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41st WEDC International Conference, Egerton University, Nakuru, Kenya, 2018**TRANSFORMATION TOWARDS SUSTAINABLE
AND RESILIENT WASH SERVICES****Water quality validation and implications for future
programming: a case study from Ethiopia***R. Okowa & S. Stroever (Kenya)***PAPER 2989**

Monitoring the quality of water that is available through improved water sources is important to ensure it is safe for human consumption. This study sought to validate a prior study that found high levels of microbial contamination among water systems in Ethiopia installed by a consortium of implementers led by the Millennium Water Alliance. The prior study assessed water systems installed or rehabilitated by all implementers, so this study is also an attempt to compare the overall results with those from one of the implementing agencies: Living Water International Ethiopia. Our study found that levels of contamination varied across different projects, which could be the result of several factors, including: seasonality of water quality, differing data collection methodologies, or even quality of project engineering. Additionally, this study further highlights the need for health promotion programs, such as Water Safety Planning, to prevent microbial contamination of the water during storage and at point-of-use.

Introduction

Diarrheal disease is the second leading cause of childhood mortality in the world, with 88% of cases attributable to unclean drinking water (Centers for Disease Control and Prevention, 2015). In an effort to reduce the burden of disease, one of the United Nation's Sustainable Development Goals (6.1) seeks to ensure all people have access to safe and affordable drinking water, which is defined as water free of microbial and chemical contamination (United Nations, 2018). This goal is monitored according to the percentage of the population that use an "improved drinking water source;" or water that is uncontaminated, and available on the immediate premises any time it is needed (World Health Organization, 2018).

To truly reduce the burden of diarrheal disease, the water must be of good quality. Simple access in the immediate area is not enough. Theoretically, any improvement in access is better than no improvement, but organisations working towards this SDG must work to a higher standard. Living Water International (LWI) is a non-profit organisation dedicated to bringing sustainable water, sanitation, and hygiene services to communities in regions of Africa, Asia, Latin America, and the Caribbean (Living Water International, 2015). Recently, a study was released that demonstrated a high level of contamination among water systems installed and rehabilitated as part of a program led by the Millennium Water Alliance (MWA), of which Living Water International was one of the implementing agencies (Shields, Christenson, Ambelu, & Liang, 2016). The purpose of this study was to validate the findings from the report, compare the overall results to those from systems installed or rehabilitated by LWI, determine the presence of risk factors for contamination among this population, and make recommendations for future operations.

Background

Living Water International, headquartered in Houston, Texas, USA, is a global Christian non-governmental organisation. LWI exists to demonstrate the love of God by helping communities acquire desperately needed clean and safe water. The goal of LWI Ethiopia's program intervention is to significantly improve access to clean and safe water and hygiene and sanitation services. The Government of Ethiopia (GoE) released the results of its National WASH Inventory (NWI) in April 2013, which showed that only 54% of Ethiopians

had access to water and 60% to basic sanitation. In August 2013, GoE released the One WASH National Programme (OWNP) – an approach towards achieving 98.5% coverage for safe water supply and 100% coverage in sanitation. This national strategy seeks to harmonise, align, integrate, and accelerate the WASH implementation in order to achieve the previous Millennium Development Goals (MDGs), Growth and Transformation Plan (GTP), and the current Sustainable Development Goals of the country.

LWI has provided WASH services in multiple districts of Ethiopia. These districts include Shashemene, Liben Chukala, Dawo, Illu, Dandi, and Ada'a of the Oromia National Regional State. One hundred and twenty water supplies were constructed in these regions from 2011 to 2017 with the assistance of our community partner, Ethiopia Kale Heywot Church Development Commission. At the time of improved water source construction, LWI also encouraged healthy sanitation and hygiene behaviours among residents via community health programs.

Per the LWI quality standards and procedures, a copy of which is provided upon request, water quality testing is performed prior to rehabilitation of existing wells and development of springs. Additionally, after a water scheme is built, water quality testing is carried out before delivery of its function to the target communities. The testing is designed to ensure the suitability of the water for drinking and identify any potential microbiological and chemical contamination that may need further treatment. The survey design involved the preparation phase (8th – 17th December 2016) that included survey questionnaires development, team setup and detail planning on logistics for the fieldwork. The survey was conducted from 15th December 2016 to 20th January 2017.

Sampling

Approximately 30% of all functional water supplies were selected, with a total sample size of 35. Additionally, 30% of all beneficiary households were sampled with a maximum of 50 households per water supply scheme. These households were selected by sampling every third household, which resulted in a sample size of 401.

Study methodology

A cross-sectional study design was used to assess the level of contamination of drinking water at improved water sources and point-of-use. All functional water supplies in the six districts were included for random sampling using a random number generator (Microsoft Excel).

Data was collected in two stages. In stage one, samples were collected from selected water sources to test both bacterial contamination and physicochemical parameters. Data on risk factors for contamination near water sources, such as latrines within 30 meters of the well, communities not declared open defecation free, and inadequate fencing surrounding sources, were also collected via staff observation. All water samples were collected according to GoE standards, including the use of sterilized and coded sample bags. Research staff also performed hand hygiene and used gloves during sample collection and testing, and maintained samples in ice or a cold box during transportation. A sterilized plastic Whirl-Pak sampling bag of 100 ml was used for water sample collection. A portable membrane filtration system was used to test for fecal coliforms, while a photometer was used for the physicochemical analysis. Membrane lauryl sulfate broth (MLSB) was used to test for *E. coli*. Filter sterilization was employed prior to pouring the water samples through the 45-micrometer filter and onto MLSB-prepared petri dishes. The samples were then incubated at 44 degrees Celsius for 14-16 hours, followed by assessment of exact colony counts of indicated bacteria. The data was then recorded for each sample and used for analysis.

The second stage of data collection included water sampling at point-of-use in selected beneficiary households and survey data collection via participant interviews. Water samples collected at point-of-use were tested only for microbial contamination with methods listed above. The survey was designed to collect data on the demographics of the surveyed population, as well as key environmental determinants of water contamination, including cleanliness of water storage containers, methods of accessing stored water, latrine access, and hand washing station availability.

Analysis

Data were cleaned and analyzed using Microsoft Excel and SPSS v20. Descriptive statistics were calculated for all water samples and environmental risk factors for contamination.

Results

Water samples were collected from 35 improved water sources throughout the region of Oromia. The distribution of sampled wells included the following: Dawo (n = 3), Dendi (n = 3), Illu (n = 8), Ada'a (n = 8), Liben Chukala (n = 7), and Shashamene (n = 6). The majority of improved water sources were shallow boreholes (91.4%), with three samples collected from gravity schemes. All water sources provided water at all times, and 91.4% of improved sources were reported to have trained caretakers. However, only 60% of water sources that needed repair were said to have had all repairs made. Only one well (2.8%) had a latrine within thirty meters of the well, and none of the wells showed signs of leaks in the main pipes of the water system. Of note, only 28.57% of kebeles that hosted the sampled wells had been declared open defecation free (ODF), and 22.86% had inadequate fencing around the water source.

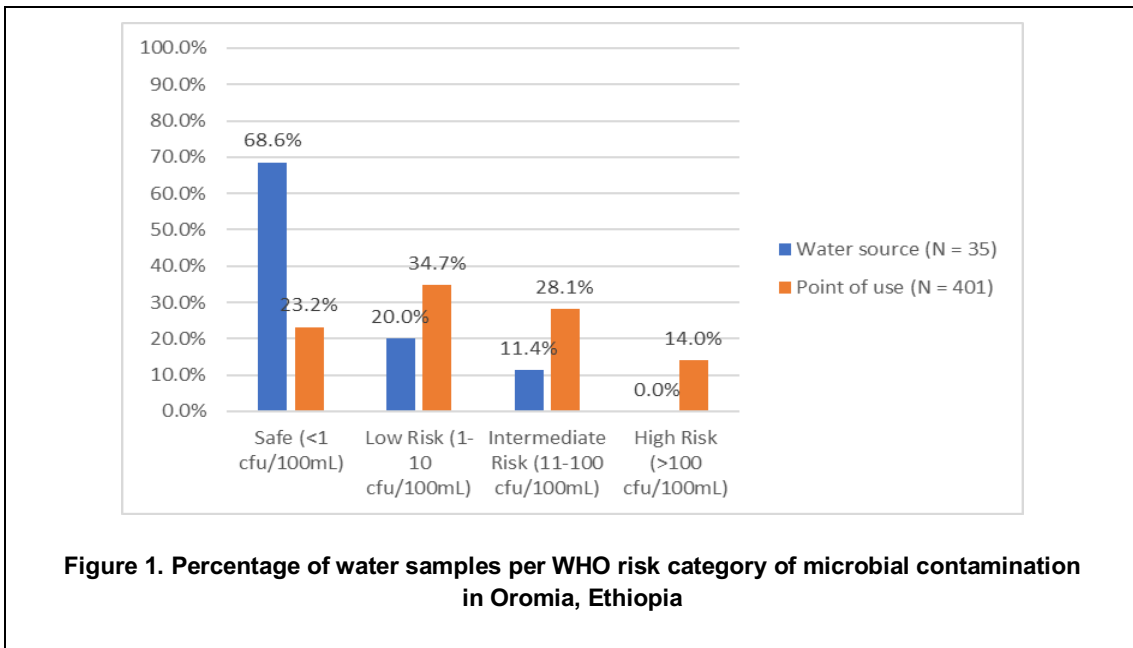
The results of microbial and physicochemical testing of improved water sources are displayed in Table 3. All sources were within acceptable limits for nitrate and free chlorine, while none were above the acceptable level of pH, nine (25.7%) above the acceptable level for fluoride, and 11 (31.4%) above the acceptable level for *E. coli*. Only one of the water supply sources (gravity spring) in Shashemene had a high concentration of nitrate (42mg/l), but it was still within the acceptable range of the drinking water quality. Further consideration of microbial contamination demonstrated that seven (20%) of the sampled water sources had microbial counts considered by the WHO as low risk, and four (11.4%) had microbial counts considered as intermediate risk (Figure 1) (World Health Organisation, 2017). None of the water schemes were classified as high risk, and all of the schemes considered intermediate risk were in the Shashemene district. Additionally, it should be noted that the highest *E. coli* counts were from the gravity scheme sources in Shashemene. Analysis of only shallow boreholes reduced the mean and standard deviation to 1.19 and 3.19, respectively.

Table 1. Microbiological and chemical results from improved water sources in Oromia region in Ethiopia (N = 35)

Parameter	Acceptable level*	N	# sources above acceptable level (%)	Mean (SD)	Range
Nitrate (mg/L)	50	35	0 (0)	7.34 (10.81)	0.20-42.00
Fluoride (mg/L)	1.5	35	9 (25.7)	1.26 (0.37)	0.50-2.10
Free chlorine (mg/L)	5	35	0 (0)	.08 (0.07)	0.00-0.26
<i>E. coli</i> all sources (cfu/100mL)	<1	35	11 (31.4)	4.40 (11.83)	0.00-57.00
<i>E. coli</i> boreholes only (cfu/100mL)	<1	32	8 (25.0)	1.19 (3.19)	0.00-16.00
pH	6.5-8.5	35	0 (0)	7.14 (0.25)	6.7-7.6

*Per World Health Organisation Guidelines for Drinking Water Quality (World Health Organisation, 2017)

The results of the microbial contamination testing at point-of-use, as well as frequencies of environmental risk factors for contamination, can be found in Table 2. Less than one quarter (23.2%) of the households surveyed for water contamination had drinking water considered safe at point-of-use. Further analysis of the microbial counts showed 34.7% were in the low risk category, 28.1% intermediate risk, and 14.0% high risk (Figure 1). Of note, levels of contamination were higher in point-of-use samples than improved water source samples. Only 66.8% of water storage containers (primarily jerrycans) appeared clean. The cleanliness of the water storage container is critical to maintaining drinking water that is safe and free of microbial contaminants. Additionally, only 8.46% of households with latrines had hand washing stations with soap within three meters of the latrines. Hand washing is another critical factor in maintaining clean drinking water, especially since 16.7% of surveyed individuals reported “dipping” as one of their methods for accessing drinking water.



Parameter	N	Mean (SD)	Range
<i>E. coli</i> (cfu/100mL)	401	33.52 (61.23)	0.00-421.00
Risk factor	N	#	%
Water storage container was covered upon observation	400	349	87.3
Water storage container appeared clean upon observation	400	267	66.8
Surveyed individual had attended sanitation and hygiene training	399	149	34.2
Surveyed household had latrine that appeared to be used upon observation	400	231	57.8
For those with latrine, there was a container with water for handwashing and soap within 3 meters	331	28	8.46
Surveyed individuals only use pour method to take water out of storage containers	401	334	83.3

Discussion and recommendations

The primary objective of this study was to assess the level of contamination at LWI-sponsored water schemes in Ethiopia in response to a third-party report that showed concerning levels of microbial contamination among all of the improved water sources as part of the consortium’s program. Unfortunately, our results were not directly comparable given some key differences in methodology with the previous study, including what we consider to be a more precise method for this type of testing. Therefore, mean contamination rates could not be directly compared to assess whether there was a statistically relevant difference between the two samples. However, the results do allow us to suggest that water quality is variable depending on the timing of testing. Evidence suggests that water contamination can be higher during wet seasons as compared to dry seasons (Kostyla, Bain, Cronk, & Bartram, 2015). Sample collection

took place during the rainy season in the prior study, whereas our sampling took place during drier months. We showed 31.6% of samples were contaminated with *E. coli*, while the third-party report showed as many as 50% of water samples were contaminated with *E. coli* (Shields et al., 2016). As an organisation dedicated to providing quality water services to communities throughout the world, these combined findings are concerning. We provide WASH services with the expectation that water quality and health outcomes will be improved. However, the variation in water quality across time suggests more is needed to sustain water quality and positive health outcomes.

In the “Guidelines for Drinking-Water Quality,” the World Health Organisation emphasises the need for on-going surveillance of water systems (World Health Organisation, 2017). Though they acknowledge the challenges communities face to carry out on-going surveillance, they also call for organisations (i.e. NGOs and governments) to provide public health oversight and information support to communities in terms of water quality and disease prevention (World Health Organisation, 2017). While many organisations have become proficient at providing access to higher quality drinking water, there is still a need to provide innovative solutions for on-going surveillance and maintenance of these sources within intervention communities. It is important for communities to have a strong sense of ownership for these services, and therefore we hope that water quality testing will become more cost-efficient and affordable to low-resource communities. Governments and NGOs should consider this aspect in their overall water safety planning.

It is also relevant to note that water contamination was high at point-of-use among surveyed communities in both studies. Our study found as many as 42.1% of sampled households had water in the intermediate and high-risk categories of contamination. Other studies have found this to be the case as well, which suggests more work is needed to change hygiene and sanitation behaviour at the point of storage and utilisation (Ercumen et al., 2015; John, Jain, Rahate, & Labhasetwar, 2014; Myint, Myint, Aung, & Wai, 2015; Smith, Dillingham, Samie, & Mellor, 2013). It is not enough to provide access to clean drinking water if the water then becomes contaminated during transport, storage, and handling. Organisations that work with communities should use evidence-based health promotion programs to encourage best practices for sanitation and hygiene at the household level. Therefore, it follows that more research is needed to determine the most salient determinants of sanitation and hygiene behaviours, as well as most effective methods to promote positive and sustainable behaviour change within the context of water safety planning.

Lastly, it is important that the leadership of organisations consider the results of such studies for future program development. Water quality and other outcome studies are important to determine the effectiveness of WASH programs, and the results must be presented in a manner that is transparent and can be used in a meaningful way to guide change towards more effective programs, and ultimately better health outcomes for our communities.

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