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Determining water quality and the associated risk factors to contamination in kalingalinga compound of Lusaka District, Zambia

Brian Mukuka [1,*], Prince Mwansa [2], Boyd Mweemba [2], Mary Simwango [2], Kingford Chimfwembe [3] and Thelma Chansa Chanda [4]

[1] *Department of Clinical Medicine and Nursing, Faculty of Health Sciences, Chreso University, Lusaka, Zambia.*
[2] *Department of Public Health, Faculty of Health Sciences, Chreso University, Lusaka, Zambia.*
[3] *Department of Research and Postgraduate Studies, Chreso University, Lusaka, Zambia.*
[4] *Department of Business, Faculty of Education, Humanities and Social Sciences, Chreso University, Lusaka, Zambia.*

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Abstract

Overview: This study investigated the quality of water and the associated risk factors leading to contamination in the Kalingalinga Compound of Lusaka District, Zambia. Given the critical role that access to clean water plays in public health, the study focused on identifying the contaminants present in water sources and assessing the underlying factors contributing to their presence.

Body of Knowledge: The study explored the crucial aspects of water quality assessment and the identification of contamination sources in a densely populated urban area. It aimed to provide a comprehensive understanding of the water quality parameters, such as microbial, chemical, and physical contaminants, and their impact on public health. By analyzing the various environmental, infrastructural, and human factors contributing to water contamination, the study sought to identify the primary risk factors, including inadequate sanitation, poor waste management, and the proximity of water sources to pollution points.

Methods: This study employed a cross sectional study design in which 90 participants of Kalingalinga compound were selected at random in relation to their drinking water sources. Water samples were collected along with a structured questionnaire which was administered to each participant's household. Physical, Chemical and Microbial tests were conducted to determine the quality of water and the Total bacterial count (TBC) and total coliform count (TCC) were established. Multiple logistic regression was used to identify risk factors for contamination in STATA software.

Results: The study found that FCC of water samples from 15 sources (17%) were above the maximum legally accepted limits. Levels of coliforms did not conform to Zambian and WHO standards. Females were 13 times more likely to contaminate water than males (AOR: 12.42; 95% CI = 1.64,94.0; P = 0.02) whereas households that did not have adequate drinking water were 9 times more likely to contaminate the water than those who did (AOR = 8.26; 95% CI = 1.23,55.46; P = 0.03).

Recommendation: Immediate solutions are required to eliminate contaminations from water sources in the Kalingalinga compound proceeded by awareness on the best hygienic practices to ensure the quality of drinking water, encouraging the use of water filtration systems from the borehole to the house and improvement of sanitation with the help of the DHO, NGO and other stakeholders.

Keywords: Microbial Contamination; Total Bacterial Counts; Total Coliforms

* Corresponding author: Brian Mukuka

1. Introduction

Poor water quality and water contamination continue to be major causes of child mortality and morbidity across the world (Jasper et al., 2012). Water contamination is the leading worldwide cause of death and diseases such as cholera, scabies, dysentery, trachoma, and typhoid just to mention a few. Chanda et al (2024)'s study noted that cholera is an infectious disease caused by the bacterium *Vibrio cholera*, primarily transmitted through contaminated water and food. This waterborne illness can lead to severe dehydration and, if left untreated, can be fatal within hours. Water contamination can originate both at the water source, as well as within the water distribution system. Contaminants can include naturally occurring chemicals and minerals such as lead, mercury, and arsenic, agricultural pesticides and fertilizers, run-off from industrial operations and wastewater overflow (Pink, 2006)

Water contamination can result in a wide range of health effects, and can be life-threatening in some circumstances. Contaminated water is the leading cause of diarrheal diseases which is the second leading cause of death in children under five years of age in developing countries. Water-borne contaminants from pesticides are responsible for significant reproductive health problems among exposed populations, and many neurological disorders are related to exposure to wastewater containing heavy metals (Meinhardt, 2006)

Water quality can be affected by pollution from point sources and non-point sources. Point sources are pipe or channels which discharge directly into a body of water. This might come from water treatment plants, factories and industrial plants, latrines, septic tanks or piped discharge from farmyard and other places where livestock is confined. Non-point sources are those where pollution arises over a wider area and it is often difficult to locate the exact place of origin. For example, fertilizer, or pesticide washed from a field by rain may seep into a river or stream at many places both on the surface and through the soil. Other non-point sources are pollution from construction sites and other land disturbances (Goel, 2006)

Additionally, (Yates et al. 2011) stated that water quality is affected by a wide range of natural and human influences. Whilst, the national water quality inventory reported that water quality is influenced by many factors like precipitation, climate, soil type, vegetation, geology, flow conditions, ground water and human activities (EPA, 2009). However, water contamination is measured by analyzing water samples. Physical, chemical, and biological tests can be conducted through collection of samples followed by analytical tests (Sasikaran et al., 2012; Durmishi et al., 2012)

In Zambia on the other hand studies conducted in in Libala South of Lusaka district revealed that the boreholes were contaminated with 31% *Escherichia coli* and 48.5% coliforms (Nakaonga et.al., 2017). Microbial test results from randomly sampled boreholes in the Ngwerere sub-catchment of Lusaka revealed a high level of fecal coliform and total coliforms (Chande and Mayo, 2019). In 2023 Zambia recorded an outbreak of Typhoid largely associated with water contaminations across the country in cities like Lusaka, Mufulira, Kitwe and Mbala whereas in Petauke, 2,219 diarrhea cases were reported (MoH, 2023). In a neighboring country Zimbabwe, burst sewage pipes, and open defecation contaminated drinking water from shallow and unprotected wells leading to the death of about 4000 people from cholera outbreak (Kasamba, 2013)

Kalingalinga is a low-income, high-density settlement in the east of Lusaka comprising of 25,000 to 30,000 residents, it borders the townships of Mtendere and Kabulonga, and many of its occupants are people who were discouraged from settling in Lusaka and moved as squatters to outlying regions of the city (Frayne, et al., 2013). Because Kalingalinga is among the densely populated compounds, water supply is quite erratic making it easier for many people to resort to alternative sources of drinking water. However, many people may be unaware of the water quality posing a great risk to consumers as the water may be a source of many diarrheal diseases in the area. So far there is limited information in Kalingalinga compound about water quality and the associated risk factors with contamination of water.

1.1. Statement problem

The problem of determining water quality and associated risk factors to contamination in Kalingalinga Compound of Lusaka District, Zambia, is critical due to the compound's dense population and limited access to reliable sanitation and clean water. Residents often rely on communal water sources, which are vulnerable to contamination from inadequate waste disposal, overcrowding, and poor infrastructure. These conditions pose significant health risks, including the potential spread of waterborne diseases. Addressing these issues requires a thorough assessment of the water quality and identification of the key risk factors contributing to contamination, with the ultimate goal of informing targeted interventions that can improve the community's access to safe water and reduce health hazards.

Objectives

The objectives of this study were:

- To identify water sources and determine the usage of water in Kalingalinga compound
- To determine the microbial content in water in Kalingalinga compound and its conformity to the set Zambian standards
- To determine the compositional quality (physical and chemical) of water in Kalingalinga and its conformity to the set Zambia standards
- To identify the possible risk factors for water contamination in Kalingalinga Compound.

1.2. Conceptual framework

The conceptual framework for determining water quality and associated risk factors to contamination in Kalingalinga Compound, Lusaka District, Zambia, revolves around understanding the interplay between environmental, infrastructural, and human behavioral factors. (Diesing, 2009) postulates that water quality is influenced by a combination of physical, chemical, and biological parameters, which are affected by sources of contamination such as inadequate sanitation facilities, poor waste disposal practices, and the proximity of water sources to potential pollutants. (Thelma & Chitondo, 2024) explained that waste management is a critical component of environmental sustainability, encompassing various processes and strategies aimed at minimizing waste generation, maximizing resource recovery, and reducing environmental impacts. The framework also considers socio-economic factors, including community awareness, household income levels, and access to clean water infrastructure, as critical determinants of water safety. By mapping out these interrelated factors, the framework aims to identify key risk points and suggest targeted interventions to mitigate water contamination, ultimately contributing to improved public health outcomes in the community.

1.3. Significance of the study

The significance of this study lies in its potential to address critical public health concerns in the Kalingalinga Compound of Lusaka District, Zambia, by evaluating water quality and identifying associated risk factors for contamination. This study is vital for informing local authorities, policymakers, and residents about the safety of drinking water, which is fundamental to preventing waterborne diseases and ensuring the overall well-being of the community. By identifying contamination sources and risk factors, the study aims to provide evidence-based recommendations for improving water management practices, promoting public health, and enhancing the quality of life in the Kalingalinga Compound. The findings could also serve as a model for other urban areas facing similar challenges, thereby contributing to broader efforts to improve water quality and public health across the region.

2. Material and methods

Research location: Kalingalinga is a low-income and high-density settlement as of 106, 148 population. The area has 17, 692 households, 17, 236 water points, of which 21 are communal taps, while 9 are boreholes. The study included all drinking water sources (tap water, borehole and wells) found in the area and at least one household owner (their proxy) for each water source and such should be known users living in Kalingalinga. Drinking water sources in Kalingalinga compound were included in the study out of which the sampling frame was generated. The probability sampling method (simple random sampling) were employed where each participant in relation to their drinking water sources were given equal chances of being selected. From the total population of 106148, at least 90 of the participants and water sources were required in order to detect the difference in the study at 80% power. Therefore, the study recruited a total of 90 participants. The study collected data using laboratory analysis and a survey. Drinking water which was used for laboratory analysis was obtained from sources whose participants in the study were elected. Microbial risk assessment was carried out by assessing water for microbial load and the presence of fecal coliforms such as *E. coli* from the same participants 90. These participants from whom water was collected were also relied upon to collect information using a questionnaire. These two approaches were employed in order to link the laboratory outcome to contamination risk factors.

Water sample handling: All samples were coded with randomly selected numbers for identification and stored in a cool box with ice packs during field work. Thereafter, the samples were stored between +2^{o}C to +8^{o}C temperature after each day's field work. Later on, samples were transported within 48 hours after collection under controlled temperature to food & drug laboratory at the University Teaching Hospital (UTH). The data collected on the microbial status in water was entered in the laboratory forms in readiness for use at analysis stage.

Laboratory analysis of water samples: Analyses was carried out in the food & drug laboratory at UTH. Analysis for microbial status of water involved establishing the total bacterial counts (TBC) and total coliform count (TCC). Bacterial speciation and characterization involved isolation of some common pathogenic microbes such as *E. coli* and *Staphylococcus aureus* and compared to Zambian standards. The primary outcome for water samples were calculated as the total number of water samples that failed microbial standards and expressed as a percentage.

Statistical analysis: Laboratory outcome and interviews data were entered in Microsoft excel and SPSS. Cleaning of data for any errors were carried and later exported to STATA V.13 (STATA Corporation, TX, and USA) for analysis. Means with associated standard deviations were used to summarize and describe continuous variables. Colony forming units (CFU) was counted to determine the microbial status in water and other variables and compared with Zambian standards. The association between social demographic characteristics and other risk factors on water contamination was measured and expressed as dichotomous outcome. Multiple logistic regression was used to identify risk factors for contamination of milk at 95% significance level. In addition, tables were used in presentation of the results.

3. Results and discussion

The study was aimed at determining the microbial content and compositional quality of water and the associated risk factors to contamination in the Kalingalinga compound. To achieve this aim, water sources were identified and the usage of water was determined. Additionally, the microbial content in water, the compositional quality (physical and chemical) in water, and its conformity to the set Zambia standards was carried out. The possible risk factors for water contamination in Kalingalinga Compound were determined.

The study had a total number of 90 participants. Out of these, 33(36.70%) participants were between the age of 18-25 years, 31(34.44) participants were between the age of 26-35 years, while 26(28.89%) were 35 years and above. The majority of the participants were Female 46(51.11%), while Men 44(48.89%). Most of the participants had attained secondary education level 47(52.22%). The study established that the majority 55(61.11%) of the population (households) access drinking water from the tap with the least 1(1.11%) population accessing drinking water from other sources. Most of the households 78(86.67%) use water for drinking with the least of the households 1(1.11%) use the water mostly for washing. Our findings compare with another study on assessment of the quantity and microbiological quality of domestic water supplied to residents of peri-urban townships of Lusaka district where it was revealed that 90% of the residents in the Peri-urban areas of Lusaka district have access to piped water of which 65% of the households fetched from communal taps (Silavwe et al., 2018)

Microbial tests from our study revealed that the Fecal Coliform Count (FCC) of water samples from 15 sources (17%) was above the maximum legally accepted limits in Zambia (<1cfu/ml of water sample). The results of the finding were also compared to WHO standards of (<1cfu/ml) on fecal coliform of water samples. The fecal coliform count ranged from 7 to above 120 x 10-4 cfu/ml of water samples. Total Coliforms Count (TCC) from 15 samples (17%) did not conform to recommended Zambian standards (<1cfu/ ml of water samples) and with WHO recommended guidelines (<0 cfu/ml of water samples) as evidenced by levels of coliforms ranging from 8cfu/ml to 124 x 104cfu/ml of water samples. Current study recorded the highest contamination fecal coliform in tap water 7(17%) and bore water 7(11%). The total coliform was 8(15%) for tap water and 5(19%) for bore water. Well water recorded 1(14%) for fecal coliform and 2(29%) for total coliform.

A study to assess water quantity and microbiological quality of domestic water supplied to residents of peri-urban townships of Lusaka district revealed that 60.0% and 52.5% were contaminated with total and fecal coliforms, respectively. The report further indicated that the contaminations in the open well were (100%) while borehole and tap water were 52% and 51%, respectively, and attributed ineffective chlorination from the source, ineffective dozers along the distribution line, or leaking pipes along the line of distribution could lead to contamination of tap water to the causation of the contaminations (Silavwe et al., 2018). Microbial test results from our study compared favorably to the microbial analyses of randomly sampled boreholes in the Ngwerere sub-catchment of Lusaka where the water was reported to have high levels of fecal coliform and total coliforms (Chande and Mayo, 2019). Our findings are further supported by the report from the bacteriological analysis of borehole water from Libala South conducted by (Nakaonga, et al., 2017) from which some water sources were found contaminated with coliforms and *Escherichia coli* (31.3% in 20 borehole water samples). In another study in St Bonaventure of Lusaka, thirty-three boreholes (51.5%) of the total 64 had water with bacteriological quality meeting the standards recommended for drinking by WHO while 33% of the boreholes were contaminated with bacteria of which *E. coli* was isolated in 10.9 % of the boreholes (Banda et al., 2014)

Our study plus several others clearly indicates that the microbiological quality of drinking water in Lusaka district as well as other towns of Zambia are not in conformity with the Zambia Bureau of Standards (ZABS) and WHO that requires drinking water or for household use to be free of faecal coliforms (Silavwe L.M et al., 2018). As indicated by several other studies, the presence of *E. coli* in water is an indication of contamination by human or animal fecal wastes usually from septic tank discharges and waste materials from a nearby dump site. Therefore, Improper disposal of sewage and wastewater from domestic activities, and discharges from septic tanks and latrines close to some of the boreholes remain the main cause of contamination. With *E. coli* in water, sensitive subpopulations like infants, immune-compromised individuals, and pregnant women become more susceptible to diseases (Wamukwamba and Share, 2001; Banda, 2013; Banda et al., 2014; Silavwe L.M et al., 2018)

Compositional quality (physical and chemical) of water revealed that all 90 (100%) water samples conformed to recommended Zambian standards in both physical and chemical composition. The main parameters considered were PH, Turbidity, Copper (mg/l), Lead (mg/l), and Floride (mg/l) with the average values of 6.5-8.5, 0.0-5.0, =<2mg/L, =<0.01 and =<1.5mg/L respectively. Our water compositional quality findings indicate that drinking water sources in Kalingalinga have a reasonably good chemical quality in accordance with the Zambian standards. The physical-chemical parameters can deteriorate water quality. Heavy metals, like lead, copper, and fluoride are dangerous for human health, since they are toxic and can be carcinogenic but, in many cases, there is little or no information about arsenic and fluoride in drinking water (Sorlini, et al., 2013). The pH of drinking water has no immediate direct effects on human health but has some indirect health effects by bringing changes in other water quality parameters such as solubility of metals and survival of Pathogens (Fadaei and Sadeghi, 2014). Turbidity itself is not a major health concern, however, high turbidity can interfere with disinfection and water treatment processes and provide a medium for microbial growth and contamination (WHO, 2017)

To identify the demographic characteristics that were influencing the compositional quality of water in Kalingalinga compound, the study investigated the association between contamination with a microbes and chemicals of public health significance and probable risk factors. These were social demographic characteristics, hygiene-related factors, and environmental-related factors. Logistic regression was used to assess the association between risk factors and contamination outcomes in water.

Bivariate analysis was conducted at a Probability value < 0.05 and only the age of the respondents and the quantity of fetched drinking water in households were significant for water contamination. In order to adjust for confounding factors, all variables were considered for the multivariate modeling. Those who were 35 years were 90% less likely to contaminate the water (OR = 0.13; 95% CI = 0.01,1.07; P = 0.05). Those who did not fetch adequate water in their households were about 3 times more likely to contaminate the water (OR = 2.45; 95% CI = 0.68,8.76; P = 0.01)

After adjusting for the confounding effects of all the hypothesized risk factors such as age, availability of water collected daily, distance of the household to the water source, condition of the water source, if participants suffered from any water borne disease, type of the disease suffered, type of the water source, education level, females were 13 times more likely to contaminate water than males (Adjusted Odds Ratio: 12.42; 95% CI = 1.64,94.0; P = 0.02). Households that did not have adequate drinking water were 9 times more likely to contaminate the water than those who did (AOR = 8.26; 95% CI = 1.23,55.46; P = 0.03).

Comparing our findings observed during an assessment of factors influencing sanitation and diarrhea in a peri-urban settlement of Lusaka by (Nyambe, et al., 2020), income, gender, access and quality of water, ownership of an improved toilet, and unimproved sanitation methods are the likely factors associated with water contamination.

Safe drinking water problems are not restricted to Zambia but to the whole of Africa. Sub-Saharan Africa is experiencing rapid urban population growth and access to safe drinking water is a priority. Because of the lack of services, self-provision of water, using groundwater sources is adopted putting pressure on the quality and quantity of the groundwater resource. High population densities have contributed to the construction of latrines in very close proximity to wells and springs used for drinking water, and can be a significant source of contamination. (Lapworth, 2017) further stated that lack of management of household and industrial waste is a possible cause of water contamination.

4. Conclusion

A majority 55(61.11%) of the household's access drinking water from the tap with the least 1(1.11%) population accessing drinking water from other sources. Most of the households 78(86.67%) use water for drinking with the least of the households 1(1.11%) use the water mostly for washing. The FCC of water samples from 15 sources (17%) were above the maximum legally accepted limits in Zambia and by WHO with the recorded range of 7 to above 120 x 104 cfu/ml. Levels of coliforms did not conform to Zambian and WHO standards as they ranged from 8cfu/ml to 124 x

104cfu/ml of water samples. All the 90(100%) water samples conformed to recommended standards for both physical and chemical composition (PH, Turbidity, Copper (mg/l), Lead (mg/l), and Floride (mg/l). Multivariate regression revealed that females were 13 times more likely to contaminate water than males (AOR: 12.42; 95% CI = 1.64,94.0; P = 0.02) whereas households that did not have adequate drinking water were 9 times more likely to contaminate the water than those who did (AOR = 8.26; 95% CI = 1.23,55.46; P = 0.03).

Compliance with ethical standards

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Disclosure of conflict of interest

Authors have no conflict of interest.

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