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TRANSFORMATION TOWARDS SUSTAINABLE
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Shock chlorination: the solution to safer water?

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The effectiveness of shock chlorination was assessed for reducing faecal contamination of water in hand-pumps, together with the feasibility of local hand pump mechanics performing shock chlorination services. Contaminated source water will directly affect all households accessing it and shock chlorination could be an opportunity for local providers to increase the value of services they offer to communities. Shock chlorination was conducted at 20 sources in Kumi District, Uganda and source samples were tested on the day of treatment and one week after. Despite significant improvement in water quality ($p = 0.035$), shock chlorination did not consistently improve the quality of the contaminated water to meet the Ugandan standard. The hand pump mechanics were able to provide this treatment at cost levels affordable to communities (2.90 USD/source), but the inconsistent improvements in water quality do not make it worth offering as an ongoing service.

Introduction

The Joint Monitoring Programme indicator for Sustainable Development Goal (SDG) 6 describes safe water as water that is free of faecal contamination (WHO & UNICEF, 2017). Since water from hand pumps in developing countries is often not safe to drink (Bain et al., 2014), one of the main questions is: how might safe source water be guaranteed? The importance of safe water is underlined by the estimate that around 88 per cent of the diarrhoeal disease is attributed to unsafe water, sanitation and hygiene (UNICEF, 2006). The aim of this study is therefore to determine the effectiveness of shock chlorination on faecal contamination of source water over time. Shock chlorination is defined as a one-time introduction of a strong chlorine solution into the water distribution system (Kranz et al., 1995). The following two questions will be addressed: 1) Can shock chlorination improve and sustain higher water quality? 2) Can local technicians conduct shock chlorination at a price affordable to communities?

In many developing countries, hand pumps provide affordable access to water (Ferguson et al., 2011). Often, however, water from hand pumps is not safe to drink and rural water sources are even more likely to be contaminated compared to water sources in urban areas (Bain et al., 2014). Although improved sources are generally safer than unimproved sources, they are also not consistently free of faecal contamination (Bain et al., 2014). This microbial contamination is usually attributed to groundwater containing human or livestock faeces, but contamination of the water could also be due to microbial attachment to surfaces inside the pump (Ferguson et al., 2011).

To test the safety of drinking water, often the *Escherichia coli* (*E. coli*) is measured. *E. coli* is reported as the best single biological indicator for drinking water safety and faecal contamination (Edberg, et al., 2000; Thomas et al., 2018). Although SDG 6 underlines that water should be free of faecal contamination, the Ugandan standard of potable water for un-piped supplies sets a standard regarding *E.coli* of below 11 colony-forming units (CFU)/100 mL (UNBS, 2014).

Shock chlorination

Chlorination with a single shock has been recommended by the World Health Organization to disinfect contaminated wells (Rowe et al., 1998; Kjaergaard et al., 2007). According to Reed et al., (2013), shock

chlorination can be done in the following way: a calculated chlorine dosage is first mixed with water and poured into the borehole, and the mixture is allowed to stand for at least 12 hours before usage. The pump will then be operated until all chlorinated water has been removed. This single shock of chlorine is expected to kill all bacteria existing in the well and is a simple and inexpensive process that can be used to disinfect water supplies that have been contaminated (Swistock et al., nd). It is, however, questionable how effective shock chlorination is in improving the bacteriologic quality of the water since there are hardly any scientific reports that demonstrate the effectiveness of shock chlorination (Luby et al., 2006). Moreover, Rowe et al. (1998) reported that the duration of an adequate residual chlorine level after a single shock of liquid bleach was short-lived and variable. In his study, he found that only four out of the ten wells had an adequate residual chlorine level after shock chlorination that lasted a median of only one day (Rowe et al., 1998). Shock chlorination could also lead to the mistaken impression that the water should be safe to drink after the treatment (Rowe et al., 1998). Moreover, chlorine treatment can give a noticeable taste to the water that people may not like (de Franca Doria, 2010).

It is uncertain if reducing the concentration of faecal coliforms in source water will reduce the incidence of diarrhoea. According to Jensen et al., (2004), public water treatment will not necessarily lead to a significant reduction of endemic childhood diarrhoea incidences. However, VanDerSlice and Briscoe (1995) reported a reduction of 40 per cent in diarrhoea incidences after reducing the concentration of faecal coliforms in source water by two orders of magnitude. VanDerSlice and Briscoe (1995) were only able to show this effect in areas with better community sanitation; no effect was reported in neighbourhoods with poor environmental sanitation. Another argument why shock chlorination could have a questionable effect is that water often gets contaminated during and after the collection from the source (Wright et al., 2004).

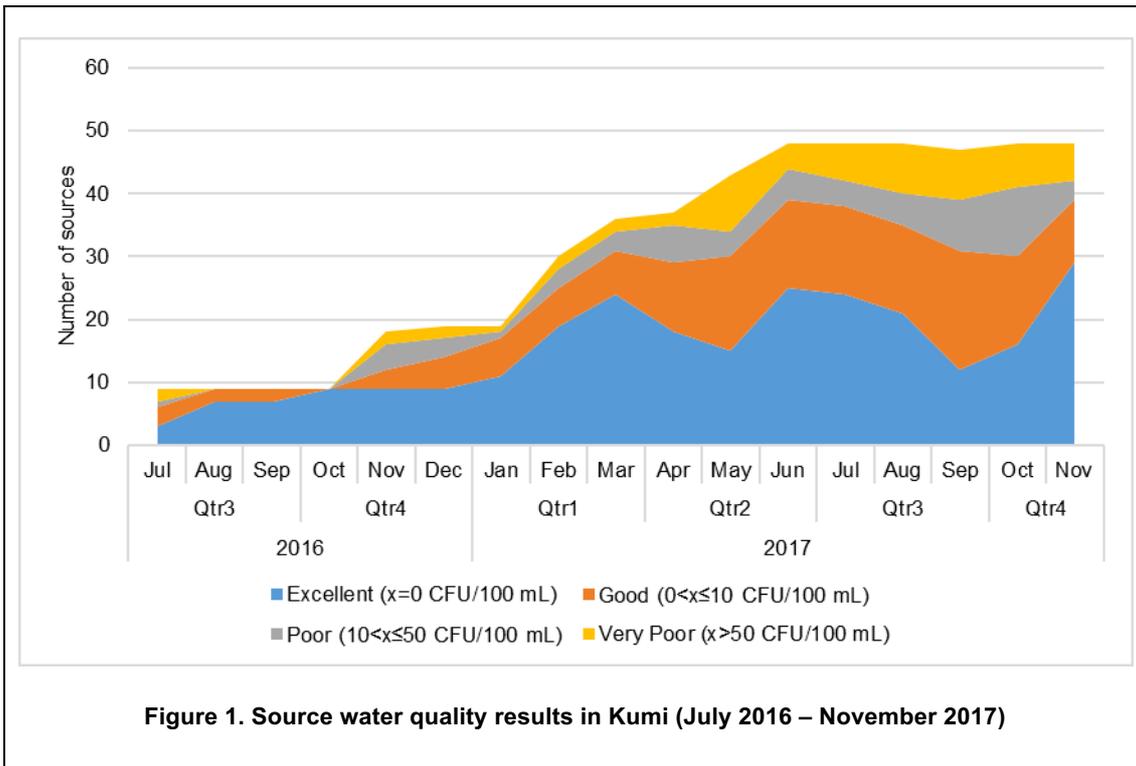
Relevance of shock chlorination

Shock chlorination may still be worthwhile because contaminated source water will directly affect all households accessing it. Furthermore, there may be potential for repeated shock chlorination to maintain acceptable water quality levels despite the variable effect of each individual treatment. Repeating shock chlorination may be an opportunity for local providers to increase the value of service they offer to communities, and therefore might be appropriate for rural service utilities.

The potential of shock chlorination as a service to communities was therefore of interest to Whave Solutions Ltd., a Ugandan non-profit social enterprise that maintains rural water points through preventive maintenance contracts with communities. Whave's network of rural pump mechanics provides an opportunity to offer shock chlorination as a service for contaminated water points consistently. If shock chlorination is found to be effective for improving water quality and increasing community perception of the value of the service they receive, the cost-recovery mechanism of the maintenance contracts with communities might allow shock chlorination and source monitoring to be sustained indefinitely. The study therefore sought to test both the effectiveness of shock chlorination, and the feasibility of the mechanics in Whave's network performing this service.

Methods

The study was carried out in Ongino Sub County of Kumi District in Uganda, where Whave is actively maintaining and testing the quality of water from rural hand pumps. Between July 2016 and November 2017, the water quality of 48 sources was tested on a monthly basis. Nine sources were tested for the full 17 months; the other sources were tested for 6-13 months, because of later inclusion in the programme (Figure 1). The total number of pumps tested therefore increases from July 2016 to present. A high risk concentration of >11 CFU/100 mL was found in 24 percent of the samples. In only 49 per cent of the samples no traces of *E. coli* were found. Sources qualified for shock chlorination treatment if at least 23 per cent of the monthly tested samples were classified as high risk, which was the case for 20 sources. The shock chlorination was done in January 2018 to determine if shock chlorination of the 20 most contaminated sources could improve the water quality to acceptable Ugandan standards.



On the same day of the shock chlorination, three water samples were collected from each source. The maximum time between collecting the samples and testing the samples did not exceed 6 hours. These samples were tested with a Wagtech incubator, capable of testing up to 200 E. coli colonies at a time. The E. coli colonies were counted after an incubation period of 18 to 22 hours at 44 degrees Celsius.

Local hand pump mechanics (HPMs) conducted a shock chlorination for the assigned sources. The cost of the shock chlorination per source was around 0.15 USD for chlorine, plus a 2.75 USD fee for the HPM. The total cost of 2.90 USD is affordable for communities, in the context of monthly payments of communities for preventive maintenance services. The HPMs used on average 1/3 cup of chlorine powder (65%) mixed with 20 L of water. The dosing was done with guidance from the service provider (Whave), but without strict external quality control in order to replicate conditions where HPMs would conduct chlorine dosing in the field. The source was closed after the shock chlorination, and all chlorinated water was pumped out after a 24 hour containment period. One week after shock chlorination three water samples were collected from each source and tested.

All statistical analysis was done with XLSTAT version 2018.1. Of the three source samples the average E. coli colonies was taken. Because the data did not follow a normal distribution and the sample size was small a Wilcoxon signed rank test was conducted to compare the E.coli colonies before shock chlorination and one week after shock chlorination.



Photograph 1. HPM calculating chlorine dosage



Photograph 2. HPM pouring 20 L of water mixed with chlorine into the borehole

Results

Only 14 of the 20 sources were found contaminated on the day of shock chlorination and of those 14 only eight proposed a high risk (>11 CFU/100 mL) to the community according to Ugandan water quality standard (UNBS, 2014). Table 1 and 2 show the water quality results for the both the low and high risk sources respectively before and after shock chlorination. The six sources that were not contaminated on the day of shock chlorination were excluded from the analysis.

Source name	WQ before (CFU/100 mL)	WQ after (CFU/100 mL)	WQ improvement	Meets Ugandan standard for potable water after shock chlorination
Source 1	6	2	4	Yes
Source 2	4	2	2	Yes
Source 3	1	0	1	Yes
Source 4	7	72	-65	No
Source 5	1	0	1	Yes
Source 6	2	16	-14	No

Source name	WQ before (CFU/100 mL)	WQ after (CFU/100 mL)	WQ improvement	Meets Ugandan standard for potable water after shock chlorination
Source 7	14	0	14	Yes
Source 8	200	86	114	No
Source 9	46	0	46	Yes
Source 10	105	5	100	Yes
Source 11	58	41	17	No
Source 12	37	0	37	Yes
Source 13	67	5	62	Yes
Source 14	19	15	4	No

Of the six low risk sources, as displayed in table 1, four sources showed an improvement in water quality after shock chlorination, with a decrease of 1-4 CFU/100 mL. For two sources, however, the water quality got worse after shock chlorination and an increase of 14 and 65 CFU/100 mL was reported. The last column of table 1 and 2 indicates if the source water quality complies with the Ugandan standard for potable water. After shock chlorination, two sources in the low risk table did not meet the Ugandan standard. Table 2 shows the water quality improvement of the high risk sources. All of the eight sources in this category showed an improved water quality, with a decrease of 4-114 CFU/100 mL. After shock chlorination three of the eight sources did not meet the Ugandan standard.

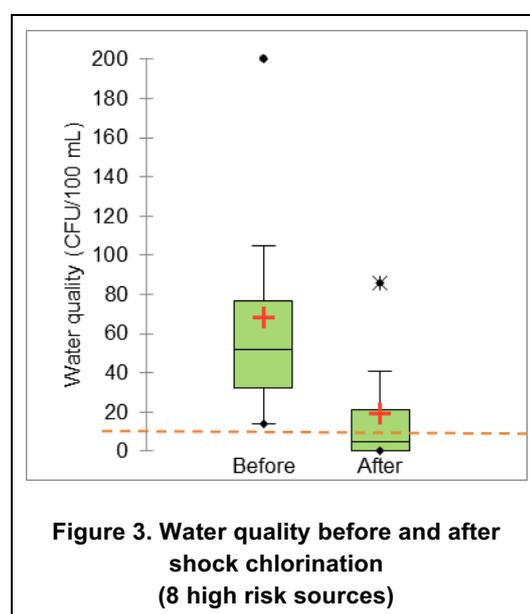
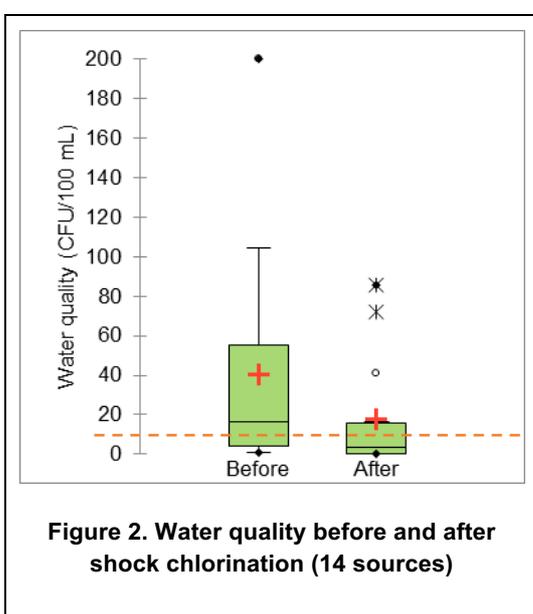
The first analysis was carried out for the 14 sources where any trace of E. coli was found in the water samples. There was a significant improvement in source water quality after shock chlorination (Mdn=3.17) compared to the water quality before shock chlorination (Mdn=16.67), two tail p=0.035. The analysis

suggest that shock chlorination is effective in improving the source water quality after one week, as displayed in figure 2.

The second analysis was carried out for the eight sources that proposed a high risk to the community. Even a stronger significant improvement in source water quality was found after shock chlorination (Mdn=4.83) compared to before shock chlorination (Mdn=52.00), two tail p=0.008. These results, displayed in figure 3, suggest that shock chlorination is effective in improving the source water quality after one week.

Of the 20 sources, 16 sources were monitored during the regular source monitoring within two months after shock chlorination. No problems regarding the taste of the water were reported.

Despite the improvement in water quality after shock chlorination of all 14 sources, only nine met the Ugandan standard for potable water, as indicated with the orange dotted line in figure 2 and 3. Moreover, of the six sources in the low risk category (table 1), the water quality of two sources got worse after shock chlorination. Although these sources, source 4 and source 6, had respectively only 56 and 25 per cent of the monthly water samples complying with the Ugandan standard in the last eight months, it still underlines that the water quality does not consistently improve after shock chlorination.



Discussion

Although a significant decrease in E. coli in source water was found one week after shock chlorination, the shock chlorination in this study did not consistently improve the quality of contaminated water to the required standard. Although we found that local technicians were able to conduct the treatment cost-effectively, the results do not indicate that shock chlorination is worth offering as an ongoing service to communities. Future research could investigate if continuous source water treatment is more consistent in reducing the levels of E. coli, but initial results do not look promising. Water treatment may be more effective if chlorine dosing occurs in collection containers or in the households. Improving water quality might focus instead on treatment methods at the household level instead of the source.

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