Using baseline surveys to inform interventions and follow-up surveys: a case-study using the Nampula Province Water, Sanitation, and Hygiene Program

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ABSTRACT

The Nampula Province Water, Sanitation, and Hygiene Program is a partnership among the Government of Mozambique, UNICEF, and the Australian Government focused on achieving the United Nations' Millennium Development Goals for water and sanitation in Mozambique and concentrated on five small towns in Nampula Province. Before implementation of water, sanitation, and hygiene (WASH) interventions in these towns, a baseline survey was carried out in 2012. We show how such a survey can be used to characterize the state of the three WASH sub-themes (water, sanitation, hygiene) pre-intervention, suggest possible new emphases of or modifications to proposed interventions, and inform the design of follow-up surveys to best gauge the impact of the interventions.

Key words | baseline study, control, Mozambique, statistical survey methods

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INTRODUCTION

The United Nations' Millennium Development Goals (MDGs) Report of 2012 announced that, while 'the target of halving the proportion of people who lack dependable access to improved sources of drinking water' had been reached five years ahead of the 2015 target deadline, sub-Saharan Africa was unlikely to reach the MDGs target by a large margin with 61% of people using an improved source in 2010 compared to a target of 75% (United Nations 2012, pp. 3, 52). In the Mozambican Report on the MDGs in 2010, the trend, while positive, reflects the greater sub-Saharan situation, which is substantially worse than the global average. This report estimated that the percentage of the population with access to clean water increased from 40.3% in 1997 to 54% in 2009 in rural areas and from 30% to 60% over the same time frame for urban areas. At the same time, access to improved sanitation rose from 25.3% in 1997 to 40% in 2009 in rural areas, and urban areas saw access reach 50% by 2009 (Republic of Mozambique 2010).

These estimates tend to be significantly higher than those reported by the World Health Organization-UNICEF Joint Monitoring Program (JMP), which estimated that access to improved water sources increased from 27% in 2000 to 33% in 2011 for those living in rural areas and that access to improved sanitation rose from 5% in 2000 to 9% in 2011 in rural areas and 29% in 2000 to 31% in 2011 in urban areas. The only area where the JMP provided a more optimistic outlook was access to improved water sources in urban areas, where it estimated that access rose from 75% in 2000 to 78% in 2011 (World Health Organization & UNICEF 2013).

The JMP estimates show a clear disparity between urban and rural areas in terms of access to improved water and sanitation. However, it is unclear whether peri-urban areas more closely reflect urban areas or rural areas in terms of water and sanitation access, and it is within this context that the Nampula Province Water, Sanitation, and Hygiene (NAMWASH) Program was conceived. The NAMWASH Program is being delivered through a partnership among the Government of Mozambique, UNICEF, and the Australian Government Department of Foreign Affairs and Trade

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with the express intention of accelerating gains towards the MDGs for water and sanitation in Mozambique. It aims to do this through an integrated approach among the three WASH sub-themes (water, sanitation, hygiene), consisting of the interventions briefly described in Table 1. The peri-urban environment means a greater emphasis on WASH interventions suited for an urban environment, so the rehabilitation of existing piped water supply and expansion of piped services (including promotion of household connections) is deemed important, as are solid and liquid waste removal services and hygiene promotion advocating soap use.

Although water infrastructure will be owned by the government, the program advocates the decentralization of operations and maintenance (O&M) to the municipal level with O&M to be carried out by the private sector on a concession, lease, or contract basis. For sanitation and hygiene interventions, the Participation and Community Education (PEC) Zonal approach will be modified in consultation with local non-governmental organizations (NGOs) for a peri-urban environment. PEC Zonal is a widely used approach in rural Mozambique that is geographically focused and implemented by NGOs. These NGOs are contracted for periods of two years and paid on a quarterly basis based on achievement of pre-specified outcomes (e.g., communities achieving open defecation free status). They are responsible for a variety of activities meant to produce locally managed sustainable WASH improvements, including: culturally relevant community-based activities meant to raise awareness of or relay information related to proper sanitation and hygiene; lending support to the operation and maintenance of WASH facilities by training maintenance groups and WASH committees; and aiding local service providers, including mechanics, artisans, and builders, in the building or repair of water sources and latrines (Pendly & Obiols 2013).

Table 1 | Proposed interventions under the NAMWASH Program

Intervention	Description
Water	• Construction of new standpipes and sustainable expansion of piped water supply through rehabilitation of existing water supply, construction of new piped water supply, and, where applicable, construction of water treatment facilities. Additionally, the program will promote household water connections. • Sustainable management of water supply through tariff setting and revenue collection, water safety plans, and reinvestment strategies for water revenue.
Sanitation and Hygiene	• Development of sanitation master plans with an emphasis on sustainability and both solid and liquid waste management. • Sanitation and hygiene promotion through PEC Zonal approach.
Capacity building	• Capacity building for local and district authorities for their engagement with water and sanitation users in water and sanitation management.
Schools	• Construction or improvement of school water supply facilities, latrines/urinals, and handwashing facilities. • School hygiene promotion activities using a combination of sports-learn hygiene, participatory hygiene and sanitation transformation, and community-led total sanitation with the intention of children being agents for transfer of knowledge and behavior change in the household.

As part of the NAMWASH Program, UNICEF Mozambique commissioned a baseline study in 2012 before interventions started. The baseline study consisted of a survey of households, schools, and water points that focused on five target towns (Mecuburi, Monapo, Namialo, Rapale, and Ribaue) projected to receive phased WASH interventions over the five-year period from 2012 to 2016. The study also included two control towns (Liupo and Namapa-Erati) expected to receive no such interventions under the NAMWASH Program. The locations of these towns are shown in Figure 1.

The five target towns largely fall along the Nacala corridor, a burgeoning export route for the extractive industries extending from the Port of Nacala, through Nampula Province and Malawi, and into the coal-exporting Province of Tete. Growth in towns along this corridor is creating both pressures upon current infrastructure and additional delays in delivery of proposed infrastructure because of increased demand. Higher gross domestic product, as well as royalties and taxes from the extractives industry, are potentially a source of funding to deal with this increased demand and to address current deficits, and the NAMWASH Program

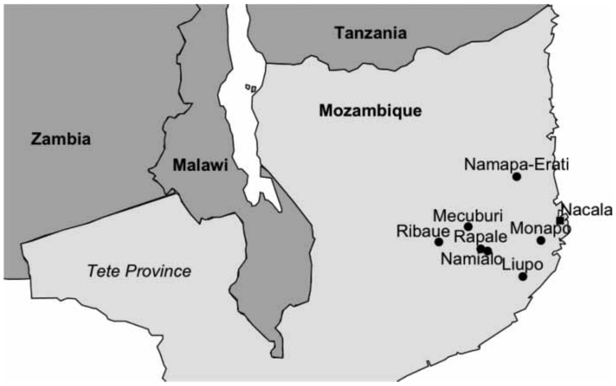

Figure 1 | Target and control towns included in the NAMWASH baseline study, along with Nacala.

has been designed to investigate the feasibility of such interventions to provide evidence in support of advocacy for scaling up the NAMWASH approach.

Current interventions are projected to impact the following numbers of residents:

1. Water interventions – 20,000 people for each of Ribaue and Mecuburi, 25,000 people for Rapale, 40,000 people for Monapo, 45,000 people for Namialo.
2. Sanitation and hygiene interventions – 10,000 people for each target town.

School interventions will be carried out in each of these target towns.

This paper presents selected results from the baseline study in order to characterize the state of the three WASH sub-themes (water, sanitation, hygiene) pre-intervention. We use these results to highlight some areas of emphasis as well as modifications to the proposed interventions that are worth considering. Finally, we provide recommendations for the design of follow-up surveys to best gauge the impact of the interventions.

METHODS

Study design and sampling

The baseline study for the NAMWASH program was set up to be an easily replicated study that could monitor the efficacy of the interventions post-program. The study was designed by UNICEF Mozambique and the Government of Mozambique and included household surveys, school surveys, and water point surveys which consisted of both questions of the respondents and interviewer observations. The sampling methodology followed that of Bennett *et al.* (1991) and the Rapid Assessment of Drinking Water Quality Approach (World Health Organization & UNICEF 2012).

For the seven small towns included in the survey, a total of 1,610 households consisting of 7,565 individuals were sampled with sampling being carried out by first selecting a total of 230 clusters of approximately equal size (based on enumeration areas) from these towns and then randomly sampling seven households from each cluster. Of these 1,610 households, 70% were from target towns (consisting of 5,680 individuals), and 30% were from control towns (consisting of 1,885 individuals). Interviews were conducted by trained interviewers with an adult at the household and in that adult's native language/dialect. Primary water sources nominated by sampled households were included in a water point survey, and a random selection of households and water points nominated by those households were also subjected to water quality testing. The water point survey was administered to an appropriate official with oversight of a given water source, and water quality testing included measuring both microbiological (thermotolerant coliforms) and physicochemical (turbidity, pH) parameters. The school survey sampled a total of 40 schools across the seven towns, 30 of which were from target towns. Further details of the sampling methodology are provided by WE Consult (2012), the firm that was contracted by UNICEF to carry out the survey.

In total, the baseline study took 5 weeks to complete (early September to early October 2012) and comprised approximately 2% of the total program budget. Subsequent to the survey, Murdoch University was contracted to carry out a rigorous independent analysis of these pre-collected data. Ethics approval covering the analysis of this survey as well as the implementation of a follow-up survey were obtained from the Murdoch University Human Research Ethics Committee (Project No. 2013/184).

Statistical methods

The correct statistical analysis of survey data similar to that contained in the NAMWASH baseline study requires that we take into account the study design. Although exact cluster sizes were not known for the household survey, these were based on enumeration areas, so we assumed that they were of roughly the same size, producing a probability proportional to size sample (Lohr 1999). In the case of the school survey, the exact number of schools in each town is known, so we were able to post-stratify on town to produce differential sample weights for schools based on the town in which they are located. Sample weights could not be incorporated for either the water point survey or the water quality data, as the number of unique water points in each town was not known, nor did we know the number of households being serviced by individual water points. Consequently, analyses based on the water point survey and water quality measurements assumed simple random sampling.

All analyses were carried out in R (R Core Team 2013), and analyses of the household and school survey data utilized the 'survey' package (Lumley 2004, 2012). This package includes functionality to obtain correct point estimates and standard errors using the Horvitz–Thompson estimator and corresponding variance (Horvitz & Thompson 1952). It also contains sample survey method extensions of a variety of common statistical methods including *t*-tests, chi-square tests, and generalized linear models, all of which were used in our analyses. We also made use of the 'censReg' package (Henningsen 2013) for censored regression models for analyses based on thermotolerant coliform colony-forming units (CFUs) per 100 mL, as CFU measurements were both right- and left-censored. When presenting point estimates, whether means or proportions/percentages, these are presented with 95% confidence intervals immediately following in parentheses.

RESULTS AND DISCUSSION

Water sources

At present, it is estimated that only 47.1% (45.6%, 48.7%) of households in target towns use improved water sources, which include piped water sources (household taps, yard taps, or public taps), boreholes, and protected wells, and only 8.1% (6.5%, 9.6%) use piped water sources. A separate willingness-to-pay study carried out by UNICEF Mozambique in Ribaue showed that the most preferred piped sources were public taps (48%) followed by yard taps (25%), and household connection (22%) with 84% of respondents being willing to pay for access to piped water (UNICEF Mozambique 2012). However, the overwhelming majority (68%) were only willing to pay between 1 and 49 meticais per month with willingness to pay (WTP) decreasing with higher payment categories. Focus group discussions suggested that this low WTP could be due to many households not currently paying for water or paying a fixed amount in the range of 5–20 meticais per month that they would not want to increase. Low WTP could also be due to people not understanding many of the benefits (particularly health benefits) associated with improved water supply. This suggests that initial subsidy schemes and increased awareness of the health benefits of piped water may be crucial to the success of piped water supply. Cairncross & Valdmanis (2006) advocate household connections, not only because of the economic returns due to increased WTP and a more effective mechanism for collecting payments, but also because of the hygiene and, consequently, health impacts of such water supply. Thus, it is advisable to give serious consideration to provision of household connections for these reasons in spite of stated preferences for public taps.

If households are appropriately informed of the benefits of piped water and such sources are properly subsidized, the proposed water infrastructure intervention should increase access to piped water sources, and this is expected to lead to a significant increase in the amount of water consumed per person per day and a significant decrease in the time spent collecting water, as highlighted in the statistical analyses presented in Table 2. Those with access to piped water sources consume 22.7 L (19.8 L, 25.5 L) per person per day as compared to 17.1 L (16.2 L, 18.0 L) for other improved water sources and 17.8 L (17.1 L, 18.6 L) for unimproved water sources. At the same time, those using piped sources spend an average of 35.1 (26.5, 43.7) minutes per day collecting water as compared to 56.8 (53.1, 60.6) and 56.0 (52.7, 59.3) minutes per day for those using other improved and unimproved water sources, respectively. The increased quantity of water collected and decreased time spent collecting water associated with piped water supply has implications that extend to hygiene, as we discuss later.

A greater presence of improved water sources should lead to an overall improvement in water quality. Water

Table 2 | Key water supply results and corresponding statistical analyses

Result	Statistical model/test	Statistical evidence
1. Those using piped water sources consume more water per person per day.	Linear regression of log-transformed water consumption on water source type, distance to water source, and sex of the head of household.	Likelihood ratio test p-value < 0.001 corresponding to water source type.
2. Those using piped water sources spend less time collecting water.	Pairwise t-tests of time spent collecting water for piped, other improved, and unimproved sources.	Water collection times are less for piped water sources than both unimproved sources ($t = -4.711$, p-value < 0.001) and other improved water sources ($t = -4.891$, p-value < 0.001).
3. Greater use of improved water sources should lead to better water quality at the source.	Censored regression of log-transformed CFUs at the source on dummy variable indicating whether the water source is improved.	Coefficient for dummy variable is highly significant and negative ($\beta = -3.878$, p-value $=$ 0.0001), corresponding to better water quality for improved sources.
4. Use of improved water sources need not lead to better water quality at the home.	Censored regression of log-transformed CFUs at the home on dummy variable indicating whether the water source is improved.	Coefficient for dummy variable is not statistically significant (p-value $= 0.125$), although p-value is still quite small.
5. Not a significant difference in rate of water treatment at the home based on water source type.	Chi-square test for water treatment rates by water source type.	p-value $= 0.945$.

quality data were available for 65 unique water sources across the seven towns, and a total of 74 complete paired household-water source water quality measurements were available for analysis. In assessing the water quality at the source (note that in the case of piped water sources, measurements at the 'source' refer to measurements taken at the point of collection), we had to account for some water sources being sampled multiple times, and we opted to use every unique set of water quality measurements for a water source in our analyses. This approach ignored the inherent dependence in multiple measurements on the same water source, but it was able to account for the variability in water quality measurements from the same source. Note that the use of a censored regression model due to left- and right-censoring of some CFU measurements prevented us from considering standard repeated measures analyses. Using all unique sets of measurements for each water source, we found improved water sources to have significantly lower thermotolerant coliform CFUs (1.00, (0.50, 34.25) (here, we present medians along with the first and third quartile due to censoring of observations and skewness in distributions) than unimproved water sources (33.00, (9.00, 50.83)). (For frame of reference, the Mozambican standard for thermotolerant coliform CFUs is 0 CFUs (Pires n.d.).) Results were similar for turbidity.

While there is strong evidence that water quality is better for improved water sources, this does not guarantee that those using improved water sources ultimately have better water quality at the home (CFUs increased to 20.50 (0.50, 101.00) (we note that a value of 101 corresponds to a right-censored observation; in other words, the number of CFUs is at least 101, but the exact value is not known) for improved sources and 65.50 (3.25, 101.00) for unimproved), as evidenced in Table 2. If there is in fact no real difference in water quality at the home for those using improved and unimproved water sources, then it suggests that either those using improved water sources compromise that quality in transit to or at the home, or those using unimproved water sources take extra measures to improve the water quality at the home.

The lack of a significant difference in water quality at the home for those using improved water sources and those using unimproved water sources is almost certainly not due to increased diligence in treating water on the part of those using unimproved sources, as there is not a significant difference in water treatment rates for those using improved water sources and those using unimproved water sources. More likely, the lack of a difference in water quality at the home is due to contamination of the water from improved sources in transit to the home due to the storage container not being properly cleaned. Even though an estimated 93.4% (92.2%, 94.8%)

of households report cleaning the water storage container every time before filling with water, contradictorily 40.2% (37.2%, 43.1%) report having no standard practice for washing the storage container, and only 3.89% (0.93%, 6.85%) report using water and soap. Field observations suggested lack of cleanliness of transport containers with cleaning of transport containers being undertaken at the water source by pre-filling the container and rubbing the inside by hand before refilling with water. In addition, only an estimated 47.0% (44.0%, 50.1%) of households pour water from the storage container into a cup using a dedicated glass when drinking water. Most simply dip a cup into the container from which to drink. In both cases the frequency and method of cleaning glasses/cups is not known. These suggest what would be expected, namely that any improvements in water quality as a result of the proposed water intervention can easily be negated by poor cleaning practice when it comes to water storage containers and cups.

Even though use of improved water sources is around 50% for households in target towns, schools in target towns have a much higher rate of access, as 96.7% (82.8%, 99.9%) use improved water sources. As with households, however, this does not necessarily translate to improved water quality, as only 23.5% (10.6%, 44.4%) of schools collect and store the water safely. Storing water 'safely' is defined as storing the water with a lid, cleaning the water storage container properly and at least once per week, and using separate containers to collect and store water. Consequently, while schools should be receiving water of consistently good quality, they still face some of the same challenges when it comes to cleaning procedures for storage containers, potentially compromising that quality. Thus, it is recommended that sanitation and hygiene promotion programs, both at the school level and community level, take special care to emphasize the variety of ways in which otherwise clean water can be contaminated after collection and the measures that can be taken to prevent this.

Sanitation

While access to safe drinking water is important and should be achievable with increased availability of improved water sources, the role of sanitation is critical in achieving positive health impacts for WASH interventions and cannot be ignored. While proper cleaning of water storage containers may be effective in maintaining water quality, methods of disposal of fecal matter can have a potentially large impact on water quality at the source, as run-off of human waste into water sources may contaminate or pollute the water. At present, it is estimated that only 7.6% (6.3%, 9.2%) of households use improved latrines, which include pour/flush toilets, ventilated improved latrines, pit latrines with concrete slabs, and composting toilets, and use of an improved latrine is related to both socio-economic status and level of education of the head of household with the poor and uneducated less likely to have such facilities. This suggests that subsidy schemes may be necessary to see an increase in improved latrine construction for those of low socio-economic status. In spite of most families using unimproved facilities or shared latrines, interviewers considered 89.0% (87.2%, 90.0%) of latrines to be clean or very clean, and women (67.3% (64.2%, 70.3%)) and children (20.0% (17.0%, 23.1%)) were most responsible for the cleaning.

Those using latrines tend to either cover a full pit and move the location of the latrine (48.6% (45.6%, 51.8%)) or have never needed to fill in the pit (50.5% (47.4%, 53.6%)). Only one household reported having their pit emptied. This was not surprising after examining the layouts of these towns, as there appeared to be ample room for households to relocate latrines. Consequently, although liquid waste removal services may become a pressing need as these towns continue to grow, the current lack of demand would make it difficult to convince residents of their need at present. This would suggest that emphasis on construction of improved latrines for those currently using unimproved latrines or openly defecating would be a much more prudent use of resources than advocacy for liquid waste removal services.

As was observed with improved water sources, schools are more likely to have improved latrines with an estimated 80.3% (65.8%, 89.6%) of schools in target towns having functioning latrines (all of which were observed to be in use), of which 72.1% (60.6%, 81.3%) are improved latrines. Approximately 90.0% (83.5%, 94.8%) of schools with functioning improved latrines have separate facilities for boys and girls. In spite of this, girls are far less likely to use the latrines at schools (see Table 3). This could be due to a number of factors, including the absence of sanitary bins in all school latrines and locks on girls' toilets for only 10.0% (3.0%, 30.2%) of the schools. This indicates a lack

Table 3 | Key sanitation results and corresponding statistical analyses

Result	Statistical model/test	Statistical evidence
1. Households that are poor or where the head of household is uneducated are less likely to use an improved latrine.	Logistic regression of use of an improved latrine on socio-economic status, sex of the head of household, level of education of the head of household, whether the head of household is under 20 years of age, and whether the household has a disabled person.	Significant positive association between use of an improved latrine and both socio-economic status and level of education (likelihood ratio p-value < 0.001 for each).
2. Girls are less likely than boys to use latrines at school.	Logistic regression of usage of latrines at school on sex and school.	The coefficient for sex is $\beta = -1.01$ with p-value $= 0.019$, meaning that the odds of a girl using a latrine at school is approximately 2.74 times less than that of a boy for a given school.

of recognition of girls' security and menstrual hygiene needs that must be addressed (Sommer 2010). The last obvious factor is cleanliness of the facilities, as interviewers estimated that only 24.3% (12.1%, 42.7%) of improved latrines in schools are clean or very clean. This is in stark contrast to the cleanliness noted for household latrines and illustrates the challenges associated with maintaining cleanliness in common spaces. This would suggest the need for a more proactive program with school children regarding maintenance and care for this element of school infrastructure.

Hygiene

The lack of improved latrines in the home and the lack of cleanliness of latrines at schools highlights the need for good hygiene practices, and this appears to be an area where great strides can (and need) to be made in these towns. In examining households, interviewers found handwashing stations in only 17.5% (15.5%, 19.7%) of households, and soap/ash were available at only 41.5% (35.0%, 48.3%) of such handwashing stations. The presence of handwashing stations in the household as well as availability of water and soap/ash were related to socio-economic status, the education level of the head of household, and the age of the head of household, as shown in Table 4. In particular, those households that were poor, had an uneducated head of household, or had a head of household under the age of 20 were less likely to have handwashing stations. Even when handwashing stations were present, these households were less likely to have water or soap/ash present at the station.

Given the low prevalence of handwashing stations as well as presence of soap/ash at handwashing stations, it is not surprising to find that very few people (approximately 9% of men, 8% of women, 7% of school children, and 5% of other children) reported washing their hands with soap/ash. Moreover, when asked to demonstrate their handwashing technique to the interviewer, only 25.0% (11.5%, 43.4%) of those who reported using soap/ash were observed to do so. Given this disparity in reported and observed handwashing behavior, it is necessary that follow-up surveys include observed handwashing behavior and for a variety of contexts.

Decisions regarding whether or not to use soap/ash seem to be context-specific. For instance, only 8.9% (6.9%, 11.4) of primary caregivers reported using water and soap when washing hands before eating, but this increased to 29.1% (25.7%, 32.7%) and 26.5% (23.2%, 30.0%) when washing hands after using the toilet or cleaning children's feces, respectively. Handwashing at such key times has health implications, as Curtis & Cairncross (2003) note an inverse relationship between handwashing at key times and incidence of diarrhea. In addition to low rates of usage of soap/ash, the overwhelming majority of people (approximately 77% of men, 81% of women, 86% of school children, and 89% of other children) wash their hands in a shared bowl or bucket, allowing for greater transfer of pathogens among those washing their hands in the stagnant water.

Table 4 | Key hygiene results and corresponding statistical analyses

Result	Statistical model/test	Statistical evidence
1. Households that are poor or have an uneducated head of household are less likely to have handwashing stations present at the home.	Logistic regression of the presence of handwashing stations on type of latrine, type of water source, socio-economic status, level of education of the head of household, sex of the head of household, and whether the head of household is younger than 20.	Socio-economic status and level of education of the head of household are positively associated with presence of handwashing stations (likelihood ratio p-value < 0.001 for each).
2. Households that are poor, have a young head of household, or have an uneducated head of household are less likely to have soap/ash available. Those with an uneducated head of household are additionally less likely to have water available at the handwashing station.	Separate logistic regressions of the availability of water and the availability of soap/ash on the type of water source, socio-economic status, level of education of the head of household, sex of the head of household, and whether the head of household is younger than 20.	Level of education is positively associated with availability of both water and ash/soap at handwashing stations (likelihood ratio p-values of 0.002 and 0.013, respectively), and socio-economic status and age of the head of household are positively associated with availability of ash/soap (p-values of 0.025 and 0.011, respectively).

The combination of not using soap/ash, failing to wash hands at key times, and using a shared bucket is cause for concern in terms of not only health but also basic hygiene knowledge. We would expect that, at minimum, most children would have this knowledge, as an estimated 60.1% (44.8%, 73.4%) of schools in target towns have hygiene education. If so, this knowledge is not being translated into home practices. Even in the schools, it is possible that there are some lapses, as we highlighted some of the cleanliness issues with the latrines, and only one of 30 schools had a hand basin in the latrines (and this hand basin did not have water or soap/ash available).

As important as hygiene knowledge is, this must be translated into action in order to gain health benefits. Biran *et al.* (2009) found massive discrepancies in reported and observed handwashing behavior (much in line with what we noted for NAMWASH target towns) and failed to show a significant increase in observed handwashing with soap at key times after a series of hygiene promotion messages for handwashing with soap delivered over an 8-week period. This shows that care must be taken in formulating hygiene messages if they are to be expected to lead to sustained behavior change. Schmidt *et al.* (2009) found that handwashing with soap was positively associated with access to piped water, level of education, number of media items (e.g., newspaper, and radio, TV) owned or exposed to, and frequency of media exposure. This highlights that, for peri-urban environments like the towns under consideration, the use of local media for hygiene promotion would be prudent. It also suggests that the success of hygiene interventions will depend, in part, on the success of water interventions.

Aunger *et al.* (2010) found use of soap for handwashing to be less of a priority than other household tasks, including bathing, laundry, and washing dishes. It is possible that this may be due to the assumption that washing hands with water is sufficient, although it has been well established that handwashing with soap and water leads to fewer bacteria on the hands than handwashing with water alone (Burton *et al.* 2011) and reduces the risk of diarrhea (Curtis & Cairncross 2003). Aunger *et al.* (2010) also found that the key psychological reasons for explaining handwashing behavior were 'having the habit of hand-washing at particular junctures during the day, the motivated need for personal or household cleanliness, and a lack of cognitive concern about the cost of soap use'.

In addition to hygiene promotion messages or activities, the impact of access to improved water supply sources on hygiene cannot be ignored. Cairncross & Valdmanis (2006) examined the link between improved water supply (particularly piped water supply) and hygiene and showed that increased quantity of water collected and decreased time spent collecting water (both of which are expected outcomes for the NAMWASH Program) lead to better hygiene and, consequently, health outcomes. In particular, piped water at the household leads to an increase in washing hands at key moments for young mothers, including an approximate two-fold increase in the odds of a primary caretaker washing hands after cleaning children's feces and a similar increase in the odds of immediately washing soiled linen (Curtis *et al.* 1995). This signals a shift in the likelihood of individuals to wash their hands at key points due to the greater abundance of water. Additionally, piped water at the household allows for greater use of running water when washing hands, avoiding the previously highlighted issue with using a shared bucket or bowl.

Bearing all of this in mind, it is vital that hygiene become a focal point of proposed interventions for these towns to the same extent as improved water and sanitation measures. Although school programs are important, it is worth re-examining how effective children are as agents of change for the family as a whole, and it is important that school hygiene programs be paired with community hygiene programs that present the same hygiene messages to adults. Hygiene promotion messages must highlight the need to use soap for handwashing at a variety of key times (e.g., not only after cleaning feces but also before feeding children or eating) because of its health ramifications, and these messages should incorporate habit-forming activities where possible (especially for children through school programs) to be most effective. Positive messages about the importance of cleanliness and the economic benefits of liberal soap use, particularly as it relates to reduced incidence of diarrhea, could also be effective. Finally, the links between water supply and hygiene suggest that the success of hygiene interventions may in part be determined by water supply interventions, and we would advocate a focus on piped water supply, particularly household connections.

Incidence of diarrhea

Ultimately, the introduction of WASH interventions in Nampula Province aims to improve the health of its residents, and one key way in which we would expect it to do this is in reducing incidence of diarrhea and other waterborne diseases. Respondents in the household survey reported incidence of diarrhea (defined as three or more loose or liquid stools per day) in the preceding 2 weeks for all members of the household, producing an estimated incidence of 2.4% (2.0%, 2.8%) across all ages and 8.5% (6.7%, 10.6%) for children under the age of five.

To see whether or not current WASH conditions could be used to predict expected changes in diarrhea incidence by the NAMWASH intervention over the five target towns, we examined incidence of diarrhea for individuals in the past 2 weeks using a logistic regression. The model included sex and age of the individual, household socio-economic status, education level of the head of household, use of an improved water source, use of an improved latrine, presence of handwashing stations in the household, and all possible interactions among use of improved water source, use of an improved latrine, and presence of handwashing stations in the household. Both age and education level of the head of household proved to be statistically significant predictors of incidence of diarrhea (likelihood ratio p-value <0.002 for both) with incidence decreasing with age (i.e., young children are more likely to get diarrhea, matching the much higher incidence we observed for children under five) and increased level of schooling. At the same time, the three-way interaction among use of an improved water source, use of an improved latrine, and presence of handwashing stations in the household was also significant (likelihood ratio p-value <0.001), but the direction of the effect was opposite of what we would have expected with those accessing an improved water source, using an improved latrine, and having a handwashing station in the home being 'more' likely to have reported incidence of diarrhea than those not fitting these three criteria. Note that this counterintuitive result is almost certainly due to the small number of individuals fitting these three criteria relative to other categories, meaning that even small changes in reported incidence of diarrhea for members of this category could lead to drastic changes in results.

A complicating factor in both of these models was that the observed incidence of diarrhea was very low overall. The diseases that cause diarrhea are known to fluctuate throughout the year (Alexander *et al.* 2013), leading to cycles of higher and lower incidence, so incidence may have been quite different if the survey had been carried out in the wet season instead of the dry season. To illustrate this point, the 2008 Multiple Indicator Cluster Survey (MICS) (Instituto

Nacional de Estatisticia 2009) reported incidence of diarrhea (defined in the same way as for the NAMWASH baseline survey) for children under the age of five as being 22.9% for Nampula Province, whereas the 2011 Demographic and Health Survey (DHS) (Instituto Nacional de Estatisticia 2013) reported incidence for this same age group as having dropped to 10.3% for Nampula Province, a rate not too different from the reported 8.5% incidence for children under the age of five represented in the NAMWASH baseline survey. While it is possible that this is indicative of a downward trend in diarrhea incidence over time, it also could be due to timing of the surveys. The 2008 MICS was carried out from August to December of 2008, meaning that approximately half of the timeline of the survey corresponded to typical wet season months when we would expect incidence to be higher. The 2011 DHS was carried out from May to September of 2011, encapsulating typical dry season months, and the NAMWASH baseline survey began in September and ended early in October of 2012, also typical dry season months, so we would naturally expect to see lower reported incidence.

When incidence is higher, effect sizes can be larger, so a sample of the size we have can more easily detect significant effects. This means that the results obtained in the baseline survey may have changed substantially if the survey had been carried out at a different time of year or the time frame designated for reporting cases of diarrhea had been extended. Extending the time frame and inquiring about prevalence may lead to a larger number of reported cases, but it also leads to greater reporting error. At the same time, asking study participants specifically for the presence or absence of '3 or more loose or liquid stools per day' may unnecessarily force a decision by the respondent that may be prone to bias (Schmidt *et al.* 2011). This may also explain, in part, the low reported incidence.

CONCLUSIONS

The NAMWASH baseline study highlights not only the need for but also anticipated benefits of the proposed interventions. The low level of use of improved latrines is more closely in line with what would be expected for rural rather than urban Mozambique, while the level of use of improved water sources in NAMWASH towns is more similar to urban centers. However, we note that the higher level of use of improved waters sources is due primarily to boreholes and not piped water supply. Interventions leading to increased access to piped water and improved sanitation are important, given the anticipated growth and subsequent urbanization in these towns. Although a WTP survey carried out in Ribaue suggests a preference for public taps, we would advocate for household connections in light of other studies which highlight not only the economic advantages but also the hygiene and health benefits afforded by piped water at the home. Uptake of piped water will almost certainly rely on an initial subsidy scheme as well as promotion messages that clearly relay the benefits of piped water, including increased water consumption, less time spent collecting water, and lower incidence of water-borne diseases due to both improved water quality and better hygiene practices afforded by running water or increased water collection capability.

The currently proposed planning surrounding solid and liquid waste removal services is prudent, but it is worth reconsidering an emphasis on advocacy for liquid waste removal services at this stage, given the lack of demand. Hygiene and sanitation promotion messages must emphasize the importance of proper storage of water and regular cleaning of water storage containers and implements used for drinking or obtaining water from the container. They must also highlight the need for handwashing with soap at key times and the health benefits of such behavior, thereby demonstrating that investment in and liberal use of soap is economically sound. Such messages can be reinforced through regular and proper use of local media, both traditional and new.

At schools, hygiene and sanitation interventions must address the security and hygiene needs of girls by ensuring that sanitation bins and locks are present with girls' latrines, and latrines should be equipped with handwashing facilities. Although the intention of the school programs was to equip children to be agents of change in their families, the cleanliness observed in household latrines, but not school latrines, signals an opportunity for families to assist schools by teaching children how to properly clean latrines and having students assume responsibility (with proper oversight) of cleaning school latrines. This and other habit-forming behaviors such as regular handwashing with soap (including before and after eating, after cleaning feces, etc.) will lead to greater sustained uptake of many of the sanitation and hygiene messages.

Follow-up surveys must not simply rely on reported handwashing practice, hygiene knowledge, or presence of handwashing stations and soap to measure the impact of hygiene messages, given the massive disparities noted in terms of reported and observed behavior. Consequently, it is recommended that follow-up surveys include extended interviewer observation to record handwashing behavior at key times. Supplementing this with focus group discussions may better elucidate the reasons why behavior change did or did not occur and inform future interventions in similar towns in the region.

The timing of follow-up surveys should also take into consideration the issues highlighted in terms of measuring diarrhea incidence. Given that follow-up surveys carried out during the dry season would require substantially larger sample sizes to demonstrate even small gains, carrying out subsequent surveys during the wet season will provide a means to better ascertain the health benefits of the intervention. Even though measurements of diarrhea incidence in subsequent surveys would not be directly comparable with those from the baseline survey because of the change from the dry season to the wet season, carrying out such surveys during the wet season would provide a means to ascertain changes in incidence over at least part of the phased intervention. At the same time, comparisons with target towns would be valid regardless of this change in timing, and any differences would be accentuated most clearly during the wet season.

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