMWASH[47].

As part of NAMWASH, the town of Ribáuè benefitted from the rehabilitation and expansion of a derelict piped water system from colonial times[48]. Approximately one year after project completion, the piped network now delivers treated water 24 hours a day, 7 days a week to the community through more than 330 yard taps, 10 water kiosks and 2 standpipes, direct connections to 14 businesses, and 31 connections to public services and the local council[49].

Sanitation and hygiene interventions were also carried out in Ribáuè and included a blend of community-led total sanitation (CLTS)[50] and participatory hygiene and sanitation transformation (PHAST)[51] approaches with sanitation marketing and multimedia communication techniques such as community radios and multimedia mobile units. The interventions involved a neighbourhood competition where households were to build improved latrines[52] with appropriate superstructures and handwashing stations[53]. This was undertaken through a joint effort of the local community, latrine slab artisans, and NAMWASH personnel. NAMWASH personnel provided supplementary training to local artisans for the production of low-cost slab models, and NAMWASH covered the costs of cement, iron, and labour for artisans to build the slabs. Organisation for the Sustainable Development (OLIPA-ODES) mobilised households to collect or buy stones, sand, and water as well as dig proper latrine pits. Households were also responsible for the transportation of slabs to their homes and construction of a durable superstructure to house the latrine. Households desiring superstructures of modern materials were required to cover the costs on their own. UNICEF Mozambique estimated the cost of a fully built latrine to be approximately 2,000 MZN ($66.67 USD) with subsidies provided by NAMWASH comprising roughly 20% of this cost. The interest in improved latrines exceeded the budgeted goals with 1,170 households in Ribáuè building improved latrines due to NAMWASH. Additionally, 25 disability-specific latrines[54] were built in Ribáuè without any contribution required from the household, and gender- and disability-specific latrines were provided to four schools, three public markets, and the Ribáuè Rural Hospital and Namiconha Health Centre. Accompanying these activities were

[44] Instituto Nacional de Estatística. *Final Report of the Multiple Indicator Cluster Survey*. Instituto Nacional de Estatística, Republic of Mozambique, Maputo, 2009

[45] Instituto Nacional de Estatística. *Moçambique Inquérito Demográfico e de Saúde*. Instituto Nacional de Estatística (with technical assistance by MEASURE DHS/ICF International), Republic of Mozambique, Maputo, 2011

[46] R. Admiraal and D. Doepel. 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, 2014

[47] The towns of Rapale, Mecubúri, Namialo, and Monapo have also benefited from NAMWASH, but none received piped water as Ribáuè did.

[48] We will describe the specifics of this rehabilitation project in greater detail later.

[49] This includes local accommodation and hospitality businesses, Ribáuè's Rural Hospital, the local primary school, and government services.

[50] K. Kar and R. Chambers. *Handbook on Community-Led Total Sanitation*. Plan International UK, London, 2008

[51] R. Sawyer, M. Simpson-Hebert, and S. Wood. *PHAST Step-by-Step Guide: A Participatory Approach for the Control of Diarrhoeal Diseases*. World Health Organization, Geneva, 1998

[52] Improved latrine include a concrete slab with lid, along with a superstructure that secures privacy and a handwashing station.

[53] In this case, tippy taps, which are household handwashing stations made of locally available materials.

[54] Wider latrine entrance, appropriate hand supports, raised seat, etc.

hygiene and sanitation promotion messages through both multimedia and face-to-face messages.

Fieldwork in November 2014

NAMWASH would form the basis for research to be carried out by MU and partners, and research carried out in support of this project was initially meant to include fieldwork in all five towns set to benefit from NAMWASH. However, the limited delivery of water infrastructure to all towns but Ribáuè led to a revised focus that considered communities with different profiles in terms of size, anticipated population growth, and economic prospects. The town of Ribáuè was the focal point for this work, as it had benefited from full-scale WSS interventions. The city of Nampula and town of Liúpo were also included to represent other locations in Nampula Province at different stages of population and economic growth.

Fieldwork led by researchers from MU and Eduardo Mondlane University (UEM) with the support of AIAS and the DPOPH of Nampula was carried out in November 2014 in the towns of Ribáuè and Liúpo and the city of Nampula. Data collected during this fieldwork provided an improved understanding of the short-term changes in the WASH situation due to NAMWASH and the associated economic benefits of the interventions.

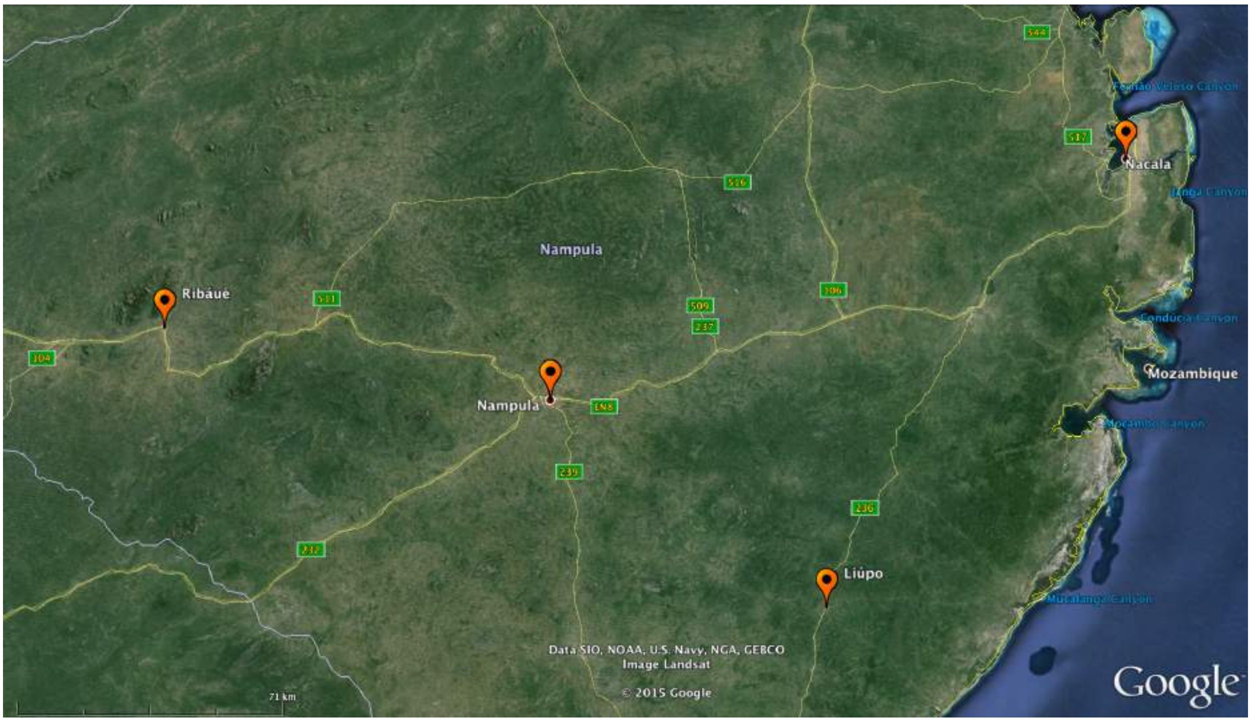


Figure 9: The towns of Ribáuè and Liúpo and the cities of Nampula and Nacala. *Source:* Google Earth [30 August 2015].

Although the town of Liúpo and the city of Nampula did not benefit from NAMWASH, they were included in the research because, together with Ribáuè, they represent different stages along a trajectory of growth associated with economic opportunity. The town of Liúpo, capital of Liúpo District, is in a stage of slow population growth and represents a town with largely rural characteristics. The town of Ribáuè, capital of Ribáuè District and situated along the Nacala Corridor, is transitioning from a rural town to a peri-urban centre and is currently experiencing population pressures. The continued growth of Ribáuè may soon reflect the situation in the peri-urban areas of the city of Nampula, capital of Nampula Province, which has experienced significant growth over the last 15 years[55]. Examination of these three locations would illuminate how governments can be proactive in anticipating the WASH needs of communities as they transition from rural towns to peri-urban and urban centres.

[55] The Mozambican National Statistics Institute projects that the district of Ribáuè will grow by a staggering 140% from 2015 to 2040, while the city of Nampula and district of Liúpo will grow by much more modest rates of roughly 40% and 30%, respectively, over the same time period [Instituto Nacional de Estatística, 2010a].

The Survey Instrument

A robust survey instrument for fieldwork was developed by MU in conjunction with UEM and the African Technology Policy Studies Network (ATPS). This instrument consisted of a household survey, a water point survey, and public sanitation facility[56] surveys. Additionally, a series of guides were produced for key informant[57] interviews.

[56] Public markets, schools, hospitals, health centres.

[57] Local health officials, businesses, non-government organisations (NGOs), community based organisations (CBOs), etc.

Household survey

The household survey consisted of three sections. Section A collected key demographic characteristics of the respondent and household members[58] as well as indicators of household socio-economic status (SES)[59]. Section B contained questions related to the current WASH situation for the household[60], and it also included an observational component related to both sanitation facilities and handwashing stations. Section C focused on WTP for a water and sanitation scenario, reasons for willingness (or unwillingness) to pay, and capacity to pay as measured through household income. On average, the questionnaire was completed in 41 minutes[61].

Prior to fieldwork, the household survey was distributed to stakeholders for comment, and the survey instrument was subjected to a rigorous peer review process involving both economists[62] and social psychologists[63] with the specific aim to ensure validity of the instrument in terms of eliciting useful economic information, specifically in the African context, while avoiding response bias. Following finalisation of the instrument, the household survey was translated into Portuguese and Makhuwa[64].

[58] Age, sex, marital status, highest level of education completed, etc.

[59] Occupation, connection to electrical grid, ownership of key items, etc.

[60] This collected information on water point, sanitation facility, and handwashing station usage; water quality and water point hours of operation and queue times; water collection and storage practice; cleaning practice; handwashing practice; knowledge in regard to water quality, cleaning, and hygiene practice; perceptions; incidence of diarrhoea; etc. It also queried respondents about payments for a variety of water and sanitation facilities or services.

[61] 50% of surveys took between 39 and 46 minutes to complete, and 95% were completed within 1 hour.

[62] Dr. John Ataguba (University of Cape Town), Dr. Hyacinth Ichoku (University of Nigeria).

[63] Prof. Craig McGarty (University of Western Sydney).

[64] This included both inland and coastal Makhuwa, the two dialects commonly found in the areas where fieldwork was conducted.

Water point and public sanitation facility surveys

A water point survey was developed to assess the functionality of, water quality provided by, and hours of operation and queue times for paid water points. The survey was administered to an appropriate person with oversight of a given water point[65]. In addition

[65] This included water committee members, the water point operator, or a neighbourhood leader with responsibility for the water point.

to information on water point functionality and operation, the survey collected information on water committees and maintenance groups with an emphasis on inclusivity of women and people with disabilities. It also queried water point operators on payment for water, subsidies for vulnerable groups, payment for repairs, and education activities organised by water committees. Complementing the questionnaire, the survey included an observational component to assess the suitability of the water point for people with disabilities[66] as well as factors that might potentially compromise water quality[67].

[66] Ramp, appropriate wall structure, appropriate T-handle for boreholes, etc.

[67] *e.g.*, household latrines, solid or faecal waste, animals, or open water points in close proximity to the water point under consideration.

Public sanitation facility surveys aimed to ascertain the types and level of functionality of public market, school, hospital, and health centre latrines, availability of facilities for both males and females, and appropriateness of facilities for females and people with disabilities. They also collected information on individuals or committees responsible for management and cleaning of the latrines, level of cleanliness and cleaning methods, and slab replacement and pit emptying frequency. As with the water point survey, an observational component was included to assess the facilities in terms of cleanliness, suitability for people with disabilities, and other important characteristics.

Both water point surveys and public sanitation facility surveys were carried out by WASH specialists from UEM. In total, 35 water points surveys were administered in each of Ribáuè and Nampula, and 20 water points surveys were administered in Liúpo. In terms of public sanitation facility surveys, 11 surveys were administered in Ribáuè, 14 were administered in Nampula, and 7 were administered in Liúpo.

Human Ethics Approval and In-Country Support

Prior to commencing fieldwork, human ethics approval for research was obtained from both MU[68] and the Mozambican Ministry of Health Bioethics for Health National Committee (CNBS)[69]. In-country support for fieldwork was provided by AIAS and the Provincial Directorate of Health (DPS) of Nampula.

[68] Approval 2013/184.

[69] Approval 307/CNBS/14

Sampling Design

For sampling of households, we followed a similar design to the NAMWASH baseline survey, 2008 MICS, and 2011 DHS and also used multi-stage cluster sampling. Sample size calculations followed the formula specified in Barrington and Admiraal [2014][70] and produced totals of 495 households per location with 15 households to be sampled in each of 33 randomly selected EAs per location. This sample size would be sufficient to guarantee location-specific inference based strictly on this survey. To guarantee comparability with the NAMWASH baseline survey for the towns of Ribáuè and Liùpo, we excluded EAs that fell in regions further

[70] D.J. Barrington and R. Admiraal. Learning by design: Lessons from a baseline study in the NAMWASH Small Towns Programme, Mozambique. *Waterlines*, 33:13–25, 2014

away from town centres than areas sampled under the baseline survey. This ultimately reduced the number of available EAs to 48 for Ribáuè and 15 for Liúpo[71]. We also excluded from consideration the cement city portion of Nampula, ensuring that only peri-urban regions of the city were considered. Additionally, INE was unable to provide EAs for the neighbourhoods of Natikire and Napipine for the city of Nampula, so these neighbourhoods were excluded from our study.

In total, numbers of households sampled for each of Nampula, Ribáuè, and Liúpo were as presented in Table 5. Within each EA, sampling of households was done according to systematic sampling[72], using an identifiable landmark (such as the neighbourhood chief's house) as a starting point.

[71] The resulting under-sampling of households in Liúpo was deemed necessary due to lower numbers of suitable enumerators than originally anticipated. Additionally, a major motivation for including Liúpo in our study was simply for comparisons with Ribáuè pre- and post-NAMWASH to better understand changes attributable to NAMWASH. Since such comparisons would incorporate not only our survey data but also baseline survey data, this pooling of data from the two surveys would ensure that we achieved the required sample sizes for resulting analyses.

[72] We sampled every fifth home.

Town/City	Enumeration areas	Households sampled
Nampula	36	535
Ribáuè	33	495
Liúpo	15	225

Table 5: Numbers of enumeration areas and households sampled in the city of Nampula and towns of Ribáuè and Liúpo in November 2014.

Fieldwork Personnel and Training

Fieldwork was carried out by 30 enumerators under the supervision of 8 supervisors. Supervisors included researchers from MU, UEM, and ATPS and qualified representatives from the DPOPH and DPS of Nampula. Supervisor training occurred over three days and was critical for sharing methodological considerations, preparing for enumerator training and piloting, and discussing field work schedules and quality control methods. During supervisor training, the household survey, water point survey, and public sanitation facility surveys were discussed in depth. Additionally, we laid out a clear local protocol communication strategy to ensure that community leaders and institutions were properly informed of our project and engaged at appropriate times so that fieldwork could proceed according to schedule.

Figure 10: Supervisor training.

The recruitment of enumerators for training was spearheaded by UEM and focused on undergraduate students at local universities[73] with previous experience with household surveys. In the recruitment process, close attention was paid to gender balance and fluency in the local dialect, Makhuwa. The focus on university students was in part due to the complexity of the household survey and, consequently, the need for enumerators who could quickly understand the aims and proper implementation of the survey. It also served as a capacity building opportunity, giving them insights into the logistics of running a household survey, sampling methodology and random household selection in a peri-urban context, and the importance of mitigating response bias when carrying out surveys through strict adherence to question wording.

[73] UniLúrio, Teaching University (UP), Catholic University of Mozambique, etc.

Figure 11: Enumerator training.

Ultimately, fifty enumerators (23 females, 27 males) were recruited for five days of training and piloting in the city of Nampula. Training included a clear exposition of the project, a methodical explanation of the household survey, its three sections, individual questions, use of visual cards to assist respondents, and strategies for increasing response rates. Close attention was paid to sensitivities around questions pertaining to finances, and we stressed the importance of these questions to our analyses[74]. Training also included a significant amount of role-playing to better familiarise enumerators with the questions, highlight common mistakes, and enable enumerators to more fluidly carry out surveys. At the end of training, enumerators were apprised of daily schedules, emergency procedures, and human ethics considerations.

[74] This was also relayed to community leaders in the hopes that this might increase response rates for questions related to finances.

Training also included pertinent language considerations. While most residents of Nampula are conversant in Portuguese, this is not the case in Ribáuè and Liúpo, where many residents speak only inland or coastal Makhuwa dialects, respectively. Makhuwa language experts produced a joint Portuguese/Makhuwa version of the household survey to be used for reference by enumerators. As Makhuwa does not have a written form, the experts presented a crash course in how to phonetically read Makhuwa, and then they explained important differences between inland and coastal Makhuwa in terms of terminology for specific water point and sanitation facility types to ensure that these were properly recorded in surveys.

Figure 12: Piloting in Nampula.

After enumerator training, piloting was carried out in Nampula city in accordance with sampling procedures that would be used in the field. Not only did this create real face-to-face interview experience and highlight any issues with the survey instrument that might need to be addressed, but it also familiarised enumerators with the use of GPS devices and orientation support materials and how sampling of households would be carried out in the field.

Figure 13: Administration of the household survey in Liúpo.

A competitive selection procedure was used to select a final group of enumerators. This selection was based on a number of factors including trainees' performances in terms of accurate survey completion, understanding of the survey, and communication and language skills. In total, 30 enumerators (composed of 15 females and 15 males) were selected for fieldwork. Enumerators were assigned for fieldwork in either Nampula, Ribáuè, or Liúpo, and assignment of enumerators to the three locations took into consideration gender balance, language capabilities[75], and religious affiliation[76].

[75] Those engaging in fieldwork in Ribáuè and Liúpo were required to be fluent in Makhuwa.

[76] Ribáuè is predominantly Christian, whereas Liúpo is predominantly Muslim.

Assignment of supervisors and enumerators to the three locations was as shown in Table 6 with equal numbers of male and female enumerators for each location. Fieldwork was carried out from November 9-22 with all enumerators and supervisors carrying out fieldwork in the city of Nampula for the first two days to help ensure that any potential issues with enumerators or procedures could be addressed before groups travelled to their respective sites.

Town/City	Supervisors	Enumerators
Nampula	2	10
Ribáuè	4	14
Liúpo	2	6
Total	8	30

Table 6: Assignment of supervisors and enumerators to the city of Nampula and towns of Ribáuè and Liúpo for fieldwork.

Local Protocol

Prior to the onset of fieldwork, meetings were held with local leaders in each town to explain the study and its aims and receive their permission to engage in fieldwork in the proposed neighbourhoods. These initial meetings were valuable in that they afforded local leaders the opportunity to provide insight into any difficulties we might potentially encounter during our fieldwork. This also gave local leaders sufficient time to inform households of our study in advance of our arrival, and we found people to be very receptive to our presence in their towns and to the survey we were carrying out. Prior to entering any neighbourhood, meetings were held with the neighbourhood chief, providing further opportunity to explain our study and obtain feedback.

Quality Control Measures

Quality control was a major point of emphasis, and proper documentation of all procedures was kept and shared during supervisor and enumerator training. During the data collection phase, monitoring checklists were kept and verified on a daily basis. Each supervisor was responsible for roughly 2-3 teams of enumerators[77], and supervisors examined all questionnaires for completeness and accuracy. If any errors were found or there were any questions about responses, these were immediately brought to the attention of the enumerators to either correct, clarify, or follow up with the respondent. Common issues were brought to the attention of all enumerators. At the end of each day, a discussion was held amongst all supervisors within a given town, and nominated supervisors from the three towns subsequently discussed by phone the day's activities in their respective towns and shared any insights or issues. To mitigate potential enumerator effects, the composition of teams was changed every day. Additionally, supervisors observed on a daily basis at least one interview per team and carried out an initial check on site of the completed questionnaire. To further ensure the validity of surveys, randomly selected households were revisited by supervisors to confirm survey responses.

[77] Enumerators were split into pairs consisting of a male and a female, and each pair worked together for a given day.

Data Entry and Cleaning

Data entry was accomplished using CSPro[78] and was carried out by eight enumerators who were identified as being particularly meticulous during fieldwork. Data entry occurred immediately following the end of fieldwork and took roughly three weeks to complete. The use of enumerators for data entry proved to be very effective because of their familiarity with the survey and the towns in which fieldwork took place. A dedicated supervisor was available to address any issues related to data input as well as carry out quality control on a random selection of no less than 20% of surveys for each data entry person. Payment was directly tied to a data entry person's accuracy on this random selection of surveys. Data cleaning and analysis were carried out using R[79], a dedicated statistical programming language that provides substantially more flexibility than CSPro's built-in tools.

Figure 14: Data entry.

[78] United States Census Bureau. *The Census and Survey Processing System (CSPRO), Version 6.0.1*. United States Census Bureau, Washington, D.C., 2015. URL http://www.census.gov/population/international/software/cspro

[79] R Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria, 2015. URL http://www.R-project.org/

The Water, Sanitation, and Hygiene Situations in Nampula, Ribáuè, and Liúpo

Just as the towns of Ribáuè and Liúpo and city of Nampula have different profiles in terms of size, population growth, and economic prospects, they also differ in regard to their WASH situations. This might not be surprising as, in general, we would expect places with very different population sizes and economic situations to differ in terms of their WASH situations. However, as we will later discuss, the town of Ribáuè was actually quite similar to (and, in some cases, worse than) Liúpo in terms of its WASH situation prior to NAMWASH. Consequently, current differences between the towns of Ribáuè and Liúpo can provide insight into the impacts of NAMWASH.

In this chapter, we compare Nampula, Ribáuè, and Liúpo in regard to their WASH situations as based on data collected in November 2014. In the cases of Ribáuè and Liúpo, we also provide comparisons with their WASH situations as estimated from data collected in the NAMWASH baseline survey from September and early October 2012. This provides insight into the short-term effects of NAMWASH and what can reasonably be expected for similar interventions in towns with profiles much like Ribáuè. The city of Nampula was not included in the NAMWASH baseline survey, but the 2011 DHS included a supplement[80] for Nampula that we will use for comparison with the data collected in November 2014 to see how the WASH situation has changed between 2011 and 2014.

[80] This supplement, DHS PLUS, was produced for the major metropolitan areas of Mozambique.

Water

Primary water point usage by location as reported by households in November 2014 is shown in Figure 15. This shows a significantly higher usage of piped water[81] in the city of Nampula (roughly 80% of households) than Ribáuè (roughly 20%) or Liúpo (0%), as would be anticipated. Liúpo, which currently does not have access to piped water and has only seasonal rivers in close proximity, is heavily reliant on boreholes (roughly 80% of households) with households with no boreholes nearby using unprotected wells. Ribáuè has a much more diverse range of water points being used with the majority of households using boreholes (approximately 40%) or unprotected wells (nearly 30%) and a growing segment of the population using piped water (over 20%)[82].

[81] Household connection, yard tap, tap of a neighbour, standpipe/water kiosk.

[82] Note that the use of yard taps has increased significantly since November 2014 with more than 120 new yard taps now in existence, a roughly 60% increase. Consequently, this estimate of piped water use is significantly lower than what we would expect to observe now.

The diversity of water infrastructure available in Nampula and Ribáuè helps alleviate the pressure on one type of water source[83], and the presence of piped water means that at least one form of infrastructure can be readily adapted to address increased demand. This would positively affect water availability, and only 14.80% (11.79%, 17.81%) of households in Nampula and 14.05% (10.99%, 17.12%) of households in Ribáuè report having insufficient water for their daily needs. By contrast, 48.21% (41.67%, 54.76%) of households in Liúpo (which is completely dependent on provision of groundwater through boreholes and wells) report having insufficient water for their daily needs. Even though boreholes are dug to sufficient depths to be able to reliably provide water year-round, the limited number of boreholes available leads to long queues, as evidenced by mean queue times reported by water point authorities in Table 7. These show a critical situation in Liúpo relative to Nampula and Ribáuè, where standpipes/water kiosks have short queue times and boreholes in Ribáuè still have a reasonable queue time. Of surveyed water point authorities in Liúpo, 20.00% estimated an *average* queue time of one hour or longer, and 80.00% estimated a *maximum* queue time of one hour or longer with 43.75% of these maximum queue times being in excess of two hours[84].

[83] Groundwater, surface water.

[84] The Sphere Handbook reports 30 minutes as being a critical cut-off point for queue times. Queueing beyond this frequently indicates insufficient water points and results in a decrease in household water consumption [The Sphere Project, 2011].

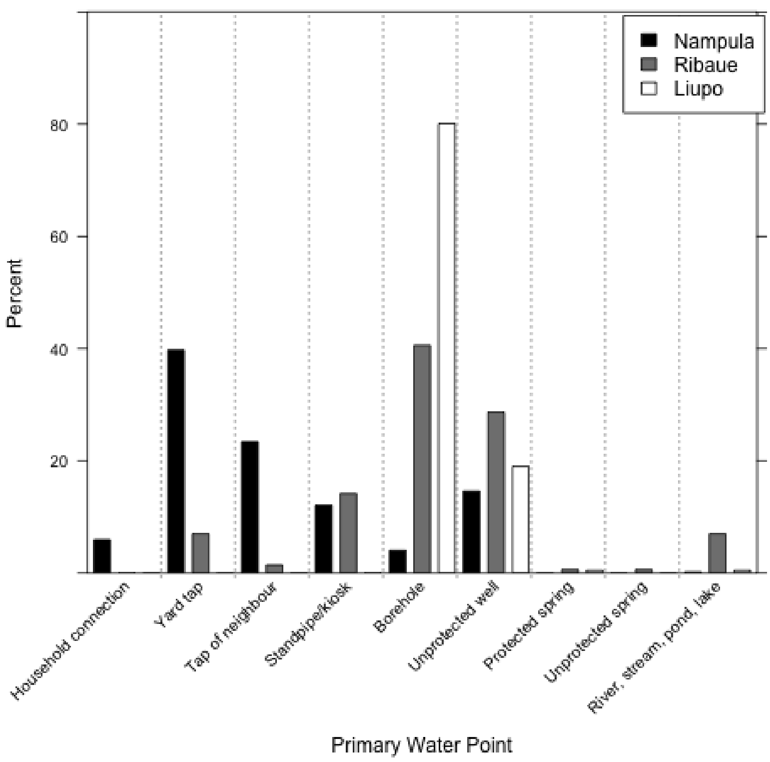


Figure 15: Reported primary water point usage in the city of Nampula and towns of Ribáuè and Liúpo in November 2014.

Water point	Nampula	Ribáuè	Liúpo
Standpipe	3.86 (2.24, 5.47)	1.22 (0.93, 1.51)	
Borehole		7.25 (4.11, 10.38)	40.56 (29.41, 51.70)

Table 7: Mean queue times in minutes (with accompanying 95% confidence intervals) by water point type and town/city, as reported by water point authorities in November 2014.

Long queues in Liúpo have led to limits on the numbers of jerrycans[85] that can be collected per day, meaning that households generally are not able to collect sufficient quantities of clean water[86]. Daily household and per capita consumption of water, as reported by households, are presented in Table 8 and show Liúpo to be in a critical situation with average consumption falling below the Sphere Project's recommended minimum standard of 15 litres of water per person per day[87]. The situations in Nampula and Ribáuè are significantly better with average per capita consumptions of 22.37 and 28.41 litres per day, respectively. These differences in water consumption are important not only in terms of highlighting the perilous water situation in Liúpo but also because studies have shown that, as water consumption increases, much of the additional water being consumed goes toward hygiene purposes[88]. This would suggest improved health benefits for Nampula and Ribáuè relative to Liúpo.

85 A jerrycan holds approximately 20 litres of water.

86 Depending on the borehole, households may withdraw from 9 to 11 jerrycans (180 to 220 litres) per day with 5-6 containers collected in the morning and 4-5 in the afternoon.

87 The Sphere Project. *Humanitarian Charter and Minimum Standards in Humanitarian Response*. 3rd edition, 2011

88 S. Cairncross and V. Valdmanis. Water supply, sanitation, and hygiene promotion. In A. Mills, A.R. Measham, P. Musgrove, J.G. Breman, D.T. Jamison, D.B. Evans, P. Jha, M. Claeson, and G. Alleyne, editors, *Disease Control Priorities in Developing Countries*, pages 771–792. The World Bank, Washington, D.C., 2nd edition, 2006

	Per Household		Per Capita	
Town/City	Litres	Jerrycans	Household size	Litres
Nampula	152.33 (140.06, 164.60)	7.62 (7.00, 8.23)	5.36 (5.19, 5.53)	28.41 (26.12, 30.70)
Ribáuè	111.07 (103.32, 118.82)	5.55 (5.17, 5.94)	4.97 (4.77, 5.16)	22.37 (20.81, 23.93)
Liúpo	75.93 (66.53, 85.33)	3.80 (3.33, 4.27)	5.13 (4.84, 5.41)	14.82 (12.98,16.65)

Table 8: Mean water consumption per household and per capita (with accompanying 95% confidence intervals) by town/city, as reported by households in November 2014.

Nampula

Within the past few years, the city of Nampula has received a massive boost to its piped water system's capacity. Prior to 2011, the water system could maximally service 250,000 people through a system that could supply up to 20,000 cubic meters[89] of water per day. The Millennium Challenge Corporation via the Millennium Challenge Account Mozambique funded project works from September 2011 to December 2013 that rehabilitated the previous water treatment plant and reconstructed a low lift pumping station, roughly doubling the system's capacity to 40,000 cubic meters per day. The project also extended the pipeline by 14,000 meters and produced an additional 5,000 cubic meters of elevated ground storage[90]. The current piped water system can now potentially support 500,000 customers, and the continued expansion of the piped system could soon signal the end for boreholes and other groundwater points in Nampula city.

Figure 16 presents a comparison between 2011 DHS PLUS[91] and household reports from November 2014 for the various water points present in Nampula city. This comparison shows a signifi-

89 1 cubic meter = 1,000 litres.

90 Nampula com mais água potável, 16 April 2014. URL http://www.jornalnoticias.co.mz/index.php/sociedade/14100-mais-agua-para-nampula; WaterTAP Technology Acceleration Project. Ontario consulting engineering firms collaborate on projects in sub-Saharan Africa, 9 May 2014. URL http://www.watertapontario.com/news/blog/ontario-consulting-engineering-firms-collaborate 67; and Water supply to city of Nampula, Mozambique to double by 2013. *Macao Magazine*, 6 September 2011. URL http://www.macauhub.com.mo/en/2011/09/06/water-supply-to-city-of-nampula-mozambique-to-do

91 Instituto Nacional de Estatística. *Moçambique Inquérito Demográfico e de Saúde*. Instituto Nacional de Estatística (with technical assistance by MEASURE DHS/ICF International), Republic of Mozambique, Maputo, 2011

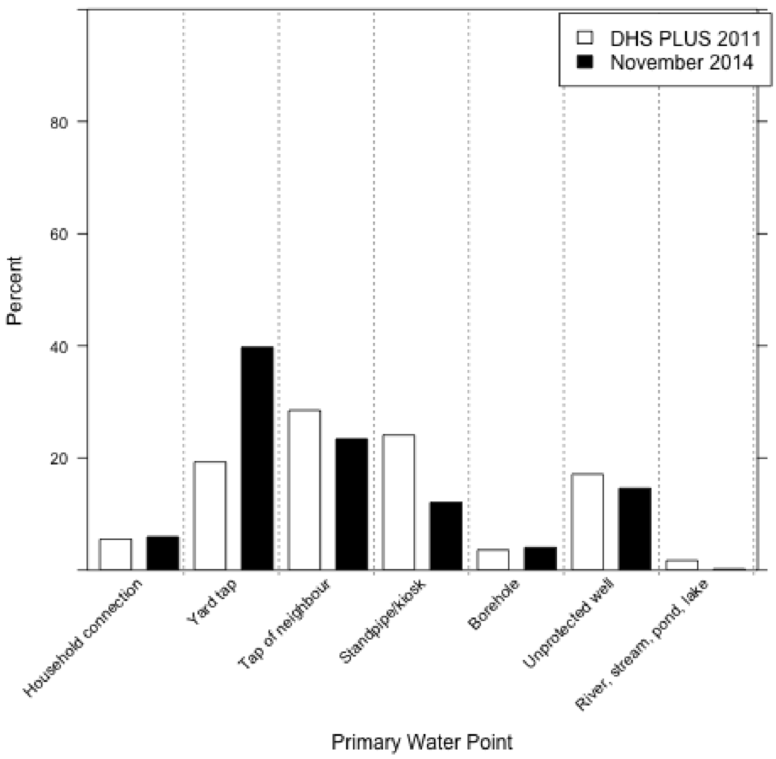


Figure 16: Reported primary water point usage in the city of Nampula in 2011 and November 2014.

cantly higher usage of yard taps and lower usage of standpipes in 2014 than in 2011. These increases in usage of yard taps could be attributable to a number of factors, including:

- significant expansion of the main pipeline that has occurred since 2011, thereby giving more households access to yard taps,
- continued economic growth in the city of Nampula, leading to greater willingness and capacity to pay for water delivered through yard taps,
- tariff structures that make yard taps more cost effective than standpipes for the typical consumer[92], and
- sampling variability[93].

To better understand the possible impacts of sampling variability and level of variability in primary water point usage that exists across the city of Nampula, we present reported primary water point usage by neighbourhood in Table 10. These are based on sample totals by neighbourhood as presented in Table 9. These primary water point usage totals show different water situations across the city with all sampled households in Namutequeliua reporting using some form of piped water and 60% having either a household connection or yard tap. By contrast, more than 25% of households in Namicopo rely on unprotected wells, and only roughly 20% use a household connection or yard tap.

[92] At present, the tariff structure for household connections and yard taps in Nampula city consists of a monthly flat fee of 55 MZN plus 70 MZN for the first 5 cubic meters of water [Conselho de Regulação de Águas, April 2012]. By contrast, users of standpipes are generally charged 1 MZN per jerrycan. A household collecting 4 jerrycans of water per day from a standpipe would have a monthly bill roughly equivalent to a household using approximately 8 jerrycans of water water per day from a yard tap.

[93] Households in Natikire are generally considered to be of lower socio-economic than households in other neighbourhoods, so exclusion of this neighbourhood may have led to estimates that suggest a better WASH situation than is true for the city of Nampula as a whole.

Table 9: Numbers of households sampled by neighbourhood in the city of Nampula in November 2014.

Neighbourhood	*Households*
Muahivire	135
Muatala	105
Muhala	105
Murapaniua	25
Namicopo	120
Namutequeliua	45
Total	535

Neighbourhood	*Tap in home*	*Yard tap*	*Neighbour's tap*	*Standpipe*	*Borehole*	*Unprotected well*	*River, stream*
Muahivire	7.09%	41.73%	13.39%	11.81%	8.66%	17.32%	
Muatala	1.94%	53.40%	33.01%	4.85%	0.97%	4.85%	0.97%
Muhala	8.74%	44.66%	10.68%	16.50%	7.77%	11.65%	
Murapaniua	4.17%	50.00%	20.83%	8.33%		16.67%	
Namicopo	1.68%	18.49%	37.82%	13.45%	0.84%	27.73%	
Namutequeliua	17.78%	42.22%	22.22%	17.78%			
Total	5.95%	39.73%	23.42%	12.09%	4.03%	14.59%	0.19%

Table 10: Primary water point usage by neighbourhood in the city of Nampula in November 2014.

Although the level of use of piped water in Nampula is high and the system has benefitted from significant improvements to its capacity, the city faces challenges in terms of reliable delivery of water. Standpipe operators noted that water availability is severely restricted with 71.43% of surveyed operators supplying water for fewer than 10 hours per day[94] and all reporting that disruptions to the water supply occur on a monthly basis. They all identified water pressure as being an issue with water pressure being so low at some standpipes that users need to wait several minutes before water begins to flow. In some instances, standpipe operators have tapped into the pipeline feeding the standpipe because water pressure is insufficient to use the standpipe. Standpipe operators noted that the distribution network is in desperate need of maintenance, and researchers verified that a number of standpipes were clearly damaged or completely inoperable[95].

[94] By comparison, only one of the ten water kiosks (*i.e.* 10%) in Ribáuè reported operating for fewer than 10 hours per day, and households and businesses both reported uninterrupted water supply for 24 hours per day, 7 days a week.

[95] Researchers observed some damage to water points which, according to community leaders, was due to political conflicts that arose with changes in ruling parties. The authors are of the understanding that standpipe operators are appointed by community leaders, so, potentially, the general population may interpret these positions as being politically linked.

The issues with the piped network mentioned by standpipe operators were also noted by households. When queried about the problems they face with their most frequently used water point, most households using piped water reported no problems. Those who did report issues, however, noted problems with limited hours of availability and insufficient water availability, as shown in Table 11. These two issues are closely related, as the lack of reliability of piped water due to insufficient pressure is responsible for producing insufficient quantities. Those using standpipes additionally noted problems with long queues and travelling distances.

Primary Problem	Household connection ($N = 29$)	Yard tap ($N = 199$)	Standpipe ($N = 65$)
None	72.41%	65.33%	40.00%
Limited or variable hours of operation	20.69%	8.04%	7.7%
Insufficient water availability	6.90%	20.10%	13.85%
Waiting in long queues			23.08%
Long travelling distances			10.77%

Table 11: Most commonly cited issues with primary water point for users of piped infrastructure in the city of Nampula in November 2014.

Even if the city of Nampula addresses these issues with its piped system and produces a fully operational distribution network, it faces challenges in terms of water supply, as current reservoirs and dams have insufficient storage capacity to sustainably meet the demand of a growing population. As noted by Deputy Minister of Public Works and Housing, Francisco Pereira, in December 2014, "One of the most critical areas of the Province in terms of water supply is the city of Nampula, because the water stored in the main dam of the Monapo River is insufficient, and the number of inhabitants who have become aggravated by this has increased greatly in recent times. The city of Nampula is in a critical situation"[96].

[96] Água continua a ser problema em Nampula. *Notícias*, 17 December 2014. URL http://jornalnoticias.co.mz/index.php/sociedade/28501-agua-continua-a-ser-problema-em-nampula

Ribáuè

As part of NAMWASH, the town of Ribáuè benefitted from the rehabilitation and expansion of its piped water system. This work was completed in June 2014, and the piped network now delivers clean water to households through approximately 330 yard taps, 10 water kiosks and 2 standpipes, direct connections to 14 businesses, and 31 connections to public services and the local council.

Data collected in November 2014 provide insight into the short-term uptake of piped water in Ribáuè, and Table 12 shows the numbers of households sampled by neighbourhood. Table 13 shows primary water point usage corresponding to these neighbourhoods, as reported by households. These totals signal a significant increase in usage of improved water points[97] due to NAMWASH. Figure 21 provides a comparison of primary water point usage in September 2012 versus November 2014, and it shows a 2.5-fold increase in usage of yard taps and a 3-fold increase in usage of water kiosks/standpipes[98] at the expense of unprotected wells, which have seen a 2-fold decrease in usage.

[97] Improved water points include piped water points and boreholes.

[98] Discussions with the private operator of the piped system, neighbourhood leaders, and long-time residents of Ribáuè suggest that few if any households would have had access to some form of piped water in September 2012, so increases in the use of piped water are almost certainly significantly larger than what is shown in Figure 21.

Since November 2014 the private operator has installed more than 120 yard taps (representing a 60% increase in yard tap customers from November 2014) and also rehabilitated two standpipes. This indicates a steady increase in the availability and uptake of piped water at the expense of less improved water points, and the level of saturation of piped water within such a short period of time is impressive, particularly considering that four neighbourhoods did not have access to piped water at the time of fieldwork.

Table 12: Numbers of households sampled by neighbourhood in the town of Ribáuè in November 2014.

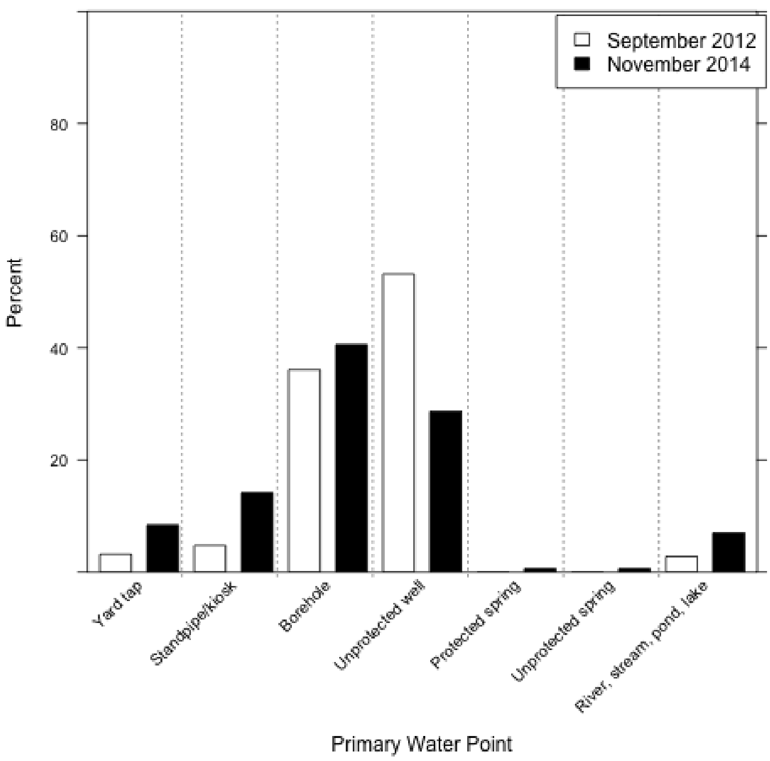
Neighbourhood	*Households*
Bairro Novo	15
Molipiha A	90
Molipiha B	90
Muatala	15
Muhiliale A	45
Muhiliale B	90
Murrapaniua A	30
Murrapaniua B	60
Quithele	15
Sauasaua	45
Total	495

Accompanying the improvement to Ribáuè's water supply was a massive boost to household water consumption. In September 2012, households in Ribáuè reported consuming an average of 71.33 (69.24, 73.42) litres of water per day. In November 2014, households reported consuming an average of 111.07 (103.32, 118.82) litres per day, an increase of roughly 2 jerrycans. By contrast, households in Liúpo reported higher levels of water consumption than households in Ribáuè in 2012 with an average consumption of 81.19 (77.78, 84.60) litres per household per day. In November 2014, this had remained relatively stagnant at 75.93 (66.53, 85.33) litres, leaving consumption in Liúpo lagging well behind that of Ribáuè.

Neighbourhood	*Yard tap*	*Water kiosk (Standpipe)*	*Borehole*	*Unprotected well*	*Protected spring*	*Unprotected spring*	*River, stream*
Bairro Novo			60.00%	26.67%			13.33%
Molipiha A	0.97%	2.91%	52.43%	31.07%			11.65%
Molipiha B	17.33%	17.33%	29.33%	32.00%			1.33%
Muatala			20.00%	66.67%		6.67%	6.67%
Muhiliale A	8.89%	8.89%	53.33%	20.00%	2.2%		2.2%
Muhiliale B	7.62%	32.38%	20.95%	24.76%	1.90%	0.95%	11.43%
Murrapaniua A	16.67%	16.67%	30.00%	26.67%			3.33%
Murrapaniua B	5.36%	17.86%	50.00%	23.21%		1.79%	1.79%
Quithele			73.33%	13.33%			13.33%
Sauasaua			56.67%	40.00%			3.33%
Total	8.38%	13.91%	40.90%	28.62 %	0.61%	0.61%	6.95%

Table 13: Primary water point usage by neighbourhood in the town of Ribáuè in November 2014.

Figure 17: Reported primary water point usage in the town of Ribáuè in September 2012 and November 2014.



The level of 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. By comparison, Liúpo had similarly low levels in 2012 with 8.73% (5.24%, 12.22%) of households treating water, and it also witnessed a significant increase to 20.98% (15.65%, 26.31%) but not to the same levels as Ribáuè. In spite of this improvement in the level of POU treatment of water, both Ribáuè and Liúpo lag well behind Nampula, which sees 43.92% (39.71%, 48.13%) of households treat their water. POU treatment of water is significant not only because it has been shown to be substantially more effective than point of entry treatment in reducing incidence of diarrhoea[99] but also because it is by far the most cost-effective form of WASH intervention[100]. To obtain the greatest impact, water treatment must be applied in a sustained manner all of the time for every household member for every purpose[101,102].

For those using piped water in Ribáuè, a common complaint that was voiced 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 until August of 2014. Because water was free until August, this resulted in unchecked usage of water 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 cost of drawing water from a borehole, for which costs range from 5 MZN to 25 MZN per month.

In spite of these complaints about high water costs and struggles to pay those first bills, according to the water system operator only 7.69% of households and one kiosk operator (*i.e.* 10%) were in arrears as of July 2015[103], suggesting that, as time has gone on, households have learned to adapt their level of usage of piped water to a quantity that they can afford on a monthly basis. Additionally, uptake of yard taps has steadily increased, suggesting that costs lie within households' willingness and capacity to pay.

Water kiosks

In the city of Nampula, water supplied through public taps is done so via standpipes. The German Development Corporation introduced water kiosks in neighbouring Zambia to great success[104], and so, in reintroducing piped water to Ribáuè as part of NAMWASH, it was decided to trial water kiosks in place of standpipes. Although kiosks are more expensive to construct than standpipes, they provide added protection for water infrastructure, and they provide the opportunity to generate income not only from the selling of water but also household goods.

Interviews with kiosk operators in November 2014 suggested that the profitability from water was low for most kiosks. This can be partially explained by many kiosks competing with functional

[99] L. Fewtrell, R. Kaufmann, D. Kay, W. Enanoria, L. Haller, and J. Colford. Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: A systematic review and meta-analysis. *The Lancet Infectious Diseases*, 5:42–52, 2005; and T. Clasen, I. Roberts, T. Rabie, W. Schmidt, and S. Cairncross. Interventions to improve water quality for preventing diarrhoea. (A Cochrane Review). In *The Cochrane Library*. Update Software, Oxford, 2006

[100] R.C.G. Varley, J. Tarvid, and D.N.W. Chao. A reassessment of the cost-effectiveness of water and sanitation interventions in programmes for controlling childhood diarrhoea. *WHO Bulletin*, 76:617–631, 2002; World Health Organization. *The World Health Report 2002*. World Health Organization, Geneva, 2002; G. Hutton, L. Haller, and J. Bartram. Global cost-benefit analysis of water supply and sanitation interventions. *Journal of Water and Health*, 5(4):481–502, 2007a; S. Cairncross and V. Valdmanis. Water supply, sanitation, and hygiene promotion. In A. Mills, A.R. Measham, P. Musgrove, J.G. Breman, D.T. Jamison, D.B. Evans, P. Jha, M. Claeson, and G. Alleyne, editors, *Disease Control Priorities in Developing Countries*, pages 771–792. The World Bank, Washington, D.C., 2nd edition, 2006; T. Clasen, L. Haller, D. Walker, J. Bartram, and S. Cairncross. Cost-effectiveness of water quality interventions for preventing diarrhoeal disease in developing countries. *Journal of Water and Health*, 5 (4):41–57, 2007; and L. Haller, G. Hutton, and J. Bartram. Estimating the costs and health benefits of water and sanitation improvements at global level. *Journal of Water and Health*, 5(4): 467–480, 2007

[101] *e.g.*, food preparation, handwashing, etc.

[102] M.D. Sobsey, C.E. Stauber, L.M. Casanova, J.M. Brown, and M.A. Elliott. Point of use household drinking water filtration: A practical, effective solution for providing sustained access to safe drinking water in the developing world. *Environmental Science and Technology*, 42:4261–4267, 2008

[103] In the modelling used in NAMWASH planning, a 20% default rate was assumed [UNICEF and Administração de Infra-estruturas de Água e Saneamento, 2012], so this falls well below that estimate.

[104] S. Klawitter, S. Lorek, D. Schaefer, and A. Lammerding, editors. *Case Study: Water Kiosks—How the combination of low-cost technology, pro-poor financing and regulation leads to the scaling up of water supply service provision to the poor*. Deutsche Gesellschaft für Technische Zusammenarbeit, 2009

boreholes and unprotected wells in close proximity. The difference in price between kiosks and boreholes (as well as unimproved water points) can be substantial, with households using a kiosk as their primary water point reporting a median monthly expenditure of 150 MZN as opposed to 20 MZN for borehole users[105]. The ability to sell goods in kiosks can offset low profit margins from water, helping to ensure that kiosks remain viable even while a loyal customer base is being built up. Where kiosk operators do not have the initial capital required to stock kiosks with goods, 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[106].

[105] Even for the average family in Ribáuè (which is estimated to consist of 4.97 people) using The Sphere Project's 2011 minimum standard of 15 litres of water per person per day, families using a kiosk would on average more than double their monthly water bill (57 MZN per month versus 5-25 MZN per month) [The Sphere Project, 2011].

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

For a town like Ribáuè where a functional piped system has not been in place for many years, multimedia messages and education programmes explaining the benefits of piped water can be important in hastening the switch from traditional water points to piped water. They can also help households understand why the increased cost is worth it and shift public perception when it comes to various forms of provision of water. To help highlight this, households were asked how they knew that water was safe to drink. In the city of Nampula, where piped water points are more commonly used than boreholes or more primitive sources despite similar disparities in cost to Ribáuè, 46.49% of respondents said that they knew that water was safe to drink if it came out of a tap. Only 18.83% of respondents in Ribáuè responded similarly. At the same time, while residents of Ribáuè 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. With continued messages and greater exposure to piped water, we would expect that community perception and prioritisation of the clean water provided through piped infrastructure would begin to reflect what is observed in the city of Nampula.

Figure 18: One of ten water kiosks in Ribáuè.

Figure 19: Water kiosk and its operator.

Economic opportunities due to piped water

Piped water in Ribáuè has also increased economic prospects for some local businesses. The economic development driven by the extractive industries has produced significant demand for construction-related services, accommodation, and restaurants. Some owners of accommodation establishments have stringent contractual agreements, and uninterrupted clean water piped into rooms is essential in fulfilling obligations spelled out in those agreements and maintaining these lucrative contracts. Due to the availability of piped water to their premises, accommodation owners have generated significant income from these arrangements, allowing them to expand their services and build new rooms. This, of course, has knock-on effects to brickmakers and builders, who

Figure 20: Owner of Sonho Real, a local accommodation establishment.

benefit from this new construction. The presence of piped water also has ramifications for sanitation facilities with water supply improvements also reflected in improved sanitation facilities in accommodation establishments, restaurants, and residences.

Table 14: List of neighourhoods falling in regions Liúpo A–E.

Regions	Neighbourhoods
Liúpo A	Carrupeia, Antena, Namunlo Expansão, 4 de Outubro
Liúpo B	3 de Fevereiro, Namunlo, Nieta
Liúpo C	Nacaca, Nanrava
Liúpo D	Unidade, Cidade Alta
Liúpo F	Carrupeia, Eduardo Mondlane

Liúpo

The town of Liúpo is situated at the intersection of a road running from the city of Nampula to Quinga and a road stretching from the Port of Nacala to Angoche. Another road connects Liúpo and Mogincual, and the point at which these three roads come together is the hub of the town. These roads effectively split Liúpo into five distinct regions, which we will refer to as Liúpo A, Liúpo B, . . ., Liúpo E. These regions are shown in Figure 21 and encompass various neighbourhoods of Liúpo, and these associations between regions and neighbourhoods are shown in Table 14. The road from Nampula to Quinga serves as the major dividing line for the town with neighbourhoods north and east of the road being overseen by one leader and neighbourhoods south and west of the road being overseen by another. Using the jurisdictions shown in Figure 21, one town leader has responsibility for Liúpo A-B, whereas the other leader has responsibility for Liúpo C-E. Fieldwork carried out in these five regions resulted in total numbers of households sampled per region as shown in Table 15.

Table 15: Numbers of households sampled by region in the town of Liúpo in November 2014.

Region	*Households*
Liúpo A	30
Liúpo B	30
Liúpo C	60
Liúpo D	75
Liúpo E	30
Total	225

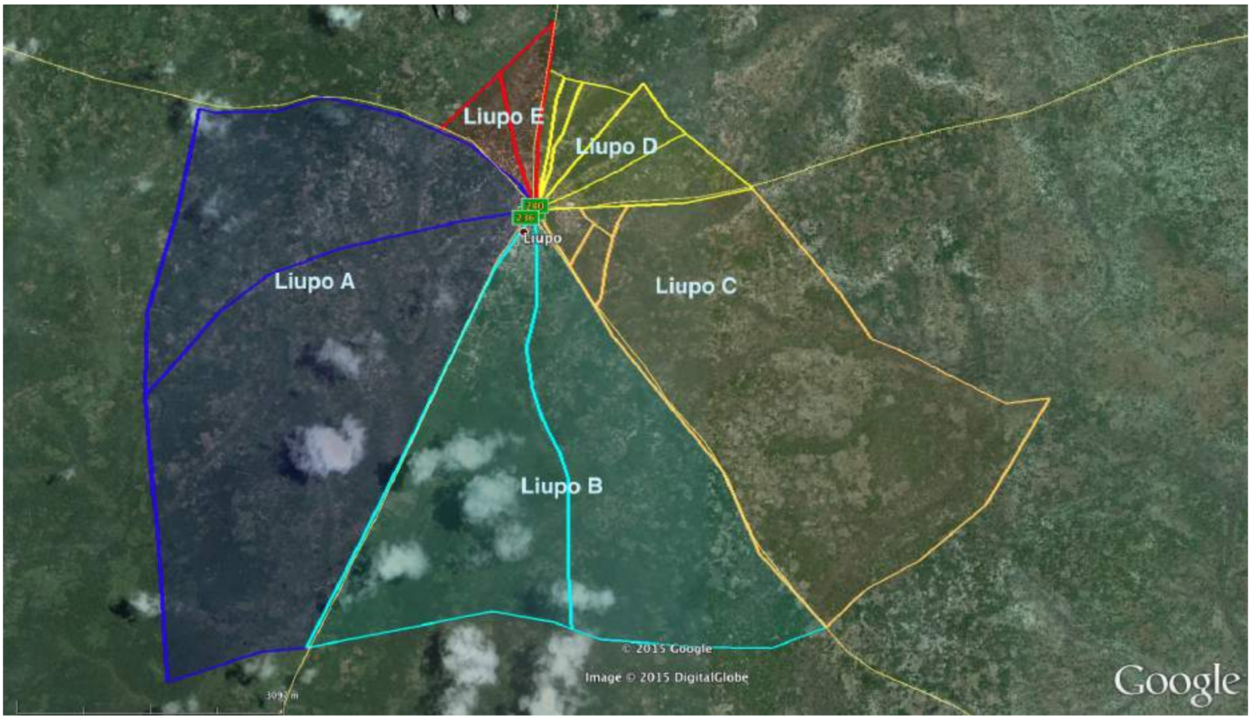


Figure 21: The town of Liúpo and divisions. The areas corresponding to Liúpo A-B are under the authority of one town leader, whereas Liúpo C-E are under the authority of another town leader.

Boreholes serve as the primary water points for the community, and approximately one-third of these were constructed or rehabilitated within the last four years with most of this work occurring in late 2011 and 2012. Boreholes are open anywhere from 9 to 14 hours per day (11 hours on average) with highest demand occurring between 5:00 and 10:00. Families with no boreholes in close proximity or requiring additional water use unprotected wells. Most of these are 5-10 meters deep and provide limited water during the dry season, usually providing water for no more than a couple of hours in the morning and a couple of hours in the afternoon with a lengthy recharge period required in between. This water tends to be turbid and would not be suitable for drinking without first filtering or treating the water. We encountered only one cluster of unprotected wells that consistently produced clear water without requiring long waits for water recharge, and these had been dug to a depth of 15 meters.

Figure 22: Owner of one of the few deep unprotected wells in Liúpo that reliably produces water.

Because of both water scarcity and poor quality of well water during the dry season, only a small percentage of families (19.00%) reported using unprotected wells as their primary water point with the overwhelming majority (80.09%) of households using boreholes. For households that use boreholes as their primary water point, 83.48% report using this as their only source of water[107]. The overwhelming reliance on boreholes means that households in Liúpo actually reported higher levels of usage of an improved water point than what was observed for either Nampula or Ribáuè[108].

[107] In other words, 66.86% of households are fully dependent on boreholes for supplying their water needs.

[108] Households in Liúpo reported greater usage of boreholes than Ribáuè in 2012 when Ribáuè did not have access to piped water, and the water situation in Liúpo was arguably better than that of Ribáuè at that point in time.

Table 16 gives reported primary water point usage broken down by region, and it suggests higher reliance on boreholes in some regions than others. Worth noting is the higher usage of unprotected wells in Liúpo A, Liúpo C, and Liúpo D. This can be explained largely by locations of boreholes, and spatial plots of borehole locations show that, on average, families in these neighbourhoods have the furthest distance to walk to a borehole.

Table 16: Primary water point usage by region in the town of Liúpo in November of 2014.

Region	*Borehole*	*Unprotected well*	*Protected spring*	*River, stream*
Liúpo A	76.67%	20.00%		3.33%
Liúpo B	93.33%	6.67%		
Liúpo C	81.36%	18.64%		
Liúpo D	69.86%	30.14%		
Liúpo E	93.10%	3.45%	3.45%	
Total	80.09%	19.00%	0.45%	0.45%

The situation in terms of primary water points that we observed in November 2014 is not much different from September 2012. Figure 23 shows reported primary water point usage for Liúpo for both 2012 and 2014, demonstrating a slight increase in usage of boreholes and slight decrease in usage of unprotected wells[109].

[109] Given that only one new borehole was reported to have been built in the period between these two surveys, this result is not surprising.

Because of the overwhelming reliance on boreholes, ensuring that these are properly maintained and quickly repaired is essential. Spare parts for routine maintenance of boreholes are available from a local vendor in Liúpo, and parts for major repairs can be sourced

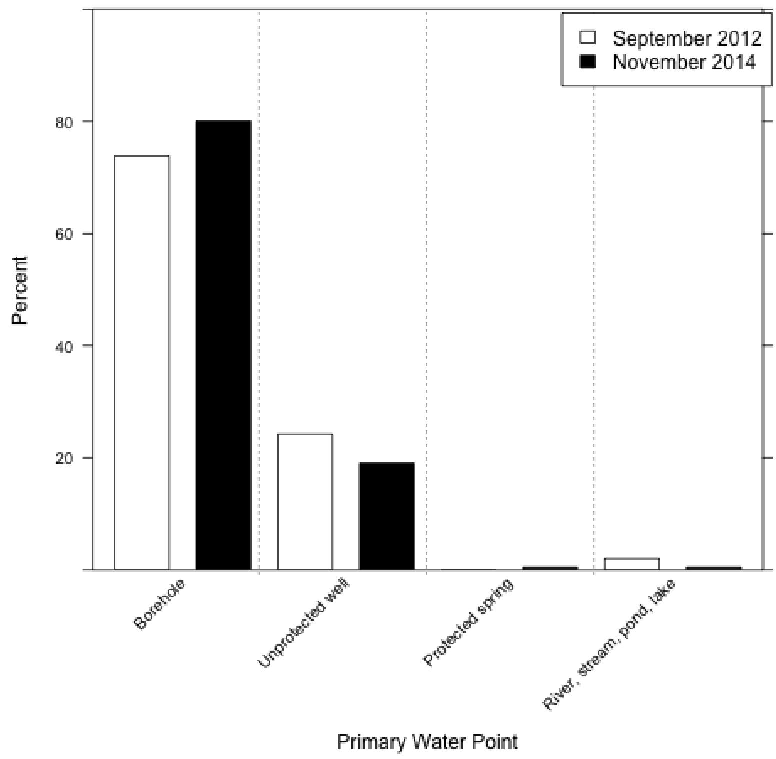


Figure 23: Reported primary water point usage in the town of Liúpo in September 2012 and November 2014.

in Nampula (2-3 hours away by automobile)[110]. Of the boreholes surveyed, 57.89% required some form of repair within the past year, and 58.33% of repairs were completed within one week and 83.33% within one month[111].

When asked about the major problems they faced with their primary water point, users of boreholes cited long queues (46.00%), and long travelling distances (18.00%). Users of unprotected wells similarly cited long queues (26.53%) and long travelling distances (14.28%)[112].

As shown in Table 7, queue times for borehole users in Liúpo (as reported by water point operators) are 40.56 minutes on average, nearly six times what was reported in Ribáuè. The fact that there are long queues is merely a symptom of the more pressing problem, which is that of a significant shortage of dependable water points. Boreholes are fairly evenly spread across the town (except for some gaps in regions Liúpo A, Liúpo C, and Liúpo D), but there simply are not enough to address household demand, and 48.21% of households reported having insufficient access to water to meet their daily needs

[110] Only two repairs in the past year required parts that could not be supplied by the local vendor.

[111] These numbers are comparable to Ribáuè, which reported 76.92% of boreholes as having required repair within the past year. Repair times were also comparable with 50% of borehole repairs being completed within one week and 75% being completed within one month.

[112] Users of unprotected wells additionally noted issues with poor water quality (20.41%) and insufficient water availability (14.29%), which is consistent with our field observations.

Sanitation and Hygiene

Just as the city of Nampula was observed to have a higher level of use of piped water infrastructure than either Ribáuè or Liúpo, it has a higher level of use of improved sanitation facilities[113], as shown in Figure 24. This is primarily because a significant percentage of households use flush toilets or toilets with manual water, as shown in Figure 25. This figure shows the town of Ribáuè to be quite similar to Nampula in terms of use of improved latrines and suggests a higher level of usage of improved traditional latrines than either Nampula or Liúpo. Residents of the town of Liúpo, on the other hand, overwhelmingly use traditional latrines[114] or else practice some form of open defecation[115]. The practice of open defecation appears to be much more widespread in Liúpo than either Ribáuè or Nampula, which report similar rates of open defecation.

Liúpo also lags behind Nampula and Ribáuè in terms of the frequency with which sanitation facilities are cleaned. Figure 26 shows relatively similar results for Nampula and Ribáuè with approximately 80% of households reporting cleaning their latrine every day. Those who do not clean their latrine daily report cleaning it when they recognise that it is dirty. Residents in Liúpo are less likely to clean their latrine every day with only roughly 50% reporting doing so.

The methods used to clean sanitation facilities suggest better cleaning practices in Ribáuè than either Nampula or Liúpo. As shown in Figure 27, residents in Nampula and Liúpo overwhelmingly report cleaning their latrines by sweeping. In stark contrast, this is only the fourth most cited method of cleaning latrines in Ribáuè where households primarily report cleaning latrines with water, water and soap, or some form of cleaning agent. Even though these are reported practices, minimally these results suggest that residents of Ribáuè better understand appropriate sanitation practices when it comes to cleaning latrines. This could possibly be attributed to the sanitation and hygiene education programmes carried out as part of NAMWASH, although we are unable to confirm this due to no corresponding data from the NAMWASH baseline survey.

Households in Ribáuè also seem to understand the importance of handwashing at key moments. Figure 28 presents totals for the three locations in terms of reported handwashing before preparing food, before eating or serving food, after defecating, and after cleaning the faeces of children. These show handwashing rates to be very similar for Nampula and Ribáuè despite households in Nampula having significantly higher rates of use of piped water[116]. Again, Liúpo lags behind in this area.

Sanitation and hygiene practice have an impact on a variety of diseases, including incidence of diarrhoeal diseases, and Table 17 presents reported incidence of diarrhoea in the past two weeks, as reported by households in November 2014 and the NAMWASH baseline survey from 2012. These totals do not show a significant shift in the incidence of diarrhoea for the towns of Ribáuè or Liúpo. As noted by Alexander et al. [2013], incidence of diarrhoea can fluctuate substantially with changes in weather[117], making com-

[113] Improved sanitation facilities include unshared latrines that are at a level equal to or better than ecological/ composting latrines [World Health Organization and Programme, 2013].

[114] Traditional latrines are made of local materials. This includes the slab. The use of local material usually makes it more difficult to clean the facility. Traditional latrines are considered to be unimproved sanitation facilities, and the practice of open defecation is also considered to be a form of unimproved sanitation.

[115] This includes both cat system and open defecation.

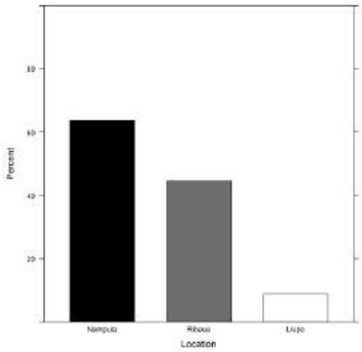


Figure 24: Percentage of households using improved sanitation facilities in the city of Nampula (*black*) and towns of Ribáuè (*grey*) and Liúpo (*white*) in November 2014.

[116] Cairncross and Valdmanis [2006] show that frequency of handwashing increases when water is piped to a household, suggesting that Nampula should have higher reported handwashing rates.

[117] K. A. Alexander, M. Carzolio, D. Goodin, and E. Vance. Climate change is likely to worsen the public health threat of diarrheal disease in Botswana. *International Journal of Environmental Research and Public Health*, 10(4):1202–1230, 2013

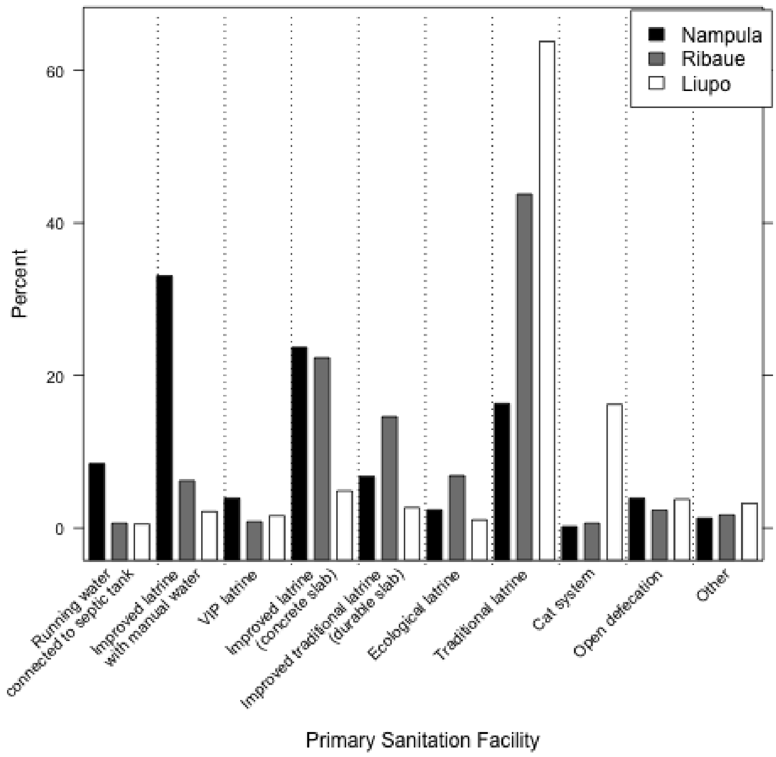


Figure 25: Reported primary sanitation facility usage in the city of Nampula and towns of Ribáuè and Liúpo in November 2014.

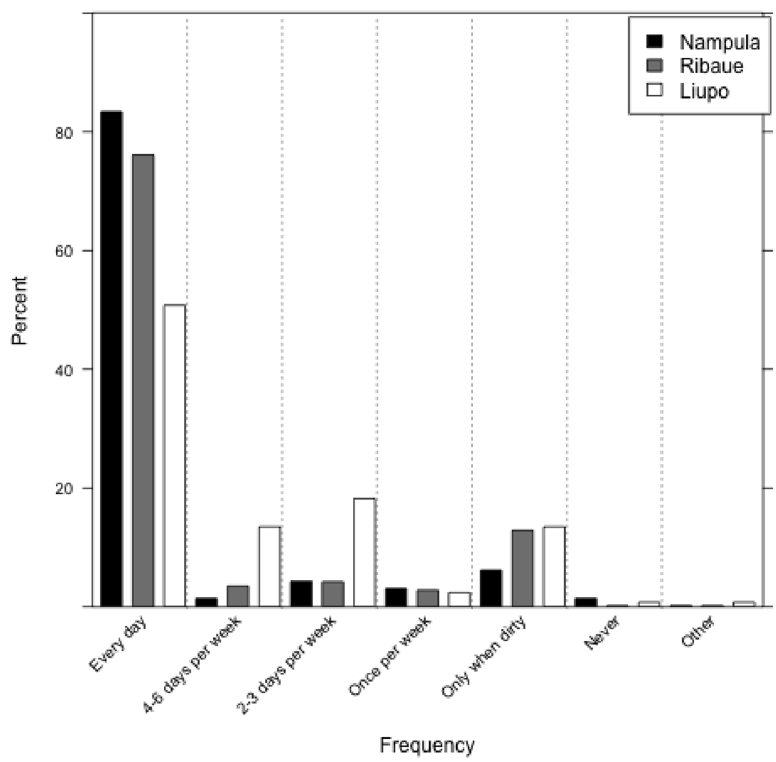


Figure 26: Cleaning frequency of sanitation facilities reported in the city of Nampula and towns of Ribáuè and Liúpo in November 2014.

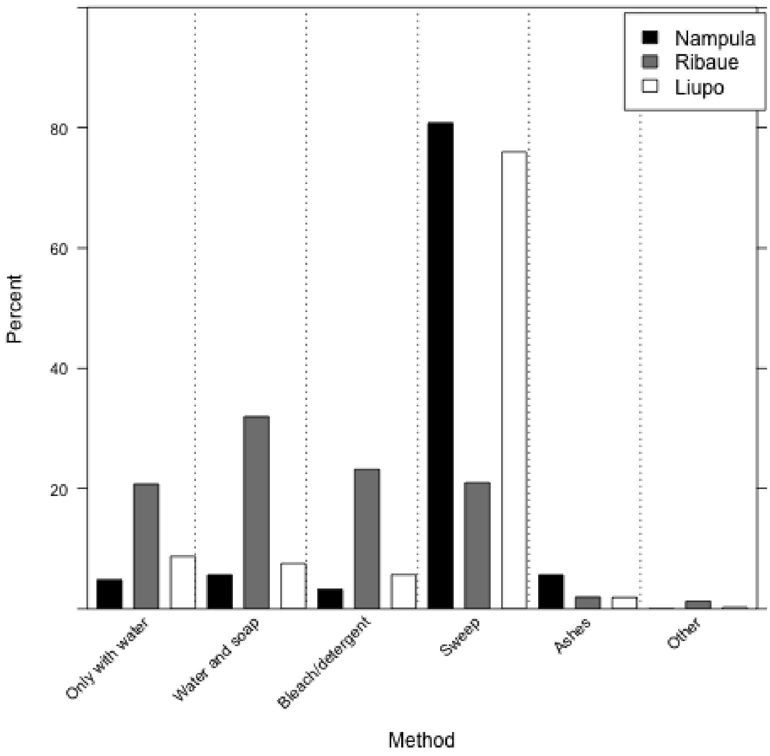


Figure 27: Cleaning method of sanitation facilities reported in the city of Nampula and towns of Ribáuè and Liúpo in November 2014.

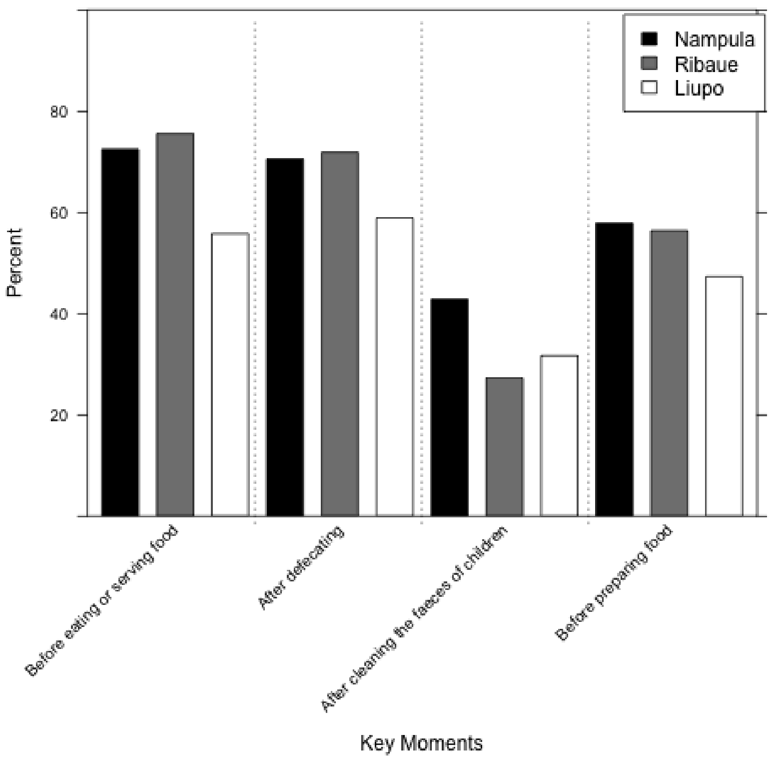


Figure 28: Comparison of reported handwashing at key moments in the city of Nampula and towns of Ribáuè and Liúpo in November 2014.

parisons between years quite difficult, and Admiraal and Doepel [2014] provide a full exposition on this, noting massive variability in incidence of diarrhoea incidence estimates from the 2008 MICS, 2011 DHS, and NAMWASH baseline survey[118]. An examination of incidence of diarrhoea prevalence using health clinic data for the Ribáuè Rural Hospital and Namiconha Health Centre, the two health centres serving residents of the town of Ribáuè, also failed to show any significant changes in incidence of diarrhoea prevalence from the period June-October of 2013 (mid-NAMWASH) to the period June-October of 2014 (post-NAMWASH).[119].

[118] R. Admiraal and D. Doepel. 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, 2014

[119] We considered analyses that both pooled data for a given year and paired across years based on month. These analyses also adjusted for age and health centre. Analyses were restricted to these sets of months due to seasonal fluctuations in incidence of diarrhoea and the desire to compare prevalence mid- and post-NAMWASH (which only concluded in June 2014).

In spite of difficulties in comparisons across years, if surveys are carried out simultaneously in locations that are sufficiently close to have similar weather patterns (as ours was), then comparisons at a given point in time may be reflective of the relative situation. We note that in both 2012 and 2014, incidence of diarrhoea was generally higher in Liúpo than Ribáuè[120]. In 2014, incidence in Nampula is generally lower than either of Ribáuè or Liúpo. If we use health outcomes as a proxy for the over all sanitation and hygiene situation for a location, then this would suggest that Nampula has the best sanitation and hygiene situation and Liúpo has the worst, much in line with what was observed for presence of improved sanitation facilities.

[120] It is worth noting, however, that differences are not statistically significant.

	Age			
	Under 5		5 or over	
Town/City	2012	2014	2012	2014
Nampula		6.91% (4.18%, 9.63%)		0.88% (0.52%, 1.25%)
Ribáuè	9.04% (4.93%, 13.15%)	8.59% (5.79%, 11.40%)	1.07% (0.44%, 1.70%)	1.17% (0.70% 1.63%)
Liúpo	13.29% (7.98%, 18.60%)	11.73% (7.02%, 16.45%)	1.76% (0.96%, 2.57%)	1.75% (0.93%, 2.58%)

Table 17: Incidence of diarrhoea in the past two weeks by age and town/city (with accompanying 95% confidence intervals), as reported in September 2012 and November 2014.

Nampula

For any densely populated area, when appropriate sanitation measures are not in place, disease can run rampant[121]. Consequently, appropriate sanitation facilities and waste removal services[122] as well as proper hygiene practices are important for community health. Recently, the Nampula Councillor for Institutional Affairs, Maria Moreno, suggested that the peri-urban areas of Nampula city (which are the areas we targeted) are facing serious sanitation problems and would benefit greatly from hygiene and sanitation promotion activities that reduce the practice of open defecation, eliminate solid waste dumping spots, and stress the importance of individual and collective hygiene[123].

[121] In the case of Mozambique, this includes not only incidence of diarrhoeal diseases and cholera but also malaria.

[122] This includes both solid waste and faecal waste removal services.

[123] Saneamento do meio: Município de Nampula capacita activistas. *Notícias*, 25 July 2015. URL http://www.jornalnoticias.co.mz/index.php/sociedade/40356-saneamento-do-meio-municipio-de-nampula-ca

Figure 29 provides a comparison of primary sanitation facility usage for households in the city of Nampula as reported in the 2011 DHS and in November 2014. This shows significantly higher levels of usage of flush toilets and toilets with manual water than reported by the DHS in 2011. At the same time, the level of use of traditional latrines or households without a latrine[124] is significantly lower than what was reported in 2011. There are a number of possible explanations for these shifts, but the most likely reasons are either changes in the economic situation in Nampula over that period or sampling variability[125].

[124] This means that either they share a latrine or practice some form of open defecation.

[125] As noted previously, the exclusion of Natikire could potentially overstate the WASH and economic situation for the city of Nampula.

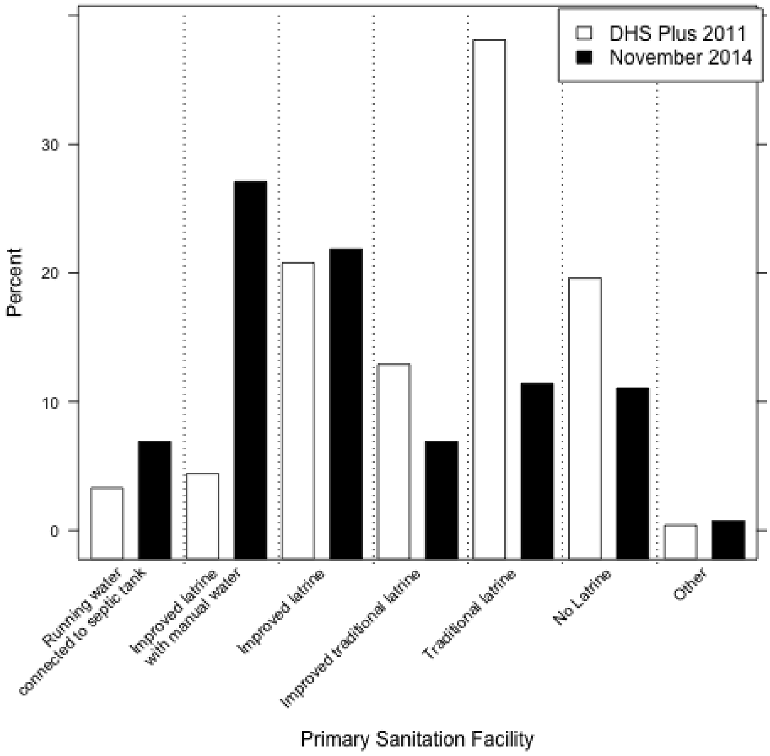


Figure 29: Reported primary sanitation facility usage in the city of Nampula in 2011 and November 2014.

When considering primary latrine by neighbourhood, Table 18 shows that differences were not as widespread in the use of improved sanitation facilities as was noted for improved water sources. Table 18 does indicate higher rates of open defection for the neighbourhoods of Muhala and Murapaniua[126].

[126] Reported cases of open defecation seem to occur in clusters, so this could potentially be attributable to sampling variability rather than more common practice in those neighbourhoods.

Neighbourhood	*Flush toilet*	*Toilet with manual water*	*VIP latrine*	*Improved latrine*	*Improved traditional latrine*	*Ecological latrine*	*Traditional latrine*	*Cat system*	*Open defecation*	*Other*
Muahivire	7.83%	29.57%	3.48%	22.61%	6.96%	5.22%	20.87%	0.87%	0.87%	1.74%
Muatala	4.49%	31.46%	6.74%	29.21%	3.37%	4.49%	15.73%		2.25%	2.25%
Muhala	16.30%	36.96%	1.09%	14.13%	6.52%		15.22%		9.78%	
Murapaniua	13.64%	27.27%	9.09%	18.18%		4.55%	13.64%		13.64%	
Namicopo	1.90%	39.05%	2.86%	32.38%	10.48%		12.38%		0.95%	
Namutequeliua	16.22%	24.32%	5.41%	16.22%	8.11%		18.92%		5.41%	5.41%
Total	8.48%	33.04%	3.91%	23.70%	6.74%	2.39%	16.30%	0.22%	3.91%	1.30%

Table 18: Primary sanitation facility usage by neighbourhood in the city of Nampula in November 2014.

In terms of waste removal, the authors witnessed a number of apparent dumping grounds for solid waste with unprotected wells in close proximity[127]. When it comes to faecal waste removal, only 4.53% of households report having had their latrine pit emptied.

[127] In one case, the well lay squarely at the bottom of a small hill which locals used for disposing of rubbish, so water runoff that flowed down the hill would deposit in the well.

Those who did paid a median cost of 500 MZN (and mean cost of 814.44 MZN). Undoubtedly, cost may be inhibiting more families from using faecal waste removal services, but the increasing density in many of these areas may soon leave families with little choice, as many will not have sufficient room in their yards to move their pit[128].

[128] If households better understand the relationship between faecal waste and groundwater contamination and the knock-on health effects of that, this may help earlier incentivise them to build lined latrine pits and opt to empty these rather than move pits once they are full.

In total four schools were visited across the neighbourhoods surveyed, and all schools visited have poor access to water which compromises cleaning, especially in the sanitation facilities. For Muatala School, the sanitation facilities are shared between teachers and students, but many students do not make use of these sanitation facilities, instead resorting to open urination and defecation. In contrast, students and teachers also share the same sanitation facilities at Muahivire School, but open defecation is rare. This is because the school organises workshops and talks involving school staff, students, and parents that focuses on ending the practice of open defecation. Muahivire School has its own challenges, however, as local residents deposit solid waste on the school grounds and practice open defecation on the school premises. Carrupeia School and Namutequeliua School each have separate facilities for students and teachers, but these were not found to be clean due to lack of water nearby. In all schools visited, although the schools had improved latrines, the latrines were not clean and had neither proper handbasins nor receptacles for solid waste[129].

[129] Waste bins are important, particularly in facilities for women and girls, where receptacles should be kept for disposal of feminine hygiene products.

Researchers also visited five health centres, including Muhala-Expansão, Namutequeliua, Namicopo, Napipine, and 25 de Setembro. In Namicopo, Napipine, and 25 de Setembro Health Centres, there were separate latrines for employees and patients. Patients have access to improved latrines, and there are separate facilities for males and females. Employees have access to flush toilets, but these are not sex-specific. An issue noted with these latrines was that they are not being emptied immediately when septic tanks become full. This is because faecal waste removal services had not been included in operating budgets. This is a similar issue for the Muhala-Expansão and Namutequeliua health centres, where patients and employees use the same outdoor facilities because the employee facilities are clogged, and these cannot be repaired due to budgetary constraints. Unlike what was observed in schools, nearly all health centre latrines have receptacles for solid waste[130].

[130] Even though the 25 de Setembro health centre has receptacles, hospital staff report that patients commonly deposit solid waste (*e.g.*, sanitary napkins, disposable diapers) in the latrines, thereby clogging them.

Ribáuè

As mentioned previously, the town of Ribáuè benefitted substantially from sanitation and hygiene interventions carried out as part of NAMWASH. These interventions included infrastructure, capacity building, and education programmes, and the most visible result was in the way of assisting 1,170 households in obtaining improved latrines and providing appropriate sanitation facilities to schools, health centres, and public markets[131].

[131] This included both gender- and disability-specific facilities.

Due to NAMWASH, the use of improved latrines has increased drastically while the rate of open defecation has dropped significantly. These shifts are evident in Figure 30, showing that the percentage of households using any type of improved sanitation facility has increased from 6.75% in 2012 to 44.53% in 2014, while the percentage of households practicing open defecation has dropped from 10.36% in 2012 to 3.00% in 2014[132]. As would be anticipated, household sanitation facility usage varies significantly by neighbourhood (as shown in Table 19) with those living in neighbourhoods closer to the town centre being more likely to use a more improved sanitation facility.

[132] The rate of use of improved sanitation facilities in Ribáuè recorded in 2012 was less than that of Liúpo. At the same time, the percentage of households reporting practicing open defecation in Ribáuè was higher than that of Liúpo.

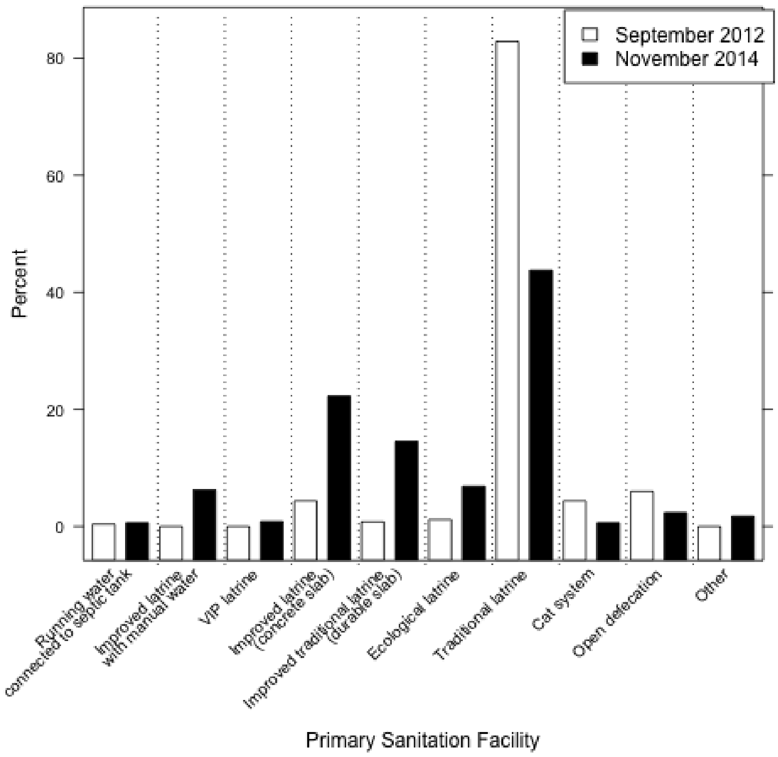


Figure 30: Reported primary sanitation facility usage in the town of Ribáuè in September 2012 and November 2014.

Neighbourhood	*Flush toilet*	*Toilet with manual water*	*VIP latrine*	*Improved latrine*	*Improved traditional latrine*	*Ecological latrine*	*Traditional latrine*	*Cat system*	*Open defecation*	*Other*
Bairro Novo		13.33%		6.67%	20.00%	6.67%	33.33%		13.33%	6.67%
Molipiha A		8.42%	2.11%	27.37%	17.89%	10.53%	31.58%			2.11%
Molipiha B	1.37%	6.85%	1.4%	30.14%	15.07%	12.33%	32.88%			
Muatala				6.67%		6.67%	73.33%		6.67%	6.67%
Muhiliale A	4.65%	2.33%		13.95%	23.26%		55.81%			
Muhiliale B		7.84%	0.98%	28.43%	8.82%	5.88%	43.14%		2.94%	1.96%
Murrapaniua A		6.67%		23.33%	23.33%	6.67%	36.67%			3.33%
Murrapaniua B		5.77%		21.15%	15.38%	3.85%	48.08%	1.92%	1.92%	1.92%
Quithele				8.333%	16.67%		58.33%		16.67%	
Sauasaua					6.67%	3.33%	76.67%	6.67%	6.67%	
Total	0.64%	6.21%	0.86%	22.27%	14.78%	6.85%	43.68%	0.64%	2.36%	1.71%

Table 19: Primary sanitation facility usage by neighbourhood in the town of Ribáuè in November 2014.

Initial uptake of tippy tap handwashing stations was reported by UNICEF Mozambique to be high[133], and reported use of soap or ash when washing hands rose slightly[134]. In several interviews, individuals reported a reduction in sanitation-related diseases as a result of these hygiene and sanitation promotion activities, although we were unable to verify this. More tangible impacts of these activities, however, are increased cleaning of latrines and better cleaning methods. Figure 31 shows a massive reported increase in cleaning frequency of sanitation facilities since 2012, and Figure 27 showed residents of Ribáuè reporting using water and cleaning agents at significantly higher rates than those in Nampula and Liúpo.

[133] UNICEF Mozambique. *NAMWASH Programme Final Report, January 2012 – June 2014*. UNICEF Mozambique, Maputo, July 2014

[134] Reported handwashing with soap or ash was 30.61% in 2012 and 38.46% in 2014.

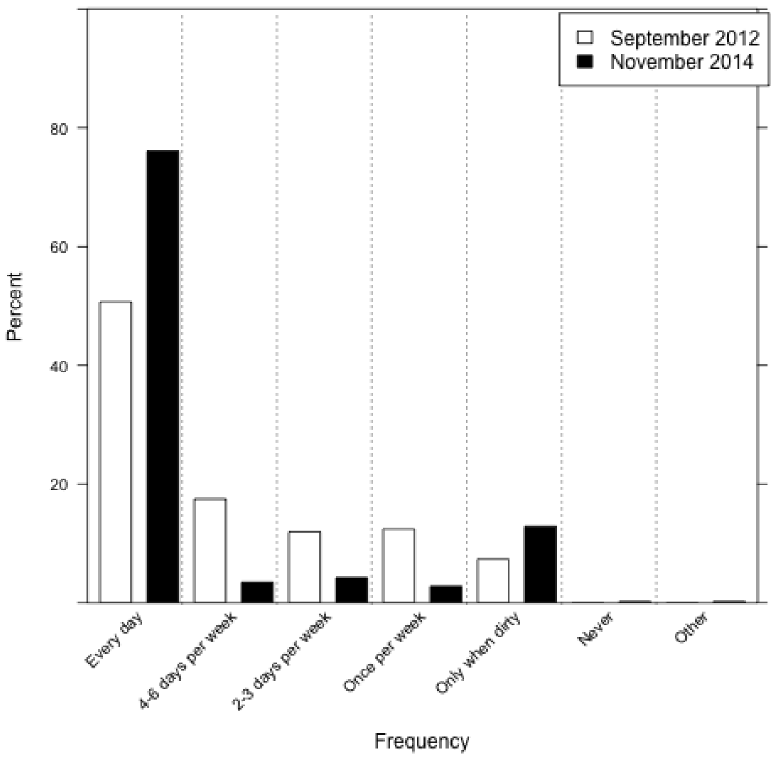


Figure 31: Cleaning frequency of sanitation facilities in Ribáuè in September 2012 and November 2014.

Although there have been massive improvements in the sanitation and hygiene situation in Ribáuè, the town still has room for growth in this area. NAMWASH rehabilitated or provided new sanitation facilities to local schools. It was noted that school latrines were not being locked, and it appeared that members of the community were using the latrines, affecting their cleanliness. Additionally, sanitation facilities provided by NAMWASH are equipped with handwashing stations with water reservoir and tap. However, it was observed that no water was available in sanitation facilities for four of the schools. It appears that this was either because the school sanitation club was not operational or the school did not include the filling of water reservoirs as one of the core duties of sanitation clubs.

At the same time, initial uptake of tippy taps was reported to be high at the conclusion of NAMWASH, but few were found to still be present in surveyed households in November 2014 (as evidenced by Figure 32). This suggests low sustainability for this particular type of handwashing station[135]. In spite of this, the inclusion of tippy tap (or alternative affordable handwashing station technology[136]) building as part of NAMWASH was important, as studies have shown the importance of accompanying hygiene and sanitation promotion campaigns with handwashing infrastructure in effecting behaviour change in terms of handwashing[137].

[135] This is consistent with issues highlighted by Biran [2011], where he noted uptake of tippy taps being stimulated more by pressure due to community-wide competitions (which was the context in which tippy taps were introduced to Ribáuè) rather than desire for the technology. The cited research noted that the majority of people view the tippy tap as unnecessary and no better than other methods for handwashing, and most were constructed as part of a WASH program or because households expected an impending WASH inspection/fine. Rates of uptake of tippy taps were low for households outside of areas directly targeted by interventions.

[136] The Selling Sanitation Initiative (jointly sponsored by the International Finance Corporation and Water and Sanitation Program) has spurred new low cost handwashing innovations that could prove to be effective alternatives to the tippy tap.

[137] N. Contzen, I.H. Meili, and H.J. Mosler. Changing handwashing behaviour in southern Ethiopia: A longitudinal study on infrastructural and commitment interventions. *Social Science and Medicine*, 124:103–114, 2015

Economic opportunities due to sanitation and hygiene interventions

The NAMWASH interventions had clear economic ramifications for local artisans in Ribáuè. One artisan reported being able to afford improvements to his house and latrine, pay secondary school fees, and start a farm, while another was able to buy a motorbike for transportation and a refrigerator to store and sell soft drinks and chicken. More importantly, one artisan has since been able to diversify his services, and he is planning to expand to a new site where he will start an atelier fully dedicated to water and sanitation products.

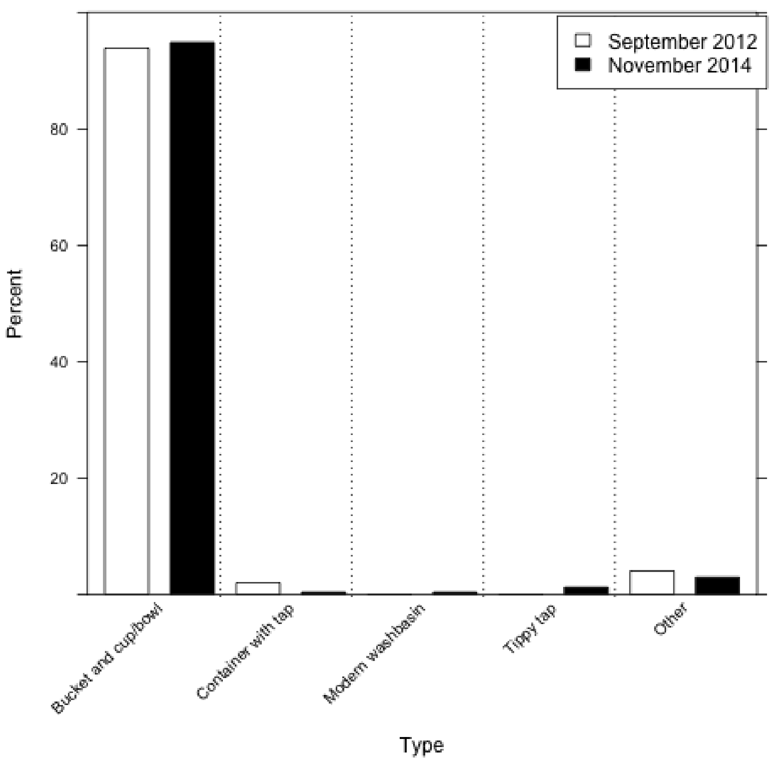


Figure 32: Observed type of handwashing station for those households in Ribáuè with dedicated handwashing stations in September 2012 and November 2014.

The quality of newly built latrines, particularly those with a deep pit and solid walls and roofs, will make it less likely that families will want to move their latrines once their pit is full. This will stimulate demand for faecal waste removal services to empty their pits[138]. Of sampled households, 52.45% said that they would pay for faecal waste removal services with the median amount that they were willing to pay being 300 MZN. The primary reason they were willing to pay for these services was not wanting to move their latrine (35.22%)[139].

[138] Looking long-term, as Ribáuè continues to grow, families will less and less have the space to be able to dig new pits and move their latrine once the pit is full, so demand in the short-term may ensure that appropriate faecal waste removal services are in place for when space constraints necessitate them.

[139] Households also cited the importance of faecal waste removal services in disease reduction and prevention (28.30%) and maintaining better home and community sanitation conditions (20.13%).

Liúpo

The town of Liúpo is similar to more rural areas of Mozambique in its usage of sanitation facilities with less than 10% of households using an improved sanitation facility[140]. Most households report using either a traditional latrine (63.78%) or some form of open defecation (20.00%), and reported sanitation facility usage by region of Liúpo is presented in Table 20. This shows high levels of open defecation in Liúpo C and Liúpo D, and spatial plots shows heavy concentrations of the practice of open defecation in specific parts of these regions.

[140] Only 8.93% of households we visited used improved sanitation facilities. According to Republic of Mozambique [2010], the percentage of rural households with improved sanitation facilities as of 2009 had reached 40%, so Liúpo appears to be lagging behind in this area.

Region	*Flush toilet*	*Toilet with manual water*	*VIP latrine*	*Improved latrine*	*Improved traditional latrine*	*Ecological latrine*	*Traditional latrine*	*Cat system*	*Open defecation*	*Other*
Liúpo A	3.33%			3.33%			73.33%	3.33%	6.67%	10%
Liúpo B		3.70%	3.70%		14.81%		70.37%	3.70%		3.70%
Liúpo C		3.85%		1.92%			59.62%	28.85%	3.85%	1.92%
Liúpo D		1.79%	3.57%	7.14%	1.79%	1.79%	57.14%	23.21%	3.57%	
Liúpo E				15%		5%	70%		5%	5%
Total	0.54%	2.16%	1.62%	4.86%	2.70%	1.08%	63.78%	16.22%	3.78%	3.24%

Table 20: Primary sanitation facility usage by region in the town of Liúpo in November 2014.

The present situation in Liúpo in terms of usage of improved sanitation facilities is not much (if any) better than what it was in September 2012 when, despite a lower use of improved sanitation facilities (3.97%), observed open defecation was also much lower (11.55%). Figure 33 gives a comparison of 2012 and 2014, showing that the drop in use of traditional latrines recorded in 2014 was largely due to increased use of cat system[141]. As would be anticipated, household sanitation facility usage varies significantly by neighbourhood (as shown in Table 20) with those living closer to the town centre being more likely to use better facilities. When it comes to cleaning latrines, the vast majority do so by sweeping (76.06%), which is consistent with the predominance of traditional latrines in the town.

[141] It is worth noting that this increase could potentially be attributable to sampling variability, as reported cases of open defecation were largely confined to specific parts of the town.

Schools tend to have better sanitation facilities than the community at large. Of the five schools in Liúpo and the surrounding area, four had improved latrines with concrete slabs with separate facilities for students and teachers as well as males and females. The other school, Primary School (1^{st} degree) of Terrene B, which is a rural school 40 kilometres outside of Liúpo town, had no latrines on the premises. Of the four schools with improved latrines, Completed Primary School (1^{st} degree) of Palacue had pits that were clogged, so the latrines were not being used and were dirty. The other three schools (Primary School [1^{st} degree] of Yawi, Completed Primary School of Nanrava, Completed Primary School of Liúpo) all had functional and clean latrines[142]. Given that two of the schools did not have a water point on the premises, it is not surprising to find that none of the sanitation facilities had handwashing stations. At the same time, none of the facilities had containers for solid waste disposal.

[142] For each of these schools, cleaning of latrines is carried out by students as an activity within education campaigns for individual and collective good hygiene and sanitation practices

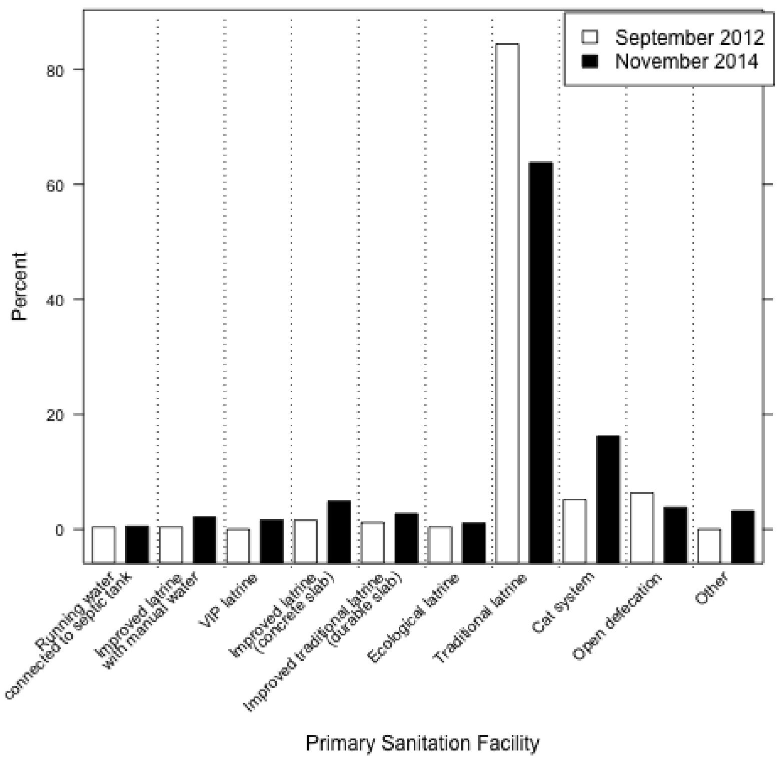


Figure 33: Reported primary sanitation facility usage in the town of Liúpo in September 2012 and November 2014.

The situation of sanitation in the local hospital and regional health centres is also mixed. Liúpo Hospital has three different sets of sanitation facilities on the premises—improved latrines with concrete slabs in the maternity ward, separate improved latrines just outside the main building that are for staff and patients and split according to sex, and and a third set of improved latrines further away from the hospital that are for families of patients. All sanitation facilities were found to be clean. In stark contrast, Nacacane Health Centre, located 17 kilometers from the centre of town, has a single improved latrine with concrete slab, but it is clogged, leaving it unusable. This has been the case for more than five years. Additionally, this health centre (unlike Liúpo Hospital) does not have a water point on the premises.

Figure 34: Clogged latrine at Nacacane Health Centre.

In terms of hygiene, presence of soap or ash at handwashing facilities was lower in Liúpo (24.55%) than both Nampula (54.65%) and Ribáuè (38.46%). For Liúpo, this represented a significant drop from 2012, when soap or ash was present at 45.00% of handwashing stations. Additionally, when queried as to when they washed their hands, households in Liúpo reported lower levels of handwashing at key moments, as show in Figure 28. This could be symptomatic of the water situation in the town.

In addition to the low level of use of improved sanitation facilities at the home and continued practice of open defecation in specific regions, none of the latrines we observed in public facilities (schools, hospitals/health centres) were appropriate for disabled persons. Additionally, two of the schools and the Nacacane Health Centre did not have a water point on the premises, which has ramifications for both hygiene and sanitation, and the fact that two schools and Nacacane Health Centre did not have functioning latrines is highly problematic.

In terms of water points, at 20.00% of boreholes visited, researchers observed animals[143] within 10 meters of the borehole with animals seen drinking from standing water at two of these boreholes. On several occasions, people were observed drawing water from pools of standing water rather than queue for water at the borehole, including at one borehole where animals were only moments before seen drinking from the standing water[144].

Additionally, at 45.00% of boreholes, standing rubbish was observed within 5 meters of the borehole, and 40.00% of boreholes had a pit latrine within 30 meters[145]. While solid and faecal waste may more commonly be thought of as problematic in contaminating unprotected wells during the wet season, studies have show general contamination of groundwater[146] with higher levels of contamination for boreholes with pit latrines in close proximity[147].

Undoubtedly, the dire water situation in Liúpo has ramifications for hygiene and sanitation. Studies have shown that increased water consumption has significant impacts for hygiene with households that collect higher quantities of water per capita using much of the additional water for hygiene purposes[148]. Use of soap or ash also increases with higher quantities of water collected as well as with targeted media messages[149].

[143] Ducks, chickens, goats.

[144] Standing water has other implications for health, as it is a breeding ground for mosquitoes.

[145] For 75.00% of these boreholes, pit latrines were within 15 meters, and 37.50% had latrines within 10 meters.

[146] J.P. Graham and M.L. Polizzotto. Pit latrines and their impacts on groundwater quality: A systematic review. *Env. Health Persp.*, 121(5):521–530, 2013; and E. Zingoni, D. Love, C. Magadza, W. Moyce, and K. Musiwa. Effects of a semi-formal urban settlement on groundwater quality, Epworth (Zimbabwe): Case study and groundwater quality zoning. *Physics and Chemistry of the Earth*, 30:680–688, 2005

[147] S. Issiaka, G.B.T. Albert, D.G. Aristide, and K.K. Innocent. Vulnerability assessment of the Abidjan Quaternary Aquifer using the DRASTIC method. In Y. Xu and B. Usher, editors, *Groundwater Pollution in Africa*, pages 115–124. CRC Press, 2006

[148] S. Cairncross and V. Valdmanis. Water supply, sanitation, and hygiene promotion. In A. Mills, A.R. Measham, P. Musgrove, J.G. Breman, D.T. Jamison, D.B. Evans, P. Jha, M. Claeson, and G. Alleyne, editors, *Disease Control Priorities in Developing Countries*, pages 771–792. The World Bank, Washington, D.C., 2nd edition, 2006

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

Factors Influencing Income and the Willingness to Reveal It

An accurate understanding of the economics of a region is critical for assessing the economic viability, sustainability, and potential return on investment of water, sanitation, and hygiene programmes, and extracting reliable household income and expenditure data is necessary for producing informed decisions. For many countries in SSA, estimates of household income and expenditure are either only at a very general level[150], highly variable, or outdated. In the absence of reliable databases, household surveys become the primary means of collecting this information.

[150] *e.g.*, national or provincial/state level.

National Statistics Institute Data

In the case of Mozambique, household income and expenditure data collected by the Mozambican INE are severely lacking with the most reliable estimates coming from the 2008-2009 Survey of Family Budgets (IOF), which only reports national- and provincial-level estimates of mean household income and expenses as well as national-level totals for urban and rural areas[151]. This wave of the IOF estimated mean monthly income for urban areas of Mozambique to be more than double that for rural areas, as shown in Table 21, with the Province of Nampula (where our study was carried out) reporting monthly incomes more in line with rural areas than urban areas. These totals for 2008-2009 represent at least a two-fold increase from corresponding estimates from the 2002-2003 wave[152].

[151] According to the heads of INE's Department of Methodology and Department of Sampling, even the 2014-2015 wave of the IOF, which consists of quarterly panel data and just finished in September of 2015, will only contain similar national- and provincial-level estimates.

[152] Instituto Nacional de Estatística. *Relatório Final do Inquérito ao Orçamento Familiar—IOF 2008/09*. Instituto Nacional de Estatística, Republic of Mozambique, Maputo, 2010b

Locality	Monthly income (2002-2003 IOF)	Monthly income (2008-2009 IOF)
Urban Mozambique	2,703 MZN	5,530 MZN
Rural Mozambique	1,073 MZN	2,480 MZN
Nampula Province	1,040 MZN	2,644 MZN

Table 21: Mean monthly household income for urban and rural areas of Mozambique as well as Nampula Province, as reported by the 2002-2003 and 2008-2009 Survey of Family Budgets.

For the 2008-2009 IOF, 29.1% of households in Mozambique were classified as residing in urban areas. For Nampula Province, there are only two major cities (the city of Nampula and the Port of Nacala) which constitute approximately 5% of the province's population, possibly explaining why Nampula Province household income estimates more closely reflected income levels for rural Mozambique. Our study included the city of Nampula as well as the towns of Ribáuè and Liúpo, which are the capitals of districts bearing their respective names. The town of Ribáuè would largely be classified as peri-urban, meaning that income data would likely be at or slightly above average relative to the province as a whole. The town of Liúpo on the other hand, would be characterised as more rural, although it has a proper town centre. Incomes for households in this town would be anticipated to be lower than that of the town of Ribáuè, although not drastically so.

Reliability of Household Survey Income Data

Household income data collected during fieldwork in November 2014 produced the mean and median household incomes[153] shown in Table 22. Mean monthly incomes are significantly higher than those reported for Nampula Province in the 2008-2009 IOF with the mean income for the city of Nampula being nearly twice that of the total reported for urban Mozambique as a whole. While at first glance this may seem unusually high, we note that this would be consistent with the doubling of mean incomes observed over the last two waves of the IOF and could reflect the increased economic activity along the Nacala Corridor. Additionally, as the largest city in the province, it would not be unexpected that mean household income for the city of Nampula would in fact be significantly higher than other urban centres within the province[154]. Incomes for the towns of Ribáuè and Liúpo would be consistent with less rapid economic growth than what was experienced in the city of Nampula, placing them at roughly the anticipated provincial average.

[153] Incomes are known to be significantly positively skewed, and this is no exception for the income data we collected for the city of Nampula and towns of Ribáuè and Liúpo. For such data, medians or geometric means (*i.e.* back-transformed means of log-transformed income) provide a much more accurate representation of the centre of the distribution, but neither of these are reported in the IOF.

[154] We additionally note that the water and sanitation situation observed in the areas sampled far exceeded that reported for Nampula as a whole in the 2011 DHS PLUS, suggesting that either there has been a significant increase in household income or our sample included a greater proportion of households with higher SES than what was observed in the DHS in 2011.

Table 22: Mean monthly household incomes (with accompanying 95% confidence intervals) and median monthly household incomes for the city of Nampula and towns of Ribáuè and Liúpo, as reported in November 2014.

Town/City	Mean income	Median income
Nampula	10,767.92 (9,202.30, 12,333.54) MZN	3,041.67 MZN
Ribáuè	3,894.47 (3,231.64, 4,557.31) MZN	2,500 MZN
Liúpo	3,088.34 (2,428.65, 3,748.03) MZN	1,510.42 MZN

Publicly available survey data for household incomes for the city of Nampula and town of Liúpo do not appear to exist for previous household surveys carried out in these locations, although income data were collected for the town of Ribáuè in June 2012 in a short WTP survey carried out by UNICEF Mozambique and AIAS as part of NAMWASH [UNICEF and Administração de Infra-estruturas de Água e Saneamento, 2012][155]. This survey was carried out to understand preferences and WTP for various forms of delivery of improved water[156] as well as capacity to pay and current expenditure for water. In this survey of 371 households, estimated mean household income was reported to be below 750 MZN per month

[155] UNICEF and Administração de Infra-estruturas de Água e Saneamento. *Willingness to Pay for an Improved Water Service: Ribáuè Municipality, Ribáuè District, Nampula Province, Mozambique*. UNICEF and Administração de Infra-estruturas de Água e Saneamento, Maputo, 2012

[156] This survey focused on delivery of water to households through piped infrastructure in the forms of household connections, yard taps, and standpipes.

for seventeen of nineteen neighbourhoods[157] with the remaining two neighbourhoods having mean household incomes of roughly 1,500 MZN and 3,000 MZN per month. These totals suggest a much worse economic situation than totals obtained from our survey in November 2014.

There are a number of possible reasons for these disparities. A simple explanation would be significant changes in household earning over the two year period from 2012 to 2014 due to economic activity in the region[158]. Another reason could be the stated purpose of the WTP survey as presented to respondents, which made it clear that the survey was trying to measure both capacity and WTP for improved water that would be provided as part of NAMWASH. Households may have believed that it would be beneficial to understate income as well as their WTP in the hope of more favourable water tariffs for the infrastructure that was to be provided. The location of the question in the survey could also partly be responsible, as questions about income occurred at the very start of the WTP survey before enumerators could establish a rapport with the respondent[159]. A fourth possible explanation could be the way in which income data were extracted. The WTP survey initially intended to inquire about monthly income but opted to instead query respondents on income over the past six months to account for month-to-month variability in income for occupations such as subsistence farming. Providing estimates for such a long time frame may have proved difficult for some respondents, resulting in underestimates of income[160]. Our survey queried respondents about income from a variety of sources including work, relatives' contributions, remittances, social subsidies, etc. to ensure that totals reflected all forms of household income, and it allowed respondents to specify income according to their preferred time period[161] for each of these sources of income to minimise recall bias.

Although any of these reasons may have come into play, the most likely explanation is sampling variability. For the WTP survey carried out in 2012, 63.7% of households reported using rivers as their primary water points, and 35% reported practicing some form of open defecation, both indicators of low SES. A more comprehensive baseline survey carried out as part of NAMWASH in September and early October 2012 and including 252 households from Ribáuè produced drastically different estimates with under 5% of households using rivers as primary water points and under 10% reporting practicing some form of open defecation. These two surveys carried out as part of NAMWASH in 2012 also produced significantly different results in terms of preferred water infrastructure with the original WTP study finding that 48% of households preferred standpipes and 25.1% preferred yard taps. The baseline survey carried out just three months later produced exactly the opposite results, finding that 55.92% of households preferred yard taps, whereas only 24.90% preferred standpipes. This would again be consistent with sampling of households with very different

[157] The overwhelming majority of these neighbourhoods were reported to have a mean household income in the range of 200-300 MZN per month.

[158] As part of the Nacala Corridor development, there have been significant rail and road projects in close proximity to Ribáuè. UNICEF Mozambique reported costs for delivery of water infrastructure to Ribáuè increasing significantly due to competing economic opportunities in the area with total expenditure being approximately 33% higher than anticipated.

[159] By contrast, our study relegated questions related to income to the very end of the survey.

[160] Indeed, some enumerators reported that respondents struggled to estimate income [UNICEF and Administração de Infra-estruturas de Água e Saneamento, 2012].

[161] Day, week, month, etc.

socio-economic situations, as households with less income would likely be cognisant of the increased cost of a yard tap and so would state a preference for a standpipe.

The NAMWASH baseline survey carried out in September and October 2012 did not collect income data, but comparisons between that study and the study carried out in November 2014 are possible for key indicators such as water point and sanitation facility usage. Figures 21 and 23 show a comparison of primary water point usage as reported by households for each of these surveys for Ribáuè and Liúpo, respectively. Due to the piped water infrastructure introduced as part of NAMWASH, there would be anticipated to be changes in primary water point usage from 2012 to 2014, but totals are largely consistent with what would be expected based on baseline survey totals, and usage of river water was again significantly lower (under 10%) than what was reported in the 2012 WTP survey. For reference, Liúpo was also included in the baseline survey, and results presented in 2014 are nearly identical to those reported in 2012, as would be expected for a town that did not benefit from any water interventions during the interim. Along the same lines, primary sanitation facility usage saw some changes in Ribáuè from 2012 to 2014 due to NAMWASH, but levels of open defecation reported in 2014 continued to be more in line with what was reported under the baseline survey than what was reported under the 2012 WTP survey, as evidenced in Figure 30. These consistencies between the baseline survey and our survey in November 2014 would suggest that the sample of households obtained for the 2012 WTP study is an anomaly, explaining the massive differences in reported income observed.

Proxies for Income

Questions about personal finances can be viewed by respondents as intrusive, leading to non-response[162] or intentional misreporting. At the same time, some respondents may find it difficult to accurately report household income due to inadequate knowledge of income of all wage earners in the household. Additionally, the lack of regularity of income or highly variable income associated with certain professions[163] can lead to complications with income estimation.

[162] Non-response for income data was 32.85% across all three locations, consisting of 26.88% non-response in Ribáuè, 32.07% in Nampula, and 47.77% in Liúpo.

[163] *e.g.*, subsistence farming, fishing.

In the face of limited or unreliable income data, proxies for (or indicators of) income can be useful, and we consider a number of proxies. These include:

- whether the household pays for water,
- whether the household treats water,
- whether the household is connected to the electrical grid,
- ownership of specific possessions,

- house roof and wall construction materials,
- the education level of the head of household, and
- the occupation of the head of household.

Descriptive statistics for these proxies for income, broken down by location, are provided in Table 23. These provide results consistent with the income data shown in Table 22, suggesting a trajectory of wealth with Nampula and Liúpo at opposite ends of the spectrum. For example, residents of Nampula have the highest rates of electricity use, treatment of water, ownership of key items, use of modern materials for house construction, and education levels for the head of household. In addition to these proxies, primary water point use and primary sanitation facility use can be used as proxies for wealth.

Factors Related to Willingness to Reveal Income

In many cultures, there is resistance to revealing financial data, so it is important to understand the factors that may explain a respondent's lack of compliance when queried about matters related to income or expenditures and understand the implications of drawing conclusions from provided income data in the face of sometimes substantial non-response. In the case of our study, non-response for income data was 32.85% across all three locations, with very high non-response in Liúpo (47.77%), the poorest of the three locations, and slightly higher levels of non-response in Nampula (32.07%) than Ribáuè (26.88%)[164]. These non-response rates are slightly better than those obtained by Fonseca [2014], who reported a non-response rate of 39.5% for income questions in household surveys carried out in Mozambique[165].

To understand the potential drivers of non-response, we considered a logistic regression model that used as its response an indicator of whether a respondent reported household income. This model included the town/city, age and sex of the respondent, and time length of the interview[166]. We also included proxies for income to see whether SES may be a driver for willingness to reveal income. These proxies for income included a number of those mentioned in Table 23 as well as the household's primary water point and reported total payments for water and electricity. Preliminary analyses suggested high correlation between primary water point and primary sanitation facility, a lack of importance of house construction materials and household ownership of key items[167], and no clear interaction effects[168], so these were not included in our model. Results for the model fit are presented in Table 24.

[164] We note that there was a significant relationship between respondents stating that they were unwilling to pay for our presented water service scenario and also being unwilling to provide their income (chi-square test p-value < 0.001), with those saying that they were unwilling to pay for the presented water service scenario being more than two times as likely to be unwilling to report income data than what would be expected. This may be indicative of a cross-section of the population exercising a heightened level of caution when confronted with questions which they believe could potentially be used to determine the pricing of water or other services. Consequently, this group of people may intentionally avoid supplying any information related to willingness or capacity to pay for these services.

[165] C. Fonseca. *The death of the communal handpump? Rural water and sanitation household costs in lower-income countries*. PhD thesis, Applied Sciences, Water Sciences, Cranfield University, 2014

[166] Since questions in regard to income were intentionally placed at the end of the interview due to their sensitivity, the length of the interview could be important in that those with longer interviews might be experiencing fatigue and desire to end the interview quickly. Alternatively, longer interview lengths could be indicative of those who are more likely to address questions related to finance and income, hence the longer interview length.

[167] Fonseca [2014] similarly found house construction materials and possession of key items to largely be insignificant in explaining household wealth.

[168] It is important to note that the model considered already has a large number of parameters. Although it is important that models capture significant relationships, it is also necessary to maintain an emphasis on model parsimony. Inclusion of interaction effects with town/city could be used to fit location-specific models, but then we would lose model generalisability.

Proxies for Income	Nampula		Ribáuè		Liúpo	
	2011	2014	2012	2014	2012	2014
Household pays for water		70.78%	46.03%	70.88%	72.62%	63.39%
Household treats water	30%	43.92%	10.71%	28.51%	8.76%	20.98%
Household has electricity	49.7%	89.37%	25.60%	57.03%	17.86%	21.42%
Household owns:						
Radio	53.6%	65.84%	56.00%	53.56%	35.71%	43.75%
Television	43.1%	80.65%	20.40%	51.53%	16.27%	22.32%
Mobile phone	53.0%	90.51%	30.00%	69.25%	31.75%	68.75%
House roof material:						
Grass/thatch/palm		20.67%	93.65%	76.30%	88.89%	76.54%
Zinc sheets		72.36%	6.35%	23.02%	11.11%	23.46%
Lusalite plates		4.27%		0.68%		
Tile		0.22%				
Concrete slab		1.80%				
House wall material:						
Bamboo/reid		1.36%	6.75%	2.95%	0.40%	3.11%
Sticks/maticados		4.08%	5.56%	3.85%	11.51%	28.57%
Adobe/adobe block		39.68%	85.71%	86.62%	86.90%	67.70%
Wood/zinc		0.45%			0.40%	
Cement/brick		53.74%	1.98%	6.58%	0.79%	0.62%
Education level of head of household:						
None		2.70%		6.95%		9.00%
Primary of 1^{st} degree		11.23%		15.79%		34.60%
Primary of 2^{nd} degree		11.64%		11.37%		16.59%
Secondary of 1^{st} degree		22.66%		20.84%		17.06%
Secondary of 2^{nd} degree		44.07%		44.00%		22.75%
Higher level		7.69%		1.05%		
Occupation of head of household:						
Managers		5.24%		2.54%		2.71%
Professionals		13.01%		10.81%		6.33%
Technicians		10.10%		15.47%		8.60%
Clerical support		1.36%		1.69%		0.45%
Services, sales		15.15%		5.51%		9.05%
Agriculture, forestry, fisheries		3.11%		17.8%		52.49%
Craft and related trade		16.31%		6.78%		7.69%
Plant/machine operators		1.75%		2.12%		
Elementary occupations		10.87%		8.69%		3.62%
Armed forces		1.36%		0.42%		0.90%
Unemployed		6.41%		18.22%		1.36%
Student		1.36%		3.18%		0.90%
Homemaker		7.57%		4.45%		1.36%
Benefits/pension		2.33%		2.12%		1.81%
Other		4.08%		0.21%		2.71%

Table 23: Descriptive statistics for proxies for income, broken down by town/city. Where appropriate, totals from November 2014 are compared with totals from the 2011 DHS or 2012 NAMWASH baseline survey.

	Estimate	Std. Error	z-value	Pr($>|z|$)
(Intercept)	-1.1087	0.9262	-1.20	0.2313
Interview length	-0.0109	0.0079	-1.38	0.1669
Female respondent	0.3163	0.1850	1.71	0.0873*
Age of respondent	0.0009	0.0074	0.13	0.9001
Town/City: (Reference: Nampula)				
Liúpo	-1.8960	0.3419	-5.55	0.0000***
Ribáuè	-0.3664	0.2410	-1.52	0.1285
Education level of head of household: (Reference: None)				
Primary of 1^{st} degree	0.3035	0.4287	0.71	0.4790
Primary of 2^{nd} degree	0.7869	0.4404	1.79	0.0740*
Secondary of 1^{st} degree	0.8580	0.4320	1.99	0.0470**
Secondary of 2^{nd} degree	0.8378	0.4313	1.94	0.0521*
Higher level	0.5018	0.6277	0.80	0.4241
Do not know	-0.2849	0.5269	-0.54	0.5887
Occupation of head of household: (Reference: Managers)				
Professionals	0.8507	0.4279	1.99	0.0468**
Technicians	1.1826	0.4265	2.77	0.0056***
Clerical support	-0.0388	0.6950	-0.06	0.9554
Services, sales	0.4526	0.4298	1.05	0.2924
Agriculture, forestry, fisheries	-0.6763	0.4242	-1.59	0.1108
Craft and related trade	0.3999	0.4289	0.93	0.3511
Plant/machine operators	-0.2342	0.6592	-0.36	0.7223
Elementary occupations	0.0680	0.4463	0.15	0.8789
Armed forces	-0.0481	0.8139	-0.06	0.9529
Unemployed	-1.7644	0.4692	-3.76	0.0002***
Student	-2.9523	0.8502	-3.47	0.0005***
Homemaker	-1.0404	0.5152	-2.02	0.0435**
Benefits/pension	-1.9530	0.7682	-2.54	0.0110**
Other	0.4444	0.5828	0.76	0.4457
Primary water point: (Reference: Household connection)				
Yard tap	-0.3966	0.5717	-0.69	0.4878
Standpipe	-0.6891	0.6156	-1.12	0.2630
Borehole	0.3677	0.6171	0.60	0.5513
Unprotected well	0.2330	0.6114	0.38	0.7032
Protected spring	0.4592	1.7368	0.26	0.7915
River, stream, lake	0.8362	0.7689	1.09	0.2768
Neighbour's tap	-0.4015	0.6106	-0.66	0.5108
Household pays for water	1.7693	0.2022	8.75	0.0000***
Monthly cost of water	-0.0001	0.0004	-0.18	0.8580
Household has electricity	-0.2907	0.2196	-1.32	0.1856
Monthly cost of electricity	0.0003	0.0003	0.79	0.4310
Household treats water	0.0941	0.1678	0.56	0.5750
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table 24: Logistic regression of willingness to reveal income on relevant variables, including town/city, age and sex of the respondent, household primary water point, and a number of proxies for income.

Based on the model fit, we obtain the relationships shown in Box 2. These suggest that households that pay for water and for which the head has a higher levels of education or a job higher up the ladder of professions would be more likely to reveal their income. In other words, those who are of higher socio-economics status are more likely to reveal their income[169].

[169] It is important to recognise that interpretations of effects are conditional on the other variables in the model. This explains why it is possible to get a negative coefficient for the town of Ribáuè, seemingly indicative of lower levels of reporting income, when Ribáuè in fact has the highest response rate in terms of income data.

Town/City:	• Households in Liúpo are less likely to reveal their income than those in Nampula. • There is not a significant difference between households in Ribáuè and Nampula in terms of willingness to reveal income.
Sex of respondent:	• Women are slightly more likely to reveal income than men.
Education level of head of household:	• Households where the head has a higher level of education tend to be more willing to reveal income than those where the head has no education.
Occupation of head of household:	• Households where the head's occupations is higher up the ladder of professions tend to be more likely to report incomes. • There is a lower rate of reporting incomes in households where the heads have professions such as managers, professionals and technicians than households where the head is unemployed, a student, a homemaker, or on pension.
Household pays for water:	• Households that pay for water are significantly more likely to report income than those that do not pay for water.

Box 2: Key relationships between willingness to reveal income and variables considered in Table 24, which include demographic characteristics and proxies for income.

Factors related to whether respondents reveal income data as numeric or ordinal

To account for the potential hesitance of respondents to reveal household income, enumerators were instructed to inquire about household income in two stages. First, respondents were asked for their numeric income according to specific sources of income[170]. If respondents were unwilling to provide a numeric response, then enumerators were to inquire about incomes according to categorisations as shown in Table 25.

[170] Work income, relatives' contributions, remittances, social subsidies (INAS), other.

None
$<$ 500 MZN
500 – $<$1,000 MZN
1,000 – $<$1,500 MZN
1,500 – $<$2,000 MZN
2,000 – $<$2,500 MZN
2,500 – $<$3,000 MZN
$\geq$ 3,000 MZN

Table 25: Income categorisations, as specified in survey questions related to household income.

Of those who provided income data, only 39.91% did so using numeric values. Those in Liúpo (61.67%) were far more likely to do so than those in Nampula (36.03%) or Ribáuè (36.59%). To understand the drivers of whether those reporting income choose to do so only as categorical data, we again fit a logistic regression model with the same explanatory variables as considered when looking at general willingness to reveal income. In this case, however, the response variable was whether income data was reported as categorical, and we restricted our population to only those who reported some form of income data. Results for this model are presented in Table 26.

	Estimate	Std. Error	z-value	Pr(> $\|z\|$)
(Intercept)	-1.7000	1.4002	-1.21	0.2247
Interview length	-0.0126	0.0116	-1.09	0.2777
Female respondent	0.1016	0.2632	0.39	0.6993
Age of respondent	0.0083	0.0114	0.73	0.4628
Town/City: (Reference: Nampula)				
Liúpo	-1.1767	0.5499	-2.14	0.0324**
Ribáuè	0.4957	0.3437	1.44	0.1493
Education level of head of household: (Reference: None)				
Primary of 1^{st} degree	0.7320	0.8218	0.89	0.3731
Primary of 2^{nd} degree	0.1491	0.7981	0.19	0.8518
Secondary of 1^{st} degree	0.6469	0.7784	0.83	0.4059
Secondary of 2^{nd} degree	0.5843	0.7690	0.76	0.4474
Higher level	0.1210	0.9118	0.13	0.8944
Do not know	0.0234	0.9541	0.02	0.9804
Occupation of head of household: (Reference: Managers)				
Professionals	0.7513	0.5609	1.34	0.1804
Technicians	0.1965	0.5550	0.35	0.7233
Services, sales	1.2379	0.6142	2.02	0.0438**
Agriculture, forestry, fisheries	0.6931	0.6170	1.12	0.2612
Craft and related trade	0.6985	0.5929	1.18	0.2388
Plant/machine operators	0.4959	0.9207	0.54	0.5902
Elementary occupations	1.5213	0.6549	2.32	0.0202**
Armed forces	-0.0099	1.2168	-0.01	0.9935
Unemployed	-0.2289	0.7552	-0.30	0.7618
Student	1.0348	1.5364	0.67	0.5006
Other	1.8296	0.8953	2.04	0.0410**
Primary water point: (Reference: Household connection)				
Yard tap	-0.6239	0.6634	-0.94	0.3470
Standpipe	-0.8921	0.7448	-1.20	0.2310
Borehole	-1.3428	0.7357	-1.83	0.0680*
Unprotected well	0.1854	0.7279	0.25	0.7990
River, stream, lake	-0.0535	0.9919	-0.05	0.9569
Neighbour's tap	-0.2184	0.7364	-0.30	0.7668
Household pays for water	1.2094	0.3420	3.54	0.0004***
Monthly cost of water	-0.0006	0.0005	-1.25	0.2100
Household has electricity	0.9855	0.3306	2.98	0.0029***
Monthly cost of electricity	-0.0006	0.0005	-1.22	0.2230
Household treats water	-0.0743	0.2268	-0.33	0.7431
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table 26: Logistic regression of willingness to reveal income as categorical but not numeric on relevant variables, including town/city, age and sex of the respondent, household primary water point, and a number of proxies for income.

Interpretations of significant effects based on this model are presented in Box 3. Proxies for income (as represented through occupation of the head of household and payment for water and electricity) provide slightly conflicting messages in terms of how household income might potentially influence whether a respondent chooses to report income data as numeric or categorical, although the statistically significant positive coefficients corresponding to the town of Liúpo and occupations further down the occupation ladder could be indicative of households with lower household income being more willing to provide income data as numeric.

Town/City:	• Households in Nampula who report income data are more likely to report it as categorical than similar respondents in Liúpo. • There is not a significant difference between households in Ribáuè and Nampula in terms of likelihood to reveal income data as categorical when considering only those who have reported income data.
Occupation of head of household:	• Those households where the head of household works in a services and sales occupation, elementary occupations, or other occupations are significantly more likely to report income data as categorical than those households where the head of household works in a managerial position.
Household pays for water:	• Households that pay for water are significantly more likely to report income as categorical than those that do not pay for water.
Household has electricity:	• Households that have a connection to the electrical grid are significantly more likely to report income as categorical than those that do not.

Box 3: Key relationships between willingness to reveal income as categorical instead of numerical and variables considered in Table 26, which include demographic characteristics and proxies for income.

Assessing the Relationship Between Reported Numeric and Ordinal Incomes

To investigate this further, we converted numeric income data to categorical according to the categorisations shown in Table 25. Pooling these with income data that originally had been reported as categorical and again restricting our population to those households for which income data was reported, we considered a cumulative logit model[171] of income on the same variables as considered in previous models. Here, however, due to the estimation routine used in fitting a cumulative logit model, it was necessary to remove variables corresponding to the monthly cost of water and monthly cost of electricity[172] to produce a model where the algorithm would converge and produce valid parameter estimates and standard errors. Additionally, in this model we included a variable that indicates whether the income data was originally reported as categorical or numeric. This variable would be critical in explaining the relationship between incomes that were reported as categorical and those reported as numeric.

Table 27 presents parameter estimates and standard errors, and some of the key results are presented in Box 4. The results in regard

[171] Cumulative logit models are a form of regression model for ordinal data.

[172] Neither of these were statistically significant in previous models, so this should not be cause for significant concern.

to the relationship between income and occupation of the head of households and household use of electricity are as would be expected, but the real focus here is on the variable providing a comparison between incomes reported as categorical and incomes reported as numeric. The statistically significant positive coefficient for this variable indicates that households reporting income as categorical tend to report higher incomes than those reporting income as numeric. This seems to confirm previous speculation that households opting to report income data as numeric actually tend to have lower household income. Thus, analyses based on numeric income data might be expected to be more conservative than those based on categorical income data.

	Estimate	Std. Error	z-value	Pr(> |z|)
Income reported as categorical	0.5940	0.2035	2.92	0.0035***
Female respondent	-0.4166	0.2207	-1.89	0.0590*
Age of respondent	0.0093	0.0099	0.94	0.3471
Town/City: (Reference: Nampula)				
Liúpo	-0.6755	0.4395	-1.54	0.1243
Ribáuè	-0.8619	0.2862	-3.01	0.0026***
Education level of head of household: (Reference: None)				
Primary of 1^{st} degree	-0.8577	0.6266	-1.37	0.1711
Primary of 2^{nd} degree	0.5804	0.6302	0.92	0.3570
Secondary of 1^{st} degree	0.4469	0.6042	0.74	0.4596
Secondary of 2^{nd} degree	0.8178	0.6030	1.36	0.1750
Higher level	1.3112	0.8583	1.53	0.1266
Do not know	1.3160	0.7998	1.65	0.0999*
Occupation of head of household: (Reference: Managers)				
Professionals	0.0378	0.5786	0.07	0.9479
Technicians	-0.4631	0.5549	-0.84	0.4040
Clerical support	0.6830	1.1968	0.57	0.5683
Services, sales	-0.4003	0.5873	-0.68	0.4955
Agriculture, forestry, fisheries	-1.7610	0.5821	-3.03	0.0025***
Craft and related trade	-1.3151	0.5688	-2.31	0.0208**
Plant/machine operators	0.7548	0.9894	0.76	0.4455
Elementary occupations	-1.6117	0.6096	-2.64	0.0082***
Armed forces	-1.3921	1.0364	-1.34	0.1792
Unemployed	-2.2076	0.7176	-3.08	0.0021***
Student	-1.7516	1.3467	-1.30	0.1934
Homemaker	-2.5058	0.7098	-3.53	0.0004***
Benefits/pension	-2.0300	1.0200	-1.99	0.0466**
Other	-0.5550	0.8515	-0.65	0.5146
Primary water point: (Reference: Household connection)				
Yard tap	-0.0218	0.7580	-0.03	0.9771
Standpipe	0.2218	0.8182	0.27	0.7863
Borehole	0.2125	0.7967	0.27	0.7897
Unprotected well	0.1110	0.7936	0.14	0.8887
Protected spring	-3.3245	1.6978	-1.96	0.0502*
River, stream, lake	-0.0150	1.0317	-0.02	0.9884
Neighbour's tap	-0.2340	0.7973	-0.29	0.7692
Household pays for water	-0.1480	0.2956	-0.50	0.6167
Household has electricity	1.1035	0.2746	4.02	0.0001***
Household treats water	0.1892	0.1979	0.96	0.3391
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table 27: Cumulative logit model of income (as categorical) on relevant variables, including town/city, age and sex of the respondent, household primary water point, and a number of proxies for income. This model also includes an indicator of whether income was originally reported as categorical.

Income reported as categorical:	• There is a significant difference between those households for which the respondent report income data as numeric and those for which the respondent reports income as categorical. In particular, households for which income data is reported as categorical report incomes falling into higher income categories on average than households reporting income as numeric. In other words, it would seem that those reporting income as numeric tend to correspond to lower income households on average than those households that report income as categorical.
Town/City:	• Households in Ribáuè report significantly lower incomes than those in Nampula.
Sex of respondent:	• Women are more likely to report lower incomes than men.
Occupation of head of household:	• Those households where the head of household works in occupations higher up the occupation ladder are more likely to report higher incomes.
Household has electricity:	• Households that have a connection to the electrical grid report higher incomes than those that do not.

Box 4: Key relationships between income (as categorical) and variables considered in Table 27, which include demographic characteristics and proxies for income. It also includes an indicator of whether income was originally reported as categorical.

Validating Proxies for Income

Considering that lack of income data results in a reduction in the set of usable observations for analyses, finding a robust set of proxies for income can be vital in ensuring that models represent a greater proportion of the population of interest. We already presented a set of potential proxies in Table 23 and previous models. To try to validate these proxies, we considered a linear regression of log-transformed income on town/city, age and sex of the respondent, household primary water point, and a number of proxies for income considered previously, including education and occupation of the head of household, whether a household treats water, whether a household pays for water and how much, and whether a household pays for electricity and how much.

Results for this model fit are presented in Table 28, and we note the key results presented in Box 5. These results are in line with what we would expect if these were in fact reliable proxies for income[173], and, consequently, in considering models for WTP, we will consider separate regression models that incorporate numeric values for income and that include proxies for income as explanatory variables. This will give us greater flexibility, as models based on proxies have fewer missing values and, consequently, may be able to more accurately represent not only those of high SES but also those of lower SES.

[173] Note that $R^2 = 0.471$ for this model.

Table 28: Linear regression of log-transformed income on relevant variables, including town/city, age and sex of the respondent, household primary water point, and a number of proxies for income.

	Estimate	Std. Error	z-value	Pr(> |z|)
(Intercept)	8.0398	0.7383	10.89	0.0000
Sex of respondent	-1.1534	0.2910	-3.96	0.0001***
Age of respondent	0.0041	0.0061	0.67	0.5063
Town/City: (Reference: Nampula)				
Liúpo	-0.5600	0.2877	-1.95	0.0526*
Ribáuè	-0.4037	0.2137	-1.89	0.0599*
Education level of head of household: (Reference: None)				
Primary of 1st degree	-0.2199	0.3953	-0.56	0.5784
Primary of 2nd degree	0.3143	0.4159	0.76	0.4505
Secondary of 1st degree	-0.0486	0.4141	-0.12	0.9066
Secondary of 2nd degree	0.3486	0.4233	0.82	0.4110
Higher level	0.7958	0.5455	1.46	0.1458
Do not know	0.5654	0.5953	0.95	0.3431
Occupation of head of household: (Reference: Managers)				
Professionals	-0.4635	0.3540	-1.31	0.1915
Technicians	-0.5989	0.3288	-1.82	0.0696*
Clerical support	-0.3853	1.1990	-0.32	0.7482
Services, sales	-0.4932	0.3728	-1.32	0.1869
Agriculture, forestry, fisheries	-0.9237	0.3399	-2.72	0.0070***
Craft and related trade	-0.6364	0.3692	-1.72	0.0859*
Plant/machine operators	-0.0033	0.6382	-0.01	0.9959
Elementary occupations	-0.6405	0.4415	-1.45	0.1480
Armed forces	-0.7841	0.7208	-1.09	0.2776
Unemployed	-1.2823	0.3618	-3.54	0.0005***
Student	-0.3737	0.4896	-0.76	0.4460
Homemaker	0.2367	0.4926	0.48	0.6313
Benefits/pension	-1.6876	0.6884	-2.45	0.0149**
Other	-0.6262	0.6481	-0.97	0.3347
Primary water point: (Reference: Household connection)				
Household size	-0.0310	0.0356	-0.87	0.3845
Yard tap	0.2781	0.4636	0.60	0.5491
Standpipe	-0.1689	0.5054	-0.33	0.7385
Borehole	0.0991	0.5119	0.19	0.8466
Unprotected well	-0.0612	0.5330	-0.11	0.9086
Protected Spring	-1.3971	1.2905	-1.08	0.2799
River, stream, lake	0.7654	0.6926	1.11	0.2701
Neighbour's tap	0.3854	0.5509	0.70	0.4847
Household treats water	0.3701	0.1493	2.48	0.0138**
Household pays for water	0.1438	0.1935	0.74	0.4580
Household has electricity	0.5451	0.1928	2.83	0.0050***
Monthly cost of electricity	0.0002	0.0001	1.58	0.1143
Note:		*p<0.1; **p<0.05; ***p<0.01		

Town/city:	• Households in Ribáuè and Liúpo report significantly lower incomes than those in Nampula.
Sex of respondent:	• Women are more likely to report lower incomes than men.
Occupation of head of household:	• Those households where the head of household works in occupations higher up the occupation ladder are more likely to report higher incomes.
Household has electricity:	• Households that have a connection to the electrical grid report higher incomes than those that do not.
Household treated water:	• Households that treat their water report higher incomes than those that do not.

Box 5: Key results for linear model of numeric income on proxies for income. This model is used to validate proxies.

Measuring the Value of Piped Water to Households

When considering any investment, it is important to understand the return on that investment. For investment in WSS, these returns are myriad and not all economically quantifiable. In particular, investment in WSS has clear ramifications for health with some of these health benefits being economically quantifiable and many of them not. In this chapter, we will use the NAMWASH interventions carried out in Ribáuè as a case study, describing in greater detail the community piped water system supplied through NAMWASH and estimating its value to households in terms of water revenue.

Piped Network Provided to Ribáuè Through NAMWASH

Planning for the piped water system to be delivered to Ribáuè began in June 2012 with the implementation of a WTP study to decide on appropriate infrastructure, and it concluded two years later in June 2014 with completion of the piped water system and final turnover to the water regulator (Water Regulatory Council, CRA) and private operator (Technical Society of Consulting and Construction, STCC). In total, UNICEF Mozambique [July 2014] reported costs for the piped system to be $1.6 million USD[174].

[174] UNICEF Mozambique. *NAMWASH Programme Final Report, January 2012 – June 2014*. UNICEF Mozambique, Maputo, July 2014

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 both operations and maintenance (O&M) costs. The piped water system delivered to the town of Ribáuè as part of NAMWASH consisted of construction works in the way of:

- rehabilitation of a dam to supply water to the town,
- rehabilitation of a water tower in the town centre with a capacity of 100 cubic meters,
- the laying of 5,000 meters of large diameter[175] pipe for the main pipeline,
- the laying of 11,000 meters of small to medium diameter[176] PVC pipe for the distribution network, and
- construction of a rapid filtration water treatment plant, along with chlorine dosing equipment.

[175] 250 mm.

[176] 50-200 mm.

Since June 2014, the distribution network has expanded by more than 3,000 meters. In that time there have been three major repairs[177] that caused disruptions to water services of no more than three days. Outside of those incidents, water has been reported to be available for 24 hours per day, 7 days per week.

[177] Two of these were due to road rehabilitation works that caused significant damage to water pipes. These were outside of the control of the water operator.

Water was delivered to households in the community in the form of:

- 170 yard taps and
- 10 water kiosks.

The number of yard taps has grown to more than 330 with an average of 17 new yard taps per month over the last three months. The private operator, STCC, reported recently completing rehabilitation of two standpipes to supplement the existing ten water kiosks. Additionally, the piped system provides direct connections to 14 businesses and 31 connections to public services.

Uptake of piped water in Ribáuè

With the introduction of any technology, adoption of that technology can take time, and we would expect no differently for piped water in Ribáuè. At the time of fieldwork in November 2014, the piped water system had been fully operational for less than six months. Rogers [2003] postulates that populations can be partitioned into five groups of people who take up a particular technology in different stages[178]. These groups and their compositions in a population are represented in Figure 35, which is commonly used to represent the diffusion of a technology and the stage of acceptance at which the technology currently is.

[178] E. Rogers. *Diffusion of Innovations*. Free Press, 5^{th} edition, 2003

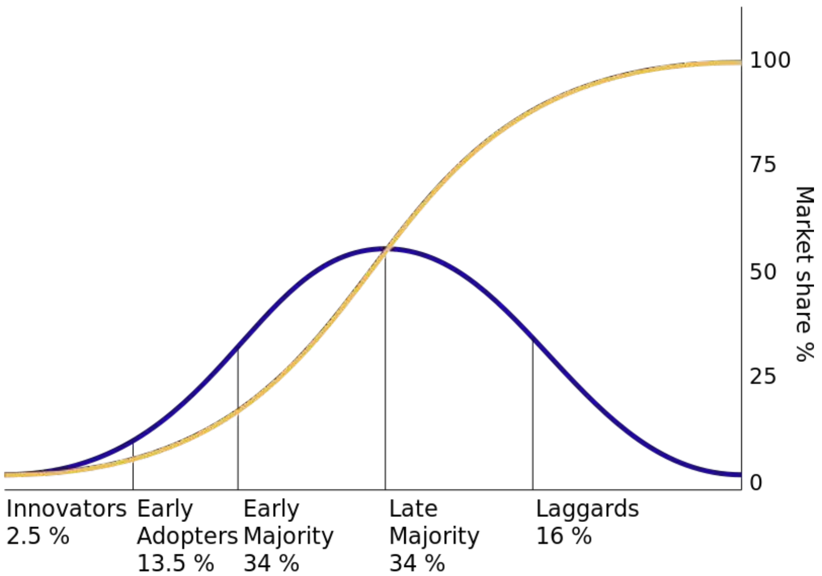


Figure 35: Rogers' curve for the diffusion of innovations.

In November 2014, 22.29% of households in Ribáuè reported using some form of piped water[179] as their primary water point with 8.38% reporting using a yard tap[180]. This would suggest that uptake of piped water in general had already hit the "early majority" within the first six months of introduction to the town, but uptake of yard taps had only hit the "early adopters," so adoption of piped water (and particularly yard taps) was still in its infancy[181]. The rate of adoption is important for understanding how quickly full impacts of the piped system can be anticipated for the town and how quickly use of yard taps would be considered the norm, but we have not seen this considered in the context of piped water, so we do not have benchmarks for comparison[182].

[179] Yard tap, water kiosk.

[180] This consisted of 6.97% of households reporting owning a yard tap and 1.43% reporting using the tap of a neighbour.

[181] By comparison, the situation in Nampula, both in terms of use of piped water in general and piped water to the home, is far more advanced with both having hit the "late majority" and piped water in general on the verge of hitting the "laggards". This suggests that piped water has been fairly normalised in Nampula.

[182] We have only seen this considered in the context of water treatment technologies [Harris, 2005, Murcott, 2006]. Note that there has been significant work done in the area of water demand and source choice models (see Nauges and Whittington [2010] for a comprehensive examination), but these models are cross-sectional, so they do not account for changing (or "dynamic") preferences (or utilities) over time, which is what leads to gradual uptake of a new form of water supply.

Up-front costs, tariff structures, and implications on piped connection uptake

For households eligible for yard taps, if supplied water is clean and is delivered with the reliability currently seen in Ribáuè, then almost certainly the primary factor determining adoption is the relationship between cost and a household's WTP. Costs for yard taps and household connections are incurred in terms of an up-front payment for the connection and tariffs based on water consumption.

In Ribáuè, the up-front charge for a yard tap connection was 1,273 MZN, the equivalent of roughly half of a month's income for the average household, until August of 2015[183]. This represented a contract fee and was either paid up front or could be split into two equal payments to be covered within two months[184]. STCC estimates that the actual cost of installing a yard tap is roughly 3,250 MZN, which covers materials, transportation, and labour. Thus, the charge to households was only roughly 1/3 of actual cost with the assumption that future water tariffs would cover this shortfall. As of August 2015, this up-front cost has been modified so that households must either supply appropriate pipes and fittings or purchase them from STCC as well as pay STCC for labour for installation of the yard tap. Thus, the up-front cost is now roughly 3,000-3,250 MZN for the actual installation of the yard tap as well as a contract fee of 1,273 MZN (which can be split into two payments). The current cost to households now represents roughly 1.7-1.8 month's income for the typical household and puts yard tap installation prices in line with Nampula[185].

[183] The median reported monthly income for Ribáuè in November 2014 was 2,500 MZN. (See Table 22.)

[184] Payment in full must be completed before metering commences.

[185] The long-term effects of a higher up-front cost for yard tap installations on uptake are unknown, although a reported 51 yard taps being lined up for installation at last correspondence with STCC would suggest that it has not dampened demand in the short-term.

Small loan schemes, rotating savings, and credit associations, much in line with what was discussed for financing for water kiosk operators, could be used to make the cost for the infrastructure less prohibitive for families[186]. However, Wedgwood and Sansom [2003] recommend that water providers try to keep the connection charge low to keep this from preventing households from entering the market[187]. This can be accomplished by the provider covering a sizeable percentage of the up-front cost and having an appropriate

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

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

payback plan (so, in essence, acting as a lender) or using slightly higher tariffs as a means of cost recovery.

Tariff structures for users of household connections and yard taps in Ribáuè as well as Nampula (for comparison) as well as businesses in Ribáuè are as shown in Table 29. These tariff structures consist of a monthly fixed cost corresponding to a meter fee and a variable cost based on water consumption[188]. These fee structures produce fairly similar monthly costs for households in the two lcoations with the difference in cost between Nampula and Ribáuè anticipated to deviate by no more than 15 MZN per month except for consumption in excess of 15 cubic meters[189].

[188] In the case of Nampula, the variable component includes a flat cost for the first 5 cubic meters of water.

[189] For households using between 4 and 12 cubic meters of water per month, total costs would be slightly higher in Ribáuè than Nampula.

	Nampula (Household)	Ribáuè (Household)	Ribáuè (Business)
Fixed cost	55 MZN	50 MZN	150 MZN
Variable cost	70 MZN (first 5 m^3) 19 MZN/m^3 (5-10 m^3) 22.5 MZN/m^3 (> 10 m^3	18 MZN/m^3	18 MZN/m^3

Table 29: Monthly tariff structure for household connections and yard taps in Nampula and Ribáuè and businesses in Ribáuè in 2014.

A variety of strategies can be used to make water more affordable for users that may otherwise not be able to afford the cost, thereby increasing uptake. These include higher fixed and/or variable costs for businesses to help subsidise household costs, as is currently implemented in both Ribáuè and Nampula. Another common strategy is the implementation of increasing block tariffs (IBTs) which increase the cost per cubic meter as water consumption passes certain thresholds. This approach is currently implemented for households and businesses in Nampula but not those in Ribáuè.

IBTs like those in Nampula have generally been implemented to subsidise costs for poorer low consumption households[190] and encourage efficient water use. Despite these potential positive effects, however, if many poorer households share a single tap, then IBTs may actually result in them paying a higher per unit cost than if the IBTs were not in place, negating one of the major purposes of IBTs. Additionally, IBTs could run the risk of a water utility avoiding the connection of poorer households or those that are more costly to serve, as the relative cost and benefits of such provision represents a larger commercial financial discrepancy with water service charges below the average[191]. This is important because it demonstrates the inherent tension in certain developing country contexts in terms of making a social good such as water simultaneously profitable (and, hence, economically sustainable) and available to as many consumers as possible, including those of low SES. Thus, the social equality that was the driver of the IBT might actually be jeopardised if the piped network is run with an emphasis primarily on economic profit and sustainability, so it is important not to lose sight of social "fairness"[192].

[190] This is accomplished by having the price for water in the first block fall below marginal cost.

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

[192] P. Rogers, R. de Silva, and R. Bhatia. Water is an economic good: How to use prices to promote equity, efficiency, and sustainability. *Water Policy*, 4:1–17, 2002

Considering these issues, Boland and Whittington [2000] claim that IBTs actually are more likely to promote inequalities, thereby potentially slowing the rate of uptake. These inequalities are partially attributable to the fact that IBTs only redistribute costs among those with private connections, and the poorest members of society typically cannot afford the up-front cost of a connection, so they fail to benefit from IBTs. Additionally, the poorest members are more likely to share taps, meaning that they are more likely to pay above cost. Boland and Whittington further explain other difficulties in implementing IBTs that lead to issues, including determining the quantity of water allowed under the first block and the correct pricing for blocks to ensure cost recovery. They recommend a system based on uniform pricing with rebates (UPR). This two-part marginal cost-based tariff sets the marginal cost of water as equal to the volumetric charges with a fixed monthly credit to ensure the total revenue to the utility equals that obtained through IBTs, and a minimum charge to households is set to ensure no zero or negative bills. They demonstrate that this approach is likely to result in significantly lower bills for a greater percentage of households, meaning that it is more effective at transferring costs from wealthy to poor households. Additionally, it is unlikely to produce less efficient use of water than use under IBTs. Furthermore, it "is simple, transparent, easy to implement, appears fair, is equitable in most circumstances, and requires less data for design and revenue estimation"[193].

[193] J. Boland and D. Whittington. The political economy of water tariff design in developing countries: Increasing block tariffs vs. uniform price with rebate designs. In A. Dinar, editor, *The Political Economy of Water Pricing Reforms*. Oxford University Press, New York, 2000

These implications of tariff structure are important to understand because decisions in regard to tariff structure (typically made by the water regulator) can have a significant impact on the level of affordability for poorer income households and, thus, impact on uptake of piped water to the home. At present, Ribáuè is using uniform pricing, but this will almost certainly change in the near future. If IBTs are implemented, as in Nampula, then it is quite possible that uptake for poorer households and sharing of yard taps may slow, dampening the impact of the piped network. Additionally, unless the terms of the management contract for the private operator include clear stipulations that ensure that certain benchmarks meant to ensure social fairness are achieved by specific timelines, market forces may prevent these from ever occurring, and only wealthy areas of the town may fully benefit from piped water.

Measuring the Value of Piped Water to Households in Ribáuè

In the context of water supply, the end goal should be water to the household for each family in the community. Boland and Whittington [2000] note that basic water needs are generally 1 cubic meter per person per month[194], a level of consumption difficult to achieve when forced to travel for water. Consequently, standpipes are not a level of service that towns or cities should be satisfied with in the long term[195]. With this in mind, we set out to determine the value of Ribáuè's piped system in terms of delivery of water to the home. At the time of fieldwork, the recency of completion of the piped system in Ribáuè made it impractical to consider a valuation

[194] This is the equivalent of 1.64 jerrycans per person per day.

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

of the system based strictly on revealed preferences as measured through actual payments for water supplied through yard taps, as only slightly over 8% of households reported using a yard tap or neighbour's tap. Consequently, we have used contingent valuation as a mechanism to ascertain the worth of the piped system in terms of the goal of provision of piped water to the home.

The Contingent Valuation Method

Contingent valuation (CV) is an economic method commonly used to extract the value of non-market goods by eliciting how much people would be willing to pay (WTP) for those goods. The method was introduced by von Ciricacy-Wantrup [1947] and originally saw much of its application in the environmental sciences[196]. The scope of applications has expanded significantly through the years, and Carson [2011] provides a comprehensive examination of the method and its implementation and uses over the past 50-60 years[197]. This includes a list of more than 7,500 studies carried out in 130 countries.

[196] S. von Ciricacy-Wantrup. Capital returns from soil-conservation practices. *Journal of Farm Economics*, 29: 1181–1196, 1947

[197] R.T. Carson. *Contingent Valuation: A Comprehensive Bibliography and History*. Edward Elger, Cheltenham, UK, 2011

To provide greater clarity on best practice for studies using CV in the face of skepticism over results based on the method, the 1993 National Oceanic and Atmospheric Administration (NOAA) Panel on Contingent Valuation recommended that studies using CV include:

- in-person interviews,
- detailed information on the good or service to be provided,
- income effects,
- questions about WTP for that good or service that evoke a response in the form of a "yes" or "no", and
- additional questions to show that the respondent understood the good or service to be provided.

These recommendations were considered in the context of valuation of resources, environmental protection, or environmental goods[198].

[198] K. Arrow, R. Solow, P.R. Portney, E.E. Leamer, R. Radner, and H. Schuman. *Report of the NOAA Panel on Contingent Valuation*. National Oceanic and Atmospheric Administration, 1993

Through the years, various sets of guidelines for best practice have been presented for sectors where CV is commonly used. CV in the context of WSS has seen widespread use, and Wedgwood and Sansom [2003] and Gunatilake et al. [2007] have provided directives specific to WSS[199]. These recommendations largely build on those of the NOAA Panel, so there is still an emphasis on in-person interviews, clear descriptions of the service, income effects, etc. Where they are able to build on the recommendations of NOAA, however, is in terms of structure of the survey and providing guidance for presenting a clear scenario. Gunatilake et al. [2007] provide a template for the structure of surveys, suggesting a format that include:

- an introduction presenting the purpose of the survey[200],

[199] A. Wedgwood and K. Sansom. *Willingness-to-pay surveys: A streamlined approach*. Water Engineering and Development Centre, Loughborough University, 2003; and H. Gunatilake, J.C. Yang, S. Pattanayak, and K.A. Choe. *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, 2007

[200] Wedgwood and Sansom [2003] note that this is vital in reducing strategic bias in responses.

- questions pertaining to demographics and SES of household,
- questions on current water supply and sanitation situation of household,
- questions related to WTP, and
- "debriefing questions", which inquire as to willingness or unwillingness to pay.

In terms of the presentation of a scenario, in the context of water supply Wedgwood and Sansom [2003] suggest that it is important to clearly explain factors including:

- the hours of service,
- the cleanliness/quality of the water,
- the quantity of water supplied,
- the location of the water source,
- how the water will be provided, and
- the regularity of billing

as well as benefits such as:

- improved reliability and/or cleanliness,
- closer proximity to the household, and
- shorter queueing.

Additionally, respondents should be reminded of their budgetary constraints. Our survey took these recommendations into consideration, following the structure proposed by Gunatilake et al. [2007] and presenting a scenario that considered key factors identified by Wedgwood and Sansom [2003] as well as specifying that respondents carefully consider their current income and expenditures in deciding on WTP.

Presented Water Supply Scenario

In presenting a WSS scenario, we maintained a focus on the interventions carried out as part of NAMWASH, so the emphasis was on the town of Ribáuè and valuing the piped system that was delivered. This scenario should represent a level of service that is both aspirational and realistic. In the peri-urban setting, a household connection would fit the bill of being aspirational but would not be realistic for the current form of piped infrastructure[201]. Yard taps, on the other hand, would be seen as aspirational for households in Ribáuè but would also be realistic, given the level of use of yard taps we see in peri-urban areas of Nampula. Consequently, we decided on a scenario where clean water would be piped to the yard and available 24 hours per day, 7 days per week.

[201] In the peri-urban areas of Nampula we surveyed, only 5.95% of households had a household connection, so it is unlikely that the use of household connections will be normalised there anytime soon. We would expect the situation in Ribáuè to be no different.

Applying to not only Ribáuè but also Nampula and Liúpo, in terms of the scenario being aspirational, the fact that residents of Liúpo do not currently have access to water piped to the home and very few residents of Ribáuè have yard taps makes the presented scenario largely aspirational for residents of these two towns[202]. In the case of Nampula, the fact that the scenario represents a reliable delivery of water (24 hours per day, 7 days per week) also makes the scenario largely aspirational, considering the issues with water reliability for the city mentioned in previous chapters.

[202] Indeed, analysis of NAMWASH baseline survey data showed that 54% of households in Ribáuè chose a yard tap as their first preferred method of water delivery (meaning that they aspired to have water piped to their yard), and more than 72% stated a preference for either a yard tap or a tap inside the house. The median price that households stated that they were willing to pay for a yard tap at that time was 30-49 MZN per month, an amount that is less than the current monthly fixed cost for piped water in Ribáuè.

Given that water delivery has been incredibly reliable in Ribáuè, the presentation of a scenario of clean water delivered to households for 24 hours per day, 7 days per week is definitely achievable even if uncommon in many of the urban centres of Mozambique. At the same time, the high level of use of water piped to the home in Nampula[203] suggests that, long term, it is likely that the use of yard taps in Ribáuè would be normalised to the same extent or a greater extent than what is currently observed in Nampula. Indeed, the steady increase in uptake of yard taps in Ribáuè and approximate doubling in the number of yard taps since the end of NAMWASH would support this.

[203] In households sampled in Nampula, we observed 69.1% of households using a household connection, yard tap, or tap of a neighbour and an additional 12.09% using a standpipe, meaning that 81.19% of households use piped water.

The high use of household connections and yard taps in Nampula means that many families experience and understand the benefits of clean water piped to the home. However, as mentioned previously, in Nampula households and standpipe operators alike commented on the lack of regularity of water supply due to water pressure issues. Thus, even though households are happy with the quality of the water being provided by the piped network, availability falls well below 24 hours per day, 7 days per week, so the scenario presented would be considered aspirational for even those with water piped to the home in Nampula.

At the same time, at the time of fieldwork in Ribáuè in November 2014, yard tap users (21.21%) and kiosk users (16.22%) reported problems with water quality. Users of piped water, including kiosk operators and local businesses, suggested that the negative assessment of water quality was due to water turbidity even though microbiological and chemical analyses of water at the source and the furthermost water point showed it to be safe to drink[204]. This issue was quickly rectified by STCC, which doubled its frequency of cleaning filters, and follow-up interviews with kiosk operators and local businesses in July of 2015 suggested a substantial increase in water clarity since November 2014 and a high degree of satisfaction with water quality. However, given the issues noted by users of piped water in November 2014 in terms of perceived water quality, the presented scenario would likely have been viewed as aspirational at the time of fieldwork as well.

[204] Issues with water turbidity are significant because the predominant criterion used by people to assess whether water is safe to drink is water clarity (86.44% of respondents).

In presenting the WSS scenario, it was important to ensure that respondents understood that the questions were not tied to a pending water intervention in order to reduce strategic bias[205], and it was also important that they carefully considered their capacity to

[205] We made this point clear in discussions with local leaders during protocol as well. This was necessary not only to prevent causing unwarranted expectations but also to help ensure that households responded as truthfully as possible.

pay. The exact wording of the scenario presented was as follows:

> *I am now going to ask you some questions regarding your willingness to pay for improved water and sanitation services in your household. These questions are strictly for research purposes. There are no right or wrong answers. We are simply interested in what you think. Throughout, please keep in mind:*
>
> - *your household income,*
> - *your current household expenses (or other alternative sources of water for your household), and*
> - *other possible uses for your household income in answering these questions.*
>
> *I am going to ask you to imagine a theoretical scenario. Imagine that you have a sustained improvement in availability of quality water and sanitation services in your neighbourhood where clean water is piped to your yard and is available 24 hours per day, 7 days per week. Also imagine that faecal waste removal services are available whenever your pit needs to be emptied.*

Respondents were then asked:

1. how well they understood the scenario according to a five point scale (ranging from "very well" to "not at all") and
2. whether they were willing to pay for the water service described.

Elicitation of Willingness to Pay

For those who stated WTP, maximum WTP was elicited using a bidding game format where respondents were asked whether they would be willing to pay a pre-specified monetary value[206]. The initial value for the water service scenario was set at 50 MZN to reflect the fixed monthly cost for water in Ribáuè[207]. After querying a respondent as to whether he or she would be willing to pay the pre-specified monetary value, this amount was continually incremented or decremented by a specified amount[208] until the respondent was either unwilling to pay (in the case of incrementing amounts) or willing to pay (in the case of decrementing amounts). This would then determine maximum WTP.

The exact wording of questions used to elicit maximum WTP differed depending on whether or not a household already had access to a yard tap or household connection. For those not using a yard tap or household connection, the question was phrased as:

> *Assume in the future you are charged ___ MZN per month for a yard connection and for the same amount of water that you currently use each month. Would you be willing to pay this amount?*

For those who currently used a yard tap or household connection, the question was phrased as:

> *Assume in the future you are charged ___ MZN per month for a yard connection, **without which you would not have access to the service**, and for the same amount of water that you currently use each month. Would you be willing to pay this amount?*

[206] Other commonly used forms of questions used for WTP include open-ended questions, payment cards where a series of values are presented on a card, and "take it or leave it" bidding where respondents accept or do not accept a single presented value

[207] This can be thought of as the cost to have the opportunity to have clean water available at the home. This value is virtually the same as the fixed cost for piped water in Nampula

[208] 5 MZN for decrements, 5 MZN for increments until 70 MZN was reached, at which point increments were raised to 10 MZN.

In other words, they were asked to consider a scenario where they did not currently have access to piped water at the home.

Determinants of Willingness to Pay for Piped Water

A large number of studies have been carried out to assess WTP for various forms of water supply, but these do this almost exclusively in the context of deciding on a preferred and appropriate form of supply for a town set to benefit from water interventions. As a small cross-section, Altaf et al. [1992], Ahmad et al. [2002], Fujita et al. [2005], Gunatilake et al. [2006], Guha [2007], Haq et al. [2007], Sattar and Ahmed [2007], Adenike and Titus [2009], Gunatilake and Tachiiri [2012], Lema and Beyene [2012], and Kanayo et al. [2013] consider WTP for everything from wells to piped water (although greatest emphasis is placed on piped water) in developing countries in Africa[209], Asia[210], and South America[211] and have similarities in terms of the variables that are considered important in determining WTP[212]. As would be anticipated, there are variations depending on the specifics of a situation considered, but variables generally considered to be important include:

[209] Kenya, Nigeria, Ethiopia.

[210] Bangladesh, Pakistan, Sri Lanka.

[211] Peru.

[212] Brouwer et al. [2015] provide a recent similar WTP study but for water filtration technology. Many of the determinants considered in their study are the same as those used in the previously cited studies on water supply.

- demographics of the respondent (age, sex),
- household size,
- education level of the head of household,
- occupation of the head of household,
- income,
- quantity of water used[213],
- distance/time to water point,
- hours of operation of water point,
- level of satisfaction with existing water service,
- whether a household treats water,
- payment for electricity, and
- incidence or prevalence of diarrhoea (or other water borne diseases).

[213] This is important for "take it or leave it" bidding.

Even though we considered WTP in the context of water supply that has already been introduced (at least in the cases of Nampula and Ribáuè), many of the factors influencing whether a household is willing to pay would be anticipated to be similar. Consequently, we considered models that included the previously listed variables as well as:

- interview length[214],
- stated level of understanding of the presented scenario, and
- current primary water point.

[214] This was included for the same reason as presented when considering factors influencing willingness to reveal income.

Level of satisfaction with existing water service was reflected in variables that measured perception of:

- water quality for the household's current primary water point,
- change in access to water in the past twelve months, and
- change in water quality in the past twelve months.

Given the previously noted difficulties with obtaining numeric measures of household income, we considered separate models based on numeric income and based on proxies for income. When considering models based on numeric income, occupation of the head of household and payment for electricity were excluded from consideration, as these would make income an intermediate variable. Additionally, income and reported time to collect water were log-transformed.

Stated willingness to pay for piped water

When it comes to stated willingness to pay, there is not much variability across Nampula, Ribáuè and Liùpo with 68.50% (64.56%, 72.44%) of households in Nampula stating WTP, 66.80% (62.65%, 70.96%) in Ribáuè, and 64.73% (58.47%, 70.99%) in Liúpo. The overwhelming reason why households said they were unwilling to pay was that they felt they could not afford the service (percentages of 54.71%, 79.88%, and 66.28% for Nampula, Ribáuè, and Liúpo, respectively). Other reasons presented included that they felt that the government should cover the cost/subsidise the service (18.24%, 9.47%, and 20.93%, respectively) or the service was not worth the cost (21.18%, 5.33%, and 10.47%, respectively).

It is also important to note that a major driving force for stated unwillingness to pay is reticence in terms of supplying any information related to willingness or capacity to pay. A cross-section of the population may exercise a heightened level of caution when confronted with questions which they believe could potentially be used to determine the pricing of water or other services, and we note that this could be the case here, as there was a significant relationship between respondents stating that they were unwilling to pay for the presented water service scenario and also being unwilling to provide their income (chi-square test p-value < 0.001). Those saying that they were unwilling to pay for the presented water service scenario were more than two times as likely to be unwilling to report income data than what would be expected.

Table 30 provides output from a logistic regression model of stated WTP on the previously mentioned set of variables, using numeric income. Some of the key results are presented in Box 6. These results are largely in line with what we might expect. Larger households would be expected to have a greater demand for a yard tap because they experience a more significant burden associated with collecting water. Those using unprotected wells are near the

Table 30: Logistic regression of stated willingness to pay on relevant variables, including numeric income.

	Estimate	Std. Error	z-value	Pr(> $\|z\|$)
(Intercept)	-2.5083	2.9309	-0.86	0.3921
Interview length	0.0437	0.0233	1.87	0.0610*
Female respondent	0.1685	0.4770	0.35	0.7239
Age of respondent	-0.0259	0.0153	-1.70	0.0895*
Household size	0.2962	0.1145	2.59	0.0097***
Level of understanding of scenario: (Reference: Very well)				
Well	1.5255	0.4177	3.65	0.0003***
Town/City: (Reference: Nampula)				
Liúpo	1.6849	1.9359	0.87	0.3841
Ribáuè	2.3800	1.1543	2.06	0.0392**
Education level of head of household: (Reference: None)				
Primary of 1st degree	0.4192	0.8310	0.50	0.6140
Primary of 2nd degree	1.3448	1.0296	1.31	0.1915
Secondary of 1st degree	0.0578	0.8991	0.06	0.9487
Secondary of 2nd degree	0.8821	0.9085	0.97	0.3316
Higher level	0.2182	1.2896	0.17	0.8656
Do not know	-0.1653	1.4506	-0.11	0.9093
Primary water point: (Reference: Household connection)				
Yard tap	-0.5992	1.1259	-0.53	0.5946
Standpipe	1.4971	1.6663	0.90	0.3690
Borehole	2.4735	1.6143	1.53	0.1255
Unprotected well	3.7341	1.7985	2.08	0.0379**
Neighbour's tap	0.0295	1.7854	0.02	0.9868
Hours operational	-0.1028	0.0334	-3.08	0.0021**
Time to collect water	-0.3956	0.4064	-0.97	0.3303
Good water quality	-0.1431	0.4912	-0.29	0.7709
Household has access to sufficient water	-0.3652	0.4859	-0.75	0.4522
Incidence of diarrhoea	1.0091	0.7577	1.33	0.1829
Household treats water	0.8984	0.4755	1.89	0.0589*
Household income	0.2175	0.1594	1.36	0.1725
Perceived change in access to water: (Reference: Decreased)				
Increased	0.9872	0.9459	1.04	0.2967
Neither decreased nor increased	-0.6083	0.8270	-0.74	0.4620
Do not know	-0.7242	1.1854	-0.61	0.5412
Perceived change in quality of water: (Reference: Decreased)				
Increased	0.3282	1.4931	0.22	0.8260
Neither decreased nor increased	-0.5267	1.3656	-0.39	0.6998
Do not know	-0.4522	1.5194	-0.30	0.7660
Liúpo:Time to collect water	-0.1146	0.5941	-0.19	0.8470
Ribáuè:Time to collect water	-0.4931	0.4035	-1.22	0.2217
Note:		*p<0.1; **p<0.05; ***p<0.01		

bottom of the ladder in regard to water point usage, so they would likely exercise the highest level of demand for any form of improved water point. Indeed, we note that, even though effects are not significant, coefficients become increasingly positive when moving from standpipes to unprotected wells, suggesting increasing demand for a yard tap for those with less improved water points[215]. At the same time, if a household must treat its water or has access to water for very limited periods of time, then we would expect demand to be higher for a water scenario (clean water for 24 hours per day, 7 days per week) that would resolve these issues.

[215] Coefficients for those using a yard tap or neighbour's tap are non-significant and quite modest, suggesting fairly similar levels of stated WTP for a yard tap for all those currently benefiting from piped water to the yard (or a yard in close proximity).

Age of respondent:	• Older respondents are slightly less likely to state WTP.
Household size:	• Larger households are significantly more likely to be willing to pay.
Town/City:	• Households in Ribáuè are significantly more likely to be willing to pay than those in Nampula.
Level of understanding of scenario:	• Those who say that they understand the scenario well are more likely to state WTP than those who say that they understand the scenario very well. (Note that all households said that they understood the scenario either well or very well.) The reason for this significant effect is not clear.
Primary water point:	• Households using an unprotected well are significantly more likely to be willing to pay than those with a household connection
Hours operational:	• Households' stated WTP decreases the longer their current primary water point is operational.
Household treats water:	• Households that treat water are significantly more likely to be willing to pay.

Box 6: Key results for logistic model of stated willingness to pay on relevant variables, including numeric income.

If we instead consider the same logistic regression model but with numeric income replaced by proxies for income, we obtain the results presented in Table 31, which reinforce many of the key findings of the previous model[216]. Key results are summarised in Box 7 and largely are in line with what would be anticipated. Female respondents might be more likely to state WTP because they are responsible for collecting water at much higher rates than men. Results in regard to household size, primary water point usage, treatment of water, and hours of operation of a household's primary water point are consistent with what we observed for the previous model. Results pertaining to the occupation of the head of household are not completely clear, although they would be consistent with those in generally higher paying professions being more likely to state WTP. Thus, before any amount has been assigned

[216] Note that the use of proxies means that we have far fewer entries excluded due to missing data, explaining the appearance of levels for some factors that did not appear in Table 30.

Table 31: Logistic regression of stated willingness to pay on relevant variables, including proxies for income.

	Estimate	Std. Error	z-value	Pr(> |z|)
(Intercept)	-1.3843	1.1971	-1.16	0.2475
Interview length	0.0122	0.0097	1.26	0.2091
Female respondent	0.3565	0.2115	1.69	0.0919*
Age of respondent	-0.0000	0.0084	-0.00	0.9989
Household size	0.1054	0.0460	2.29	0.0219**
Level of understanding of scenario: (Reference: Very well)				
Well	-0.0101	0.1837	-0.06	0.9560
Neither well nor poorly	-0.5210	1.2776	-0.41	0.6834
Town/City: (Reference: Nampula)				
Liúpo	0.8819	0.7731	1.14	0.2539
Ribáuè	0.6535	0.4478	1.46	0.1445
Education level of head of household: (Reference: None)				
Primary of 1st degree	-0.2890	0.4487	-0.64	0.5195
Primary of 2nd degree	0.1191	0.4902	0.24	0.8080
Secondary of 1st degree	-0.0015	0.4774	-0.00	0.9975
Secondary of 2nd degree	0.1187	0.4832	0.25	0.8059
Higher level	-0.5118	0.6936	-0.74	0.4606
Do not know	-0.9367	0.5816	-1.61	0.1073
Primary water point: (Reference: Household connection)				
Yard tap	0.7477	0.6041	1.24	0.2159
Standpipe	1.9270	0.7672	2.51	0.0120**
Borehole	2.0832	0.7340	2.84	0.0045***
Unprotected well	3.4839	0.7586	4.59	0.0000***
Protected spring	3.8762	2.3956	1.62	0.1057
River, stream, lake	5.1940	0.9604	5.41	0.0000***
Neighbour's tap	1.1737	0.7687	1.53	0.1268
Hours operational	-0.0766	0.0140	-5.47	0.0000***
Time to collect water	0.0156	0.1549	0.10	0.9197
Good water quality	0.1550	0.2093	0.74	0.4592
Household has access to sufficient water	0.2071	0.2385	0.87	0.3853
Incidence of diarrhoea	1.5602	0.4576	3.41	0.0006***
Household treats water	0.4734	0.2057	2.30	0.0213**
Perceived change in access to water: (Reference: Decreased)				
Increased	0.1961	0.3429	0.57	0.5673
Neither decreased nor increased	-0.1943	0.3195	-0.61	0.5430
Do not know	-0.2124	0.4056	-0.52	0.6005
Perceived change in quality of water: (Reference: Decreased)				
Increased	-0.9643	0.5289	-1.82	0.0683*
Neither decreased nor increased	-0.5572	0.4768	-1.17	0.2425
Do not know	-1.7567	0.5372	-3.27	0.0011***
Occupation of head of household: (Reference: Managers)				
Professionals	-0.6507	0.5774	-1.13	0.2598
Technicians	-1.0820	0.5626	-1.92	0.0545*
Clerical support	-1.2414	0.8694	-1.43	0.1533
Services, sales	-0.7301	0.5895	-1.24	0.2156
Agriculture, forestry, fisheries	-0.7253	0.5698	-1.27	0.2030
Craft and related trade	-0.6933	0.5868	-1.18	0.2374
Elementary occupations	-1.3259	0.5980	-2.22	0.0266**
Armed forces	-0.4277	0.9971	-0.43	0.6680
Unemployed	-0.5869	0.5989	-0.98	0.3270
Student	-1.3989	0.7325	-1.91	0.0562*
Homemaker	-1.1018	0.6727	-1.64	0.1014
Benefits/pension	-1.2497	0.7815	-1.60	0.1098
Other	-0.6279	0.7884	-0.80	0.4258
Household pays for water	2.8090	0.2248	12.50	0.0000***
Household has electricity	0.0718	0.2469	0.29	0.7712
Liúpo:Time to collect water	-0.4601	0.2472	-1.86	0.0627*
Ribáuè:Time to collect water	-0.5050	0.1645	-3.07	0.0021***
Note:		*p<0.1; **p<0.05; ***p<0.01		

to the service, poorer households may be more likely to eliminate themselves, much in line with the primary rationales stated for unwillingness to pay. This would also explain the significantly positive coefficient corresponding to households that pay for water. The significant effects related to perception of water quality may not be so clear, but this could reflect households that are satisfied with the current water situation (and, consequently, respond affirmatively or noncommittally to the question in regard to perceived change in water quality in the neighbourhood), so they do not have the same demand for clean water as other households.

Sex of respondent:	• Female respondents are slightly more likely to state WTP.
Household size:	• Larger households are significantly more likely to be willing to pay.
Primary water point:	• Households using less improved water sources are increasingly and significantly more likely to be willing to pay than those with a household connection.
Hours operational:	• Households' stated WTP decreases the longer their current primary water point is operational.
Incidence of diarrhoea:	• Households reporting incidence of diarrhoea are more likely to state WTP.
Household treats water:	• Households that treat water are significantly more likely to be willing to pay.
Perceived change in water quality:	• Households that believe that there has been a significant increase in water quality in their neighbourhood or do not know are less likely to state WTP.
Occupation of head of household:	• Households where the head is employed as a technician, in an elementary occupation, or is a student are less likely to be willing to pay than households where the head is in management.
Household pays for water:	• Households that pay for water are significantly more likely to state willingness to pay.
Time to collect water:	• In Liúpo and Ribáuè, households that spend longer collecting water are less likely to state WTP.

Box 7: Key results for logistic model of stated willingness to pay on relevant variables, including proxies for income.

Maximum willingness to pay for piped water

Where stated WTP simply attempts to ascertain a respondent's predisposition to the water service scenario presented, maximum WTP attempts to extract the value of that service for those who are willing to pay. For WTP elicited using a bidding game or payment card method, values actually represent an interval where the elicited values represent a minimum corresponding to that interval[217]. Cameron and Huppert [1989] propose a maximum likelihood interval regression approach that reflects the fact that the true value lies somewhere in this interval, and this approach is less prone to bias than ordinary least squares (OLS) estimation based on the midpoint of the interval[218]. This approach has its own assumptions in regard to the distribution of values over this interval, however, and we are interested in providing a conservative estimate of value based on WTP, so we use the minimums corresponding to each interval, in which case OLS would be expected to provide unbiased estimates of the minimum.

[217] To make this clear, consider the case where a person accepts the originally proposed value. Bids are then incremented until the respondent rejects a bid, at which point the highest bid that was accepted is recorded. The true value can lie anywhere between the last accepted bid and the rejected bid. It can be easily shown that we get a similar result if the first bid is rejected.

[218] T.A. Cameron and D.D. Huppert. OLS versus ML estimation of non-market resource values with payment card interval data. *Journal of Environmental Economics and Management*, 17 (3):230–246, 1989

In determining the factors that explain maximum WTP, we consider the same set of variables as when determining factors that explain stated WTP[219]. Here, we restricted analyses to respondents who had stated WTP, and the response variable used was log-transformed maximum WTP. Effects for the model incorporating reported numeric incomes are provided in Table 32. Key results are presented in Box 8 and are largely in line with what we would expect. Households where the head of household has a higher level of education may understand the value of piped water and, consequently, be able to pay more[220]. At the same time, those who understand the scenario better may recognise the full set of benefits from the presented scenario and, consequently, be willing to pay more. The income effect is also significantly positive, so we see that WTP is correlated with capacity to pay. The significance of effects corresponding to water points is likely representing an income effect more than anything, as these effects simply show that those with household connections report the highest WTP.

[219] One slight modification we make is removing the variable corresponding to interview length. This was included in models for stated WTP to account for some respondents potentially stating unwillingness to pay because they were impatient for the interview to end.

[220] There may be a bit of an income effect here as well, as higher levels of education tend to correlate with higher income. Education is not strictly a proxy for income, though, hence the need to include it in this model.

Level of understanding of scenario:	• Those reporting a better level of understanding of the scenario are willing to pay more.
Education level of head of household:	• Households where the head of household has a higher level of education report increasingly higher and significant WTP.
Primary water point:	• Maximum WTP is significantly higher for users of household connections than most all other primary water point users.
Income:	• As income increases, so does maximum WTP.
Perceived change in water access:	• Households that believe that there has been a significant increase in water quality in their neighbourhood or do not know report higher maximum WTP.

Box 8: Key results for linear regression of log-transformed maximum willingness to pay on relevant variables, including numeric income.

	Estimate	Std. Error	z-value	Pr(> $\|z\|$)
(Intercept)	3.4984	0.8843	3.96	0.0001
Female respondent	-0.0855	0.1512	-0.57	0.5723
Age of respondent	-0.0008	0.0057	-0.13	0.8958
Household size	0.0283	0.0299	0.95	0.3455
Level of understanding of scenario: (Reference: Very well)				
Well	-0.2688	0.1304	-2.06	0.0406**
Town/City: (Reference: Nampula)				
Liúpo	-0.0763	0.5262	-0.14	0.8849
Ribáuè	0.1936	0.3253	0.60	0.5523
Education level of head of household: (Reference: None)				
Primary of 1^{st} degree	0.5222	0.3242	1.61	0.1088
Primary of 2^{nd} degree	0.5852	0.3414	1.71	0.0880*
Secondary of 1^{st} degree	0.7098	0.3460	2.05	0.0415**
Secondary of 2^{nd} degree	1.1126	0.3394	3.28	0.0012***
Higher level	1.4438	0.4868	2.97	0.0034***
Do not know	0.8566	0.5331	1.61	0.1096
Primary water point: (Reference: Household connection)				
Yard tap	-0.9021	0.4373	-2.06	0.0404**
Standpipe	-0.9771	0.5383	-1.82	0.0710*
Borehole	-0.9446	0.5105	-1.85	0.0657*
Unprotected well	-1.1927	0.5361	-2.22	0.0272**
River, stream, lake	-0.9935	0.6534	-1.52	0.1300
Neighbour's tap	-0.2971	0.6099	-0.49	0.6267
Hours operational	-0.0104	0.0094	-1.11	0.2675
Time to collect water	0.0772	0.1238	0.62	0.5335
Good water quality	-0.1720	0.1465	-1.17	0.2419
Household has access to sufficient water	0.1943	0.1471	1.32	0.1879
Incidence of diarrhoea	0.0131	0.1769	0.07	0.9408
Household treats water	-0.0988	0.1380	-0.72	0.4750
Household income	0.1529	0.0557	2.75	0.0066***
Perceived change in access to water: (Reference: Decreased)				
Increased	0.6451	0.2613	2.47	0.0144**
Neither decreased nor increased	0.2773	0.2556	1.08	0.2792
Do not know	0.9213	0.4005	2.30	0.0224**
Perceived change in quality of water: (Reference: Decreased)				
Increased	-0.0032	0.3460	-0.01	0.9926
Neither decreased nor increased	0.0374	0.3160	0.12	0.9060
Do not know	-0.4011	0.4315	-0.93	0.3537
Liúpo:Time to collect water	-0.0863	0.1820	-0.47	0.6359
Ribáuè:Time to collect water	-0.0796	0.1309	-0.61	0.5436
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table 32: Linear regression of log-transformed maximum willingness to pay on relevant variables, including numeric income.

Again replicating this linear regression model for maximum WTP but replacing numeric income with proxies for income, we obtain the results presented in Table 33. These results are again largely consistent with that of the model incorporating numeric income, and proxies for income that are significant all have a positive relationship with maximum WTP. Key results are presented in Box 9.

Sex of respondent:	• Women report significantly lower maximum WTP than men.
Level of understanding of scenario:	• Those reporting a better level of understanding of the scenario are willing to pay more.
Education level of head of household:	• Households where the head of household has a higher level of education report increasingly higher and significant maximum WTP.
Primary water point:	• Maximum WTP is significantly higher for users of household connections than most all other primary water point users.
Occupation of head of household:	• Households where the head of household is in a managerial position report higher maximum WTP than households where the head of household is in other professions.
Household pays for water:	• Households that pay for water report significantly higher actual WTP.
Household has electricity:	• Households that are connected to the electrical grid report significantly higher maximum WTP.
Time to collect water:	• In Liúpo, households that spend more time collecting water tend to report lower maximum WTP.

Box 9: Key results for linear regression of log-transformed maximum willingness to pay on relevant variables, including proxies for income.

Validity of Maximum Willingness to Pay Values

Gunatilake et al. [2007] provide a small set of simple checks to assess the validity of results for a WTP instrument. These again tend to be in the context of competing options, so not all are applicable. Those applicable to our situation are those related to income, incidence of water borne diseases, and education level, which should all be positively associated with maximum WTP. In both of our models this is the case except in terms of incidence of water borne diseases (specifically diarrhoea), which is not statistically significant. This should not be cause for concern in that, when reported incidence of diarrhoea is low (as it was in the case of our survey), it

Table 33: Linear regression of log-transformed maximum willingness to pay on relevant variables, including proxies for income.

	Estimate	Std. Error	z-value	Pr(> |z|)
(Intercept)	4.8189	0.4302	11.20	0.0000
Female respondent	-0.2101	0.0802	-2.62	0.0090***
Age of respondent	0.0053	0.0033	1.59	0.1115
Household size	-0.0016	0.0168	-0.10	0.9237
Level of understanding of scenario: (Reference: Very well)				
Well	-0.1672	0.0695	-2.41	0.0164**
Neither well nor poorly	0.2833	0.6286	0.45	0.6524
Town/City: (Reference: Nampula)				
Liúpo	0.1181	0.3063	0.39	0.6999
Ribáuè	-0.0387	0.1675	-0.23	0.8176
Education level of head of household: (Reference: None)				
Primary of 1^{st} degree	0.1136	0.1815	0.63	0.5316
Primary of 2^{nd} degree	0.3776	0.1924	1.96	0.0502*
Secondary of 1^{st} degree	0.3979	0.1876	2.12	0.0343**
Secondary of 2^{nd} degree	0.4991	0.1862	2.68	0.0075***
Higher level	0.8700	0.2647	3.29	0.0011***
Do not know	0.1859	0.2363	0.79	0.4317
Primary water point: (Reference: Household connection)				
Yard tap	-0.7435	0.2408	-3.09	0.0021***
Standpipe	-0.6293	0.2948	-2.13	0.0332**
Borehole	-0.7831	0.2861	-2.74	0.0064***
Unprotected well	-0.7528	0.2940	-2.56	0.0107**
Protected spring	-1.1695	0.5913	-1.98	0.0483**
River, stream, lake	-0.6714	0.3712	-1.81	0.0709*
Neighbour's tap	-0.3474	0.3040	-1.14	0.2536
Hours operational	-0.0033	0.0054	-0.62	0.5377
Time to collect water	0.0773	0.0563	1.37	0.1705
Good water quality	0.0208	0.0796	0.26	0.7938
Household has access to sufficient water	0.0898	0.0940	0.95	0.3399
Incidence of diarrhoea	0.1012	0.1048	0.97	0.3346
Household treats water	-0.0130	0.0740	-0.18	0.8602
Perceived change in access to water: (Reference: Decreased)				
Increased	0.1869	0.1205	1.55	0.1213
Neither decreased nor increased	0.0144	0.1142	0.13	0.8994
Do not know	0.2500	0.1729	1.45	0.1487
Perceived change in quality of water: (Reference: Decreased)				
Increased	0.1326	0.1801	0.74	0.4618
Neither decreased nor increased	0.2021	0.1575	1.28	0.1999
Do not know	-0.3636	0.2063	-1.76	0.0785*
Education level of head of household: (Reference: None)				
Professionals	-0.3277	0.1754	-1.87	0.0621*
Technicians	-0.1826	0.1801	-1.01	0.3112
Clerical support	0.1188	0.3109	0.38	0.7024
Services, sales	-0.4652	0.1868	-2.49	0.0130**
Agriculture, forestry, fisheries	-0.5043	0.1827	-2.76	0.0059***
Craft and related trade	-0.5759	0.1848	-3.12	0.0019***
Plant/machine operators	-0.1193	0.2646	-0.45	0.6521
Elementary occupations	-0.2155	0.2031	-1.06	0.2890
Armed forces	-0.9453	0.3955	-2.39	0.0171**
Unemployed	-0.4547	0.1968	-2.31	0.0211**
Student	-0.9142	0.2942	-3.11	0.0020***
Homemaker	-0.6256	0.2342	-2.67	0.0077***
Benefits/pension	-0.8288	0.2946	-2.81	0.0051***
Other	-0.7173	0.2930	-2.45	0.0146**
Household pays for water	0.2977	0.1124	2.65	0.0083***
Household has electricity	0.3446	0.0987	3.49	0.0005***
Liúpo:Time to collect water	-0.1839	0.0981	-1.88	0.0611**
Ribáuè:Time to collect water	-0.0613	0.0613	-1.00	0.3178
Note:		*p<0.1; **p<0.05; ***p<0.01		

is difficult to obtain a significant effect[221]. If we examine the coefficient for this variable, although not significant, it is positive, in line with what would be expected.

Importantly, Griffin et al. [1995], Cameron et al. [2002], Bhatia and Fox-Rushby [2003] and Gunatilake et al. [2007] all provide evidence to suggest that actual behaviour closely reflects what is predicted by CV methods in the context of water supply for properly constructed CV scenarios[222]. In other words, maximum WTP, a value based on a hypothetical scenario, should correspond quite closely to what households would pay in reality. Although we are unable to check the validity of reported WTP rigorously in our case, a basic check with NAMWASH baseline data from 2012 can provide a sense of whether these claims are reasonable.

Table 34 provides the percentage of households in Ribáuè in 2012 who reported being willing to pay at least a specified monthly amount. This total was based on the 71.83% of households who stated a yard tap as their first or second preference for water supply, a total close to the 66.80% of households in Ribáuè who stated WTP for a yard tap in 2014. Next to these totals are the corresponding percentages of households from the subpopulation of households in Ribáuè who are willing to pay and who use yard taps and reported monthly water costs in the specified range in Ribáuè in 2014[223]. We observe higher percentages paying above 200 MZN or 300 MZN per month than what would be expected based on 2012 data. At the same time, we also observe lower percentages paying above 100 MZN.

It might be argued that this would suggest a small percentage of wealthy households who will pay exorbitant amounts for water, leading to greater percentages of households paying at least 200 MZN per month than what would be expected based on 2012 data. At the same time, however, in general maximum WTP overestimates actual behaviour, as only roughly half of the percentage of households we would expect to have a yard tap at a particular price point actually do.

This argument fails to take into consideration the fact that percentages presented for 2012 reflect what would be expected if all households in Ribáuè were offered a yard tap at the given price. As noted previously, four of the neighbourhoods sampled did not have access to the distribution network at the time of fieldwork[224], and yard taps are not pushed out to all households at once, as evidenced by the continued steady uptake of yard taps. Accounting for the increase in yard taps since November 2014[225] along with the lack of availability of yard taps in certain neighbourhoods produces an adjusted estimate of 8.55% of households having a yard tap and paying at least 100 MZN per month. Thus, at present (and ignoring the fact that the continued demand for yard taps would push this percentage significantly higher), WTP totals from 2012 are almost certainly conservative relative to what has been observed in terms of actual payments for 2014.

[221] Admiraal and Doepel [2014] provide further explanation of this.

[222] C.C. Griffin, J. Briscoe, B. Singh, R. Ramasubban, and R. Bhatia. Contingent valuation and actual behavior: Predicting connections to new water systems in the state of Kerala, India. *The World Bank Economic Review*, 9(3): 373–395, 1995; T. A. Cameron, G.L. Poe, R.G. Ethier, and W.D. Schulze. Alternative non-market value-elicitation methods: Are the underlying preferences the same? *Journal of Environmental Economics and Management*, 44 (3):391–425, 2002; M.R. Bhatia and J.A. Fox-Rushby. Validity of willingness to pay: Hypothetical versus actual payment. *Applied Economics Letters*, 10(12): 737–740, 2003; and H. Gunatilake, J.C. Yang, S. Pattanayak, and K.A. Choe. *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, 2007

Value	Projected (2012)	Actual (2014)
$\geq$ 300 MZN	0.00%	1.56%
$\geq$ 200 MZN	2.09%	2.49%
$\geq$ 100 MZN	8.38%	4.36%

Table 34: Projected percentages of households in Ribáuè that would pay at least specified monthly amounts for a yard tap, as estimated from the 2012 NAMWASH baseline survey, along with the estimated percentages of households paying at least those monthly amounts for a yard tap in November 2014.

[223] This subsetting is necessary for a fair comparison, as WTP values from 2012 are reported only for households who specify a yard tap as a first or second choice. Those who do not fall into this group would be significantly more likely to be unwilling to pay.

[224] Adjusting for this would minimally increase percentages for 2014 by an estimated 22.45%.

[225] This was estimated at more than 60%.

This is important because WTP totals from 2014 are actually quite similar to those reported for 2012 despite following a more rigorous means of elicitation[226]. Figure 36 shows cumulative percentages of people being willing to pay particular amounts for service from a yard tap, as estimated from the surveys carried out in 2012 and 2014[227]. The cumulative percentages are remarkably close, and a Wilcoxon-signed rank test fails to find a significant difference in terms of the two distributions (p-value = 0.4515). This means that, just as we would expect WTP totals from 2012 to be conservative, we would likewise expect WTP totals from 2014 to be conservative.

[226] The 2012 NAMWASH baseline survey was not meant to be a WTP study, so it did not follow the bulk of the recommendations of Wedgwood and Sansom [2003] and Gunatilake et al. [2007]. It also used a different means of eliciting maximum WTP, opting for an open-ended question.

[227] The 2014 totals were categorised to match those presented in the 2012 survey.

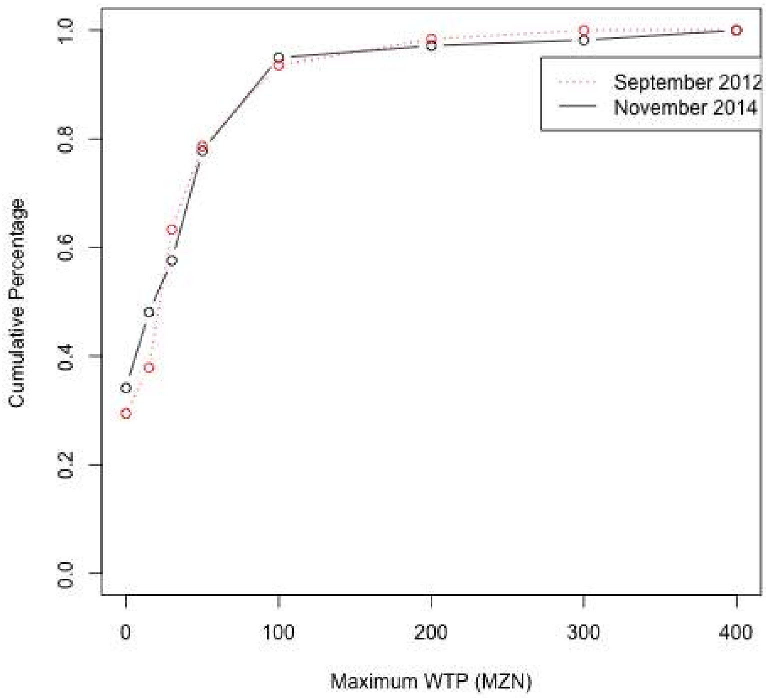


Figure 36: A comparison of household maximum willingness to pay as recorded in September 2012 and November 2014.

To further validate the reliability of maximum WTP across Nampula, Ribáuè, and Liúpo, we present mean and median maximum WTP for the three locations in Table 35. As WTP values are highly positively skewed, we also present geometric means of maximum WTP, along with corresponding (non-symmetric) 95% confidence intervals. These WTP values show a relationship much in line with what we would expect with maximum WTP highest in Nampula and lowest in Liúpo. These differences may partially be attributed to the length of time that piped water has been available in each of these three locations with those in Nampula understanding well both the convenience and higher cost of piped water and, consequently, being willing to pay more. Almost certainly, though, the primary reason for these differences is disparities in household income, which are highlighted in Table 22.

Town/City	Mean	Median	Geometric Mean
Nampula	302.45 MZN	155 MZN	173.62 (158.31, 190.41) MZN
Ribáuè	191.46 MZN	100 MZN	120.36 (110.66, 130.91) MZN
Liúpo	101.09 MZN	70 MZN	74.20 (67.06, 82.11) MZN

Table 35: Mean and median maximum willingness to pay by town/city, along with geometric means and corresponding 95% confidence intervals, as estimated in November 2014.

Table 36 provides comparisons of both incomes and maximum WTP for each of the locations, and it does so in terms of both means and medians. For example, the mean income reported in Ribáuè is 1.26 times larger than that of Liúpo, and the median maximum WTP reported in Nampula is 1.55 time larger than that of Ribáuè. If there was some form of systematic bias in terms of reported maximum WTP across these three locations, then this might be expected to appear in terms of clear departures from observed relationships in terms of the incomes (which should represent capacity to pay) for these locations. Here, we note that the difference in mean maximum WTP between Nampula and Ribáuè is smaller than the ratio of mean incomes for the two locations, potentially suggesting systematic bias where households in Ribáuè report higher WTP than what they would actually pay[228]. At the same time, though, this relationship changes when considering median income and median maximum WTP, which would be consistent with exactly the opposite bias. This would suggest that there is no consensus in terms of bias in these reports, so differences in maximum WTP in Nampula and Ribáuè could very well be consistent with the observed differences in income. The same relationship holds when comparing Nampula with Liúpo. When comparing Ribaúè and Liúpo, the difference in mean maximum WTP is actually more substantial than the differences in mean income[229]. However, we get the reverse relationship when comparing medians, again suggesting that the relationships between maximum WTP for the two towns could be consistent with the observed differences in income. Thus, we do not have clear evidence of systematic bias in terms of maximum WTP (when comparing with reported incomes) across the three locations.

[228] Conversely, it could reflect households stating lower WTP than what they would actually pay. A third and more plausible explanation would be that there is no bias, as maximum WTP may be linearly related with income only to a point, at which it would begin to plateau.

[229] An explanation for this could be that, as households in Ribáuè had exposure to piped water, they potentially understood not only the true cost but also the greater convenience and value, so were wiling to pay more. Households in Liúpo did not have this exposure.

Finally, there is the question of whether reported maximum WTP exceeds what households would reasonably pay for water. It has long been claimed that, as long as water costs fall below 5% of household income, then water is affordable[230]. However, this rule has been called into question with Wang et al. [2010] noting that this threshold may depend on the particular country or even particular regions and groups of households in that country with a variety of factors ultimately influencing the percentage of household income spent on water[231]. Further, in an examination of five towns in Morocco, McPhail [1993] showed that households were both willing to pay and able to pay well over 5% of household income with respondents willing to pay 7-10% of household income[232],

[230] See Fankhauser and Tepic [2007] for one such example of this claim.

[231] H. Wang, J. Xie, and H. Li. Water pricing with household surveys: A study of acceptability and willingness to pay in Chongqing, China. *China Economic Review*, 21:136–149, 2010

[232] A.A. McPhail. The "Five Percent Rule" for improved water service: Can households afford more? *World Development*, 21(6):963–973, 1993

Ratios of means

Income

	Nampula	Ribáuè
Ribáuè	2.77	
Liúpo	3.49	1.26

Maximum WTP

	Nampula	Ribáuè
Ribáuè	1.58	
Liúpo	2.99	1.89

Ratios of medians

Income

	Nampula	Ribáuè
Ribáuè	1.21	
Liúpo	2.01	1.65

Maximum WTP

	Nampula	Ribáuè
Ribáuè	1.55	
Liúpo	2.21	1.42

Table 36: Ratios between locations in terms of income (*top*) and maximum willingness to pay (*bottom*). These ratios are presented in terms of both means (*left*) and medians (*right*).

and Cairncross and Kinnear [1992] found households in Khartoum, Sudan to be willing to spend a significant percentage of household income (sometimes in excess of 50%) if potable water was particularly scarce[233]. If we consider the percentage of household income that would be spent on water as based on mean maximum WTP and mean household income (or, alternatively, medians or geometric means of maximum WTP and household income), we obtain the percentages shown in Table 37. These show totals ranging from 2.81-3.73% for Nampula, 4.00-6.61% for Ribáuè, and 3.27-5.61% for Liúpo. Although one of these percentages exceeds the informal affordability threshold of 5% for each town/city, these do not fall far above that threshold and appear to be plausible based on the previously noted research of Wang et al. [2010], McPhail [1993], and Cairncross and Kinnear [1992]. This would suggest that maximum WTP is appropriately taking into consideration capacity to pay and is in line with what would largely be considered "affordable," providing still more evidence to lend credibility to these results.

[233] S. Cairncross and J. Kinnear. Elasticity of demand for water in Khartoum, Sudan. *Social Science and Medicine*, 34 (2):183–189, 1992

Town/City	Mean	Median	Geometric Mean
Nampula	2.81%	5.10%	3.73%
Ribáuè	4.92%	4.00%	6.61%
Liúpo	3.27%	4.63%	5.61%

Table 37: Maximum willingness to pay as a percentage of household income as based on mean maximum willingness to pay and mean income as well as medians and geometric means of the two.

The Value of Piped Water to Households

To estimate the value of clean water reliably piped to the home, we use mean WTP as based on fitted values from the linear models considered when examining the determinants of WTP. Commonly, the empirical means for each variable included in the linear model are used to produce fitted values, and these then represent (or can be used to calculate) mean maximum WTP[234]. This approach requires modification when considering linear models that include a number of factors and wanting to calculate mean maximum WTP according to certain groups based on these factors. Additionally,

[234] It is important to note that, since we have log-transformed WTP in our linear models, when we refer to "mean" maximum WTP as based on these models this is actually referring to the geometric mean.

while producing an estimate of mean maximum WTP, it does not provide any indication of the level of precision of that value.

To estimate mean maximum WTP for each of Nampula, Ribáuè, and Liúpo, we instead use a Monte Carlo-based approach whereby we sample from the subpopulation of observations for individuals from each town. This allowed us to not only efficiently estimate mean maximum WTP but also produce a measure of precision in that mean. In particular, we considered two different sampling approaches based on:

1. empirical marginal distributions (*i.e.* the observed distribution for each individual variable), and

2. the empirical joint distribution (*i.e.* the observed multivariate distribution of observations across individuals).

Sampling based on the empirical marginal distribution would produce a mean maximum WTP that, in expectation, would match the mean maximum WTP produced by using the means of each of the variables included in the linear regression model. It would also allow for a quick calculation of the standard error corresponding to this mean. Sampling based on the empirical joint distribution of variables (or, equivalently, "bootstrapping") would recognise that not all variables function completely independently of each other[235], so it would be anticipated to be more accurate than estimates based on sampling from empirical marginal distributions.

In implementing the Monte Carlo-based approach, we carried out 1,000 simulations of sample sizes corresponding to town sample sizes[236]. We applied to both sampling from empirical marginal distributions and joint distributions and calculated mean and median maximum WTP for both the linear model incorporating numeric measures of income and the linear model that instead used proxies for income. This produced the town/city-specific means (and corresponding 95% confidence intervals) and medians shown in Table 38. These show that the most conservative estimates for mean and median maximum WTP (shaded in black) are produced by using the linear model including proxies for income and sampling from the empirical marginal distributions for individual variables included in the model[237].

These mean and median maximum WTP values provide useful information in terms of the sustainability of piped water for each of these three locations. If we consider mean maximum WTP for Liúpo and assume the same tariff structure as for Ribáuè (shown in Table 29), then, when using the conservative estimate of 62.05 MZN, the average households in Liúpo would consume 21.99 litres of water per day or, equivalently, 4.29 litres per capita per day, totals more than three times under the minimum standard specified by The Sphere Project [2011][238]. Even using the most generous maximum WTP estimate of 74.86 MZN per month would only roughly double household consumption to 45.40 litres per day, still far below daily household needs[239]. Thus, households would not

[235] For instance, you are unlikely to find a household that simultaneously reports low income and uses a household connection as their primary water point. Using sampling based strictly on the empirical marginal distributions would make this much more likely than what is observed in reality, however.

[236] In other words, we sampled 535 observations for Nampula, 495 for Ribáuè, and 225 for Liúpo.

[237] We would most likely expect WTP models based on proxies for income to be more conservative. Our previous modelling for income showed that those of lower SES were less likely to report their income, so these individuals are excluded when considering the model for WTP based on numeric income. Given the relationship between income and WTP, this model would tend to exclude lower WTP values. Thus, the model based on proxies, which includes more of these low SES individuals would be expected to be conservative.

[238] The Sphere Project. *Humanitarian Charter and Minimum Standards in Humanitarian Response*. 3^{rd} edition, 2011

[239] If we further consider the upper bound of the corresponding 95% confidence interval and assume household expenditure of 84.25 MZN per month, we still only arrive at daily consumption of 62.56 litres per day (or 12.20 litres per capita per day), still under the Sphere Project's minimum standard.

Nampula

	Numeric Income		Proxies for Income	
Sampling	Mean	Median	Mean	Median
Joint	190.97 (166.04, 215.91) MZN	190.38 MZN	168.06 (158.84, 177.28) MZN	168.17 MZN
Marginal	191.16 (180.50, 201.82) MZN	191.14 MZN	160.04 (153.09, 166.99) MZN	159.97 MZN

Ribáuè

	Numeric Income		Proxies for Income	
Sampling	Mean	Median	Mean	Median
Joint	125.77 (112.78, 138.77) MZN	125.95 MZN	118.82 (112.78, 124.87) MZN	118.75 MZN
Marginal	114.37 (108.60, 120.14) MZN	114.5487 MZN	109.71 (105.39, 114.03) MZN	109.73 MZN

Liúpo

	Numeric Income		Proxies for Income	
Sampling	Mean	Median	Mean	Median
Joint	74.86 (65.46, 84.25) MZN	74.66 MZN	62.56 (58.16, 66.96) MZN	62.43 MZN
Marginal	74.49 (68.92, 80.07) MZN	74.44 MZN	62.05 (58.37, 65.74) MZN	62.05 MZN

Table 38: Mean and median maximum willingness to pay for households in the city of Nampula (*top*) and towns of Ribáuè (*middle*) and Liúpo (*bottom*), as estimated from linear models using (*1*) numeric income and (*2*) proxies for income and Monte Carlo sampling based on the (*1*) joint empirical distribution and (*2*) marginal empirical distribution of variables incorporated in the models.

be expected to embrace piped water as delivered through yard taps for the quantity of water that they currently use[240], as they would have insufficient water for daily needs.

By comparison, mean maximum WTP in Ribáuè under the most conservative scenario of 109.71 MZN per month would support household consumption of 109.05 litres per day or, equivalently, 21.94 litres per capita per day, more than five times more than what we get in Liúpo under the same scenario[241]. At the same time, if we look at the most conservative estimate for Nampula, this would correspond to daily consumption of roughly 230 litres per household and 43 litres per capita. In the cases of both Ribáué and Nampula, mean maximum WTP would be sufficient to support households' daily needs.

[240] Recall that the scenario presented to respondents was "... *for the same amount of water that you currently use each month*".

[241] It is important to note that this quantity is actually slightly higher than the geometric mean of reported water consumption in Ribáuè, which is 107.36 litres per day.

The Total Value of Piped Water to All Households in a Community

Based on the mean maximum WTP for households in a community, we can project the total value of piped water to households in a community. We consider this only for Ribáuè, as this is the only community where it is reasonably feasible to infer the total cost of delivery of piped water to each home. However, the approach demonstrated for Ribáuè can be easily extended to each of Nampula and Liúpo.

Let $\overline{WTP}$ denote the mean maximum WTP per month for water to the home in Ribáué, N denote the population size of Ribáuè, n denote the mean number of people per household (so $\frac{N}{n}$ provides an estimate of the number of households in Ribáuè) and P denote the percentage of households that are willing to pay for piped water to the home. Then the total maximum WTP, representing the total value of piped water to the home, for Ribáuè can be estimated by

$$WTP_{Total} = \overline{WTP}\left(\frac{N}{n}\right)P$$

Using the most conservative estimate of mean maximum WTP, an estimated population of 33,931[242], and previously reported household size and stated WTP percentage for Ribáuè, the relevant parameters and resulting total monthly maximum WTP are given by

$$\begin{aligned} \overline{WTP} &= 109.71 \\ N &= 33{,}931 \\ n &= 4.97 \\ P &= 0.6686 \\ WTP_{Total} &= 500{,}786.80 \text{ MZN } (= \$12{,}953.46 \text{ USD}) \end{aligned} \quad (1)$$

This corresponds to a yearly value of 6.01 million (5.77 million, 6.25 million) MZN or $200,314.70 ($192,427.00, $208,202.40) USD[243].

[242] This estimate of town population is based on the population size of 26,328 reported in the 2007 census and district growth projection rates as reported by Instituto Nacional de Estatística [2010a].

[243] This is using the informal in-country exchange rate of $1 USD = 30 MZN that was commonly used in in 2014. Over the course of fieldwork, exchange rates ranged from $1 USD = 30.2512 MZN to $1 USD = 31.8700 MZN with an average of $1 USD = 31.17552 MZN [XE, 2015].

Accounting for population growth

We do not know how valuations of water piped to the yard will change over time for residents of Ribáuè, although we would expect a gradual increase to bring them more in line with what we observe in Nampula[244]. Given that we are not certain of how valuations will change, we will assume that these will remain stagnant. However, we have projections of how the population should change over time. Instituto Nacional de Estatística [2010a] projects a growth rate for the District of Ribáuè of 141.94% over the next 25 years, meaning an average annual growth rate of 5.68% per year for the district. This growth rate would likely be higher in the town of Ribáuè, the district capital, than more rural areas of the district, so we would expect that this estimate of 5.68% would be conservative for the town of Ribáuè over this time. This is a much higher rate of growth than is anticipated for Nampula Province as a whole, which is projected to grow by 62.89% over the next 25 years, meaning an average growth rate of 2.52% per year.

[244] This would suggest that valuations could increase by as much as 46% to reach Nampula's conservative mean maximum WTP estimate of 160.04 MZN per month.

If we assume that growth rates produce proportional growth in revenue and use INE's projections for the next 25 years, then we obtain yearly total WTP for the town of Ribáuè for 2015-2040 as shown in Figure 37. This includes projections based on both the provincial and district growth rates. These would put valuations of WTP up to $484,646.40 ($465,562.70, $503,730.10) USD by 2040 if using the district growth rate and $326,301.3 ($313,452.6, $339,149.9) USD if using the provincial growth rate, and the corresponding total valuations over the period 2015-2040 would be estimated at

$7.96 million ($7.64 million, $8.27 million) USD and $6.82 million ($6.55 million, $7.09 million) USD, respectively.

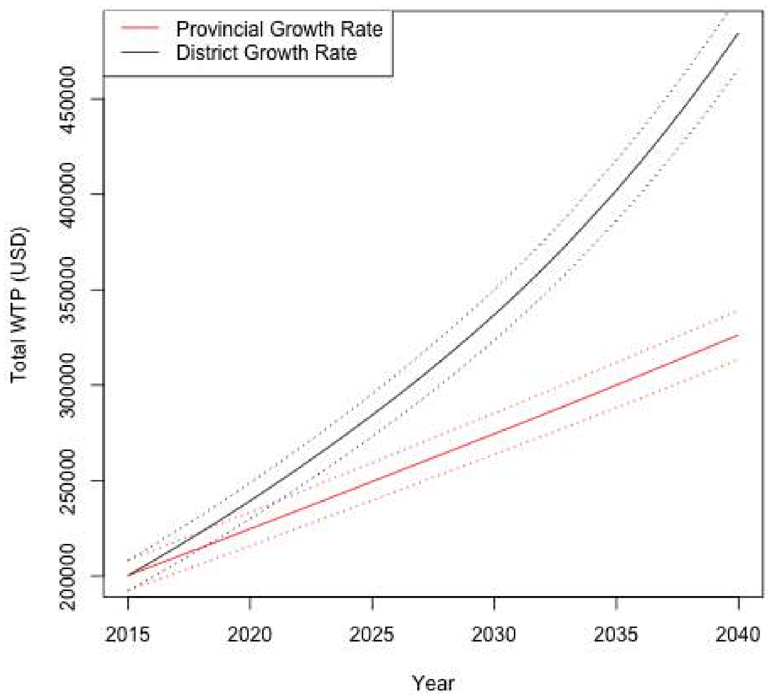


Figure 37: Projected increase in total willingness to pay for piped water to the home for the town of Ribáuè, based on growth in willingness to pay that follows projected growth for the Province of Nampula (*red*) and the District of Ribáuè (*black*). 95% confidence bounds are represented by dashed lines.

Marginal Value of Piped Water to Households

Because the uptake of yard taps will typically mean movement away from other paid water points, the total value of yard taps does not correspond to its marginal, or incremental, value. The marginal return (or "consumer surplus") must take into consideration the current value of water, which we will estimate by reported household expenditure on water. In the case of Ribáuè, we note that there has been a substantial increase in people moving from non-revenue-generating to revenue-generating forms of water supply from 2012 to 2014 with an estimated increase from 39.22% (33.20%, 45.25%) to 63.64% (59.40%, 67.88%). This would suggest that the marginal increase in the value of water brought on by introduction of piped water should be substantial.

For households that pay for water, we use a linear model (based on log-transformed total payment for water) to estimate mean trends similar to what was done when estimating mean maximum WTP. The model fit is presented in Table 39 and shows expected trends with those in Nampula paying the most for water (and those in Liúpo paying the least) and cost increasing with more advanced water point usage (with those using household connections as their primary water points reporting the highest payment for water).

	Estimate	Std. Error	t-value	Pr(> $\|t\|$)
(Intercept)	6.0109	0.3888	15.46	0.0000
Female Respondent	0.0402	0.1319	0.30	0.7605
Age of Respondent	0.0101	0.0035	2.93	0.0035***
Household size	-0.0154	0.0175	-0.88	0.3783
Town/City: (Reference: Nampula)				
Liúpo	-1.9447	0.1541	-12.62	0.0000***
Ribáuè	-1.0511	0.1143	-9.20	0.0000***
Primary water point: (Reference: Household connection)				
Yard tap	-0.5669	0.2342	-2.42	0.0158**
Standpipe	-0.8991	0.2844	-3.16	0.0016***
Borehole	-1.8663	0.2855	-6.54	0.0000***
Unprotected well	-1.5802	0.2884	-5.48	0.0000***
Protected spring	-1.0871	0.7054	-1.54	0.1238
River, stream, lake	-0.6704	0.4139	-1.62	0.1058
Neighbour's tap	-0.7748	0.2816	-2.75	0.0061***
Hours operational	0.0048	0.0055	0.87	0.3840
Time to collect water	0.0149	0.0401	0.37	0.7099
Good water quality	-0.1043	0.0857	-1.22	0.2240
Education level of head of household: (Reference: None)				
Primary of 1^{st} degree	-0.1367	0.2004	-0.68	0.4956
Primary of 2^{nd} degree	-0.0803	0.2116	-0.38	0.7043
Secondary of 1^{st} degree	0.0901	0.2032	0.44	0.6578
Secondary of 2^{nd} degree	0.2249	0.2003	1.12	0.2620
Higher level	0.5159	0.2715	1.90	0.0578*
Do not know	0.3832	0.2569	1.49	0.1362
Occupation of head of household: (Reference: Managers)				
Professionals	-0.1175	0.1809	-0.65	0.5160
Technicians	-0.0558	0.1800	-0.31	0.7566
Clerical support	-0.8227	0.3236	-2.54	0.0113**
Services, sales	-0.2562	0.1900	-1.35	0.1781
Agriculture, forestry, fisheries	-0.2007	0.1841	-1.09	0.2762
Craft and related trade	-0.3706	0.1868	-1.98	0.0477**
Plant/machine operators	0.2900	0.2926	0.99	0.3220
Elementary occupations	0.0742	0.2062	0.36	0.7191
Armed forces	-0.7392	0.4277	-1.73	0.0844*
Unemployed	-0.2884	0.2026	-1.42	0.1551
Student	-0.3134	0.2715	-1.15	0.2489
Homemaker	-0.4411	0.2625	-1.68	0.0934*
Pension/benefits	-0.5503	0.3281	-1.68	0.0940
Other	-0.1010	0.3036	-0.33	0.7395
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table 39: Linear regression of log-transformed total payment for water on age and sex of the respondent, household size, town/city, primary water point, education level and occupation of the head of household, and water-point specific variables.

Again applying Monte Carlo methods to estimate mean monthly payments for water from this model, we obtain estimates for sampling from both empirical marginal and joint distributions of variables, and the highest estimate is produced by sampling from the empirical joint distribution (*i.e.* by bootstrapping). The estimated geometric mean of 43.08 (41.03, 45.13) MZN (or $1.44 ($1.37, $1.50) USD) per household for Ribáuè produced from fitted values for this liberal model is comparable to the estimated geometric mean of 42.99 MZN based strictly on water cost data for Ribáuè. An estimate of total monthly cost based on this mean water expenditure and accounting for 36.46% of the population of Ribáuè reporting not paying for water produces an average town-level monthly cost of 187,065.40 MZN, or $6,235.51 USD. The corresponding yearly value is 2.24 million MZN, or $74,826.14 USD. Discounting the total value of the piped system (in terms of delivery of water to the home) by this amount produces a marginal increase of $125,488.6 USD per year.Accounting for growth trends for the District of Ribáuè and Nampula Province, we obtain the estimated yearly marginal values of piped water to the home for the town of Ribáuè for 2015-2040 shown in Figure 38, and these produce total marginal valuations of $4.99 million (using the district growth rate) and $4.27 million (using the provincial growth rate) over that period of time.

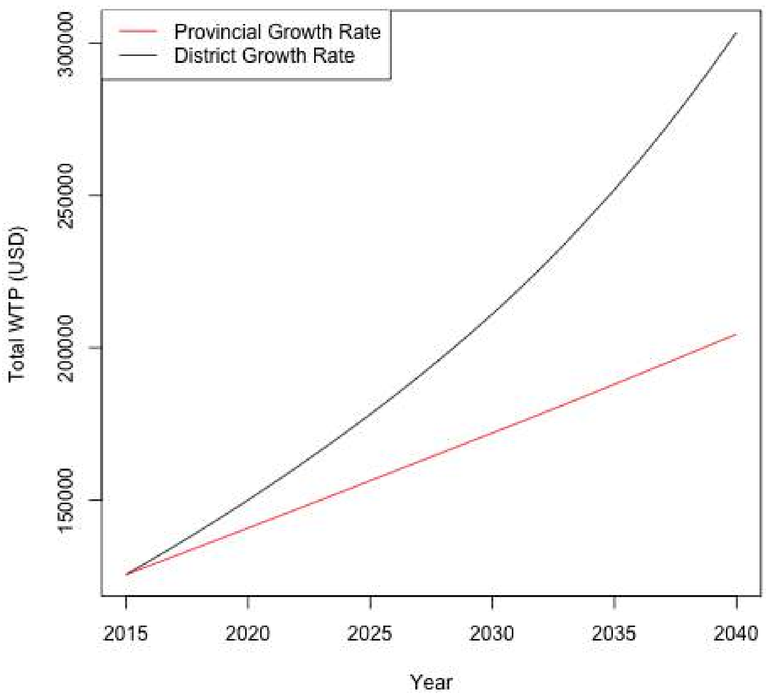


Figure 38: Estimated marginal value (or consumer surplus) of piped water to the home for the town of Ribáuè, based on growth in willingness to pay that follows projected growth for the Province of Nampula (*red*) and the District of Ribáuè (*black*).

It is important to note that these valuations are exclusive to yard taps and ignore the value of water kiosks or connections to local businesses and public institutions. Data supplied by STCC for the period January–July 2015 showed 63% of revenue from the piped system to come from yard taps and only 2.5% to come from water kiosks. This reinforces that the real value of piped water to households in Ribáuè comes in the form of yard taps, and, even though water kiosks or standpipes may have greater value in other parts of the town, they appear to have minimal value relative to yard taps.

Over the same period, however, businesses and public institutions added significant value to the system, constituting 34.5% of revenue. How this stream of revenue will fluctuate over time is not clear, though, as we would not necessarily expect the growth of new businesses or uptake of piped water to businesses to follow population trends. Consequently, we do not provide estimates for the value added to the system through water kiosks and direct connections to businesses and public institutions but instead acknowledge that these would contribute significant additional value to the piped system.

The Cost of Supplying Piped Water to Households

If the value of piped water to households is not sufficient to support the initial cost of the infrastructure, ongoing O&M, network expansion, and significant infrastructure repair or replacement, then injection of additional funds must come from the government, foreign aid, or other sources, impacting on water supply sustainability. Consequently, understanding the cost of water supply is vital to gauging its sustainability based on community demand and WTP and revealing whether additional financing may be needed.

Estimating the Cost of Piped Water to the Home

Based on total household WTP for water piped to the home for Ribáuè, as shown in (1), annual per capita WTP for households that have stated WTP is \$8.83 (\$8.48, \$9.18) USD, while per capita WTP (including those who were not willing to pay) is estimated to be \$5.90 (\$5.67, \$6.14) USD. Following the WASHCost [2012a] project approach of estimating unit costs[245], Hutton [2012] provides estimates of annual unit costs[246] for piped water to the home for a number of countries, and estimates for both rural and urban systems in Mozambique are presented in Table 40[247]. The costs reported by Hutton [2012] are based on estimates provided by or extrapolated from WASHCost [2012a], Robinson [2009], Trémolet et al. [2010], Hutton et al. [2014], and Hutton et al. [2015][248], and these costs reflect annual per capita capital costs and recurrent (or O&M) costs, assuming a 20 year lifespan for the piped system[249].

The estimated total annual cost suggests a situation where household WTP for Ribáuè would be expected to just be sufficient to support the cost of sustainably supplying piped water to the home for a typical rural system[250] and quite comfortably for an urban system if only those who stated WTP were considered and we considered adjustment based on the GDP deflator. If adjusting by changes in the Consumer Price Index (CPI), then additional funding would be required. In order to supply to everyone, however, supplementary financing would be required to ensure sustainability, regardless of which adjustment method is used or whether the system in Ribáuè is more in line with typical rural systems or urban systems. Of course, actual costs vary depending on the specifics of the system implemented, so, for example, the gravity-fed system introduced in Ribáuè would be anticipated to have lower O&M costs

245 WASHCost. *Providing a basic level of water and sanitation services that last: Cost benchmarks*. IRC International Water and Sanitation Centre, The Hague, 2012a

246 A "unit" may represent a person, a household, or even a water point, so, for example, a single household connection. This must be clearly defined, although throughout we will assume that a unit refers to a person, so it represents per capita cost.

247 G. Hutton. *Global Costs and Benefits of Drinking-Water Supply and Sanitation Interventions to Reach the MDG Target and Universal Coverage*. World Health Organization, Geneva, 2012

248 A. Robinson. *Global Expenditure Review: Water Supply and Environmental Sanitation*. Plan Limited, Woking, 2009; S. Trémolet, P. Koslky, and E. Perez. *Financing On-Site Sanitation for the Poor: A Global Six Country Comparative Review and Analysis*. World Bank, Water and Sanitation Programme, Washington, D.C., 2010; G. Hutton, U.-P. Rodriguez, A. Winara, V.A. Nguyen, P. Kov, L. Chuan, I. Blackett, and A. Weitz. Economic efficiency of sanitation interventions in Southeast Asia. *Journal of Water, Sanitation and Hygiene for Development*, 4(1):23–26, 2014; and G. Hutton, U.-P. Rodriguez, A. Winara, V.A. Nguyen, P. Kov, L. Chuan, I. Blackett, and A. Weitz. *Economic Assessment of Sanitation Interventions in Southeast Asia: A Six-Country Study Conducted in Cambodia, Indonesia, Lao PDR, the Philippines, Vietnam and Yunnan Province (China) under the Economics of Sanitation Initiative*. World Bank, Washington, D.C., 2015

249 Hutton [2012] justifies attributing such a short lifespan to piped infrastructure by noting that capital maintenance is rarely appropriately carried out in developing countries, leading to shorter lifespans for infrastructure. WASHCost [2012b] largely attributes this to communities having limited understanding of or budgeting for recurrent costs.

250 Rural systems are typically characterised by being small or single-town standalone systems.

than a similar network relying on pumps. Consequently, accurate accounting practices to reflect the costs of the infrastructure, operating costs, software, etc., are critical in assessing the economic sustainability of a particular system after it has been introduced.

	Capital Cost	Recurrent Cost	Total	GDP Deflator Adjusted Total	CPI Adjusted Total
Rural	$5.60 USD	$2.20 USD	$7.80 USD	$8.78 USD	$9.44 USD
Urban	$2.40 USD	$3.80 USD	$6.20 USD	$6.98 USD	$7.50 USD

Table 40: Estimated annual capital costs, recurrent costs, and total costs for water piped to the home for rural and urban areas in Mozambique, as reported by Hutton [2012]. Values reported by Hutton are for 2010, and GDP deflated totals and CPI adjusted totals reflect changes in real currency value in Mozambique from 2010 to 2014.

To that end, WASHCost, an initiative of the IRC International Water and Sanitation Centre, included work in Mozambique until 2012, engaging with both the Mozambican National Directorate of Water (DNA) and Water and Sanitation Group (GAS)[251] to improve accounting practices for costs in the WASH sector to increase the level of sustainability of WASH projects. Much of the work of WASHCost Mozambique focused on rural water supply in the form of boreholes, attempting to produce a comprehensive database of projects carried out in that sector, including contract data that can be used to inform costs[252]. This provided some clarity in terms of capital expenditure (CapEx) and direct support costs[253] for projects and what is required to produce a basic level of service or better[254]. However, there still are significant gaps in terms of data for O&M costs. To the best of our knowledge, WASHCost Mozambique did not include an examination of urban water supply or piped systems, although this has been considered in other countries as part of WASHCost.

[251] GAS includes a number of stakeholders in the WASH sector in Mozambique, including CRA, DNA, AIAS, FIPAG, UNICEF, WaterAid, IRC International Water and Sanitation Centre, World Bank, DFID, SNV, Helvetas, Care International, Oxfam, World Vision, and the Red Cross.

[252] WASHCost Mozambique. Monitoring WASH contracts in Mozambique: Triggering transparency in the WASH sector, 2012. URL `http://www.ircwash.org/sites/default/files/Naene-2012-Monitoring.pdf`

[253] *i.e.* certain capacity building and community mobilisation costs.

[254] Fonseca et al. [2011] define a "basic" level of service to be water supply that can reliably provide 20 L of water per capita per day at an acceptable quality (based on both user perception and testing) and within a 10-30 minute travel time of the home. The piped system provided to Ribáuè would be characterised as providing water at a "high" service level.

The Life-Cycle Costs Approach

To promote rigorous methods of assessing the sustainability of WASH interventions, WASHCost developed the life-cycle costs approach (LCCA) to water supply, which examines the cost of delivering water supply in perpetuity. This includes not only the initial cost of the infrastructure but also O&M costs, expansion costs, major infrastructure repair or replacement costs, and software costs (*e.g.* planning, capacity building, monitoring).

Fonseca et al. [2010] explain this in greater detail, breaking down costs into six components and the resulting total cost, which are described in Box 10[255]. Understanding the relative weightings of each of these can help an investor better understand the sustainability of an existing system or how budgeting or revised cost structures[256] can improve the sustainability of a system. At the same time, it may reveal how a system can be effectively extended to those of lower SES, thereby improving social inclusivity.

[255] C. Fonseca, R. Franceys, C. Batchelor, P. McIntyre, A. Klutse, K. Komives, P. Moriarty, A. Naafs, K. Nyarko, C. Pezon, A. Potter, R. Reddy, and M. Snehalatha. *Life-Cycle Costs Approach: Glossary and cost components*. IRC International Water and Sanitation Centre, The Hague, 2010

[256] *e.g.* different tariff structures, organisational changes.

Capital Expenditure (CapEx):
Investment in both the hardware and software needed for the introduction or expansion of a particular form of water supply. This includes the infrastructure, support equipment (vehicles, computers, offices), consultation with stakeholders, and capacity building needed for those involved with the delivery or regulation of water supply.

Operating Expenditure (OpEx):
Ongoing costs for operating water supply, including labour, energy, and water treatment costs as well as minor repair. OpEx is commonly assumed to range from 5% to 20% of CapEx.

Capital Maintenance Expenditure (CapManEx):
Costs incurred for major repairs, rehabilitation, or replacement of infrastructure. For an appropriately managed system, many CapManEx costs will be incurred not in response to failures but rather in anticipation of hardware reaching the end of its useful life.

Cost of Capital (CoC):
The cost of obtaining the funds needed to introduce a water supply system, usually taking the form of interest payments. For commercial systems, this may reflect the required rate of return for the investor.

Expenditure on direct support (ExpDS):
Costs largely consisting of consultation with local stakeholders and capacity building for regulatory bodies or system operators.

Expenditure on Indirect Support (ExpIDS):
Costs largely consisting of consulting with national bodies, developing institutional arrangements or regulatory frameworks, and general macro-level planning that may not be directly attributable to any one water supply system.

Total Expenditure (TotEx):
The total cost, as determined using fixed asset accounting.

Box 10: Expenditure or cost components of the life-cycle costs approach.

Fonseca et al. [2011] present what may be considered as typical relative weightings of recurrent expenditures (which excludes CapEx) for both urban and rural settings, presented in Figure 39. However, they note that the breakdowns proposed for rural settings are speculative, as there is not sufficient good quality data to provide reliable estimates for rural or peri-urban settings[257], and the relative contributions to recurrent costs may change depending on the source of funding. For example, in the case of financing coming through foreign aid (as was largely the case for the system provided to Ribáuè through NAMWASH), there would be no cost of capital (CoC). Additionally, provision of infrastructure in a rural or peri-urban setting that may be more in line with typical urban water supply (such as a piped system) may have different associated relative cost breakdowns, so operating expenditure (OpEx) may be higher while expenditure on support (both direct and indirect) may be less. Further, different cost structures may be able to achieve sustainable delivery of water, but they may do so at differing levels of service.

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

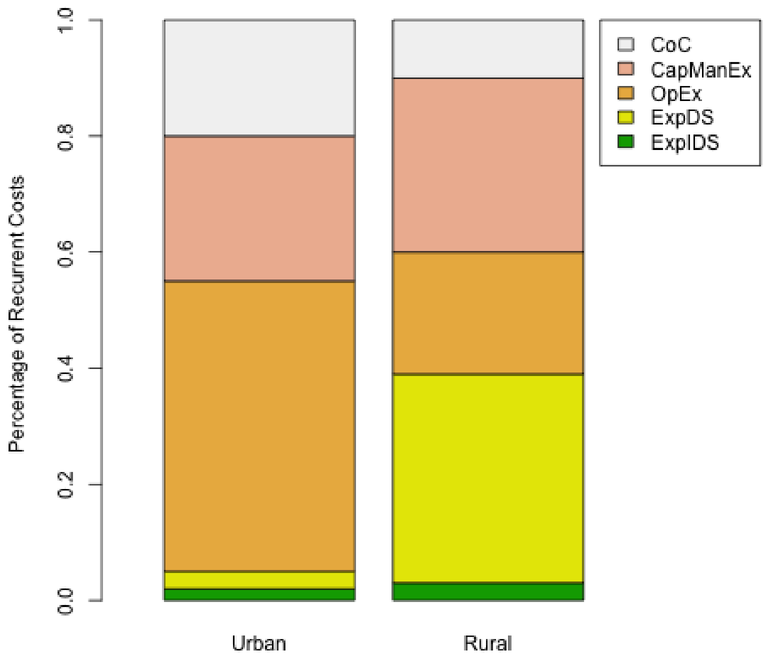


Figure 39: Estimated breakdown of recurrent costs between cost of capital, capital maintenance expenditure, operating expenditure, direct support costs, and indirect support costs for both urban and rural water systems. Estimates for urban systems are based on totals presented by Shugart and Alexander [2009].

The piped system provided to Ribáuè would be characterised by Fonseca et al. [2011] as providing water at a "high" service level, meaning that it is able to support large per capita consumption[258] at water points in close proximity to the home[259] while meeting strict water quality standards and being very reliable. Fonseca et al. [2011] do not provide clear prescriptives of what breakdown of

[258] Specifically, at least 60 L per capita per day.

[259] Specifically, less than 10 minutes required for water collection.

expenditure would generally be required in each cost category, as there simply is insufficient data in the developing world context (and none in the Mozambican context). However, if in-country examples exist of water systems that are running at this level and in a sustainable manner, that can help set benchmarks for each of these individual costs. That can also inform the total amount that should be budgeted for capital costs (CapEx) and recurrent costs (CapManEx, OpEx, CoC, ExpDS, and ExpIDS). If the expected life of a system is known and the timing of costs is well understood, then this can be used to estimate the net present value (NPV) of both capital and recurrent costs using an appropriate discount rate and adjusting for inflation (to reflect the timing with which costs are incurred). These, in turn, can then be used to inform the expected annual cost (according to present currency valuations) and unit costs needed for sustainable delivery of water according to a particular form of delivery and level of service, producing estimates such as those considered by Hutton [2012] and presented in Table 40.

In the case of the piped system supplied to Ribáuè as part of NAMWASH, UNICEF Mozambique reported the cost of the water system to be $1.58 million USD with $1.376 million USD going toward construction costs and $204,000 USD going toward supervision costs. Additionally, $140,000 USD was spent on technical plans for the system, resulting in a total cost (including both hardware and software costs) of $1.72 million USD[260]. All of these costs would be classified as CapEx.

[260] UNICEF Mozambique. *NAMWASH Programme Final Report, January 2012 – June 2014*. UNICEF Mozambique, Maputo, July 2014

Capacity building was also a major component of NAMWASH with a reported total expenditure of just over $790,000 USD. This capacity building was largely concentrated at the local or provincial levels and would have comprised ExpDS. However, the exact amount as it applies to the delivery of piped water to Ribáuè would be difficult to determine, as capacity development activities spanned multiple towns and were not necessarily singularly restricted to either water, sanitation, or hygiene.

The provision of the piped system through funding from the Government of Australia, UNICEF, and the Government of Mozambique would suggest that there is no CoC, although this will likely change if further expansion of the piped system is carried out, in which case CoC will largely depend on whether financing comes from the government or the private sector. As noted by Naafs and Rousseau [2011], if financing comes from the government through government loans, then the interest rate is typically low but for a period of 25-50 years[261]. Private loans will have a much higher interest rate. Alternatively, if a private investor does not require a loan, then CoC may be assumed to be the investor's required rate of return.

[261] A. Naafs and K. Rousseau. *Finance and Cost of Capital: An additional cost made visible*. IRC International Water and Sanitation Centre, The Hague, 2011. URL http://www.ircwash.org/sites/default/files/washcost_moc_f01_cost_of_capital-revealing_a_hidden_cost_0.pdf

Contractual agreements spell out the responsibilities of AIAS and the private operator, STCC. Responsibilities for STCC include minor expansion of the primary network[262], more substantial ex-

[262] 500 meters.

pansion to the secondary network[263], and installation of yard taps, all of which fall under CapEx. Additionally, STCC assumes O&M costs, which fall under OpEx. AIAS is responsible for rehabilitation of standpipes as well as major repairs and expansion, suggesting that the bulk of costs incurred by AIAS should reflect CapManEx.

[263] 1,000 meters.

Under its contractual agreement, STCC is to pay AIAS 2% of water revenue, so this would need to provide sufficient revenue to cover CapManEx in the absence of external supplementary funding. Consider the relative percentages of spending by category for recurrent costs shown in Figure 39. As mentioned previously, the percentages provided for rural water supply are speculative and may reflect a system consisting primarily of boreholes or standpipes, but the breakdowns for the urban scenario should represent spending for a piped system. If the system for Ribáuè lies between these two scenarios, then CapManEx would typically consist of 25-30% of recurrent costs. If that is the case, the ratio of revenue to cost for the system would have to be at least 13-to-1 (after adjusting for any CapEx for a given year) for this percentage allocation to AIAS to cover annual CapManEx. Now, the fact that the system presently is strictly gravity-fed and does not use any pumps means that CapManEx is likely to be significantly lower than piped systems considered by Fonseca et al. [2011] and Shugart and Alexander [2009][264], but a 2% allocation of revenue would still appear to be low. Additionally, when the system expands and requires pumps to maintain water pressure, CapManEx will also go up, and the contractual agreement would need to specify increased payment to AIAS if the system is to be self-sufficient.

[264] C. Fonseca, R. Franceys, C. Batchelor, P. McIntyre, A. Klutse, K. Komives, P. Moriarty, A. Naafs, K. Nyarko, C. Pezon, A. Potter, R. Reddy, and M. Snehalatha. *Life-cycle costs approach: Costing sustainable services*. Briefing Note 1a, IRC International Water and Sanitation Centre, The Hague, 2011; and C. Shugart and I. Alexander. *Tariff Setting Guidelines: A Reduced Discretion Approach for Regulators of Water and Sanitation Services*. World Bank, Washington, D.C., 2009

While there are largely clear delineations that should make tracking of CapEx, OpEx, CoC, ExpDS, and CapManEx fairly straightforward to measure, there are some complications. So far, contractual agreements have not been adhered to strictly. For instance, STCC has taken on the responsibility of rehabilitating two standpipes at the request of the local council even though this is the obligation of AIAS. At the same time, the local council has covered costs incurred so far in expanding the network even though this is the responsibility of the operator.

Even though these shifts in responsibility may have implications for the level of profitability for the private operator, they should not impact on the recording of costs against correct categories, provided that all parties maintain proper books, so costs corresponding to individual categories should theoretically still be feasible. We note that proper accounting practices are not being followed, however, significantly impacting this. This is particularly true in the case of STCC, which appears to have only begun keeping books in January 2015. Although a template was provided to assist with reporting both accounting and performance data, the manner in which cost and revenue data are included appears to be ad hoc with the operator unable to explain what costs or revenues are included against certain line items[265]. This means

[265] It would be expected that AIAS would recognise these issues, given that it is meant to collect this information and perform financial audits.

that costs incurred for installations of yard taps (which would go against CapEx) can only be partially identified in the cost data. Additionally, an "other" category was liberally used, sometimes comprising 40% of reported monthly costs, yet the specific costs that contributed to that could not be explained. More problematic, it became clear that one set of books was being used to reflect the finances of two businesses—the operation of the piped system and a second business that sells pipes, fixtures, and a variety of other hardware[266]. All of this made it virtually impossible to estimate OpEx and CapEx as it relates to STCC's costs incurred for the piped system.

[266] As of last correspondence, STCC reported that they would begin to keep separate books for the two businesses.

These highlight an important problem and area for future emphasis. In explaining the failure to adequately budget for maintenance costs for many rural and peri-urban systems, Fonseca et al. [2011] observe that,

> *In developing countries, regulatory accounting in the water sector, if used at all, applies only to utilities, and therefore mostly to urban areas. However, the solution to the maintenance problems in the sector will not improve unless the "asset maintenance" mind-set expands to the organisations responsible for funding, planning and managing rural and peri-urban WASH services.*

In other words, while capacity building in terms of the technical skills for maintaining a system has been a high priority for rural and peri-urban water supply, this capacity building needs to be expanded to include proper accounting practices and a clear understanding of costs, as as this can be just as important to the sustainability of a system as having the skills to maintain the system. Proper accounting can also help highlight areas of inefficiency, and Estache and Kouassi [2002] found that roughly 2/3 of 21 sampled water utilities in Africa could reduce OpEx simply by exploiting areas for efficiency[267].

[267] A. Estache and E. Kouassi. *Sector Organization, Governance, and the Inefficiency of African Water Utilities*. World Bank, Washington, D.C., 2002

Approximating the Total Cost of Delivering Piped Water to Households in Ribáuè

Even if proper accounting practices were followed, the limited data available at the time of this study[268] would make any assessment of the level of sustainability of the piped system in Ribáuè premature. Consequently, when considering cost data for the piped system for Ribáuè, we instead use the unit costs presented in Table 40 to estimate the total cost of sustainably supplying piped water to households in Ribáuè. These produce the totals shown under the "Unadjusted" totals in Table 41. If we recall that annual total maximum WTP for the town is estimated to be \$200,314.70 (\$192,427.00, \$208,202.40) USD, then, as noted previously when comparing per capita WTP with total unit costs, WTP for those who state WTP is sufficient to cover costs for delivery to only those households except when using CPI-adjusted annual cost estimates[269]. If considering all households, then WTP cannot support costs, although it is worth

[268] At the time of analysis, only six months of data were available, and clear issues with misreporting reduced this to at most five usable months.

[269] World Health Organization [2003] suggest that the GDP deflator is the most appropriate adjustment for costs related to the health sector, but it is not clear whether that would be true for the cost of construction and infrastructure costs, as reflected here in costs for a piped water system. Consequently, we present adjustments using both GDP deflator and CPI.

noting that this requires that we assume that households who did not state WTP will in fact have a household connection yet pay nothing and still incur the same recurrent costs to the operator, an assumption that would be highly improbable.

		Households Stating WTP		All Households	
		GDP Deflator Adjusted Total	CPI Adjusted Total	GDP Deflator Adjusted Total	CPI Adjusted Total
Unadjusted	Rural	$199,143 USD	$214,113 USD	$297,851 USD	$320,240 USD
	Urban	$158,293 USD	$170,192 USD	$236,753 USD	$254,550 USD
CapEx Adjusted	Rural	$113,143 USD	$128,113 USD	$211,851 USD	$234,240 USD
	Urban	$72,293 USD	$84,192 USD	$150,753 USD	$168,550 USD

Table 41: Estimated total annual cost for sustainably piping water to the home for the town of Ribáuè, as based on Table 40. This cost is presented under cost assumptions in line with both rural and urban systems, supplying water to all households and only those who state willingness to pay, and using both GDP deflated and CPI adjusted estimated totals. Additionally, we present both unadjusted totals and totals that adjust for UNICEF's reported capital expenditure of $1.72 million USD.

The unadjusted totals fail to account for the CapEx of $1.72 million USD reported by UNICEF. If we take this into consideration, assuming a 20 year lifespan for the infrastructure in line with Fonseca et al. [2011] and Hutton [2012], these produce a reduction of $86,000 USD in annual costs, producing the "CapEx Adjusted" totals shown in Table 41. These suggest that, if spent efficiently, the expenditure that went towards delivering this system would reduce the required annual expenditure on behalf of households to such a level that, if considering delivery only to households that are WTP, the difference between revenue and cost would be substantial, potentially reaching $70,000 USD annually. This would suggest that, if run efficiently, there is every indication that the piped system should be financially sustainable. This is consistent with WASHCost's Share tool, which similarly concludes that this level of CapEx and WTP should be sufficient to sustainably support a high level of service[270,271].

[270] WASHCost. Life-cycle costing tools, 2015. URL http://washcost.ircwash.org/en/calculators

[271] We note that, as of the time of this report, the formulae underlying WASHCost Share have not been publicly released.

Estimating the Benefits of Piped Water to Households

With the introduction of piped water to the household comes both significant health improvements and economic benefits. The health benefits, primarily in the way of reduced diarrhoea morbidity and mortality, have educational implications in the way of less time missed from school and greater cognitive functioning. Additionally, they have significant economic implications, as they help avoid expenditure in the health sector as well as allow for more years of income earning (due to increased life expectancy), so we first examine the health implications of piped water to the home before estimating the economic impacts.

The Health Impacts of Piped Water to Households

Although many households may be introduced to piped water first in the form of standpipes (or, in the case of Ribáuè, water kiosks), there is little evidence to suggest that this leads to significant health improvements. 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[272], and 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. Simply by moving the water point within close proximity to the house (and particularly the yard), however, significant health benefits occur with a significant reduction in diarrhoea risk[273].

[272] A.J. Pickering and J. Davis. Freshwater availability and water fetching distance affect child health in sub-Saharan Africa. *Environmental Science and Technology*, 46:2391–2397, 2012

[273] S. Cairncross and V. Valdmanis. Water supply, sanitation, and hygiene promotion. In A. Mills, A.R. Measham, P. Musgrove, J.G. Breman, D.T. Jamison, D.B. Evans, P. Jha, M. Claeson, and G. Alleyne, editors, *Disease Control Priorities in Developing Countries*, pages 771–792. The World Bank, Washington, D.C., 2nd edition, 2006

Health consequences of collecting water

The primay explanation for this improvement in health is the relationship between water consumption and time spent collecting water. Pickering and Davis [2012] report that approximately 44% of the global population (mostly women and children) must travel to fetch water for drinking and domestic water, causing a massive physical and time burden. Geere et al. [2007] provide an examination of the physical toll of water collection, noting that women and children (the two groups most responsible for water collection) "have reduced injury tolerance for physical loading through the cervical spine compared to men and in rural areas may be particularly vulnerable to physical injury due to high levels of poverty, poor health and chronic disease"[274]. They found that water carrying, particularly through the common practice of head loading, was significantly related to spinal problems with nearly 70% of primary water carriers they surveyed in South African communities reporting some form of spinal pain and roughly 40% reporting some form of back pain. They postulate that, similar to issues observed for porters by Joosab et al. [1994], Jumah and Nyame [1994], Jäger et al. [1997], and Badve et al. [2010][275], water carrying can lead to significant musculoskeletal disorders.

The time burden of collecting water has indirect implications for health, as long travel times are associated with decreased water consumption[276]. Cairncross and Valdmanis [2006] found that, as water consumption increases, much of the additional water being consumed goes toward hygiene purposes, and Moe and Rheingans [2006] found 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)[277]. In general, the closer and more convenient the water source is to the home, the more likely that proper sanitation and hygiene will be the norm. In particular, 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 diarrhoea prevalence, improved nutritional status[278], and a 11% relative reduction in mortality for children under the age of five, a benefit comparable to water disinfection and hygiene promotion programmes.

Piped water to the home and diarrhoeal diseases

As shown previously in Table 17, we did not observe a significant reduction in incidence of diarrhoea from October 2012 (pre-NAMWASH) to November 2014 (post-NAMWASH), and this could be due to a number of factors, the most prominent being the significant variability that occurs in diarrhoea due to weather. If we consider diarrhea prevalence, a comparison of health clinic data from June-October 2013 with June-October 2014 also failed to show any significant difference. In part, this could be due to the recency of completion of NAMWASH, so uptake of yard taps was still low at that point, and clear health benefits had yet to eventuate. Additionally, these time periods do not include typical wet season months where impacts on diarrhoeal diseases are likely to be more pronounced.

Of course, it is also possible that piped water will have limited or no impact, as other factors can potentially jeopardise the anticipated health benefits. For instance, research by Jalan and Ravallion [2003] in India found that, while there are significant reductions in both the prevalence and duration of diarrhoea for young children as a result of piped water to the home, health benefits were not evenly distributed with those households that are poorer or

[274] J.-A.L. Geere, P.R. Hunter, and P. Jagals. Domestic water carrying and its implications for health: A review and mixed methods pilot study in Limpopo Province, South Africa. *Environmental Health: A Global Access Science Source*, 9(52), 2007

[275] M. Joosab, M Torode, and Rao P.V. Preliminary findings on the effect of load carrying to the structural integrity of the cervical spine. *Surgical and Radiologic Anatomy*, 16:393–398, 1994; K.B. Jumah and P.K. Nyame. Relationship between load carrying on the head and cervical spondylosis in Ghanaians. *West African Journal of Medicine*, 13:181–182, 1994; H.J. Jäger, L. Gordon-Harris, U.M. Mehring, G.F. Goetz, and K.D. Mathias. Degenerative change in the cervical spine and load-carrying on the head. *Skeletal Radiology*, 26:475–481, 1997; and S.A. Badve, S. Bhojraj, A. Nene, A. Raut, and R. Ramakanthan. Occipito-atlanto-axial osteoarthritis: A cross sectional clinico-radiological prevalence study in high risk and general population. *Spine*, 35:434–438, 2010

[276] G.F. White, D.J. Bradley, and A.U. White. *Drawers of Water: Domestic Water Use in East Africa*. University of Chicago Press, Chicago, 1972; R. Feachem, E. Burns, S. Cairncross, A. Cronin, P. Cross, D. Curtis, M.K. Khan, D. Lamb, and H. Southall. *Water, Health and Development: An Interdisciplinary Evaluation*. Tri-Med Books, London, 1978; J. Thompson, I.T. Porras, J.K. Tumwine, M.R. Mujwahuzi, M. Katui-Katua, N. Johnstone, and L. Wood. *Drawers of Water: 30 Years of Change in Domestic Water Use and Environmental Health*. International Institute for Environment and Development, London, 2002; X. Wang and P.R. Hunter. 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, 2010; and S. Subaiya and S. Cairncross. 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, 2011

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

[278] Keusch et al. [2006] and Montgomery and Elimelech [2007] also note that diarrhoeal diseases have implications for nutrition, and they further mention impacts on cognitive function.

have less-educated mothers seeing only minimal health benefits [279]. More recent research by Lechtenfeld [2012] in Yemen actually found an *increase* in risk of diarrhoea for children associated with access to piped water, but much of this increased risk was attributed to reduced water quality in the system from broken pipes and water supply interruptions and in unhygienic storage receptacles at the home[280]. Although water contamination in storage containers is always a possibility[281], issues with water contamination being introduced through broken pipes and intermittent water supply do not appear to be an issue for Ribáuè in the short term as suggested by the newness of the infrastructure, water quality tests carried out by STCC, and consistent supply of water for 24 hours per day, 7 days per week.

Despite this lack of evidence of noticeable health effects in Ribáuè in terms of diarrhoeal diseases in the immediate aftermath of NAMWASH, the evidence provided by most studies would suggest that quite significant effects can be anticipated in the long term. Cairncross and Valdmanis [2006] suggest that some of the most rigorous examinations of the impact of piped water to the home on diarrhoeal diseases are those carried out by Esrey and Habicht [1985] and Esrey et al. [1991], who provide overviews of twelve studies investigating the effects of piped water to the home. They report a median reduction of 49% in the incidence of diarrhoeal diseases with the two most comprehensive studies considered reporting an average reduction of 63%[282]. Accompanying this reduction in incidence was reduced severity in symptoms. Separate research by Bukenya and Nwokolo [1991] also found a 56% reduction in incidence when moving from a public standpipe to a tap in the home[283]. These would suggest that it would not be unreasonable to expect a 50% reduction in diarrhoeal diseases for the town of Ribáuè.

Estimating the expected reduction in diarrhoea risk for Ribáuè

Other estimates of reductions in diarrhoea risk are presented by Prüss et al. [2002] and Waddington et al. [2009], who consider reductions in a full WSS setting[284]. As improvements in water supply can be confounded by a household's sanitation situation, their estimates adjust for a household's sanitation situation. They also consider whether households practice POU treatment of water. These estimates are based on six general scenarios (with further breakdowns of two of these scenarios) proposed by Prüss et al. [2002] for classifying WSS based on increasing level of risk of diarrhoeal diseases. These scenarios can be used to characterise the WSS situation for a location and are presented in Box 11. The scope of scenarios considered ranges from an ideal scenario where there is no diarrhoea morbidity or mortality due to inadequate WASH to a scenario where households do not have access to improved water or improved sanitation and, consequently, are at highest risk.

[279] J. Jalan and M. Ravallion. Does piped water reduce diarrhea for children in rural india? *Journal of Econometrics*, 112(1):153–173, 2003

[280] T. Lechtenfeld. *Why does piped water not reduce diarrhea for children? Evidence from urban Yemen*. Courant Research Centre Discussion Papers, University of Göttingen, Germany, 2012

[281] See Admiraal and Doepel [2014] for a clear example of this in the case of NAMWASH communities, where a reduction in water quality from the water point to the home was noted, likely attributable to storage and cleaning practices.

[282] S.A. Esrey and J.-P. Habicht. *The Impact of Improved Water Supplies and Excreta Disposal Facilities on Diarrheal Morbidity, Growth, and Mortality among Children*. Cornell International Nutrition Monograph Series 15, Cornell University, New York, 1985; and S.A. Esrey, J.B. Potash, L. Roberts, and C. Shiff. Effects of improved water supply and sanitation on ascariasis, diarrhea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bulletin of the World Health Organization*, 69(5):609–621, 1991

[283] G. B. Bukenya and N. Nwokolo. Compound hygiene, presence of standpipe, and risk of childhood diarrhea in an urban settlement in Papua New Guinea. *International Journal of Epidemiology*, 20(2):534–539, 1991

[284] A. Prüss, D. Kay, L. Fewtrell, and J. Bartram. Estimating the global burden of disease from water, sanitation, and hygiene at the global level. *Environmental Health Perspectives*, 110 (5):537–542, 2002; and H. Waddington, B. Snilstveit, H. White, and L. Fewtrell. *Water, sanitation and hygiene interventions to combat childhood diarrhoea in developing countries*. 3ie, New Delhi, 2009

Scenario		Description
I:		No transmission of diarrhoea through WASH
II:		Regulated water supply (typically piped), full sanitation coverage, partial treatment of sewage
III		
	***a*:**	Improved water supply, improved sanitation, POU water treatment
	***b*:**	Improved water supply, improved sanitation, improved hygiene
	***c*:**	Further improved water supply (typically piped), improved sanitation
IV:		Improved water supply, improved sanitation
V		
	***a*:**	Unimproved water supply, improved sanitation
	***b*:**	Improved water supply, unimproved sanitation
VI:		Unimproved water supply, unimproved sanitation

Box 11: Classifications for water supply and sanitation considered by Prüss et al. [2002].

Neither of the first two scenarios considered by Prüss et al. [2002] typically apply to developing countries, but the remaining scenarios describe the situation for households in Ribáuè in 2012 and 2014. Table 42 presents the relative prevalence of the various WSS scenarios in Ribáuè in both September 2012 and November 2014, and, in line with previously discussed changes in Ribáuè due to NAMWASH, these show a significant improvement in terms of WSS and anticipated lower risk of diarrhoeal diseases.

	III*a*	III*c*	IV	V*a*	V*b*	VI
September 2012	0.79% (0.00%, 1.89%)	0.40% (0.00%, 1.17%)	3.17% (1.01%, 5.34%)	2.38% (0.50%, 4.26%)	39.68% (33.64%, 45.72%)	53.57% (47.41%, 59.73%)
November 2014	10.86% (7.02%, 14.70%)	2.66% (0.68%, 4.65%)	18.24% (13.47%, 23.01%)	13.11% (8.95%, 17.28%)	31.97% (26.21%, 37.73%)	23.16% (17.95%, 28.36%)
Piped Water 2014	0.79% (0.00%, 1.89%)	5.95% (3.03%, 8.87%)			93.25% (90.16%, 96.35%)	

Table 42: Estimated distribution of water and sanitation scenarios in the town of Ribáuè in September 2012 and November 2014. We also present a theoretical estimate ("Piped Water 2014") of what would be anticipated in 2014 if piped water was supplied to all households and there was no change in the way of sanitation.

As totals for Ribáuè from November 2014 only reflect the short-term impacts of introduction of piped water while also reflecting the significant sanitation interventions carried out in Ribáuè, we consider the impact that would have been expected from 2012 to 2014 if piped water had been delivered to all homes and no sanitation interventions took place, and these are shown in the last row ("Piped Water 2014") of Table 41. These totals reflect a shift of households in Scenario VI to Scenario V*b* and households in Scenarios V*a* and IV to Scenario III. Understanding these shifts between scenarios allows for an understanding of the full scope of health benefits that could be anticipated from piped water to the home, corresponding to the totals costs presented in the previous chapter. These will help shape the estimation of economic benefits related to those costs.

Based on the scenarios presented by Prüss et al. [2002], estimates of reductions in risk from Prüss et al. [2002],[285] and subsequent updates by Waddington et al. [2009] to incorporate more recent studies, Hutton [2012] presents the relative risks of diarrhoea shown

[285] These estimates take into consideration a wide swathe of studies that include examinations of water interventions (including those by Esrey and Habicht [1985] and Esrey et al. [1991]), sanitation interventions, and hygiene interventions.

in Table 43, which consider Scenario VI as reflecting baseline risk and subsequent relative risks representing reductions in risk based on progressive improvements in WSS. Note that the estimate for the relative risk corresponding to Scenario III is based on the relative risks presented by Prüss et al. [2002] and was not included by Hutton [2012][286]. Although Prüss et al. [2002] report several studies that could be used to estimate relative risks corresponding to to Scenarios III*a* and III*b*, they could not identify any studies that would allow for direct estimation of Scenario III*c*, and they instead uniformly apply a relative risk to all sub-components (*a*-*c*) of Scenario III, producing the relative risk shown.

[286] This is presumably because that study only considered what would be required to meet the water and sanitation targets specified by the Millennium Development Goal, and Scenario III consisted of improvements (piped water, hygiene improvements, POU water treatment) that exceeded what would be required to meet these targets.

Scenario	III	IV	V*a*	V*b*	VI
Relative Risk	0.41	0.61	0.64	0.82	1.0

Table 43: Relative risks for diarrhoea corresponding to the scenarios presented in Box 11.

The relative risks presented in Table 43 can be used calculate percentage reductions in risk, so, for instance, a transition from scenario VI to Scenario IV should correspond to a 39% reduction in diarrhoea morbidity and mortality, while a transition from Scenario V*b* to Scenario IV should correspond to a roughly 25% reduction. If we know diarrhoea mortality and morbidity, we can estimate reductions based on transitions between scenarios due to introduction of piped water to the home.

Estimates of diarrhoea incidence for children under the age of five and all others are presented in Table 17. As already noted, we do not observe a significant difference between incidence recorded in 2012 and 2014 for the town of Ribáuè, and, in the interest of producing a conservative estimate for expected reduction in diarrhoea incidence, we use the lower of the two estimates of incidence for each age category, meaning that we consider incidence to be as shown in Table 44. Note that, rather than consider all individuals over the age of 4 as one group, we further break this category down according to typical school age and adult years, as done by Hutton [2012]. For the town of Ribáuè in 2014, this would produce an estimated 20,612 cases of diarrhoea per year. Calculations used to produce these estimates are presented in Appendix A.

	< 5 years	5-14 years	≥ 15 years
Incidence	8.59% (5.79%, 11.40%)	1.53% (0.32%, 2.75%)	0.78% (0.10%, 1.47%)
Cases	12,389.61	4,458.97	3,763.28

Table 44: Estimated incidence of diarrhoea and number of cases annually by age for the town of Ribáuè.

Due to the absence of town-, district-, or provincial-level estimates of mortality due to diarrhoeal diseases, we rely on country-level mortality (due to all causes) reported by World Bank [2015] and reports of death due to diarrhoeal diseases reported by World Health Organization Global Health Observatory [2015] for 2013[287]. These are used to estimate the age-specific probabilities of death due to diarrhoeal diseases, as shown in Table 45, allowing us to estimate total deaths due to diarrhoea for the town of Ribáuè in 2014.

[287] World Bank. World Development Indicators, Mozambique, 2015. URL http://data.worldbank.org/country/mozambique/#cp_wdi; and World Health Organization Global Health Observatory. *Mozambique: WHO statistical profile*. World Health Organization, Geneva, 2015. URL http://www.who.int/gho/countries/moz.pdf?ua=1

Appendix A provides information on the data and calculations used to produce these estimates.

	< 5 years	5-14 years	≥ 15 years
Probability of Death	0.16%	0.03%	0.03%
Deaths	8.92	3.88	6.41

Table 45: Estimated probability of death due to diarrhoea and number of deaths annually by age for the town of Ribáuè.

Note that some have taken the approach of using case fatality rates to estimate mortality by calculating mortality as a percentage of cases of diarrhoea. For instance, Prüss et al. [2002] used case fatality rates derived from Murray and Lopez [1996] and then applied this proportionally to all instances of diarrhoea[288]. This approach can be shown to be equivalent to the approach we have taken when the data used are estimates produced using case fatality rates[289]. Now, it is important to recall that Cairncross and Valdmanis [2006] report not only a reduction in incidence of diarrhoea with water in close proximity to the home but also a reduction in severity, suggesting that case fatality rates are likely to be associated with the water situation of a household. To the best of our knowledge, no one has yet investigated this relationship, so the nature of changes in fatality rates due to improved WSS situations is not known. Consequently, in line with other studies, we do not consider differential case fatality rates based on WSS situation of the household.

[288] C.J.L. Murray and A.D. Lopez. *Global Health Statistics*. Harvard School of Public Health, World Health Organization, and World Bank, Cambridge, 1996

[289] In fact, it is likely that World Bank [2015] reports are actually estimates based on case fatality rates. We used World Health Organization Global Health Observatory [2015] reports for over all mortality due to diarrhoea, however, and these differed substantially from projections from World Bank [2015]. Given that the World Health Organization Global Health Observatory [2015] total was substantially lower, we would expect our estimates to be more conservative than estimates relying on published case fatality rates (or estimates produced using them).

If we assume that diarrhoea morbidity and mortality for a given age rage are uniformly distributed across households[290], then a change from the situation in terms of WSS scenarios observed in 2012 to the situation that would be expected if only piped water was introduced to all households (as shown in Table 42) produces an estimated 11.54% reduction reduction in morbidity and mortality. This would lead to the total reduction in cases of diarrhoea and deaths that could be expected in a given year for Ribáuè shown in Table 46.

[290] In reality, we would expect morbidity and mortality to be higher for scenarios corresponding to worse WSS situations.

	< 5 years	5-14 years	≥ 15 years
Morbidity:			
Cases (September 2012)	11,947.20	4,299.78	3,628.59
Cases (Piped Water 2014)	10,569.57	3,803.61	3,209.87
Reduction	1,378.63	496.17	418.72
Mortality:			
Deaths (September 2012)	8.60	3.74	6.18
Deaths (Piped Water 2014)	7.61	3.31	5.47
Reduction	0.99	0.43	0.71

Table 46: Estimated diarrhoea morbidity and mortality for Ribáuè for 2014 and anticipated reduction as based on a WSS situation in line with what was observed for 2012 and as estimated based on transitions due to an intervention consisting strictly of piped water to the home. These correspond to the distributions shown in Table 43.

The reduction of slightly over 10% appears small when considering that Cairncross and Valdmanis [2006], Esrey and Habicht [1985], and Esrey et al. [1991] cited reductions in excess of 50% due to introduction of piped water to the home. We note that the seemingly small reduction in diarrhoea morbidity and mortality can partially be attributed to a large percentage of households corresponding to Scenario V*b* not seeing a shift to an improved scenario due to the fact that they had unimproved sanitation facilities. If there was a greater use of improved sanitation facilities prior to NAMWASH, percentage reductions would be more substantial. However, it would also be expected that the baseline incidence would have been lower than what we observed, so, even though the percentage reduction would be greater, the reduction in terms of raw numbers would still be less. At the same time, our estimated reduction is likely to be conservative, given that Scenario V*b* is meant to represent a situation where households would likely have access to boreholes and possibly standpipes but not yard taps or household connections. A situation where water is piped to the home would likely lead to a more significant reduction, but no estimates of the change in relative risk corresponding to such a situation are available.

The Impacts of Piped Water to the Household on Education

Hutton et al. [2007a] estimated that improvements in the way of water and sanitation could reduce the number of days that children miss school each year by between 76 million and 1.3 billion days with impacts for SSA being in the range of 16.5-250.2 million days[291], and World Health Organization [2004] reported that children with whipworm infections (which are completely avoidable with improved WASH[292]) missed roughly twice as many days of school[293]. More recently, Fehr [2010] found that roughly 40% of girls in South Gondar, Ethiopia who had water collecting responsibilities reported being late for school at least once in the past month with more than 1/3 noting that it was a significant issue.

The impacts of diarrhoeal diseases (which can be reduced significantly through piped water to the home) can be more insidious, however, with Guerrant et al. [1999], Niehaus et al. [2002], and Keusch et al. [2006] noting the impacts of early childhood diarrhoea on cognitive ability[294]. Fischer Walker et al. [2012] finds that this relationship may potentially be an indirect one with early childhood diarrhoea leading to increased likelihood of stunting which, in turn, leads to decreased cognitive ability[295]. Regardless, the link between diarrhoea and cognitive function (whether direct or indirectly through stunting) has been well-established, and has implications for educational attainment.

Education and income

For girls alone, Hanushek and Woessmann [1999] estimate that each year of additional schooling leads to an increase of 0.58 percentage points in GDP[296], and Dollar and Gatti [1999] estimate that a 1% increase in secondary schooling is associated with a per capita increase of 0.3% in income[297]. Using income data and consider-

[291] G. Hutton and L. Haller. *Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level*. World Health Organization, Geneva, 2004

[292] J. Bethony, S. Brooker, M. Albonico, S.M. Geiger, A. Loukas, D. Diemert, and P.J. Hotez. Soil-transmitted helminth infections: Ascariasis, trichuriasis, and hookworm. *The Lancet*, 367(9521):1521–1532, 2006

[293] World Health Organization. *Report of the Third Global Meeting of the Partners for Parasite Control: Deworming for Health and Development*. World Health Organization, Geneva, 2004

[294] D.I. Guerrant, S.R. Moore, A.A. Lima, P.D. Patrick, J.B. Schorling, and R.L. Guerrant. Association of early childhood diarrhea and cryptosporidiosis with impaired physical fitness and cognitive function four-seven years later in a poor urban community in northeast Brazil. *American Journal of Tropical Medicine and Hygiene*, 61(5):707–713, 1999; M.D. Niehaus, S.R. Moore, P.D. Patrick, L.L. Derr, A.A. Lima, and R.L. Guerrant. Early childhood diarrhea is associated with diminished cognitive function 4 to 7 years later in children in a northeast Brazilian shantytown. *American Journal of Tropical Medicine and Hygiene*, 66(5):590–593, 2002; and G.T. Keusch, O. Fontaine, A. Bhargava, C. Boschi-Pinto, Z.A. Bhutta, E. Gotuzzo, J. Rivera, J. Chow, S. Shahid-Salles, and R. Laxminarayan. Diarrheal diseases. In A. Mills, A.R. Measham, P. Musgrove, J.G. Breman, D.T. Jamison, D.B. Evans, P. Jha, M. Claeson, and G. Alleyne, editors, *Disease Control Priorities in Developing Countries*, pages 371–387. The World Bank, Washington, D.C., 2nd edition, 2006

[295] C.L. Fischer Walker, L. Lamberti, L. Adair, R.L. Guerrant, A.G. Lescano, R. Martorell, R.C. Pinkerton, and R.E. Black. Does childhood diarrhea influence cognition beyond the diarrhea-stunting pathway? *PLoS One*, 7(10), 2012

[296] E. Hanushek and L. Woessmann. The role of education quality in economic growth. Policy Research Working Paper 4122. Technical report, World Bank, Washington, D.C., 1999

[297] D. Dollar and R. Gatti. *Gender Inequality, Income, and Growth: Are Good Times Good for Women?* World Bank Policy Research Report on Gender and Development, Series 1, 1999

ing a minimal model based on Table 28, where the sex and age of the head of household is used and proxies for income (other than education level of the head of household) are excluded, we obtain the predictive relationship between income and level of education as shown in Table 47[298]. To assess the claim made by Dollar and Gatti [1999], we dichotomised education into those reporting having had some form of secondary schooling and those who did not. If we restrict our focus to the town of Ribáuè and use the empirical proportions corresponding to each of the dummy variables in this model, we find that a 1% increase in the level of education from the observed percentage of 63.23% for the town of Ribáuè is associated with an estimated increase in monthly income from 1,864.00 MZN to 1,870.46 MZN, a percentage increase of 0.34%. This result is strikingly close to that reported by Dollar and Gatti [1999], appearing to validate their projection. This rate of increase in income actually increases with further 1% increments in the level of secondary schooling, as shown in Figure 40.

[298] Note that a likelihood ratio test comparing this model with the same model but including a sex-education interaction was not statistically significant (p-value = 0.4036), suggesting that it would not be prudent to make sex-specific projections for the impacts of education on income.

	Estimate	Std. Error	z-value	Pr($>|z|$)
(Intercept)	8.1071	0.3025	26.80	0.0000***
Female head of household	-1.0895	0.2114	-5.15	0.0000***
Age of head of household	0.0037	0.0054	0.69	0.4901
Town/City: (Reference: Nampula)				
Liúpo	-1.2359	0.1949	-6.34	0.0000***
Ribáuè	-0.8799	0.1593	-5.52	0.0000***
Secondary eduction or higher	0.5412	0.1625	3.33	0.0010***
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table 47: Linear regression of log-transformed income on sex and age of head of household, town/city, and whether the head of household has achieved some form of secondary education.

The Economic Impacts of Piped Water to Households

The health improvements alone from piped water to the home would produce significant economic benefits in the way of a reduction in medical costs, greater household income through less time missed from work, and improved economic prospects due to increased levels of education from less school time missed for children. Estimation of the value of avoided costs and increased income earning opportunities forms the basis of the economic benefits for a cost-benefit analysis.

In estimating the economic benefits of piped water to the household, we follow the considerations of the model by Hutton [2012], which is the most recent and conservative version of a standard model that has gone through a series of revisions over the past decade and can be considered the benchmark for CBA in the WASH sector[299]. Although the model was developed to produce estimates at a global or regional level, the general form of the model is appropriate for calculations at a more localised level (national, provincial, district, town/city) if informed by data reflecting the local situation, and, where possible, we use survey data from Ribáuè to produce more accurate estimates for local benefits. Where local data do not exist, we use national data.

[299] G. Hutton and L. Haller. *Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level*. World Health Organization, Geneva, 2004; G. Hutton, L. Haller, and J. Bartram. Global cost-benefit analysis of water supply and sanitation interventions. *Journal of Water and Health*, 5(4):481–502, 2007a; G. Hutton, L. Haller, and J. Bartram. *Economic and health effects of increasing coverage of low cost household drinking water supply and sanitation interventions to countries off-track to meet MDG target 10*. World Health Organization and United Nations Development Programme, Geneva and New York, 2007b; T. Clasen, L. Haller, D. Walker, J. Bartram, and S. Cairncross. Cost-effectiveness of water quality interventions for preventing diarrhoeal disease in developing countries. *Journal of Water and Health*, 5(4):41–57, 2007; G. Hutton and J. Bartram. *Regional and global costs of attaining the water supply and sanitation target (Target 10) of the Millennium Development Goals*. World Health Organization, Geneva, 2008a; G. Hutton and J. Bartram. Global costs of attaining the Millennium Development Goal for water supply and sanitation. *Bulletin of the World Health Organization*, 86:13–19, 2008b; G. Hutton. *Global Costs and Benefits of Drinking-Water Supply and Sanitation Interventions to Reach the MDG Target and Universal Coverage*. World Health Organization, Geneva, 2012; and G. Hutton. Global costs and benefits of reaching universal coverage of sanitation and drinking-water supply. *Journal of Water and Health*, 11(1):1–12, 2013

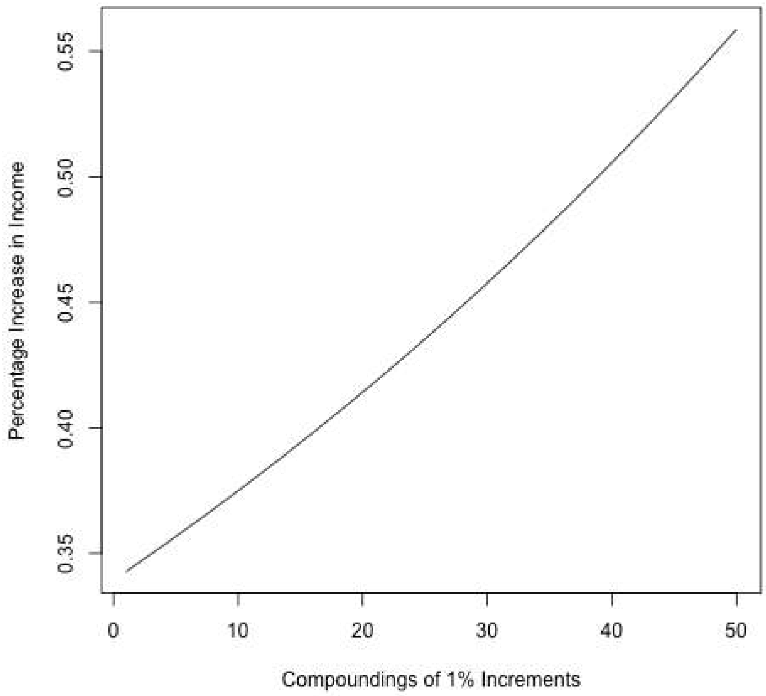


Figure 40: Incremental increase in income for households in Ribáuè with each additional 1% increase in secondary schooling for head of household, starting from the observed level of schooling in Ribáuè.

The model considered by Hutton [2012] considers direct costs, opportunity costs, and costs due to fewer years of productive (*i.e.* income-earning) life from poor health, and it additionally measures the opportunity cost associated with time spent collecting water. Improvements in health and reductions in time spent collecting water lead to avoided costs, and these form the heart of the estimated benefit corresponding to piped water to the household. We examine each of these individual costs before presenting the full form of the model used for estimating the economic impact of piped water to households in Ribáuè.

Health-Related Costs

Treatment and related costs

World Health Organization [2015b] provides estimates of both inpatient and outpatient costs associated with health centres and hospitals, and in Table 48 we present Mozambique-specific estimates for the types of facilities found in Ribáuè. These estimates are based on regression models that factor in per capita GDP, number of visits or hospitalisations, average length of stay, and type of health facility. The provided unit costs assume that outpatient facilities are urban "public facilities, operating at the 80% percentile of a sample of similar such facilities in terms of capacity utilization and output"[300], so these may not reflect costs in a rural or peri-

[300] World Health Organization. *Note on the Methodology Used to Predict Unit Costs for Patient Services WHO-CHOICE 2011*. World Health Organization, Geneva, 2011

urban setting. Discussions with both the Mozambican Ministry of Health and Provincial Health Directorate of Nampula in an attempt to provide more accurate costings failed to elucidate the financial burden to the government for health care costs related to standard outpatient and inpatient costs nor costs borne for the treatment of or medicines for diarrhoeal diseases[301]. As an estimate for unit costs, we have taken the average of all values (across both facility types and both value adjustment methods) for a given unit cost, producing estimates of $1.12 USD per visit and $2.94 per bed day.

[301] According to those we spoke to within the Ministry of Health, the Ministry does not collect such data.

Using WHO data, Hutton [2012] reports that roughly 90% of cases include outpatient visit with 10% requiring hospitalisation. We have modified this slightly to reflect home treatment, instead considering a 90-10 split only for those who present to a clinic or hospital. This rate of presentation is dependent on age. For instance, in Ribáuè, 80.00% (70.28%, 89.72%) of cases of diarrhoea for children under the age of 5 were treated at a clinic or hospital[302]. This dropped to 63.27% (49.77%, 76.76%) when considering all other cases.

[302] Clinics are interpreted to include health posts, private clinics, and traditional medical facilities.

We have no information on the relative frequency with which cases of diarrhoea require hospitalisation in Ribáuè (or Mozambique). Even though there are many reports of treatment at the Ribáuè Rural Hospital, this is largely because it is the closest health facility and not because the symptoms required hospitalisation. Consequently, we have no information to suggest a split different from 90-10, nor do we have more precise data in terms of typical hospital stay, so we use the Hutton [2012] estimate of 5 days. Similarly, we do not have an estimate of the frequency of return visits, so we assume that each reported outpatient visit actually corresponds to 1.2 visits due to 20% of cases requiring a follow-up visit.

Hutton [2012] also considers a transportation cost of $0.50 per health centre or hospital visit. This almost certainly reflects the underlying assumption of urban facilities, meaning that vehicle transportation is likely to be required. This is less likely the case in a rural or peri-urban setting, where cars and taxis are far less common and most will walk to the nearest facility. In the case of Ribáuè, only 12.04% (5.90%, 18.17%) of reported cases of diarrhoea incurred some form of transportation cost with the mean cost being $1.53 ($0.00, $3.47) USD. This corresponds to an average transportation cost of $0.18 ($0.00, $0.63) USD.

Factoring in the relative frequency of outpatient versus inpatient treatment, number of visits and cost per outpatient case, number of bed days and cost per hospitalisation, and transportation costs, the expected total cost for an individual who is not treated at home is $2.86 USD. This amount is assumed to cover both the cost to the individual and the cost to the health sector.

Outpatient visit:	*Frequency*: 90% of in-patient/outpatient visits	*Visits*: 1.2 / visit
Costs:	Primary-level hospital	Health centre (no beds)
Visit (2008)	29.3 MZN	20.8 MZN
GDP deflator	37.4 MZN ($1.25 USD)	26.5 MZN ($0.88 USD)
CPI-adjusted	41.2 MZN ($1.37 USD)	29.3 MZN ($0.98 USD)

Hospitalisation:	*Frequency*: 10% of in-patient/outpatient visits	*Bed days*: 5
Costs:	Primary-level hospital	
Bed day (2008)	65.8 MZN	
GDP deflator	83.9 MZN ($2.80 USD)	
CPI-adjusted	92.6 MZN ($3.09 USD)	

Table 48: Estimated unit costs for outpatient and inpatient visits in Mozambique in 2008, as estimated by the World Health Organization. To bring costs in line with 2014 currency values, these are adjusted using both the GDP deflator and changes in CPI. the relative frequency of outpatient and inpatient visits is also presented.

Household reported costs for treatment of diarrhoea

As noted, a significant percentage of individuals are treated at the home, in which case costs are assumed by the household but, presumably, not by the health sector. Using our survey data for Ribáuè, we were able to estimate the cost of diarrhoea to households related to outpatient costs, medicine, transportation, and incidentals. These costs, broken down into young children and all others, is presented in Table 49. These show the largest costs for children coming in the way of special food and medicine, whereas adults are additionally likely to spend a substantial amount on transportation. If we only consider those who reported home treatment, then the average cost for treating a child with diarrhoea is $0.82 USD, whereas it is only $0.22 USD for all others.

Cost	< 5 years	≥ 5 years
Admission/consultation	0.44 MZN ($0.01 USD)	0.64 MZN ($0.02)
Diagnosis	0.18 MZN ($0.01 USD)	0.42 MZN ($0.01 USD)
Medicine/drugs	8.95 MZN ($0.30 USD)	11.11 MZN ($0.37 USD)
Traditional medicines	0.48 MZN ($0.02 USD)	
Transportation	2.66 MZN ($0.09 USD)	9.35 MZN ($0.31 USD)
Special food	23.66 MZN ($0.79 USD)	6.09 MZN ($0.20 USD)
Total	36.37 MZN ($1.21 USD)	27.61 MZN ($0.92 USD)
Total (Home Treatment)	24.63 MZN ($0.82 USD)	6.67 MZN ($0.22 USD)

Table 49: Mean costs reported by household in Ribáuè for costs incurred the last time a child under the age of 5 and a person of at least 5 years of age experienced diarrhoea.

Opportunity cost

In addition to expenditure to treat diarrhoeal diseases, there is an opportunity cost corresponding to recovery time (for adults and school-age children) and caretaking by adults for younger children. To estimate the opportunity cost associated with recovery from diarrhoeas diseases, Hutton [2012] assume the duration of each case of diarrhoea is 5 days, regardless of the age of the individual. In Table 50, we provide estimates for the town of Ribáuè based on survey data, and these suggest significantly lower duration. Consequently, we use these reduced estimates in our model.

Age	Duration (days)
$<$ 5 years	2.94 (2.11, 3.77)
5-14 years	2.17 (1.56, 2.77)
$\geq$ 15 years	3.60 (0.86, 6.34)

Table 50: Age-specific mean durations of cases of diarrhoea for the town of Ribáuè in 2012.

For adults, time spent recovering from diarrhoea symptoms is assumed to result in no work, and Hutton [2012] attach a value of 30% of hourly income as based on per capita GDP, which was 18,875.9 MZN ($629.20 USD) in 2014[303]. In considering cost-effectiveness, World Health Organization [2003] caution against using wage rates to estimate the cost of decreased productivity and lost time due to disease, noting that it "would require firstly estimating the change in GDP over time... something that requires heroic assumptions about trends in economic growth rates. Secondly, the value of non-market production with and without the intervention would need to be calculated over time—non-market production can be a large component of the economy in many poorer countries"[304], and this would especially be true in the context of Mozambique, where subsistence farming is common in rural and peri-urban settings. They also discourage using per capita GDP "because GDP divided by the workforce overestimates the marginal product of labour by a considerable margin." Consequently, an appropriate discount of GDP in line with that proposed by Hutton [2012] may be more in line with the true value of the sacrificed time.

[303] World Bank. World Development Indicators, Mozambique, 2015. URL http://data.worldbank.org/country/mozambique/#cp_wdi

[304] World Health Organization. *Making Choices in Health: WHO Guide to Cost-Effectiveness Analysis*. World Health Organization, Geneva, 2003

Churchill et al. [1987] suggested that wages for females should be discounted to reflect decreased expected earnings as a result of their work in generally lower wage occupations[305]. Consequently, it might be argued that estimates of opportunity cost for women should reflect the Organisation for Economic Co-Operation and Development [2015] reported average gender wage gap of 15.5% or be based strictly on occupation- or household-specific wages[306]. If the desire is strictly to reflect actual wages, then such an adjustment may appropriate, but if used to place a value on that time, then such measures would reflect gender discrimination. Consequently, no such distinction is made, and the value of time is treated the same for both males and females in our study.

[305] A.A. Churchill, D. de Ferranti, R. Roche, C. Tager, A.A. Walters, and A. Yazer. *Rural Water Supply and Sanitation: Time for a change*. World Bank, Washington, D.C., 1987

[306] Organisation for Economic Co-Operation and Development. Employment: Gender wage gap, 2015. URL http://stats.oecd.org/index.aspx?queryid=54751

For school-age children, Hutton [2012] also attach a value of 30% of hourly income to school days missed even though students are not technically missing out on income earning opportunities. Here, the attribution of income is meant to reflect decreased educational attainment and impacts to income as a result of that. Even though we previously discussed how income increases with level of educational attainment, how educational attainment is affected by the rate of diarrhoea morbidity is not known, so this can be considered as a proxy. As when considering valuations of time for adults, we opt to use per capita income for the town of Ribáuè in place of per capita GDP to estimate hourly income.

Finally, for young children a value of 15% of hourly income is attached to the time spent caring for the child. This valuation is lower than for school-age children based on the assumption that a caregiver may need to spend time looking after the child regardless, so the extra time dedicated to the child is fractionally less.

Loss of life

In those instances where diarrhoea leads to death, there is the potential loss of productive income-earning years. Suarez and Bradford [1993] estimate the loss of income-earning years according to the age categories we have considered ($<$ 5 years, 5-14 years, $\geq$ 15 years) as shown in Table 51[307]. These totals are valued at the yearly income rate. However, as this income is earned over time, it needs to be adjusted for an expected growth in wages as well a specified discount rate to produce the NPV. Hutton [2012] uses an income growth rate of 2% and discount rate of 8%. We will assume the same income growth rate but use a discount rate of 7.5% of based on the Banco de Moçambique [2015] lending rate of 7.5% for 2014[308].

[307] R. Suarez and B. Bradford. *The economic impact of the cholera epidemic in Peru: An application of the cost-of-illness methodology*. Water and Sanitation for Health Project, WASH Field Report No. 415, 1993

[308] Banco de Moçambique. Taxas de Juro Médias Mensais MMI, 2015. URL http://www.bancomoc.mz/fm_MercadosMMI.aspx?id=4

Age	Income-earning years
$<$ 5 years	16.2
5-14 years	21.9
$\geq$ 15 years	19.0

Table 51: Estimated income-earning years lost due to death by age range.

The Cost of Collecting Water

Hutton et al. [2007a] found that, in the African context, the time spent collecting water (referred to as "convenience time") proved to be the greatest cost, accounting for 82% of the total benefit of improved water supply. Although the most expensive, universal access to piped water to the household leads to the largest gains in convenience time with an estimated increase of 200 hours per person annually[309].

[309] G. Hutton, L. Haller, and J. Bartram. Global cost-benefit analysis of water supply and sanitation interventions. *Journal of Water and Health*, 5(4):481–502, 2007a

The burden of collecting water

In 2006, United Nations Development Programme [2006] estimated that women in Mozambique spent between 15 and 17 hours per week collecting water[310]. If we consider the burden of collecting water in Ribáuè pre-NAMWASH, this disproportionately fell to females with more than 95% of households having a female as the primary water collector, as shown in Table 52. The mean time spent collecting water was in excess of two hours, and estimated weekly time spent collecting water (roughly 16.5 hours) falls in

[310] United Nations Development Programme. *Human Development Report 2006—Beyond scarcity: Power, poverty and the global water crisis*. United Nations, New York, 2006

line with the estimates provided by United Nations Development Programme [2006]. This time spent collecting water represents an opportunity cost with adults potentially sacrificing income-earning opportunities and children potentially losing time from school. Similar to time lost due to diarrhoeal diseases, the value of time to adults is valued at 30% of hourly income (as based on per capita GDP), while the time of all children (including school-age children) is valued at 15% of the hourly rate.

Collector	Percentage	Time (Minutes)
Adult Female	96.43% (94.14%, 98.72%)	140.94 (128.97, 152.91)
Adult Male	1.98% (0.26%, 3.71%)	
Girl	0.79% (0.00%, 1.89%)	90.00 (48.42, 131.58)
Boy	0.79% (0.00%, 1.89%)	

Table 52: Primary water collector by sex and age categories for households in the town of Ribáuè in 2012.

Estimating Total Economic Benefit and the Benefit-Cost Ratio

With a means to enumerate and estimates losses incurred due to health costs, loss of life, and opportunity costs, we can estimate the economic benefits of piped water to the home for the town of Ribáuè through avoidance of the costs. The estimation is then based on all of the components presented in Box 12. In addition, in line with the approach of Hutton [2012], we conducted a sensitivity analysis where, under a conservative scenario:

- the value of years of productive life lost were reduced by 50%,
- the value of lost time was reduced to 15% of hourly for adults and $0.00 for children, and
- discount rates corresponding to future year earnings were discounted at 12% rather than 7.5%.

By contrast, under a more generous scenario

- the value of lost time was increased to 100% of hourly income for adults and 50% for children, and
- discount rates corresponding to future year earnings were discounted at 3%.

Benefits according to the various forms of cost avoided are presented in Table 53 and show benefits ranging from $234,979.20 USD to $1,525,477.00 USD annually with an expected benefit of $474,797.20 USD. Using the cost to provide piped water to all homes for a rural system based on the GDP deflator (producing a total cost of $297,851, as shown in Table 41), we obtain an expected BCR of roughly 1.6, suggesting a worthwhile investment from a purely economic perspective. The conservative estimate shows benefits nearly recovering costs, whereas the more generous estimate shows a more than five-fold return on investment. Similar calculations using a CPI-adjusted estimate of total costs for the piped system ($320,240 USD, again from Table 41), produce slight reductions in the BCR to 1.48 (0.73, 4.76).

Health-Related Costs			
Treatment cost (Health facility)	Outpatient	*Frequency:*	90% of cases
		Duration:	1.2 visits / case
		Cost:	$1.12 USD / visit
	Inpatient	*Frequency:*	10% of cases
		Duration:	5 days / hospitalisation
		Cost:	$2.94 USD / day
	Transportation	*Cost:*	$0.18 USD / visit
Treatment cost (Home)	$<$ 5 years	*Cost:*	$0.82 USD / case
	5-14 years	*Cost:*	$0.22 USD / case
	$\geq$ 15 years	*Cost:*	$0.22 USD / case
Opportunity cost	$<$ 5 years (Caretaking)	*Duration:*	2.94 days
		Cost:	15% of hourly income
	5-14 years (School)	*Duration:*	2.17 days
		Cost:	15% of hourly income
	$\geq$ 15 years (Work)	*Duration:*	3.6 days
		Cost:	30% of hourly income
Loss of Life	$<$ 5 years	*Years lost:*	16.2 income-earning years
		Cost:	Yearly income, discounting future years at 7.5% and assuming income growth of 2%
	5-14 years	*Years lost:*	21.9 income-earning years
		Cost:	Yearly income, discounting future years at 7.5% and assuming income growth of 2%
	$\geq$ 15 years	*Years lost:*	19.0 income-earning years
		Cost:	Yearly income, discounting future years at 7.5% and assuming income growth of 2%
Cost of Collecting Water			
Opportunity costs	$<$ 15 years	*Duration:*	90.00 minutes / day (if primary water collector)
		Cost:	15% of hourly income
	$\geq$ 15 years	*Duration:*	140.98 minutes / day (if primary water collector)
		Cost:	30% of hourly income

Box 12: Cost components and utilised values for estimation of avoided costs, as based on a modified version of the Hutton [2012] model.

If we examine component contributions to total benefit, as shown in Figure 41, total benefit overwhelmingly comes from the time gained by not having to collect water with this accounting for roughly 95% of the economic benefit. Additionally, we notice that benefits overwhelmingly come to individuals as opposed to the health sector (roughly 2% at its highest). This should not be surprising, given the low reported diarrhoea incidence and anticipated reduction of only a little over 11% as compared to the reported collection times for water that stand at 1.5 hours for children and nearly 2.5 hours for adults.

Cost	Costs Avoided	Relative Percentage
Treatment cost (facility)	$4,816.95 USD	1.03% (2.07%, 0.32%)
Treatment cost (home)	$301.04 USD	0.06% (0.13%, 0.02%)
Health opportunity cost	$3,625.61 ($1,015.53, $12,085.37) USD	0.78% (0.43%, 0.80%)
Loss of life (productive years)	$16,669.24 ($6,262.66, $23,720.88) USD	3.57% (2.70%, 1.57%)
Water collection opportunity cost	$442,139.28 ($219,937.00, $1,473,797.61) USD	94.56% (94.66%, 97.30%)
Total	$467,552.10 ($232,333.19, $1,514,721.90) USD	BCR: 1.57 (0.78, 5.09)

Table 53: Estimated costs avoided and relative contribution to total estimate for piped water to the home for the town of Ribáuè, using GDP deflator and assuming rural water supply. Estimates based on the conservative and generous scenarios are presented in parentheses, and estimates of total annual economic benefit and benefit-to-cost ratios are provided as well.

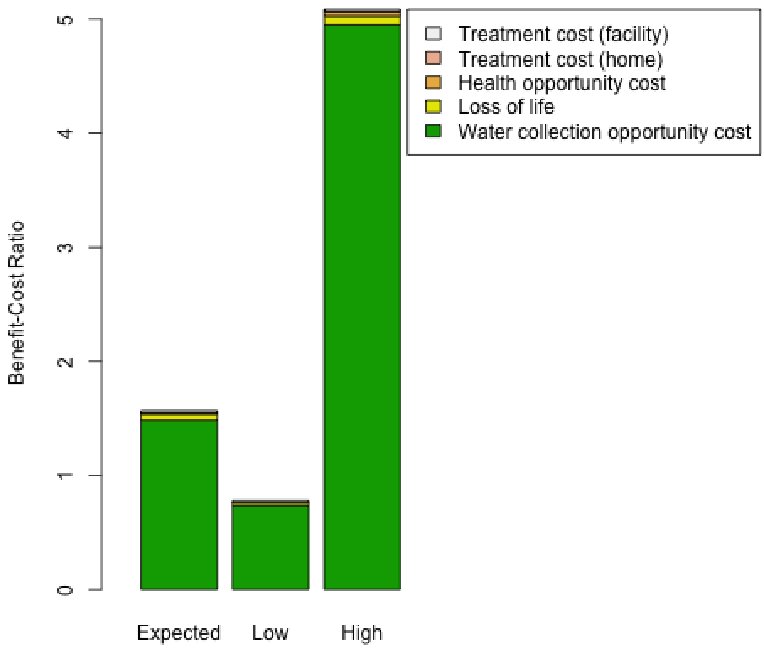


Figure 41: Component contributions for the total economic benefit of water piped to the home. Bar heights represent estimated benefit-to-cost ratio corresponding to our model parameters (*left*), a conservative estimate (*middle*), and a more generous scenario (*right*).

Given the total maximum WTP for the town of Ribáuè of $200,314.70 ($192, 427.00, $208,202.40) USD, the ratio of WTP to benefit is 0.43 (0.86, 0.13), implying that households either do not adequately understand the true value of piped water to the home or otherwise value their time under 30% of per capita GDP. This could be a result of the massive disparity between per capita GDP for Mozambique (18,875.9 MZN, $629.20 USD) and mean and median per capita income for Ribáuè for 2014, which were estimated at 9,411.90 MZN ($313.73 USD) and 6,041.84 MZN ($201.39 USD). If we use these in place of per capita GDP in estimating the estimated annual benefit to the town of Ribáuè, we obtain estimated total benefits of $235,695.70 (based on the mean) and $153,134.10 (based on the median), placing benefits more in line with maximum WTP for the town.

This may be used to argue that the use of per capita GDP to determine wage rate is not appropriate for rural or peri-urban settings, as lower incomes mean that time savings are less profitable. However, much in line with the argument of Schweitzer et al. [2013] that use of household income in valuing the cost of lost time inherently disadvantages poor households[311], using town income to measure the value of lost time immediately devalues not only the time lost by rural and peri-urban communities in collecting water, given that wages are substantially lower for these areas than urban centres, but it has similar implications for devaluing loss of life in these communities by reducing the value of productive income-earning years lost due to decreased life expectancy.

[311] R. Schweitzer, C. Pezon, A. Pinjari, C. Fonseca, and J.R. Mihelcic. *Household expenditure on water services in Burkina Faso: Rinancial and economic expenditures of rural and peri-urban households across socio-economic classes and seasons in Burkina Faso*. IRC International Water and Sanitation Centre, The Hague, 2013

Factoring Sanitation Into the Equation and Final Discussion

So far, we have only considered community demand for piped water to the home, anticipated benefits, and sustainability in the case of Ribáuè. NAMWASH consisted of significantly more than just water supply interventions, however, with interventions in the way of both improved latrine and handwashing station building proving to be highly successful with nearly 1,200 households in Ribáuè buying concrete slabs and building improved latrines with appropriate superstructures and lined pits. These were accompanied by tippy tap handwashing stations. At the same time, the practice of open defecation dropped from roughly 10% in 2012 to only 3% in 2014. As previously shown in Figure 30, the use of unimproved forms of sanitation was almost halved, and cleaning practices for latrines were vastly improved, thanks to education programmes.

The integrated WASH approach employed as part of NAMWASH may be optimal with Esrey et al. [1990] finding that the cumulative health impacts of integrated WSS programmes exceeded the marginal effects of water supply interventions and sanitation interventions for three studies. These results are far from conclusive, however, as Esrey et al. [1991] quickly backtracked on their previous claim, suggesting that integrated WASH programmes should be no more effective than the marginal effects of water supply interventions and sanitation interventions. More recently, Cairncross and Valdmanis [2006] concluded that, based on the evidence available at that point, it was reasonable to assume that the total impact of integrated programmes is given by the sum of the marginal effects of improvements in water supply and improvements in sanitation. This would suggest that, although an integrated WASH programme such as NAMWASH may be useful not only in terms of bringing about rapid improvements in WSS but also in providing a mechanism to effectively integrate piped water system and sanitation plans (including, in some cases, sewage system plans), separate water supply interventions and sanitation interventions do not sacrifice potential synergies that exist when the two are combined.

In this chapter, we first examine the costs and benefits of investment in improved sanitation facilities to understand the anticipated health and economic benefits associated with sanitation interventions. We then examine the economic benefits of integrated WSS interventions relative to cost before providing a final discussion.

The Cost of Improved Sanitation Facilities to Households in Ribáuè

Similar to estimates of unit costs for piped water to the home, Hutton [2012] provides unit cost estimates for improved pit latrines in Mozambique, and these estimates, along with appropriate value adjustment are shown in Table 54. These unit costs again represent annual per capita capital and recurrent costs, this time for an improved latrine assumed to have an eight year lifespan.

	Capital Cost	Recurrent Cost	Total	GDP Deflator Adjusted Total	CPI Adjusted Total
Rural Pit Latrine	$8.50 USD	$0.90 USD	$9.40 USD	$10.58 USD	$11.37 USD
Town Cost				$334,734.00 USD	$359,896.20 USD

Table 54: Estimated annual capital costs, recurrent costs, and total costs for improved latrines for rural areas in Mozambique, as reported by Hutton [2012]. Values reported by Hutton are for 2010, and GDP deflated totals and CPI adjusted totals reflect changes in real currency value in Mozambique from 2010 to 2014. Total costs for the town of Ribáuè to provide improved latrines to all those without a latrine or using unimproved latrines are presented for both GDP deflated and CPI adjusted totals.

If we consider the cost per latrine as reported by Hutton [2012] in Table 54, we note that the estimated total capital cost *per person* for a pit latrine in 2012 was estimated to be $68 USD. UNICEF Mozambique reported the *per latrine* cost to build an improved latrine in Ribáuè was roughly 2,000 MZN ($66.67 USD). Similarly, Trémolet et al. [2010] reported a *per latrine* cost of roughly $70 for latrines built as part of the Improved Latrine Programme (PLM)[312]. Meanwhile, Haller et al. [2007] present a *per person* cost for a pit latrine for SSA of $39. This is based on WHO and UNICEF Joint Monitoring Programme [2000], which seems to suggest that the cost of $39 applies to a single pit latrine[313].

These differences may in part reflect software costs, which are not estimated by Trémolet et al. [2010] and which are difficult to accurately gauge for the town of Ribáuè for NAMWASH, given that activities were split across multiple towns[314]. van de Reep [2010] reports actual costs for a variety of hygiene and sanitation promotion programmes in Mozambique, including CLTS and Participatory and Community Education (PEC) Zonal approaches with costs ranging from roughly $3.80 USD to $19.65 USD per person annually with an average of roughly $5.10 USD[315]. Potter et al. [2013] more recently presented estimated costs of $5.60 per person annually[316]. These costs incorporated not only ExpDS in the way of training, mobilisation, and multimedia campaigns but also OpEx, which included the costs for those carrying out the training and training materials[317]. van de Reep [2010] found average OpEx to be anywhere from 4 to 45 times higher than ExpDS depending on the approach employed with this difference being roughly 4 in the case of CLTS and 30 in the case of PEC Zonal. These significant software costs, particularly in the way of OpEx, would suggest that the results presented by Hutton [2012] may actually quite reasonably reflect the totality of annual per capita hardware and software costs. Consequently, we present results based on Hutton [2012] but note that further examination of these reported per person costs would be warranted, at least in the case of Mozambique.

312 S. Trémolet, P. Koslky, and E. Perez. *Financing On-Site Sanitation for the Poor: A Global Six Country Comparative Review and Analysis*. World Bank, Water and Sanitation Programme, Washington, D.C., 2010

313 We note that the authors of Haller et al. [2007] all have close affiliations with the WHO, so it is not clear if they have further information on costs presented in WHO and UNICEF Joint Monitoring Programme [2000] and those estimates in fact reflect *per person* costs or if this is simply an oversight.

314 UNICEF noted a software cost of $24.00 USD per latrine (approximately $4.80 per person) [UNICEF Mozambique, July 2014], but this is reported based only on mobilisation and training costs.

315 Costs GDP-deflated to 2014 USD.

316 We note that none of the studies considered were carried out in Nampula, which, based on CPI, has higher costs than the national average [Instituto Nacional de Estatística, 2015a,b].

317 This included salaries, administration costs, transportation and related costs, development and printing of training materials, etc.

Although the reported uptake of 1,170 improved latrines in Ribáuè is impressive, research by Trémolet et al. [2010] does not suggest high sustainability (in terms of continued demand for improved latrines) for programmes in Mozambique carried out with the specific aim of increasing usage of improved latrines and including subsidies. The PLM in Mozambique has reached approximately 2 million people and provided subsidies (roughly $20 per latrine, similar to NAMWASH's reported subsidy of $18[318]) for improved latrines. Trémolet et al. [2010] note that, in an examination of households with an improved latrine, nearly all had obtained it through the PLM, and private contributions constituted roughly 40% of the total cost. Based on the low uptake outside of PLM and substantial external investment required, they concluded that the programme had "low sustainability." In the case of NAMWASH, we do not have longitudinal data to suggest the level of uptake of improved latrines since the end of NAMWASH and whether the massive improvements gained through NAMWASH will continue with consistent steady uptake of improved latrines. As might be expected, local artisans reported that they had sold substantially fewer latrine slabs since the end of NAMWASH, but this could be in part because most households that desired an improved latrine built one during the programme, so there would inevitably be a significant drop-off[319].

[318] UNICEF Mozambique. *NAMWASH Programme Final Report, January 2012 – June 2014*. UNICEF Mozambique, Maputo, July 2014

[319] According to two artisans, the cost of the slab, which is heavily dependent on the price of concrete, is the biggest obstacle to households building an improved latrine. The NAMWASH sanitation masterplan considers the concrete procurement process to be critical in helping to keep slab costs affordable.

Similarly, although the sanitation and hygiene promotion programme used as part of NAMWASH included the building of tippy tap handwashing stations, producing high uptake, we found very few to still be present in November 2014. This would call into question the sustainability of this form of handwashing station which has commonly been included in hygiene and sanitation programmes. The low sustainability of tippy taps in Ribáuè is in line with observations by Biran [2011], who found that tippy taps were overwhelmingly built as part of programmes but rarely built outside of such programmes, suggesting low demand except in the context of community-wide competitions.

The Benefits of Improved Sanitation Facilities to Households

The benefits of improved sanitation facilities in many ways mirror the major benefits of piped water to the home, producing significant health benefits in the way of reduction of diarrhoea[320], and, for those practicing open defecation, there are additional savings related to the time spent accessing a defecation location. Additionally, particularly for those who do not have a latrine and practice open defecation, an improved latrine has social ramifications.

[320] Diarrhoeal diseases can result not only through direct contact with human excreta but also indirectly through water pollution.

The social benefits of improved sanitation facilities

When considering sanitation facilities, Cairncross and Valdmanis [2006] note that most households who do not have a latrine desire one for social reasons more than health reasons[321]. Jenkins [1999] found that some of the primary reason households desired a latrine was for social prestige, avoiding discomfort, avoiding danger (both animals and humans), and privacy[322]. None of the top ten ranked reasons included health impacts. Of surveyed respondents from Nampula, Ribáuè, and Liúpo who reported practicing open defecation, nearly 50% reported having problems or safety concerns related to animals (primarily snakes) or insects, 6% noted problems with lack of privacy, and 3% cited concerns for their personal safety from other humans. Health-related issues related to not having a latrine were not a reported concern[323]. Thus, the introduction of improved latrines to households would likely have important social ramifications related to household perception of status and personal security (especially for women and girls), safety, and comfort.

[321] S. Cairncross and V. Valdmanis. Water supply, sanitation, and hygiene promotion. In A. Mills, A.R. Measham, P. Musgrove, J.G. Breman, D.T. Jamison, D.B. Evans, P. Jha, M. Claeson, and G. Alleyne, editors, *Disease Control Priorities in Developing Countries*, pages 771–792. The World Bank, Washington, D.C., 2nd edition, 2006

[322] M.W. Jenkins. *Sanitation Promotion in Developing Countries: Why the Latrines of Benin Are Few and Far Between*. PhD thesis, Department of Civil and Environmental Engineering, University of California at Davis, 1999

[323] Many households practicing open defecation lived in sparsely populated areas and did not cite any problems associated with open defecation.

Improved sanitation facilities and diarrhoeal diseases

Like piped water to the home, improved sanitation facilities are linked to health benefits. Cairncross and Valdmanis [2006] note that faecal waste can cause a number of diseases, including diarrhoeal diseases, intestinal worms, and trachoma. The effects of appropriate sanitation on health are dependent on a number of factors. For instance,

> *sanitation is likely to have a greater effect on diarrheal disease in high-density urban areas, where open defecation leads to gross fecal pollution of the neighborhood, and less effect in rural communities, where all but the youngest children use communal defecation sites some distance away from their homes*[324].

[324] The low population density or Ribáuè relative to urban centres could explain why, despite very low levels of use of improved latrines in 2012, incidence of diarrhoea observed in Ribáuè in 2012 was not significantly higher than what was observed for Nampula in 2014.

Additionally, sanitation and hygiene practices are strongly correlated, so it is difficult to determine the true impact of proper sanitation.

As in the case of estimating the reduction in diarrhoea risk due to piped water to the home, the scenarios presented by and risk ratios derived from Prüss et al. [2002] can be used to estimate reduction in both diarrhoea morbidity and mortality. Table 55 provides previously presented WSS scenario distributions for 2012, 2014, and the theoretical distribution when all households are provided with a piped connection. The new scenario, "Improved Latrines 2014," presents the distribution of WSS scenarios that we would expect to observe in Ribáuè if no interventions had taken place in the way of water supply and households currently using some form of unimproved sanitation were to obtain an improved latrine.

Using the risk ratios in Table 43, we can then estimate cases of diarrhoea avoided and reduced mortality due to diarrhoea. These reductions are shown in Table 56, and they would suggest much more significant health impacts than what is anticipated from piped water to the home, which is shown in Table 46. In particular, diarrhoea morbidity and mortality is anticipated to decrease by 29.45%, as compared to an 11.54% reduction due to piped water.

	III*a*	III*c*	IV	V*a*	V*b*	VI
September 2012	0.79% (0.00%, 1.89%)	0.40% (0.00%, 1.17%)	3.17% (1.01%, 5.34%)	2.38% (0.50%, 4.26%)	39.68% (33.64%, 45.72%)	53.57% (47.41%, 59.73%)
November 2014	10.86% (7.02%, 14.70%)	2.66% (0.68%, 4.65%)	18.24% (13.47%, 23.01%)	13.11% (8.95%, 17.28%)	31.97% (26.21%, 37.73%)	23.16% (17.95%, 28.36%)
Piped Water 2014	0.79% (0.00%, 1.89%)	5.95% (3.03%, 8.87%)			93.25% (90.16%, 96.35%)	
Improved Latrines 2014	0.79% (0.00%, 1.89%)	0.40% (0.00%, 1.17%)	42.86% (36.75%, 48.97%)	55.95% (49.82%, 62.08%)		

Table 55: Estimated distribution of water and sanitation scenarios in the town of Ribáuè in September 2012 and November 2014, along with theoretical estimates of the distribution if piped water was supplied to all households ("Piped Water 2014") or improved latrines was supplied to all households ("Improved Latrines 2014").

	$<$ 5 years	5-14 years	$\geq$ 15 years
Morbidity:			
Cases (September 2012)	11,947.20	4,299.78	3,628.59
Cases (Improved Latrines 2014)	8,428.95	3,033.56	2,560.03
Reduction	3,518.25	1,266.21	1,068.56
Mortality:			
Deaths (September 2012)	8.60	3.74	6.18
Deaths (Improved Latrines 2014)	6.07	2.64	4.36
Reduction	2.53	1.10	1.82

Table 56: Estimated diarrhoea morbidity and mortality for Ribáuè for 2014 and anticipated reduction as based on a WSS situation in line with what was observed for 2012 and as estimated based on transitions due to an intervention consisting strictly of improved latrines for households. These correspond to the distributions shown in Table 55.

Access time opportunity cost

Finally, for those practicing open defecation, a pit latrine provides time savings from not having to find a private location in which to defecate. Water and Sanitation Program [2012] estimates that open defecation costs Mozambique at least $124 million USD annually as of 2012 with $22 million USD attributable to time spent accessing a location for open defecation[325,326]. Hutton [2012] estimates that providing access to a sanitation facility for households that do not have a latrine will save 30 minutes per person per day, and, in the absence of data for Ribáuè related to time spent accessing locations to defecate, we use the estimate provided by Hutton [2012].

[325] Water and Sanitation Program. *Economic impacts of poor sanitation in Africa: Mozambique loses MZN 4 billion annually due to poor sanitation.* World Bank, Water and Sanitation Programme, Washington, D.C., 2012. URL https://www.wsp.org/sites/wsp.org/files/publications/WSP-ESI-Mozambique-brochure.pdf

[326] The largest cost is estimated to come in the form of premature death ($79 million USD), and health care costs are estimated to match the costs of access time.

Estimating Total Economic Benefit and the Benefit-Cost Ratio for Universal Access to Improved Latrines

The economic benefit of improved latrines is estimated by avoided health-related costs and the opportunity cost associated with finding a location to openly defecate. If we recall the cost components comprising total economic benefit for piped water to the home, as presented in Box 12, all of these are used in estimating the total economic benefit of improved latrines other than the opportunity cost associated with collecting water. In place of this opportunity cost is the cost of access time, which has similar valuations placed on time for children and adults as was considered for the opportunity cost of collecting water. This cost component is shown in Box 13.

Cost of Access Time		
Opportunity costs	$<$ 15 years	*Duration:* 30 minutes / day *Cost:* 15% of hourly income
	$\geq$ 15 years	*Duration:* 30 minutes / day *Cost:* 30% of hourly income

Box 13: Cost component corresponding to sanitation access and utilised values for estimation of opportunity costs, as based on the Hutton [2012] model.

This produces the costs avoided shown in Table 57. These reflect far greater savings in terms of health-related costs than what was observed for interventions consisting solely of piped water to the home. This is as expected, given the far greater reduction in diarrhoea risk associated with an intervention consisting strictly of improved latrines. However, the opportunity cost associated with accessing a place to defecate is significantly lower than the opportunity cost associated with collecting water. Even though the time saved would correspond to roughly 150 minutes per day for families that practice open defecation[327], exceeding the time savings to both adults and children collecting water (150 minutes and 90 minutes, respectively), only approximately 10% of households in Ribáuè reported openly defecating in 2012, whereas nearly all households reported collecting water.

[327] Recall that the average household size in Ribáuè is estimated to be 4.97 people.

Cost	Costs Avoided	Relative Percentage
Treatment cost (facility)	$12,292.79 USD	10.91% (25.56%, 4.66%)
Treatment cost (home)	$768.26 USD	0.68% (1.60%, 0.29%)
Health opportunity cost	$9,252.52 ($2,591.62, $30,841.72) USD	8.21% (5.39%, 11.68%)
Loss of life (productive years)	$42,539.69 ($15,982.23, $60535.39) USD	37.74% (33.23%, 22.93%)
Sanitation access opportunity cost	$47,870.11 ($16,464.22, $159,567.03) USD	42.47% (34.23%, 60.44%)
Total	$112,723.37 ($48,099.13, $264,005.19) USD	BCR: 0.34 (0.14, 0.79)

Table 57: Estimated costs avoided and relative contribution to total estimate for universal coverage of improved sanitation facilities for the town of Ribáuè, using GDP deflator. Estimates based on the conservative and generous scenarios are presented in parentheses, and estimates of total annual economic benefit and benefit-to-cost ratios are provided as well.

As a result of this reduced time savings and associated opportunity cost, the benefit of investment in improved latrines is significantly reduced, producing a BCR well under 1. This reduced time savings also means that health-related costs, especially the value of loss of productive years due to early death, represent a much more substantial portion of the total benefit. This can be seen in Figure 42, which gives a comparison of estimated BCRs for interventions in the way of water supply and in the way of sanitation, showing far greater returns for investment in piped water to the home with nearly all of this coming from the opportunity cost associated with collecting water.

The Costs and Benefits of Integrated Water and Sanitation Programmes

Given the expected returns on investment for water supply interventions (which should exceed cost) and sanitation interventions (which are less likely to exceed cost), we would expect that an in-

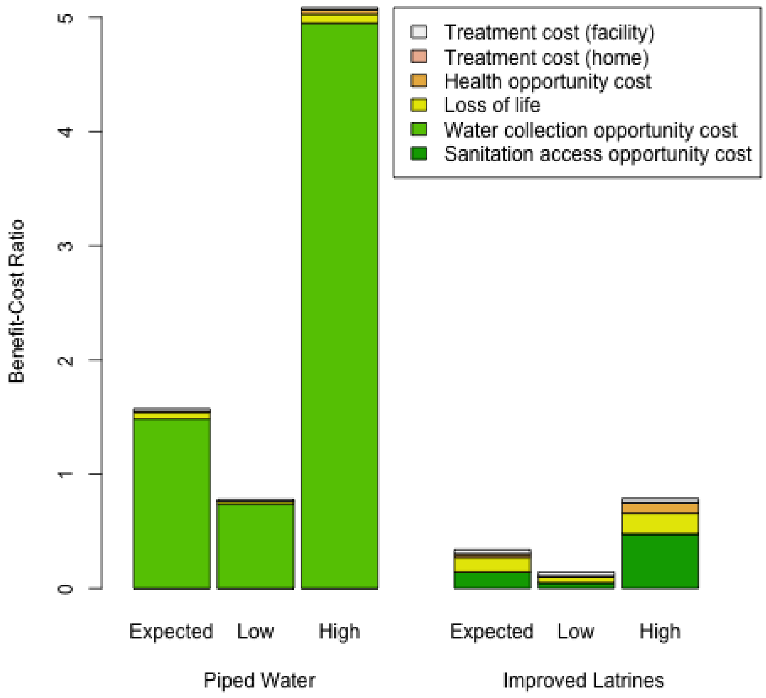


Figure 42: Component contributions for the total economic benefit of improved latrines (*right*) and water piped to the home (*left*). Bar heights represent estimated benefit-to-cost ratio under the presented scenario, and estimates for a conservative ("Low") and generous ("High") scenario are presented as well.

tegrated WSS intervention consisting of piped water to the home and improved latrines would fall somewhere in between. Such an intervention has a total cost given by the sum of costs for supplying piped water and improved latrines to all homes without piped water or improved sanitation facilities, and this total cost is shown in Table 58.

Intervention	GDP Deflator Adjusted Total	CPI Adjusted Total
Piped Water	$297,851 USD	$320,240 USD
Improved Latrines	$334,734 USD	$359,896 USD
Water Supply and Sanitation	$632,585 USD	$680136 USD

Table 58: Estimated total annual cost for the town of Ribáuè to achieve only universal coverage of piped water to all homes, only universal coverage of improved sanitation facilities, and universal coverage in terms of both piped water and improved sanitation facilities. Totals are presented for both GDP deflated and CPI adjusted totals.

If we recall the WSS situation for Ribáuè in 2012, as shown in the first row of Table 55, such an integrated WSS approach would transition all households in Scenario IV or higher to Scenario III*c*, leading to improvements in health and producing significant time savings for those collecting water or practicing open defecation. The health improvements in the way of reduced diarrhoea morbidity and mortality are as shown in Table 59, showing the most significant reduction in risk for integrated WSS interventions (as would be expected) with an anticipated decrease of 53.34%.

This decrease in diarrhoea risk would lead to greater avoidance of health-related costs (including opportunity cost from recovery time and lost income from productive years of life lost), but it has

	< 5 years	5-14 years	≥ 15 years
Morbidity:			
Reduction (Piped Water)	1,378.63	496.17	418.72
Reduction (Improved Latrines)	3,518.25	1,266.21	1,068.56
Reduction (Water Supply and Sanitation)	6,373.23	2,293.71	1,935.67
Mortality:			
Reduction (Piped Water)	0.99	0.43	0.71
Reduction (Improved Latrines)	2.53	1.10	1.82
Reduction (Water Supply and Sanitation)	4.59	1.99	3.30

Table 59: Estimated reduction in diarrhoea morbidity and mortality for Ribáuè based on a WSS situation in line with what was observed for 2012 and as estimated based on transitions due to only a piped water intervention (*top*), only an improved latrine intervention (*middle*), and an integrated water supply and sanitation intervention producing universal piped water to the home and use of improved sanitation facilities (*bottom, black*).

no bearing on the time savings previously considered when examining the benefits of piped water to the home and improved latrines. This is reflected in Table 60. The estimated BCR is slightly under 1, but it would suggest that the benefits related to water would almost completely offset the losses incurred in regard to sanitation, mining that the pairing of sanitation interventions with piped water to the home would be one way of improving the over all WSS situation for the town without assuming a substantial (if any) loss on investment.

Cost	Costs Avoided	Relative Percentage
Treatment cost (facility)	$22,268.10 USD	3.67% (7.58%, 1.22%)
Treatment cost (home)	$1,391.69 USD	0.23% (0.47%, 0.08%)
Health opportunity cost	$16,760.71 ($4,694.66, $55,869.04) USD	2.76% (1.60%, 3.07%)
Loss of life (productive years)	$ 77,059.63 ($28,951.44, $109,658.41) USD	12.68% (9.86%, 6.02%)
Water collection opportunity cost	$442,139.28 ($219,937.00, $1,473,797.61) USD	72.78% (74.88%, 80.87%)
Sanitation access opportunity cost	$47,870.11 ($16,464.22, $159,567.03) USD	7.88% (5.61%, 8.76%)
Total	$607,489.50 ($293,707.10, $1,822,551.90) USD	BCR: 0.96 (0.46, 2.88)

Table 60: Estimated costs avoided and relative contribution to total estimate for integrated water and sanitation intervention consisting of piped water to the home and improved latrines for the town of Ribáuè, using GDP deflator. Estimates based on the conservative and generous scenarios are presented in parentheses, and estimates of total annual economic benefit and benefit-to-cost ratios are provided as well.

The relative contributions of the various cost components to total benefit, as shown in Figure 43, show time savings related to collecting water to be the most substantial area of economic benefit. At the same time, the impact of sanitation on total benefit can be seen in the importance of health cost savings, most noticeably in the value associated with reduced mortality.

Final Discussion

BCRs are useful for getting a sense of the relative return on investment for interventions in the way of water supply, sanitation, and integrated WSS. However, it is important to understand what our BCRs fail to account for. As they are focused on estimating those benefits for which an economic value would be feasible, they fail to include many of the social benefits related to improved WSS. They also do not specify who will cover the costs. There are a number of

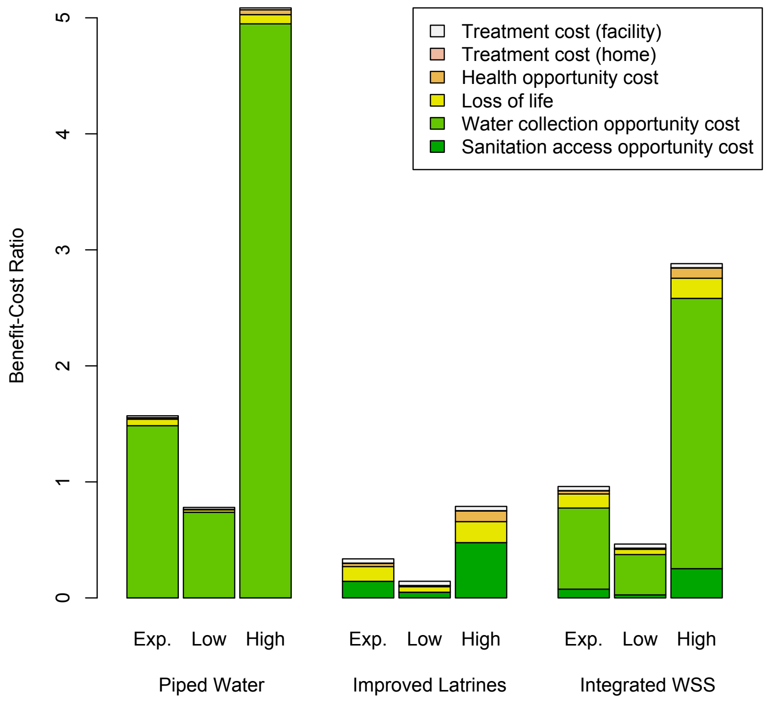


Figure 43: Component contributions for the total economic benefit of an integrated water supply and sanitation intervention (*right*), improved latrines (*center*) and water piped to the home (*left*). Bar heights represent estimated benefit-to-cost ratio under the presented scenario, and estimates for a conservative ("Low") and generous ("High") scenario are presented as well.

economic benefits that are not considered as well, and we describe those first before examining some of the social benefits of improved WSS and exploring the issue of attribution of costs.

Economic benefits not considered by benefit-to-cost ratios

Although our BCRs attempt to account for the impacts of WSS on diarrhoeal diseases, they do not measure other health effects. For instance, WSS is well know to be associated with malnutrition with improved WSS lowering the risk of malnutrition as well as the risk of infection from a variety of other diseases[328]. Günther and Fink [2011] consider this wider range of health impacts in attempting to estimate the impact of improved WSS on reducing child mortality[329]. While incorporating their methodology is beyond the scope of our research, this suggests that the estimates of reduced mortality and economic returns presented in our BCRs are conservative.

As mentioned previously, estimates do not account for lost productivity due to diarrhoeal diseases because of the difficulty in producing an accurate estimate of this. Additionally, even though a monetary value is attached to time missed from work or school for those infected with diarrhoeal diseases, it does not consider potential time lost by caregivers. Time lost by caregivers is only considered in the case of diarrhoea morbidity for young children. Although less common, for 2 of 19 (10.5%) reported cases of diarrhoea involving a person over the age of 5 in Ribáuè, a caregiver

[328] L. Jeyaseelan and M. Lakshman. Risk factors for malnutrition in south Indian children. *Journal of Biosocial Science*, 29(1):93–100, 1997; A.T. Merchant, C. Jones, A Kiure, R. Kupka, G. Fitzmaurice, M.G. Herrera, and W.W. Fawzi. Water and sanitation associated with improved child growth. *European Journal of Clinical Nutrition*, 57(12):1562–1568, 2003; R. Pongou, M. Ezzati, and J.A. Salomon. Household and community socioeconomic and environmental determinants of child nutritional status in Cameroon. *BMC Public Health*, 6:98, 2006; N.J. Bomela. Social, economic, health and environmental determinants of child nutritional status in three Central Asian Republics. *Public Health Nutrition*, 12(10):1871–1877, 2009; and A. Prüss-Üstü, R. Bos, F. Gore, and J. Bartram. *Safer Water, Better Health*. World Health Organization, Geneva, 2008

[329] I. Günther and G. Fink. *Water and Sanitation to Reduce Child Mortality: The Impact and Cost of Water and Sanitation Infrastructure*. World Bank, Washington, D.C., 2011

was reported to have missed working days. This opportunity cost is not included in our estimates, nor is a direct estimate of the impacts of WSS on greater earnings due to increased educational attainment. Given the higher incidence of diarrhoea for young children and impacts on cognitive function, school attendance, and educational attainment, reductions in diarrhoea would be anticipated to lead to greater educational attainment. This is correlated with income, so we would anticipate subsequent significant increases in earning potential.

Finally, the focus on costs to households and costs borne by the health sector ignores economic impact in the private sector with improvements in WSS potentially increasing business opportunities and stimulating new industry. In a rural or peri-urban setting these benefits may be less common, but as a town begins to grow, this would be anticipated to open up new opportunities. As noted in the town of Ribáuè, piped water has already benefited local accommodation establishments by allowing them to secure long-term lodging contracts. Although there are costs associated with these opportunities, the economic return would be anticipated to far outweigh those costs. Considering that the estimates for benefits cannot adequately estimate a number of important benefits, it should be recognised that, minimally, the conservative estimates presented for BCRs are grossly so.

Social benefits not accounted for by benefit-to-cost ratios

Universal access to piped water and sanitation disproportionately benefits women, children, and those of lower SES. Those of lower SES are more likely to use unimproved water sources and practice open defecation, thereby incurring a greater burden of costs in terms of both health-related costs and opportunity costs. At the same time, being the overwhelming primary water collectors, women have the greatest opportunity costs related to collecting water. And children share a load of the water collecting responsibilities while also having greater risk of diarrhoeal diseases when young. Thus, in terms of anticipated economic benefits, piped water to the home and improved sanitation facilities leads to massive gains for these groups, reducing social inequality.

The effects are more than that, though. Not needing to travel long distances to collect water or search for places to defecate would be expected to lead to greater security (particularly for women and girls) and increased safety from snakes or other animals. Households that previously had to spend hours a day collecting water now may have leisure time. And greater educational opportunities for children (and especially girls) would be anticipated to bring about significant social benefits to the community. Thus, the social benefits are not brought about strictly through economic gains to certain groups but also through a variety of other factors that have great value but simply are not economically quantifiable.

Who pays?

The benefits estimated as part of a BCA are usually clearly attributable. For instance, in our case the benefits are largely gained by individuals or households with some additional return going to the public health sector. The costs are not so clear, though. Someone needs to pay the costs to receive the benefits, but who? The answer to this question has implications for sustainability.

In the case of water supply, in theory if communal benefits outweigh costs, this could be left to the government, in which case taxes would need to be sufficient to cover the cost. Such an approach would be in line with the recognition of water as a basic human right (as formally recognised in 2010 resolutions by United Nations General Assembly [2010] and United Nations Human Rights Council [2010]), ensuring that all individuals have access to clean water, regardless of whether they can afford the cost[330]. If cost savings to the public health sector were well understood, the government could also cover costs commensurate with this and leave remaining costs to be covered by households.

[330] United Nations General Assembly. *Resolution on the human right to water and sanitation*. UN doc. A/RES/64/292, 2010; and United Nations Human Rights Council. *Resolution on Human rights and access to safe drinking water and sanitation*. UN doc. A/HRC/RES/15/9, 2010

In the African context, however, these approaches currently are not realistic with African Ministers' Council on Water [2011] noting that "other than South Africa there are few countries in SSA that have been consistently providing even 50 percent of the overall funding to the WSS subsectors"[331], leaving much of the burden on aid organisations to address gaps. Typically, the government or foreign aid covers the cost of CapEx, and it is assumed that households would minimally cover recurrent costs. As mentioned previously, household WTP for the town of Ribáuè would likely be able to just cover both CapEx and recurrent costs for sustainably supplying water to those households stating WTP, but it would be unable to do so when expanding to universal coverage. However, the CapEx contribution as part of NAMWASH would address this shortcoming, so household WTP would be anticipated to be sufficient to cover costs.

[331] African Ministers' Council on Water. *AMCOW Country Status Overviews Regional Synthesis Report—Pathways to Progress: Transitioning to Country-Led Service Delivery Pathways to Meet Africa's Water Supply and Sanitation Targets*. African Ministers' Council on Water, African Development Bank, World Bank, UNICEF, 2011

In the urban context, small-scale private water providers (SSPWPs) who typically extract groundwater and distribute via mini-networks with small gauge pipe are playing an increasingly significant role in water supply. SSPWPs have largely evolved due to the lack of reliability of water supply in many urban centres. In the Mozambican context, Blanc [2012] notes that SSPWPs have a staggeringly high connection rate of 50,000 connections and 380 standpipes in Maputo, representing roughly 50% of all water sales in the city[332]. The low-cost water supply offered by SSPWPs relative to public utilities means that, if WTP is significant enough, the expected return would prompt the private sector to cover the cost of CapEx for at least small-scale systems. This also suggests that, for a town such as Liúpo where WTP is not sufficient to cover the cost of piped systems like those found in Nampula and Ribáuè (assuming tariffs would be similar), low-cost SSPWPs may be able to step in to

[332] A. Blanc. The small-scale private water providers (SSPWPs) of Maputo: An alternative model to be encouraged? In A. Blanc and S. Botton, editors, *Water services and the private sector in developing countries: Comparative perceptions and discussion dynamics*. Agence Française de Développement, Public-Private Infrastructure Advisory Facility, Paris, 2012

temporarily make piped water to homes a possibility for households that are willing to pay sufficiently high amounts[333]. If costs for larger-scale systems come down over time or WTP increases, then large-scale systems may become a possibility in the future, replacing (or, in some cases, incorporating) these small-scale systems. The lesson, though, is that if the private sector has an accurate understanding of household WTP for piped water to the home and knows that it can deliver water profitably, it can step in to address gaps in water supply. This leads to a significant reduction in the role of the government in covering costs.

333 Because SSPWPs have typically been informal, they have not abided by the stringent water quality regulations that public utilities must follow. Proactive planning on behalf of a community to formalise this sector and enforce water treatment and regular water quality testing can help address this.

What are the implications of benefit-to-cost ratios for future interventions?

Although results from a cost-benefit analysis suggest that the benefit-to-cost ratio for investment in improved latrines (or other improved sanitation facilities) for the town of Ribáuè falls well below 1, this is largely due to town characteristics that may be atypical for peri-urban or rural areas, so it is important to interpret BCRs strictly in terms of the location under consideration[334]. If we look specifically at the town of Ribáuè, pre-NAMWASH Ribáuè had very low use of improved sanitation facilities, practice of open defecation, and incidence of diarrhoea for those over the age of 5. The low use of improved sanitation facilities means that the cost of universal coverage with improved sanitation facilities is high. At the same time, the low practice of open defecation and diarrhoea morbidity for all but young children means that the opportunity costs related to access time and time missed from work/school are not as significant as what was observed for a water supply intervention. Consequently, the low BCR related to investment in sanitation is not a reflection of inefficiencies in NAMWASH but rather town characteristics that would be unlikely to produce high estimates of benefits for a CBA.

334 From a methodological perspective, extending our model to other towns for which relative WSS and diarrhoea morbidity data are available is relatively straightforward.

Taking a step back, the presented BCRs to some degree provide a sense of both where the greatest value of WSS interventions lie and potential areas of emphasis for interventions, but they should be viewed as only one aspect of a broader examination of the impacts of improved WSS. If viewed strictly from a private sector "profitability" perspective where BCRs represent actual return per unit of currency spent, then all spending would go towards piped water supply in towns similar to Ribáuè. This would result in far less significant health benefits than if there was significant expenditure in the area of sanitation as well (11% reduction in diarrhoea risk versus 53% reduction). If viewed from a government perspective, on the other hand, a BCR of 1 would mean that costs are recovered, in which case an integrated WSS intervention in towns similar to Ribáuè would be anticipated to either very nearly or fully recover cost while tapping into the full set of health and social impacts previously described. This would be sufficient grounds to consider an integrated WSS approach. Finally, even if BCRs for various interventions are higher for one community than another, WTP (or other factors) may suggest a lower level of sustainability. Thus, BCRs need to be considered as one component in a broad set of considerations for investment in WSS.

Thinking more broadly about sustainability

The greater African push for decentralisation has attempted to decrease reliance on central governments in the hopes of increased autonomy for local communities to address local needs and issues. This has resulted in communities assuming greater responsibility for their own WSS. It would be expected that this sense of ownership would lead to greater adherence to proper maintenance and operation of water and sanitation infrastructure provided to these communities. However, Montgomery and Elimelech [2007] note that

> *Decentralization has not solved perhaps the largest problem facing water and sanitation projects—sustaining long-term use and operation. For example, at the conclusion of the 5-year, $135 million Indonesian Rural Water Supply and Sanitation Sector Project, fewer than half of the ≈3 million intended beneficiaries had received any services. In addition, only 30-40% of the water and sanitation facilities constructed were still functioning or in use 4 years after the project was completed. This demonstrates both an initial lack of capacity and/or political will to implement services and a lack of local incentive to operate and maintain facilities. Efforts in rural Africa had similar outcomes. Throughout the continent, of the ≈250,000 hand pumps currently installed, <50% are estimated to be operational*[335].

[335] M.A. Montgomery and M. Elimelech. Water and sanitation in developing countries: Including health in the equation. *Environmental Science and Technology*, 41(1):17–24, 2007

In the Mozambican context, the Japanese Grant Aid Project carried out work in eight districts in Zambezia Province to construct and rehabilitate deep wells as well as procure machinery (such as excavators) for extending water supply. Japan International Cooperation Agency [2009] reports that the project met the development needs over the course of the project from May 2001 to February 2004. Between 2005 and 2008, however, the Ministry of Public Works and Housing noted that 25% of deep wells in these districts were non-functional and in need of repair, suggesting that the project had not achieved its ultimate goals and sustainability was a serious problem[336].

[336] Japan International Cooperation Agency. *Ex-Post Evaluation of Japanese Grant Aid Project "The Project for Groundwater Development for Rural Water Supply in Zambezia Province"*. Japan International Cooperation Agency, 2009. URL http://www2.jica.go.jp/en/evaluation/pdf/2009_0019500_4.pdf

This should make it clear that, even if management is local, simply providing infrastructure is not sufficient. This is not a new lesson, and Improve International [2015] provides a list of statistics and studies related to non-functional water points or frequent water point breakdown in the developing world[337]. 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[338], but more often they reflect an overly simplistic

[337] Improve International. Statistics on water point failures, 2015. URL https://improveinternational.wordpress.com/handy-resources/sad-stats/

[338] P. Ryan. *Madagascar WASH Sector Sustainability Check*. Peter Ryan Consulting, 2014

approach in addressing the complexities of water delivery in the developing world 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.

Common fundamental barriers to achieving universal and sustainable WSS globally in areas without it (in addition to lack of investment) include:

- lack of political will and governance,
- lack of innovative or new technology adoption,
- lack of adequate community consultation,
- lack of local financing and cost recovery planning and collection,
- lack of dynamic operation and maintenance, and
- failure to evaluate if the existing programmes and systems are successful and sustainable[339].

Indeed there is a general lack of funding for WASH project monitoring or maintenance post interventional completion, and as such systematic documentation or consequences for entities responsible for poor functioning WASH systems[340]. There is an additional need for clarity in WSS market and regulatory structures, commercial incentives for private entities, greater active engagement between local and national regulators and governments, and where the roles and responsibilities of each public and private entity begin, end, and interface/cooperate.

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 system failure[341]. For example, without proper planning and foresight, even after a competitive tender process, poor communities can remain tied to a water monopoly with no competitors once contracts have been awarded [Davis, 2005]. Exclusivity in contracts is a contentious issue with most contracts in SSA being short-term management and lease contracts with renegotiation common, largely at the expense of the community directly or indirectly [Budds and McGranahan, 2003, Davis, 2005].

For example, WASH contracts can be grouped into three common types based on their scope and length:

1. management contracts (3-5 years),
2. lease contracts (5-15 years), and
3. concession contracts (20-30 years).

Lease or management contracts generally require only O&M of water supply infrastructure for a specified time by the contractor. In contrast to lease and management contracts, concessions are

339 C.L. Moe and R.D. Rheingans. Global challenges in water, sanitation and health. *Journal of Water and Health*, 4(Supplement):41–57, 2006; and M. Montgomery, J. Bartram, and M. Elimelech. Increasing functional sustainability of water and sanitation supplies in rural sub-Saharan Africa. *Environmental Engineering Science*, 26 (5):1017–1023, 2009

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

341 C. Kirkpatrick, D. Parker, and Y.-F. Zhang. State versus private sector provision of water services in Africa: An empirical analysis. *The World Bank Economic Review*, 20(1):143–163, 2006; J. Budds and G. McGranahan. Are the debates on water privatization missing the point? Experiences from Africa, Asia and Latin America. *Environment and Urbanization*, 15(2): 87–114, 2003; and J. Davis. Private-sector participation in the water and sanitation sector. *Annual Review of Environment and Resources*, 30:145–183, 2005

when the private sector contractor assumes the commercial risk and responsibility for CapEx with multi-decadal contracts necessary for any private operator to recover their investment and achieve a profit [Budds and McGranahan, 2003, Davis, 2005]. Generally in management or lease contracts, the ownership of assets and responsibility for CapEx, network extension, and commercial risk remains with the public sector [Davis, 2005]. In Ribáuè, we see a conventional competitive tender process with a private operator awarded an exclusive contract of 5 years. As noted previously, the private operator, STCC, largely assumes O&M costs, although STCC also has responsibilities for network expansion[342]. This may potentially place greater commercial risk on STCC than what might be the case for a typical management or lease contract, although the terms of this contract (including expected network expansion) were clearly spelled out in advance. In general, unnecessary risk can commonly be avoided (or at least mitigated) if clear lines of responsibility, engagement, and effective communication occur between all relevant stakeholders to improve the probability of a sustainable WSS programme engendering consistently positive outcomes over time.

[342] STCC also is responsible for CapEx in the way of yard tap installations, but this would be expected for a piped system.

The WSS sector has rightly made capacity building an area of major emphasis, and this has led to improvements in terms of technical skills for O&M of water systems and strengthening of institutional capacity (including monitoring and evaluation) at local, provincial, and national levels for governance. However, this capacity building may need to be expanded to include other elements, including the financial aspects of water supply. In the case of Ribáuè, given that the system only supplies to one town, limited local capacity for and interest in operating the piped system existed[343]. Although the operator has received technical training in O&M, 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 can help maintain transparency in the level of profitability of a system, areas where costs must be reigned in, areas where necessary costs are being avoided (such as CapManEx), and opportunities for increased revenue. While increasing costs in the short-term, provisions for longer engagement on the part of supervisory organisations to provide continued capacity building in these areas may have significant positive implications for sustainability that warrant the additional investment.

[343] The same is true for water kiosk operators.

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 can arise when people with low education and no previous experience in small or informal businesses are left to manage water infrastructure without any training. 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[344]. 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.

[344] H. Lockwood and S. Smits. *Supporting rural water supply: Moving towards a service delivery approach*. Practical Action Publishing, UK, 2011

Data collection and analysis, clear accounting books, 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 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[345].

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

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Appendix A: Calculating Age-Specific Diarrhoea Morbidity and Mortality

In this appendix, we provide information on the age-specific estimates of diarrhoea morbidity and mortality that are used in estimating the health benefits of water piped to the home. As we will be attempting to estimate both cases of diarrhoeal diseases and mortality due to such diseases for the town of Ribáuè for a given year, we first provide estimates of the age distribution for Ribáuè and then produce age-specific estimates of diarrhoea morbidity and mortality.

The Age Distribution for Ribáuè

Both the UNICEF-sanctioned baseline survey from September and October 2012 and our survey from November 2014 collected the ages of household residents for each household sampled. Although full age distributions can be produced, we will only consider the age range of 0-4 years, 5-14 years, and 15 years and older, as these are common age ranges for reporting of mortality. Consequently, when we refer to "age-specific" morbidity or mortality, it will be considered in the context of these age ranges. Estimates of the age distribution for the town of Ribáuè based on these ranges and for the years of 2012 and 2014 are presented in Table 61. Additionally, shown in black are the estimated number of individuals falling into each of these age ranges for the town of Ribáuè in 2014. These totals are based on an estimated population size of 33,931[346].

[346] This total is extrapolated from the town population size of 26,328 reported in the 2007 census, using district growth projection rates as reported by Instituto Nacional de Estatística [2010a]. Estimates shown in the table sum to 33,932 due to rounding.

	< 5 years		5-14 years		≥ 15 years	
	N	Percentage	*N*	Percentage	*N*	Percentage
2012	188	15.45% (13.42%, 17.48%)	391	32.13% (29.50%, 34.75%)	638	52.42% (49.62%, 55.23%)
2014	384	15.76% (14.31%, 17.20%)	774	31.76% (29.91%, 33.61%)	1,279	52.48% (50.50%, 54.47%)
Est. 2014	5,347		10,777		17,808	

Table 61: Distribution of ages for the town of Ribáuè in household surveys carried out in 2012 and 2014. Cells shaded in black represent the estimated number of individuals in the town of Ribáuè falling into each age category.

Age-Specific Diarrhoea Morbidity

From both the baseline survey of 2012 and our survey from 2014, we can estimate age-specific diarrhoea morbidity, as measured through incidence of diarrhoea[347] in the two weeks preceding the survey for the town of Ribáuè. Due to slight differences between the survey instruments in terms of how they collected data on diarrhoea incidence, the 2012 survey allowed for estimation for the same age ranges considered in Table 61, whereas the 2014 survey only allowed for calculating incidence for children under the age of 5 and those who are at least 5 years of age. To allow for direct comparison, we present a corresponding estimate of those ages 5 or higher for 2012, and estimates of incidence are shown in Table 62.

[347] Here, incidence of diarrhoea is defined to be three or more loose or liquid stools in a given day.

<table>
<tr><th></th><th>< 5 years</th><th>5-14 years</th><th>≥ 15 years</th></tr>
<tr><td rowspan="2">2012</td><td rowspan="2">9.04% (4.94%, 13.14%)</td><td>1.53% (0.32%, 2.75%)</td><td>0.78% (0.10%, 1.47%)</td></tr>
<tr><td colspan="2">1.07% (0.44%, 1.70%)</td></tr>
<tr><td>2014</td><td>8.59% (5.79%, 11.40%)</td><td colspan="2">1.17% (0.70% 1.63%)</td></tr>
</table>

Table 62: Incidence of diarrhoea in the past two weeks by age (with accompanying 95% confidence intervals), as reported in the town of Ribáuè in September 2012 and November 2014. Cells shaded in black represent minimum incidence recorded for a particular age range.

In the interest of producing conservative estimates of health impacts, we opted to use the lowest age-specific estimates of incidence of diarrhoea. These are shaded in black in Table 62. Given that the lowest estimate of incidence for those of at least 5 years of age occurred for 2012 estimates, and this year allows for further breakdowns into ages 5-14 and ages above 14, we opted to use estimates based on these further breakdowns. Thus, in our calculations, we have assumed incidence of diarrhoea by age is as shown in Table 63. Using estimated numbers of individuals in each of these age ranges for the town of Ribáuè in 2014, we can estimate the total number of individuals in each age range who would be expected to experience diarrhoea within a two week period, and this can the be adjusted to an annual total. This produces the total number of cases by age category, which are shaded in black.

	< 5 years	5-14 years	≥ 15 years
Incidence	8.59%	1.53%	0.78%
Cases	12,389.61	4,458.97	3,763.28

Table 63: Incidence of diarrhoea used for each age range in estimation of health impacts for the town of Ribáuè. Cells shaded in black reflect the expected annual cases by age category for the year 2014.

Age-Specific Diarrhoea Mortality

As is the case in many developing countries, Mozambique has limited data on causes of death at all levels (national, provincial, district, local), making it virtually impossible to produce town-level estimates and meaning that national level estimates will need to be applied for the town of Ribáuè[348]. Even at a national level, it is difficult to accurately estimate not only mortality by cause of death but mortality rates as a whole. Consequently, in order to estimate age-specific diarrhoea mortality for Mozambique, we had to

[348] Although household surveys could be used to produce estimates, the ethics of including questions related to mortality in household surveys is contested, and we chose not to include such questions in our survey instrument.

combine multiple sources of information. These were necessarily restricted to two age ranges ($<$ 5 years, $\geq$ 5 years) due to data limitations. To assess the credibility of these estimates, we computed corresponding age-specific diarrhoea mortality for the WHO Africa Region. These estimates are provided in Table 64.

		All Causes		Diarrhoea		
	Population	Deaths	Percent	Deaths	Percent	Probability
Africa Region (2012):						
$<$ 5 years	147,882,000	3,070,148	2.08%	317,085	10.33%	0.21%
$\geq$ 5 years	746,365,000	7,617,131	0.83%	285,632	4.60%	0.04%
Total	894,247,000	9,274,388	1.04%	602,717	6.50%	0.07%
Mozambique (2013):						
$<$ 5 years	4,316,715	86,765	2.01%	6,941.2	8.00%	0.16%
$\geq$ 5 years	22,150,465	217,935	0.98%	7,684.4	3.53%	0.03%
Total	26,467,180	304,700	1.15%	14,625.6	4.80%	0.06%

Table 64: Age-specific mortality by all causes of death and due to diarrhoeal diseases. Totals are presented for both Mozambique for 2013 and the WHO Africa Region for 2012. Cells shaded in grey are totals presented by the World Health Organization Global Health Observatory for 2013, while cells shaded in black present the estimated probability of death due to diarrhoeal diseases for individuals in a particular age range for the World Health Organization Africa Region for 2012 and Mozambique for 2013.

Although mortality is usually measured as deaths per 1,000 individuals for a given age interval, we present these as percentages representing the percentage of individuals in that particular age interval that would be expected to die in a given year. In the case of estimates of overall mortality and diarrhoea mortality presented for the WHO Africa Region, these estimates are based on totals for 2012 reported by World Health Organization [2014], so estimation was straightforward.

For Mozambique, World Health Organization Global Health Observatory [2015] reports the total number of deaths for 2013, along with the percentages of all deaths caused by diarrhoeal diseases and a similar percentage for children under the age of 5. These are all shaded in grey in Table 64. In order to calculate age-specific mortality rates and diarrhoea mortality for those of at least 5 years of age, we had to combine this with both population distribution information and age-specific mortality reported for 2013 by World Bank [2015]. Although the reported number of deaths for children under the age of 5 seemed credible, crude mortality rates reported for the general Mozambican population produced an estimate of roughly 375,000 deaths for 2013, more than 20% higher than the estimate of 304,700 reported by World Health Organization Global Health Observatory [2015]. We opted for the lower estimate, which brought over all mortality rates more closely in line with those observed for the WHO Africa Region. With estimates of age-specific mortality rates, we could estimate diarrhoea mortality for the entire population and for children under the age of 5, allowing us to back out an estimate for deaths to those of at least 5 years of age. This then allowed us to estimate the diarrhoea mortality rate for those over the age of 5. Finally, we produced probability calculations which represented the likelihood that an individual in a given age category will die from a diarrhoeal disease in a given year.

To estimate the number of deaths by age range as considered in Table 61 for the town of Ribáuè, we assumed that the probabilities presented for Mozambique in Table 64 were applicable to 2014 and that the probability presented for all those who were at least 5 years of age applied uniformly to all ages in that range. In other words, the probability of death was the same for individuals in the age range of 5-14 years and those who were 15 or older. Under these assumptions, estimated deaths due to diarrhoea for those in the town of Ribáuè in 2014 are as highlighted in black in Table 65.

	$<$ 5 years	5-14 years	$\geq$ 15 years
Incidence	0.16%	0.03%	0.03%
Cases	8.92	3.88	6.41

Table 65: Probabilities of death due to diarrhoeal diseases used for each age range in estimation of health impacts for the town of Ribáuè. Cells shaded in black reflect the expected annual deaths due to diarrhoeal diseases by age category for the year 2014.

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