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Original Paper

Microbiological Assessment of Borehole Water in Libala South, Lusaka District, Zambia

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ABSTRACT

Background: The rapid population growth coupled with massive infrastructure development in the city of Lusaka has resulted into the extensive use of contaminated ground water leading to adverse health effects on human health.
Aim: This study was conducted to assess the levels of microbial contamination in boreholes water in Libala South of Lusaka District.
Methods: A cross-sectional study was conducted in Libala South Township involving 64 households. Households were randomly sampled using stratified systematic method. Borehole water samples were collected, and analyzed for microbial contamination at the Food and Drugs Laboratory, Lusaka. The samples were tested for the presence of coliforms and *Escherichia coli* bacteria by using Colitag™ testing kit and the confirmation was done using multiple tube fermentation method.
Results: The study revealed that 31% and 48.5% of the boreholes were contaminated with *Escherichia coli* and coliforms, respectively.
Conclusion: Almost half of the borehole water in Libala South is contaminated with harmful bacteria and poses a public health risk to the residents who opt to use it for drinking and cleaning foods.

Key words: Borehole water, Microbial contamination, Total coliforms, *Escherichia coli*, Libala South Township, Lusaka

1. Introduction

Groundwater is mostly assumed to be an excellent source of potable water due to the process of purification that takes place in the soil [1]. On a daily basis an average of 1.5 billion people worldwide benefit from the underground water sources [2]. Despite being known to be potable, borehole water does get contaminated or polluted and may not be as safe as generally assumed [3]. The regions most affected by faecal contamination of groundwater are Africa and Southeast Asia; these are also the two regions with the lowest coverage of both improved water and sanitation [4]. Sources of water are classified as improved or unimproved according to whether they are "protected from outside contamination" [5]. Improved water sources include public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs and rainwater collection [6].

An estimated 880 million people globally have no access to improved water supply [7]. In Sub-Saharan Africa, 319 million people are without access to improved drinking water sources [8] and previous studies conducted have shown possible contamination of groundwater in Southern Africa [9, 10, and 11]. In Limpopo Province, South Africa, Potgieter *et al* (2006) reported poor quality of groundwater consumed by the population [9] and Samie *et al*. (2011) 10] also reported similar results in their study of borehole water used by schools in Mopani District, South Africa. In Lusaka, Zambia, Banda *et al* (2014) reported that 33% of borehole water in St. Bonaventure was contaminated with bacteria pathogenic in nature [11]. Consumption of water contaminated with faecal bacteria is an important route of transmission of enteric pathogens, and the developing world has high incidence of waterborne diarrheal diseases due to inadequate infrastructure and poor management of sewage [12, 13]. In order to test the level of microbiological contamination in water, indicator pathogens such as *Escherichia coli*, faecal and total coliforms are isolated and quantified [14]. The Zambia Bureau Standards (ZABS) drinking water quality recommends that drinking water should have the following microbiological parameter (a) Total coliforms (0-3cfu/100ml), (b) faecal coliforms (0 cfu/100ml) and (c) *Escherichia coli* should be absent [15].

The population of Lusaka district has been growing rapidly in the last 10 to 15 years and new residential areas have been reported to have mushroomed throughout the city [16]. The rapid development of the residential infrastructure has resulted in an increased burden on provision of municipal water by the local utility company [16]. In order to meet the demand for water, several households have resorted to the use of groundwater through drilling of boreholes. Libala South is an urban community located in the southern part of Lusaka District. The residential area has developed very rapidly and has experienced very high infrastructure development.

Despite the construction of houses and other infrastructure, provision of reticulated water and sewage systems by the local utility company has lagged behind. This has therefore resulted in many households drilling boreholes in order to utilize groundwater for domestic use in their houses and constructing septic tank and soakaway systems for in situ disposal of sewage.

This study was, therefore, conducted to assess microbiological contamination of borehole water intended for domestic use in Libala South, Lusaka. Microbiological indicator parameters that were evaluated for safe water status included *Escherichia coli* and total coliforms.

2. Methodology

Study design

This was a cross-sectional study conducted in Libala south located south of Lusaka district. The township is a middle to high income residential area and the geographical coordinates are 15° 27' 0" South, 28° 19' 0" East (Figure 1). Over 1100 boreholes exist in Libala South and they constituted the study frame.

Sample size determination

Sample size for this study was calculated using the formula below:

$$n = \frac{z^2 p(1-p)}{d^2}$$

Where, n = sample size, *d* = standard error of the proportion, z = 95% confidence interval level, and *p* = prevalence. In the study we estimated the prevalence of contaminated boreholes at 11.25% [17].

$$n = \frac{1.96^2\ 0.1125(1-0.1125)}{0.08^2}$$

We calculated 60 boreholes but sampled 64 from the 8 zones of the study area. Eight (8) households were randomly selected from each zone and if the selected household did not have a borehole the next house was automatically included.

Sample collection

All the samples were collected in pre-labelled sterilized (auto-claved) 500 ml glass containers. The faucet of the borehole sources were sterilized by the use of flame and the tap was allowed to flow for about three minutes at medium flow rate before sample collection. Within this interval it was assumed that stable conditions would exist. Sample bottles were also rinsed thrice with the sample (water) before samples were collected. Collected samples were kept at 4°C in the cooler box packed with ice and transported to the laboratory for analysis within six hours.

Colitag™ Test

The water samples were tested for Total coliform and *Escherichia coli* (*E. coli*) bacteria qualitatively, by using Colitag™ (Neogen, USA) test kit in field. The Colitag™ (Neogen, USA) Water Test Kit uses a selective and differential medium to detect total coliforms and *E. coli* in water samples in 16-48 hours [18]. Colitag™ (Neogen, USA), which is an enzymatic indicator-based medium, contains o-nitrophenyl-β-d-galactopyranoside (ONPG), 4-methylumbelliferyl- β-D-glucuronide (MUG), and other selective ingredients that are specific to coliforms with little interference from high heterotrophic bacteria counts [19]. The method was performed as follows: 10 ml of water was added to each sterile test tube, dissolving the Colitag™ (Neogen, USA) powder after agitation and producing a colourless solution. The test tubes were incubated at 37°C for 24hours [19]. Development of a yellow colour after incubation indicated the presence of total coliforms in the test tube. Each positive total coliform test tube was exposed to a fluorescent (366-nm) light. Fluorescence in the test specifically denoted the presence of *E. coli* [18].

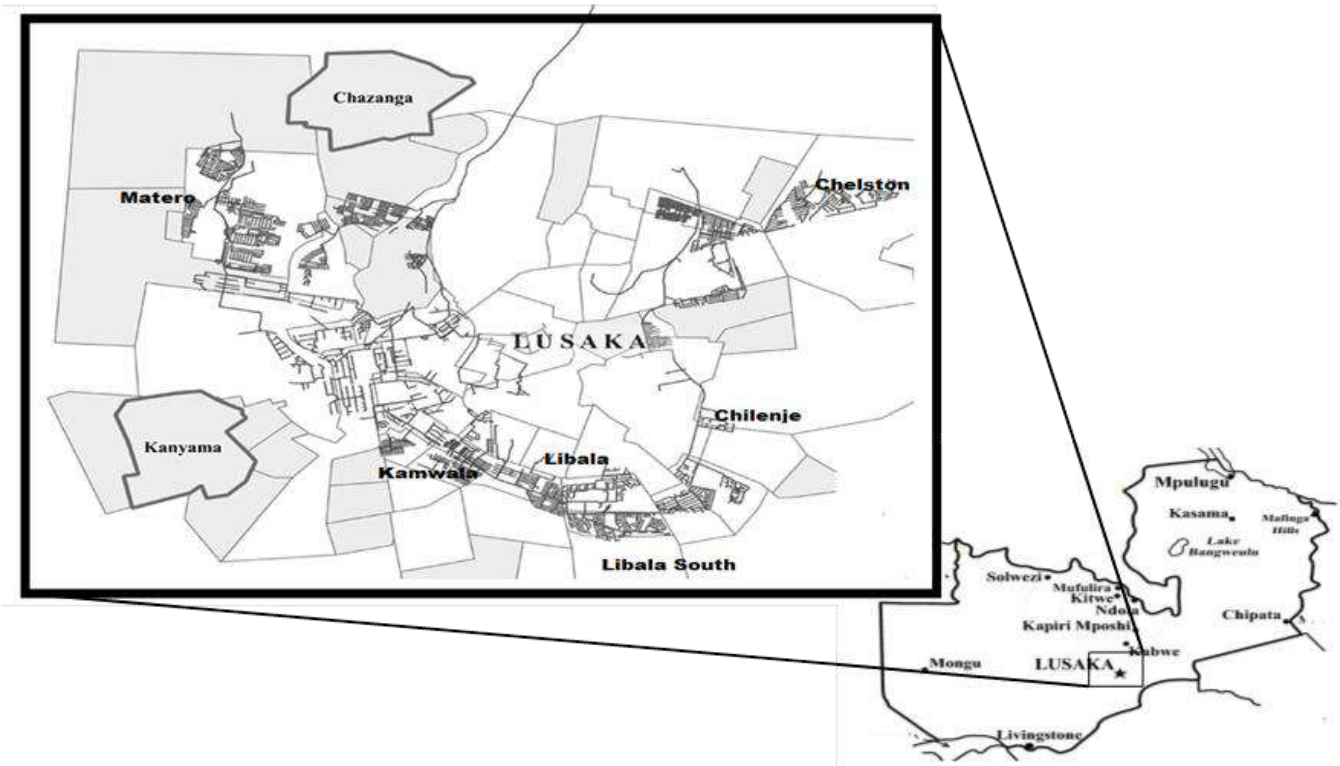

Figure 1; Map of Lusaka districts showing the main townships

Multiple-tube fermentation test

The confirmation of coliforms and *E. coli* was also done using multiple tube fermentation method (MFT) [20]. Quantitative microbiological tests were carried out through multiple tube fermentation technique, where by most probable number (MPN) of coliform and *E. coli* was determined and categorized according to their number [20].

The medium, 10 and 5 ml, was distributed in 10 fermentation tubes (5 tubes for each volume) with inverted Durham tubes. The fermentation tubes were sterilized by autoclaving at 121°C for 15 min. The tubes were cooled before inoculation. Approximately 10 ml portions of the each water sample was inoculated in the 5 fermentation tubes containing the 10 ml medium, while 1 ml and 0.1 ml were inoculated in 5 ml medium. For the presumptive test the medium used was Lauryl sulphate lactose broth (Himedia, India). The fermentation tubes were arranged in a test tube rack and placed in a water bath for 48 hours. The tubes which showed gas in the tubes were recorded as positive tests and the absence of gas formation recorded as negative tests. . From the most probable number (MPN) table, the number of coliforms corresponding to positive tubes were read and recorded.

From the presumptive test the completed test was then conducted skipping the confirmation test. For isolation of *E. coli* a loopful from each tube positive was plated onto Maconkey agar and incubated at 37˚C for 24 hours.

3. Results

Colitag™ Test

The Colitag™ (Neogen, USA) kit in this study was used as a qualitative microbiological test for water samples. Observations made from the Colitag™ tests showed the presence of total coliforms and *E. coli* in borehole water of Libala South, Lusaka. The results revealed total coliforms were detected in 31 (48%) and E. coli in 20 (31%) of the 64 water samples (Figure 2).

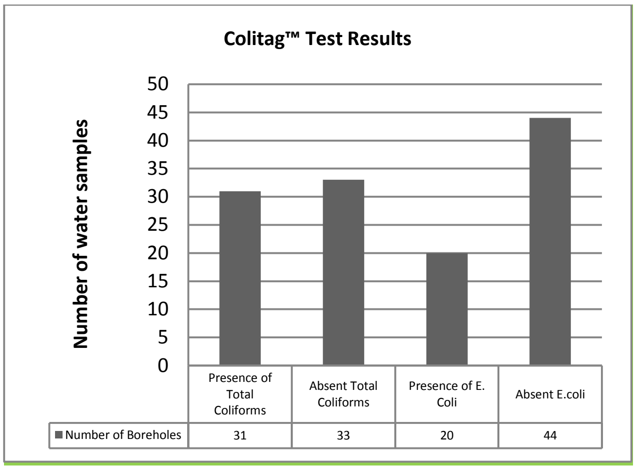

Figure 2: Colitag™ test results of borehole water in Libala South, Lusaka

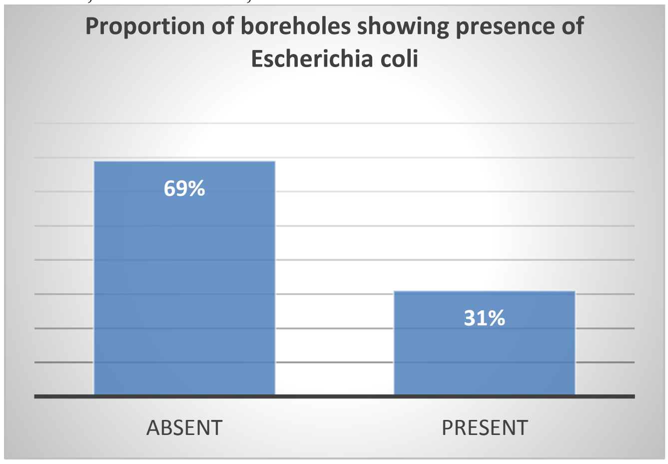

Figure 3: Presence/absence of Escherichia coli in borehole water in Libala South, Lusaka

Table 1: Multi-tube fermentation results of borehole water in Libala south, Lusaka

S/N	No of Boreholes	Total Coliforms (MPN/100ml).
1	33	0
2	1	4
3	11	10
4	3	20
5	1	25
6	5	30
7	1	49
8	1	60
9	1	95
10	2	100
11	1	410
12	4	>640

Multiple-tube fermentation test

The multi-tube fermentation test was used as a quantitative microbiological test for the evaluation of water samples and it revealed similar results as those observed in the Colitag test were total coliforms were detected in 31 (48%) and E. coli in 20 (31%) of the 64 water samples. Furthermore, the multi-tube fermentation test showed that the MPN of the water samples ranged from zero to above 640 MPN/100ml (Table 1). From the MFT presumptive tests 34 borehole water samples recorded zero MPN/100ml, 12 samples had 1 to 10 MPN/100ml), 2 samples 11 to 20 MPN/100ml and 16 samples 21to MPN/100ml and above. The mean and median values of the presumptive results were 73MPN/100ml and 30MPN/100ml, respectively. Isolation of *E. coli* from tube positive of the presumptive test revealed that 20 water samples (31.3%) were positive for the microorganism (Figure 3).

4. Discussion

The results of the bacteriological analysis of borehole water from Libala South showed that some sources are contaminated with coliforms and *Escherichia coli*. The World Health Organisation (WHO) international standards for drinking-water states that coliform bacteria shall not be detected or the MPN index of coliform micro-organisms shall be less than 1.0 [21]. Thirty three boreholes (51.5%) of the total 64 had water with bacteriological quality (0MPN/100ml) meeting the standards recommended for drinking by WHO. In a study by Banda *et al* (2014), it was reported that 33% of the boreholes in St Bonaventure, Lusaka, were contaminated with bacteria that were likely to be pathogenic in nature [11]. In another study by Nyirenda, Kaputula, and Ngulube (2016), conducted in Kitwe, Zambia, they reported 100% contamination of groundwater with total and faecal coliforms [22].

Escherichia coli was isolated in 20 borehole water samples (31.3%) and this indicates a public health risk if used for drinking and cleaning fresh foods. Banda *et al* (2014) reported that in St Bonaventure *E. coli* was isolated in 10.9 % of the borehole water while Uzoigwe and Agwa (2012) reported that only 14.3% of water collected from boreholes located near dumpsites in Port Harcourt, Nigeria, had *E. coli* [11, 23]. The results of the present study are not consistent with the two other studies indicating an increase in *E. coli* contamination of borehole water. The presence of *E. coli* is an indication that water is contaminated with human or animal faecal wastes. Therefore, the water quality guidelines of the ZBS and WHO require that all drinking water should not have any *E. coli* detected [15, 21]. The presence of *E. coli* in the water sources could be due to any of the following: improper disposal of sewage and wastewater from domestic activities, discharges from septic tanks and latrines close to some of the bore holes [11, 23]. Nwachukwu and Otokunefor (2006) stated a correlation between presence of *E. coli* in borehole water supplies and discharges from septic tanks and waste materials from a nearby dumpsite and Banda *et al* (2014) reported that boreholes and septic tank in the same piece of land is not suitable system because it results in bacterial contamination of the groundwater [11, 24].

It must be highlighted that waterborne pathogens of faecal origin such as pathogenic *E. coli* are a public health concern because of an increase in the size of sensitive subpopulations (geriatrics, paediatrics, immune compromised individuals, and pregnant women). It has been reported by other studies that sensitive subpopulations have demonstrated to be more susceptible to diseases due to microbial water contamination [14, 25]. Therefore, the sensitive populations in Libala south in the households with contaminated borehole water are at higher risk of diarrheal and other waterborne diseases.

The United Nations (UN) through the Sustainable Development Goals (SDGs), goal number six (6), advocates that every human on the planet accesses clean and sustainable water sources. Goal six (6) not only addresses the issues relating to drinking water, sanitation and hygiene, but also the quality and sustainability of water resources worldwide [26]. It should therefore stand as a priority for the residents of Libala south to ensure that the water they are consuming is free of microorganisms and falls within the recommendations of the ZBS and the WHO to prevent any waterborne diseases.

5. Conclusion

This study established that 51.5% of boreholes in Libala South Township had water that was safe for drinking purposes while 48.5% of boreholes were contaminated with coliforms, of which 31.3 % were contaminated with *E. coli*. The contaminated borehole water poses a public health risk to the residents that opt to use it for drinking and cleaning foods.

6. Recommendations

Several measures can be taken to address bacteria contamination of borehole water. Short term and immediate solutions include (a) installation of water filtration system from the borehole to house; (b) physical and chemical disinfection (boiling and chlorination) of water that will be used for drinking and cleaning food. Contamination of underground water has been reported in different townships in Zambia [11, 16, 22], and many workers have attributed it to poor sanitation and inadequate distance between borehole to the septic tank and soakaway system [11]. It is therefore important that long term, the local municipality and water and sewage utility companies consider servicing new residential areas with reticulated water and sewage facilities before the plots are sold for infrastructure development. It therefore calls for active involvement of local government and environmental agency such as Zambia Environmental Management Agency working closely to discourage onsite sewage treatment and accessing of groundwater through boreholes on the same residential yard.

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