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LOCAL ACTION WITH INTERNATIONAL COOPERATION TO IMPROVE AND SUSTAIN WATER, SANITATION AND HYGIENE SERVICES

Operational research on water safety plans: implementations in India, DRC, Fiji, and Vanuatu

G. String (USA), R. Singleton, P. N. Mirindi, F. Polo & D. Lantagne

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Despite the promotion of Water Safety Plans (WSPs) as a comprehensive risk assessment and management strategy for water delivery, there is a lack of documented outcomes and impacts from this approach, particularly for community-managed supplies. Through a mixed-methods protocol of household surveys, water quality testing of source and stored water samples, key informant interviews, and focus group discussions, this study looked at WSP implementation in four countries to ascertain lessons learnt from these programs. From 817 household surveys and 256 key informant discussions, it was determined that there was no clear evidence linking WSPs to improvements in water quality. However, interviews indicated improved capacity of local committees in understanding their water supply systems and in identifying key risks to the delivery of safe water. Additional outcomes of WSPs and challenges associated with their implementation are discussed.

Introduction

As the world has transitioned from the conclusion of the Millennium Development Goals to the beginning of the Sustainable Development Goals, we were left with new targets for water and sanitation provision. Target 6.1 is to "By 2030, achieve universal and equitable access to safe and affordable drinking water for all" which will be monitored by indicator 6.1.1 "Percentage of population using safely managed drinking water services (UN Economic and Social Council 2015). While Water Safety Plans (WSPs) have been promoted since 2004 as a water supply management tool and implemented in over 90 countries worldwide, it has been noted that there is a lack of standardized methods for evaluating the effectiveness of those implementations (World Health Organization 2011; World Health Organization and International Water Association 2015).

Although the United States Centres for Disease Control and Prevention developed a method for evaluation across four key outcomes areas, evidence in support of the WSP methodology is still lacking in published literature, particularly for rural, community-managed implementations (Gelting *et al.* 2012; String and Lantagne 2016). Under funding and direction from the United Nations International Children's Fund, we conducted studies in India, the Democratic Republic of Congo (DRC), Fiji, and Vanuatu to ascertain and share lessons learnt from the implementation of WSPs in community-managed water supply schemes within local contexts.

Methods

The study was completed with support from implementing partners using a mixed-methods protocol, including: household surveys, water quality testing, key informant interviews, and focus group discussions. Protocols were approved by the Tufts University Institutional Review Board and the local ethics review process in each country.

The goal of the study was to visit 200 households in each country, 100 in WSP villages and 100 in non-WSP villages. In India, WSP villages were those that operated water supplies under a risk coloured card system maintained by the Department of Health and non-WSP villages were those where water management committees had been established but not yet trained. In DRC, WSP villages were those that had received certification in the comprehensive WASH training program Village Assaini from the Ministry of Health and supported by UNICEF, and controls were villages in early stages of the program that had not yet achieved certification. In Fiji and Vanuatu, WSP villages were those that had received training from implementing partners under the Drinking Water Safety and Security Plan program with support from UNICEF, and controls were communities that had not yet entered the process.

Implementing partners and UNICEF Country Offices in India, Fiji, and Vanuatu provided lists of WSP villages from which 10 were randomly chosen for inclusion. An attempt was made to match 10 control villages on location and population. Ten households per village were randomly selected for participation by starting in the village centre and skipping a certain number of houses. In DRC, implementing partners and UNICEF provided lists of certified villages, from which 20 were randomly chosen for inclusion. An attempt was made to match 20 control villages based upon location and population. Households were selected in the same random manner, but the number of households visited per village was determined by sampling 3.5% of all households in the village.

Household surveys were carried out in the local language by trained enumerators and comprised 57-60 questions and observations on household demographics, knowledge, attitudes, and practices (KAP) towards water, sanitation, and hygiene, and knowledge of Water Safety Plan work. Two water samples: household collection point and household stored water (if available), were collected aseptically and either placed on ice and analysed within 12 hours, or in situations where ice was unavailable analysed immediately, using standard methods of membrane filtration for simultaneous detection of total coliforms and *Escherichia coli* (*E. coli*) using m-ColiBlue24 media. All water samples were analysed on site for the physical and chemical parameters of temperature, pH, EC, and total and free chlorine residual (if reportedly treated with chlorine).

Quantitative data analysis of the household surveys and water quality was conducted for all countries, while supporting analysis of sanitary surveys from Fiji and Vanuatu and a Tanahashi framework in DRC was completed in addition. Data was manually recorded, entered into Microsoft Excel 2010, and cleaned and statistically analysed using R 3.3.2. Microbiological water quality results were grouped by the World Health Organisation's disease risk classification levels of: conforms to guidelines: <1 *E. coli* CFU/100mL, low risk: 1-10 CFU/100mL, medium risk: >10-100 CFU/100mL, high risk: >100-1000 CFU/100mL, and very high risk: >100 CFU/100mL. Additionally, by country, a Fisher's exact statistic test of independence was conducted for each type of water sample to compare WSP households to control households at two classification levels: samples conforming (<1 CFU/100mL) vs. non-conforming and samples <10 CFU/100mL vs. >10 CFU/100mL. Furthermore, paired t-tests were performed on log-transformed values to compare the geometric mean *E. coli* concentration of household collection point water to household stored water for all pairs where both samples were collected.

Focus group discussions (FGD) and key informant interviews (KII) contained 5-34 questions and were carried out in each village consisting of separate interviews with water management committees, village chiefs, village healthcare workers, village WASH committees, village plumbers and water system maintainers, as appropriate to the local context.

Qualitative data from the FGDs and KIIs were analysed and summarized according to five themes pertinent to the implementation of Water Safety Plans: documentation, risk identification and assessment, water safety, water security, and capital and technical assistance. Villages considered successful at documentation would have: gender balanced membership of water management committees that is formally recorded and includes relevant stakeholders, a schedule for regular meetings, meeting minutes, action plans and responsibilities clearly delineated, and schematics of water supply systems. Villages considered able to successfully identify and assess risks could: identify and prioritize hazards, characterize types of risk, and identify control measures. Villages that manage water safety would have: an understanding of how water quality is assessed, the ability to test water quality, operational measures to maintain quality in the system to the point of consumption, and procedures alerting users if there is a water safety emergency. Villages that manage water security would have: an understanding of their water system supply and demand amounts as well as patterns of usage, comprehension and action on water access issues, and operational measures to address seasonality of the supply. Villages that manage capital and technical assistance would: collect water user fees or fundraise for their system, organize maintenance and upgrades, and solicit external assistance where required.

Results

This study was carried out between August-December, 2016. In total, 817 household surveys encompassing 1,113 water samples, 120 key informant interviews, and 136 focus groups were conducted across the four country study. In India there was no concerted WSP implementation or training that had occurred, as existing programs focused primarily on the collection of water quality monitoring data. While conceptual integration of aspects of WSPs into the Village Assaini program was evident in DRC, actual use of WSP elements particularly around risk assessment were found to be lacking for both Village Assaini and water management committees. In Fiji, WSP implementations were conducted as a series of trainings for pre-existing government mandated Water Committees in each village. WSPs were primarily implemented in Vanuatu as part of Tropical Cyclone Pam recovery programs, but the Department of Water has recently mandated in their water standards that all community-managed systems be operated under a WSP, which utilizes a WSP as a sector planning tool (Vanuatu Department of Water 2016).

Quantitative results

Household KAP survey data, physical and chemical water quality data, and additional secondary data analysis for specific countries is yet to be analyzed and not presented in this report. Results from the microbiological water quality assessment grouping *E. coli* concentrations by recommended guidelines present several statistically significant results (Table 1). For household collection point water samples, there was a statistically significant difference between WSP villages and control villages in DRC and Fiji at the <1 *E. coli* CFU/100mL classification level (p=0.009 and 0.020, respectively) and in Fiji and Vanuatu at the <10 CFU/100mL classification (p<0.001 and p=0.004, respectively), where more control collection point samples fell into lower risk categories than WSP ones. For household stored water samples, there was a statistically significant difference between WSP villages and control villages in Fiji and Vanuatu at both the <1 CFU/100mL classification level (p=0.014 and 0.009, respectively) and the <10 CFU/100mL classification (p=0.001 and 0.002, respectively), where more control stored water samples fell into lower risk categories than WSP ones.

In evaluating the water quality of paired source and household water samples in India, the geometric mean for all collection point samples was 24.5 *E. coli* CFU/100mL (range: <1-9,700) and for stored water was 13.3 CFU/100mL (range: <1-2,001), which was not statistically significantly different. In DRC, the geometric mean for all collection point samples was 8.0 *E. coli* CFU/100mL (range: <1-4,000) and for stored water was 56.5 CFU/100mL (range: <10-17,300) representing a statistically significant increase in the stored samples (p<0.001). In Fiji, the geometric mean for all collection point samples was 15.0 *E. coli* CFU/100mL (range: <1-1,280) and for stored water was 8.3 CFU/100mL (range: <1-1,340) representing a statistically significant decrease in the stored samples (p=0.020). In Vanuatu, the geometric mean for all collection point samples was 3.3 *E. coli* CFU/100mL (range: <1-2,001) and for stored water was 3.6 CFU/100mL (range: <1-680), which was not statistically significantly different.

Qualitative results

The most commonly noted ideas from all countries pertaining to WSP integration in the operation of water supplies were aggregated and are presented by thematic area.

Documentation - Documentation of meeting minutes and outcomes was common for water committees in all countries regardless of whether there was training on WSPs. In particular, evidence of meetings were sent on to local authorities in India, DRC, and Fiji, in compliance with local policy. Besides 10 WSP trained villages in Fiji, maps of source points and water supply distribution systems were not common as villages primarily relied upon informal knowledge of source and tap locations. In DRC, Fiji, and Vanuatu almost all WSP trained communities had documented improvement plans, while their counterpart control villages had 'wish-list' goals. In India, all villages kept track of plans for the installation of new tube wells or dug wells, but any improvement plans related to large infrastructure such as piped water supply systems was handled by the district.

Risk identification and assessment - Control villages in Fiji and Vanuatu, as well as water management committees in DRC, indicated pipe breakages as the principal hazard monitored and mitigated for water supply systems. Additional risk identification in villages in India, as well as WSP trained villages Fiji and Vanuatu were primarily based on sanitary surveys of the water systems. It was not clear from discussions held in any country, regardless of WSP training, whether there was an understanding of risk prioritization. Most commonly, participants discussed how communities would come together to solve problems when something was broken, indicating a reactive approach, frequently associated with obstruction of water delivery.

Table 1. N(%) water samples by WHO disease risk category (*E. coli* CFU/100mL)

	n	Conforms (<1)	Low Risk (1-10)	Medium Risk (>10-100)	High Risk (>100-1000)	Very High Risk (>1000)	Fisher p-value (<1)	Fisher p-value (<10)
Household Collection Point Water Sample								
India WSP	27	2 (7.4%)	3 (11.1%)	14 (51.9%)	8 (29.6%)	0 (0.0%)	0.593	0.720
India Control	31	1 (3.2%)	3 (9.7%)	22 (71.0%)	5 (16.1%)	0 (0.0%)		
DRC WSP	30	5 (16.7%)	13 (43.3%)	8 (26.7%)	3 (10.0%)	1 (3.3%)	0.009*	1
DRC Control	18	10 (55.6%)	1 (5.6%)	1 (5.6%)	3 (16.7%)	3 (16.7%)		
Fiji WSP	99	10 (10.1%)	15 (15.2%)	57 (57.2%)	12 (12.1%)	5 (5.1%)	0.020*	<0.001*
Fiji Control	97	22 (24.2%)	38 (41.8%)	25 (27.6%)	11 (12.1%)	1 (1.1%)		
Vanuatu WSP	84	40 (47.6%)	13 (15.5%)	22 (26.2%)	9 (10.7%)	0 (0.0%)	0.373	0.004*
Vanuatu Control	97	46 (53.9%)	26 (29.2%)	3 (4.5%)	9 (10.1%)	2 (2.2%)		
Household Stored Water Sample								
India WSP	101	3 (3.0%)	0 (0.0%)	81 (80.2%)	17 (16.8%)	0 (0.0%)	1	0.082
India Control	100	3 (3.0%)	6 (6.0%)	70 (70.0%)	21 (21.0%)	0 (0.0%)		
DRC WSP	96	0 (0.0%)	31 (38.6%)	39 (40.6%)	24 (25.0%)	2 (2.1%)	1	0.379
DRC Control	106	0 (0.0%)	41 (38.7%)	24 (22.6%)	26 (24.5%)	15 (14.2%)		
Fiji WSP	38	5 (13.2%)	5 (13.2%)	21 (55.3%)	5 (13.2%)	2 (5.3%)	0.014*	0.001*
Fiji Control	48	18 (37.5%)	12 (25.0%)	15 (31.3%)	3 (6.3%)	0 (0.0%)		
Vanuatu WSP	82	29 (35.4%)	12 (14.6%)	26 (31.7%)	14 (17.1%)	1 (1.2%)	0.009*	0.002*
Vanuatu Control	55	32 (58.2%)	10 (18.2%)	7 (12.7%)	6 (10.9%)	0 (0.0%)		

*Significant at the $\alpha = 0.05$ probability level that WSP and control households were statistically different

Water safety - There was no regular water quality testing documented in DRC, Fiji, or Vanuatu regardless of WSP implementation. Water quality testing was conducted regularly in India as per national and state guidelines, with discussion participants indicating rotating test schedules and sample collection by a paid member of the village for analysis by the district. Treatment of water sources was noted via the use of bleaching powder at open wells and piped water systems in some villages in India, and the use of community slow sand filters was noted in two control villages in Fiji. Household treatment was discussed as being advocated by community health workers in India and DRC particularly during rainy seasons and times of outbreak, as being advocated in Fiji and Vanuatu during emergencies.

Water security - Issues of water security were noted in all four countries, particularly related to the available quantity of water. In India the Groundwater Survey and Development Agency had an ongoing well water-level monitoring project in villages to observe for indications of drought. In Fiji, six WSP villages and zero control villages were able to calculate the supply and demand of water for their villages. In Vanuatu, water shortages, particularly during El Niño seasons, were noted regardless of WSP training. Several water security issues were noted by stakeholders in the DRC, including unknown water usage amounts, uneven coverage of piped water systems and point sources, and long distances from households to their water source.

Capital and technical assistance - Water collection fees were noted in Vanuatu communities regardless of WSP implementation and by one water committee in the DRC. Stakeholders in the DRC, Fiji, and Vanuatu all indicated the need for external financial assistance with water system upgrades. In India, it was noted that villages fundraised for installation and maintenance of community tube wells while the district funded piped water supply projects. Encouragingly, four of the WSP trained villages in Vanuatu had used their action plans to solicit external funding assistance. Stakeholders across countries frequently requested more technical support and trainings on operation and maintenance, improvement plans, and risk assessment.

Discussion

Overall, data were collected on the implementation of Water Safety Plans in four countries, encompassing 817 household surveys with 1,113 accompanying water samples, 120 key informant, and 136 focus group discussions. We found no improvement in microbiological water quality in villages that had implemented WSPs in any type of sample, in any country, at either classification level, but we did find qualitative indicators of change in management of water supplies, particularly in relation to improved understanding of risk, water safety and security, and in the development of improvement plans. This shows that 1) water safety results were not achieved; 2) it is difficult to implement WSPs in a community-managed system, and 3) significant capital and technical assistance is needed to realize improvements to water supplies.

Source water treatment was only present in 12 villages in the study indicating a need for funding of infrastructure upgrades. Furthermore, local capacity for water quality testing was low in three of the four countries, indicating a barrier in the ability of WSP trained committees to ensure that the water systems they were managing were delivering potable water.

The complexity of the WSP process is a barrier to successful implementation. It was commonly noted in Vanuatu that the speed of training (3 days) was too short for communities to digest all aspects of the process. This creates a risk for communities to discontinue use of the WSP program. Integration into existing programs, such as Village Assaini in DRC, provide a promising example for avoidance of parallel programs. Tools utilized in WSP training, especially for risk identification and assessment, need to be simple and repeatable, as discussed as a major barrier to understanding of a WSP in DRC.

Outcomes of a WSP process typically revealed upgrades and improvements that were needed to operate a water supply in a manner that meets quality and quantity standards. Often, committees discussed how they were able to do small fixes on their system (e.g. pipe breakages, tap leakages, fencing), but lacked the capital and technical capacity to carry out necessary improvements.

Limitations on this study include small number of countries and WSP implementation contexts, a small total number of WSP implementations per country, a lack of baseline data for longitudinal analysis in WSP implementations, and the need to analyse KAP data to understand differences between WSP and control village water quality. Future research on WSP implementations in various contexts and through time are required to further clarify the effect of this process on water quality.

Findings from this study suggest: 1) the continued need for water treatment and water quality monitoring at the source and in the household; 2) the need to adapt WSP trainings and tools to local context; 3) promising integration of WSP processes within existing WASH programs, such as Village Assaini in DRC; 4) possibility to utilize WSPs as a standardized sector planning tool, such as in Vanuatu; 5) early evidence of increased capacity to self-manage water supplies from an operation and maintenance perspective, such as in

Fiji; and 6) the need to consider funds for repairs and upgrades of water supply systems managed by WSP trained teams. There continues to be an overwhelming need for fundamental evidence on the value of WSPs in community managed supplies, in particular related to how WSPs assure the delivery of safe water to the point of consumption, or WSPs risk becoming a burden to communities to implement.

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Contact details

Gabrielle String is a PhD candidate at Tufts University. She is interested in the use of appropriate technology to address access to safe drinking water with a focus on household and community scale interventions. Dr Lantagne is an Assistant Professor at Tufts University; her group focuses on reducing the burden of infectious diseases by investigating and evaluating the effectiveness of water and sanitation interventions in developing countries and emergency contexts.

Gabrielle String
Tufts University,
200 College Avenue,
Medford, MA 02155
Tel: +1-717-422-4337
Email: Gabrielle.String@tufts.edu

Daniele Lantagne
Tufts University,
200 College Avenue,
Medford, MA 02155
Tel: +1-617-627-3211
Email: Daniele.Lantagne@tufts.edu