A community-based rainwater monitoring and treatment programme in Grahamstown, South Africa.

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Abstract — **South Africa is a water scarce country and its potable water supple suffers from problems such as pipe breaks and interruption of supply. This forces a large part of the population use rainwater for domestic consumption. In this climate, the current paper investigated the design of information tools about the source of rainwater contamination and the use of the modified hydrogen-sulphide test kit to detect the faecal contamination of rainwater. An information pamphlet was designed on the contamination sources of rainwater and the modified test kit was successfully used by the NGO volunteers to detect faecal contamination. The modified hydrogen-sulphide test kit and a combination of the *E. coli* enumerations correctly identified microbial water quality problems. These were then remedied using a collaboration between the authors and the community volunteers. The rate of correspondence between the m-TEC *E. coli* enumeration and the hydrogen-sulphide test kit was 71 %.**

Key-Words—the hydrogen-sulphide test kit, bleach addition, m-TEC agar, *E. coli*, community-based programme.

I. Introduction

Precipitation data indicate that South Africa is a water scarce country [1], [2]. Only 73.9 % of the population in rural areas, such as the Eastern Cape Province, had access to piped water inside the households in 2009 [3]. Pipe breaks and insufficient maintenance are common; and increase the risk of microbial contamination of the potable water distribution systems [4], [5]. In 2011, it was reported that up to 63.4 % of the water supply interruptions in the Eastern Cape were longer than 15 days in duration [6]. The Makana Local Municipality where Rhodes University is located ranked 7th in potable water service delivery in the Eastern Cape province with very low frequency of compliance monitoring [7]. This increases the dissatisfaction of inhabitants of the province with the potable water quality [8], [9]. It also forces the citizens to turn to alternative water resources such as rainwater to meet their drinking water needs.

Rainwater has been used as the primary potable water source in 55000 homes in South Africa [9]. Literature data have shown that the concentration of indicator microorganisms in rainwater often exceed regulatory limits for human consumption [10]. Therefore microbial quality of rainwater must be monitored regularly [11], [12]. If microbial contamination is detected then rainwater should be subjected to minimum treatment, such addition of bleach, before human consumption [13]. Awareness about minimum treatment and regular monitoring of microbial quality of rainwater can be accomplished, even in resource-limited environments, using a community microbial water quality monitoring programme. In this article, we report on the results from the pilot phase of this type of programme as run in the Grahamstown area of the Makana Local Municipality between March and June 2013.

II. MATERIALS AND METHODS

The community-based monitoring and treatment programme was based on the combination of the modified hydrogen-sulphide test (designated as the test kit in further text) according to Luyt et al. [14]. The pamphlet detailing the sources of faecal contamination and treatment of rainwater tanks was designed using literature data and applied as source of reference information to educate the community (see Appendix for details) [15]. Control samples were taken and analysed using the test kit and the *E. coli* concentration on the m-TEC selective agar (Sigma-Aldrich, Johannesburg, South Africa). This was done to obtain reference data for the applicability of the test kit in relation to regulatory data water quality data.

Bacterial enumerations, sterilisation and samples processing were performed as described by Tandlich et al. [16]. The volunteers were recruited through collaboration with a local non-governmental organisation (NGO), the Kowie Catchment Campaign (referred to as KCC in further text). The authors have worked on the microbial water-related issues with this NGO in the past. By the same token, a substantial part of the KCC membership had installed rainwater tanks in their private residences in previous years. Thus working with volunteers from this NGO will provide easy access to sampling sites. It would also equip the authors with the ability to gather information on the major uses/public health threats from rainwater consumption or domestic water in Grahamstown.

Firstly, the chairperson of the KCC was contacted and a dedicated e-mail list was set up with KCC membership and the authors. This e-mail list was then used to recruit particular volunteers with an installed rainwater tank from amongst the KCC membership. Recruitment took place during April 2013. A meeting of the authors and the volunteers took place at the Faculty of Pharmacy at Rhodes University on 2nd May 2013. A total of eight volunteers from the KCC membership took part and were given seven test kits each. A short introduction into the principle of the test kit took place and the sampling procedure was demonstrated to the volunteers by the project team. Agreement was made that one rainwater tank per household would be sampled by the volunteers once a week for six to seven weeks. Members of the project team would come and sample each rainwater tank on two or three occasions throughout the six-week sampling period. The aim of these visits would be to get feedback from the volunteers on the use of the test kits and their experiences with their rainwater. The authors would also provide to the volunteers on any problems that have arisen.

The samples taken by the project team would be subjected to the enumeration of *E. coli* (the standard indicator microorganism for faecal contamination of potable/drinking water in South Africa) and the test kit procedure. These samples are termed control samples in further text. The aim of the control samples was to determine the rate of correspondence between the test kit positive results and the m-TEC agar which is commercially available for the enumeration of *E. coli*. Such determination were recently done for the m-FC agar, but more correspondence rate data is needed to widen the acceptability of the test kit by the water regulatory community in South Africa. After the inaugural meeting, the volunteers were emailed the pamphlet on maintenance and treatment of rainwater. The dedicated email list was used as the primary communication avenue and the dissemination avenue for results during the remainder of the project.

III. RESULTS AND DISCUSSION

Seven out of the original eight volunteers maintained contact with the authors and continued the testing/feedback for the duration of the six-week agreed sampling period. A total of eight rainwater tanks were sampled where one volunteer sampled two tanks due to an urgent need for microbial water quality data. In two of the seven households, the rainwater tank was connected to the household water supply and used for potable purposes throughout the duration of the sampling period. In the remaining five households, the rainwater tanks had outside dispensing taps and the rainwater was only used as emergency supply during a water outages. No cases of diarrheal diseases were reported by the volunteers during the six-week sampling period. The results from the sampling using the test kits and the control samples are shown in Tables 1 and 2.

Table 1. Results of the test kit sampling by volunteers in the respective rainwater tanks.

Site number	Tank description	Number of volunteer test kit samples taken	Number of positive volunteer test kit samples
1	Rainwater tank with connection to household water supply	7	0
2	Outside rainwater tank, no connection to household water supply	7	1
3	Outside rainwater tank, no connection to household water supply	4	0
4	Outside rainwater tank, no connection to household water supply	7	0
5	Outside rainwater tank, no connection to household water supply	7	2
6	Outside rainwater tank, no connection to household water supply	7	0
7	Outside rainwater tank, no connection to household water supply	5	1
8	Rainwater tank with connection to household water supply	7	1

Between 4 and 7 samples were taken by the volunteers, giving a total of 55 samples using the test kit. No microbial contamination was found in four out of the eight sampled water tanks. The remaining four tanks were positive for faecal contamination in one or two occasions. The problems were communicated by the volunteers to the authors and the advice was given to dose the bleach into the rainwater tank according to the pamphlet in Appendix. In all cases, the follow-up samples were negative using the test kit. The volunteers found the test kit and the pamphlet easy to use and the authors approachable for the advice. Remedial action could be done on-site and upon need. As 87.5 % of the original volunteers completed the sampling in the scope of this project, even though 25 % of all volunteers did not sample every week as agreed at the start of the project. Overall the programme did deliver the desired results and provides a paradigm for the microbial rainwater quality monitoring in rural municipalities with low government based level of microbial monitoring.

The control sample results indicate that the problems in the microbial quality of the rainwater tested were detected by the volunteers themselves, as well as the project team (see Tables 1 and 2 for details). The *E. coli* concentrations ranged from below 0 to 35 colony-forming units/100 mL (designated CFUs/100 mL in further text) and the correspondence rate between the test kit results and the E. coli enumeration was 71 %. The concentrations of *E. coli* in Grahamstown rainwater have previously been reported to range from 0-1 CFU/100 mL [16]. Thus the data from this study spans a wider interval in comparison to literature data. The *E. coli* concentrations indicate that the rainwater should not be used for drinking and domestic uses unless chlorination or boiling are done prior to this. This is based on the medium to high risk to human health [11].

IV. Conclusion

An information pamphlet was designed on the contamination sources of rainwater and the modified test kit was successfully used by the NGO volunteers to detect faecal contamination. The modified hydrogen-sulphide test kit and a combination of the E. coli enumerations correctly identified microbial water quality problems. These were then remedied using a collaboration between the authors and the community volunteers. The rate of correspondence between the m-TEC E. coli enumeration and the hydrogen-sulphide test kit was 71 %.

Appendix

The H_2S strip test pamphlet

The H_2S strip test allows you to identify if hydrogen sulphide producing bacteria are present in the tank. If this is the case then the rainwater tested contains faecal matter and is potentially dangerous to human health upon consumption. The H_2S strip test is a bottle with a piece of paper impregnated with nutrients inside it. The paper will release

Table 2. Results of the control samples and the description of interventions to remedy microbial rainwater quality problems.

Site	Treatment	Control samples taken	Positive control test kits	Control *E. coli* (CFUs/ 100 mL)
1	None	1	0	< 0
2	1 Bleach addition by the volunteer and 2 additions after the control sample results were communicated by the project team	2	2	< 0
3	1 Bleach addition after the control sample results were communicated by the project team	2	2	0-4
4	None	2	0	< 0
5	1 Bleach addition by the volunteer and 1 addition after the control sample results were communicated by the project team	2	1	0-35
6	None	1	0	< 0
7	1 Bleach addition by the volunteer and 1 addition after the control sample results were communicated by the project team		0	0-4
8	1 Bleach addition by the volunteer	1	0	< 0

the nutrients into the water once the sample has been added and the kit hand-shaken. This will allow the bacteria to grow and the bottles can be kept at room temperature in a sunlight protected box. To use the H_2S strip test you will have to:

- Allow the water to run for thirty seconds.
- Then let the water run slowly, before opening the bottle. Sterilise your hands, the outside of the test kit bottle and the rainwater tap with the provided hand-sanitiser.
- Without touching the inside of the bottle with your hands. Half fill the bottle with water to the line indicated on the bottle.
- Close the bottle and shake the bottle.
- Place in a sunlight protected box in a warm place.
- Check the bottle for a colour change.
- Check the bottle every 12 hours for 72 hours (3 days).
- Colour changes after 72 hours are not positive results.
- If the water turns a black colour then the test shows that bacteria are present. (Positive result).
- All the water in the bottle must be discarded into the sewage system. Be careful to wash your hands carefully after doing this. The bottle should be discarded with the refuse.

When the test is positive the water is not suitable for drinking without first boiling or treating with disinfectant. If the rainwater is being used for irrigation of food which is cooked before being consumed, then no actions needs to be taken, however if it is being used for drinking or washing then place 5 cm^3 (for every 1000 cm^3 of water) of sodium hypochlorite or JIK (not perfumed) into the tank. Never place more than 25ml into the tank. Allow the tank to stand unopened for at least 12 hours before using the water. Preventively add half a glass (150 cm^3 of bleach) into a 5000 dm^3 or standard rainwater tank once or twice a month.

NEGATIVE POSITIVE

Figure 1. The illustration of the results interpretation of the hydrogen-sulphide test kit.

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