

Practical Paper

Willingness of boarding school students in Tanzania to employ point-of-use water treatment: a case study

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ABSTRACT

Access to safe drinking water is a challenge for students in primary and secondary schools in Tanzania. Only 32.7% of primary and secondary schools in Tanzania have access to safe drinking water and the point-of-use water treatment is rarely used. The traditional water disinfection method by boiling is often limited in boarding schools due to cost and time constraints. The objectives were to assess the willingness and attitude of boarding school students toward the use of the alternative water treatment method and determine the quality of drinking water before and after the introduction of the new method. Chlorine tablets were used due to their availability, ease of use, cost, and effectiveness. Weekly evaluations on usage, performance, and acceptability of chlorine tablets were assessed on 42 randomly selected students over a 3-week period in parallel with water sampling and testing before and after using chlorine tablets. Before the introduction of chlorine, only 17% of the students were aware of chlorine tablets, and water sources tested positive for fecal coliform. After introducing the new method, there was a significant increase ($p < 0.05$) in the attitude of students toward water treatment (100%), water quality (78%), and water consumption (67%). The work demonstrates the need to provide access to cost-effective household water treatment methods, especially in public schools that lack access to safe water.

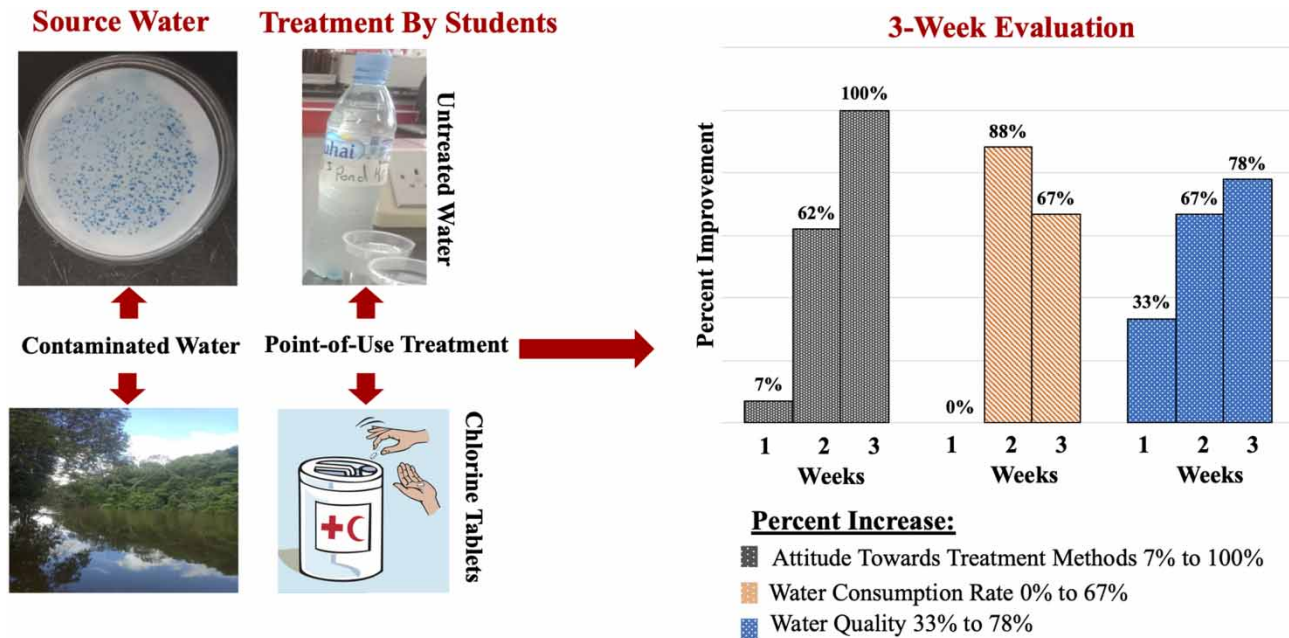
Key words: boarding school, chlorine tablets, fecal coliform, point of use, water quality, water treatment methods

HIGHLIGHTS

- In boarding schools in Tanzania, boiling is the traditional point-of-use water treatment, but uncommonly used.
- The study assessed the willingness of the students toward the use of chlorine tablets as a new treatment method.
- Chlorine significantly reduced fecal coliform, furthermore, water consumption rate and students' attitudes toward the new method increased.
- More than 90% of the students were willing to buy chlorine tablets if made available.

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GRAPHICAL ABSTRACT



INTRODUCTION

Ensuring universal access to water and sanitation and the elimination of waterborne diseases by 2030 is among the United Nations Sustainable Development Goal 6 (SDG 6) of 2019 that Tanzania and other nations have adopted. Worldwide, 780 million individuals lack access to improved drinking water, and 2.5 billion lack improved sanitation (CDC 2018). About 40% of households in Tanzania use unimproved drinking water sources (Ministry of Health *et al.* 2016). Many of these water sources are contaminated due to poor sanitation practices, such as the proximity of septic tanks and pit latrines, which increase the transmission of waterborne diseases (Ngasala *et al.* 2019a).

Practices such as safe water storage and point-of-use (POU) water treatments have been found to significantly reduce the fecal contamination bacteria contamination of household stored drinking water (Lantagne & Clasen 2012; Mohamed *et al.* 2016; Ngasala *et al.* 2019b, 2020). Water treatment technologies comprise a range of options that enable individuals and communities to treat collected water or contaminated piped water to remove or inactivate microbial pathogens. A study conducted in Dar es Salaam concluded that peri-urban household water quality concerns involve blending water, inadequate storage, misplaced trust in water vendors' claims, and use of contaminated groundwater (Clasen & Bastable 2003; Ngasala *et al.* 2019b). In some cities, the water systems extract unsafe water from unprotected or contaminated sources and deliver it to consumers with no or inadequate treatment, yet these water systems are classified or categorized as improved and safe (Sobsey & World Health Organization 2002; Ngasala *et al.* 2019a).

Only 32.7% of primary and secondary schools in Tanzania treat their water before drinking (UNICEF Tanzania 2020). The National Bureau of Statistics in Tanzania recognizes the insufficiencies in the quantity and quality of data available on schools concerning the availability of safe drinking water, adequate sanitation, and hygiene services (UNICEF Tanzania 2020). In many urban and rural areas of Tanzania including boarding schools, traditional POU water treatment involves boiling or the use of clay filtration pots (Makutsa *et al.* 2001; Zereffa & Bekalo 2017). However, disinfection treatment by boiling is often limited due to time constraints, cost, and the limited availability of energy sources such as charcoal, wood, and fuel (McGuigan *et al.* 1999; Ravindra *et al.* 2019). Thus, users' willingness to incorporate more efficient water treatment methods needs investigation.

Our study uniquely linked boarding school water quality and the attitude of boarding school students toward their use of water treatment methods. Chlorine was chosen for this study due to its low cost, ease of use, and ability to inactivate coliform bacteria. A 20 L bucket of water in Tanzania can be treated by one chlorine tablet which costs between Tshs. 100 and 500

(approximately US\$0.04 and US\$0.22). In comparison, the cost of chlorine is about five times cheaper than boiling (Aquatabs/Medentech 2007; Clasen *et al.* 2008; PATH 2013; Makhuvele & Moganedi 2019). Two main objectives of this study were as follows: (1) to introduce chlorine tablets as an alternative to the current water treatment practice that will be more acceptable for the boarding school to incorporate and (2) to assess the perception and attitude toward the treatment method introduced. To our knowledge, this is the first study to report on the performance of chlorine as a domestic water treatment in a boarding school.

METHODS

The study was conducted at one of the boarding secondary schools located at Pwani Region, Tanzania. Owing to water scarcity in the area, the school relies on multiple water sources depending on seasonal availability and electricity. The study received approval from the Ardhi University and Kisarawe District Council, Tanzania. Field visits to the original water sources, water samples, and one-on-one interviews from students were obtained over a 3-week period. The source water was sampled once at the start of the study. Details of the sampling and analysis are provided in Supplementary Material, Appendix A. Forty-two students were randomly selected within the study of 323 students who were present at that time. Students were paired and each pair was provided with chlorine tablets. The water sample from each pair of students interviewed was collected for a 3-week period and tested for total coliform and fecal coliform immediately upon collection using the membrane filtration method (HACH 2012). The survey responses were analyzed using the Mann–Whitney *U*-test method, a non-parametric test that is optimal for small sample sizes and non-uniform distributed data (MacFarland & Yates 2016). Details of weekly surveys and statistical analysis are provided in Supplementary Material, Appendix A.

RESULTS

There are two main water sources used by the school, well water and rainwater (see Figure S1 in Supplementary Material). Field observation and water testing revealed that water sources used by the school were not safe for consumption (Figure S2 in Supplementary Material). Of 42 students, 39 (93%) reported that they do not treat their water with reasons such as time constraints (36%), the school environment does not allow them to treat their water (46%), and the costs associated with treating water are high (18%). Diarrhea and stomachache were the most common waterborne diseases reported from the school clinic and by the students themselves (see Supplementary Material, Figures S3 and S4).

Weekly water quality

During the first week as shown in Figure 1, water was tested before the introduction of the new treatment and 67% of the samples showed the presence of coliform bacteria while 33% of the samples did not. During the second week, the students administered the treatment on their own, samples showed a drastic decrease in the number of fecal coliform bacteria that accounted only for 33% present. In the third week, some students were done with their exams and some of them had left school. This resulted in the number of students being reduced from 42 to 27, which also reduced the number of samples. The reduced sample size was taken into account during the statistical analysis for the weekly comparison. The results show that 78% of the samples tested negative. Only 22% of the samples had coliform bacteria present.

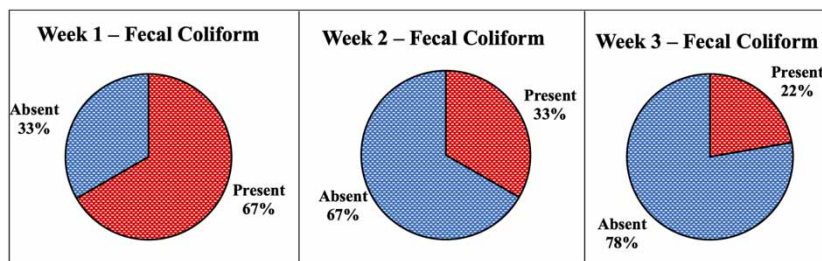


Figure 1 | Microbial analysis of the disinfected water in the 3-week evaluation period showing a significant improvement in water quality over time.

Weekly evaluation responses

As shown in Figure 2, Week 1 represents the test results from the 21 samples of drinking water before the new water treatment method was administered by the students on their own. Weeks 2 and 3 represent water quality results after the introduction of a new household water treatment method whereby the students administered the treatment on their own. There was a significant improvement in water quality, water treatment attitude, and water consumption rate after using the new water treatment method when all 3 weeks were compared. The improvements in water quality between Weeks 1–2 and 1–3 were significantly different at the 95% confidence level, but not significantly different for Weeks 2–3 (see Table S3 in Supplementary Materials).

The increase in water consumption for Weeks 1–2 and 1–3 was significantly different at the 95% confidence level (see Table S3 in Supplementary Materials). Overall, there was an improvement in the consumption rate of the students to 67% from their usual water drinking and this was compared to Week 1 which was set to zero as the baseline (summary results are shown in Table S1 in Supplementary Materials). The slight decrease of water consumption from Week 2 to Week 3 could be due to a reduced number of students as mentioned earlier. An increase in the attitude to treating water was significantly different for all 3 weeks (Weeks 1–2, 2–3, and 3–1), which agrees with survey responses that all students are willing to go on with the same treatment method.

During the first week, of 42 students participated, only 7% reported treating their water regularly (summary results are shown in Table S2 in Supplementary Materials). All students were willing to start using the new treatment method. Week 2 going on to Week 3, 62% of the students were willing to continue the treatment method. During Week 3, all 27 students who were at the school were willing to continue using it. The same number of students that reported to have used the treatment also said that they would be willing to buy the treatment if it was made available at their school. The improvement was obvious between Weeks 3 and 1 for all three variables. Most of the students were tolerable with the taste of the disinfected water, and only 36% argued that at first, the taste was not very pleasant.

DISCUSSION

Water testing results showed that the water sources used by the school are not safe for drinking due to poor hygiene and unprotected water sources (Ngasala *et al.* 2018, 2019a). From the study, it is found that there is a lack of awareness on the domestic water treatment methods and practices with only 17% of the participants knowing about chlorination. During interviews, students who reported that they treated their water were aware of the dangers of untreated water. Despite

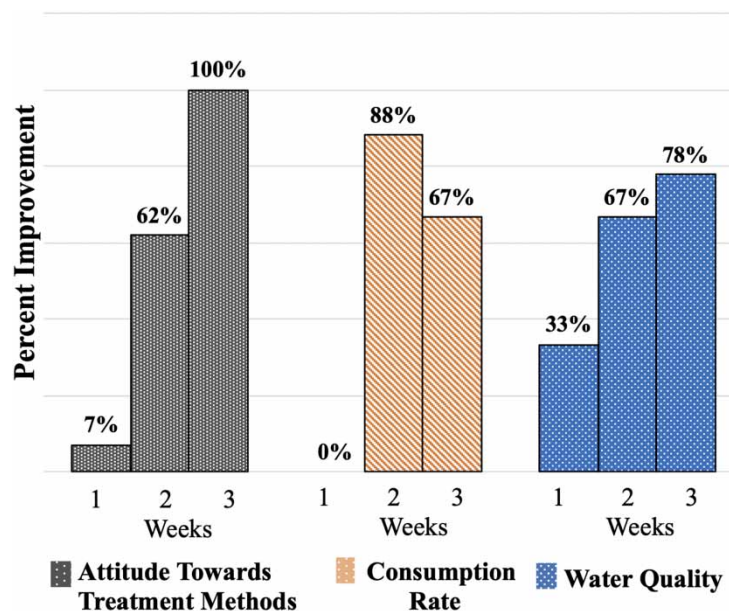


Figure 2 | Weekly results of the water treatment attitude, consumption rate, and the water quality results for all 3 weeks.

their attempts to treat their water, the tested water still had fecal contamination in Week 1. During the second week, there was a significant decrease in the percentage of samples that tested positive, which is most likely due to the use of chlorine tablets.

The presence of fecal coliforms in some samples may be due to the contamination during storage from placing treated water into uncleaned storage containers or by mixing treated with untreated water in the storage containers. Also, some students may not have followed instructions for the proper use of the chlorine tablets, resulting in poor treatment efficacy. As shown by [Ngasala *et al.* \(2019b\)](#) in a study conducted in a peri-urban community in Dar es Salaam, Tanzania, proper storage after treatment is critical to avoid re-contamination. According to [Mintz *et al.* \(1995\)](#), poorly designed storage containers can contribute to contamination of treated drinking water during storage. The results presented by [Ngasala *et al.* \(2019b\)](#) and [Mintz *et al.* \(1995\)](#) demonstrate the importance of educating primary schools, secondary schools, and the community as a whole about proper water sanitation, storage, and management.

The smell and taste of chlorine in treated water were highlighted as a major obstacle in the use of chlorine tablets. Most individuals can taste chlorine or its byproducts at concentrations of 5 mg/L, and some levels as low as 0.3 mg/L ([WHO 2003](#)). However, the consumption rate increased by 67% and most of the students are willing to buy the chlorine tablet if it was made available. The quality of water increased effectiveness to 78% during the third week of the research. At concentrations that are used for household water treatment, chlorine is effective at inactivating most bacteria and viruses that cause diarrheal diseases ([CDC 2014](#)). Our results are consistent with [Ngasala *et al.* \(2020\)](#) where they also found a significant improvement in water consumption, water quality, and people's attitude after introducing three different treatment methods including chlorine at the household level.

These results suggest that the use of chlorine was effective in significantly reducing fecal coliform bacteria. As noted by [Casanova *et al.* \(2012\)](#), to promote the continued use of disinfection treatment, distribution and education must be joined with capacity building for long-term water monitoring, supply chains, and local production.

CONCLUSIONS

The purpose of this short study was to assess the quality of drinking water of the students and determine the acceptability of the introduced alternative household water treatment method to identify a suitable method that could be used in schools. During the 3-week period, the introduction of chlorine has proved to be successful in eliminating the presence of coliform bacteria. After the introduction of the new water treatment method, all the students reported that the method was easy to use and all of them were willing to try another method if it was introduced. From this, we could conclude that implementing a simple and cost-effective treatment method into public boarding schools would greatly increase the number of students who will drink safe water.

It is recommended that the government invests in making low-cost POU water treatment technologies available in boarding schools. In addition, an integrated approach that addresses education and knowledge on domestic water treatment methods to boarding schools is called for. Creating an educational program within the school would increase their awareness of the importance of treating water and that water can be easily, cheaply, and effectively treated. More time and bigger sample size are recommended for better representation of the long-term effectiveness of the water treatment methods. This would support the findings to be a better representation of the effectiveness of the alternative household water treatment method and whether or not the students would be able to adopt the new method into their daily lives. Other POU water treatment methods such as ultraviolet disinfection and gravity-fed ultrafilter have been proved to be effective and of low-cost water treatment technology ([Chaidez *et al.* 2016](#)), and they could be implemented to see if the willingness of the subjects to treat drinking water would increase even more than already observed.

ACKNOWLEDGEMENTS

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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