Bacteriological and Chemical Quality of Packaged Water Produced in Lusaka, Zambia and Associated Quality Control Measures

By

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A dissertation submitted to the School of Public Health of the University of Zambia in partial fulfilment of the requirements for the award of a Master of Public Health in Environmental Health degree.

University of Zambia

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DEDICATION

This work is dedicated to my family: my wife Chanda Mungulube; my children Nandi, Thando and Kambuza; Dad and Mum Mr and Mrs Greyford and Esther Kachikoti Banda and all my siblings William, Mercy, Lena, Greyford and Patrick for their encouragement.

ABSTRACT

Many people in the world lack safe basic drinking water sources and rely on untreated water sources. Unsafe drinking water is responsible for transmission of diseases such as Cholera, Dysentery and Typhoid. Packaged water can be considered as an alternative to other water sources if measures are put in place to ensure its safety for human consumption. Studies prior to this one focused on the quality of water sold in Lusaka regardless of the district the water is produced from. There has also been less focus on the quality control measures that may influence quality.

A cross-sectional study was conducted to assess the bacteriological and chemical quality of packaged water produced in Lusaka and associated quality control measures. Water samples from 17 companies producing packaged water in Lusaka were analyzed for total and feacal coliforms as well as concentrations for Lead, Chromium and Cadmium. Stata version 15 was used for data analysis. The fisher's exact test was used to test for associations between the quality of packaged water and quality control measures.

The study found that 35.3 percent of the packaged water produced in Lusaka did not comply with the standard for drinking water on bacteriological quality. It also found that the concentrations for Lead were less than 0.01mg/l in all the 17 samples, thus compliant to WHO/ZABS standards. Concentrations of Chromium were between 0.002mg/l and 0.62mg/l and compliance to the standard was 11.8 percent. Concentrations for Cadmium were as low as 0.009mg/l and as high as 0.2mg/l as such, non-compliant. All brands of packaged water from companies inspected quarterly by Lusaka City Council were compliant to the bacteriological standards of drinking water. Packaged water produced by companies that own bacteriological laboratories accounted for 47.1 percent of satisfactory results while only 17.3 percent were satisfactory from companies without bacteriological laboratories. None of the companies had means of removing heavy metals from water during processing.

Both the bacteriological and chemical quality of the packaged water need to be improved to safeguard the health of the people. Processing of the water should therefore target removal of all bacteria and heavy metals. Government agencies should also monitor the companies regularly to ensure compliance to standards.

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LIST OF ABBREVIATIONS/ ACRONYMS

AAS	Atomic Absorption Spectroscopy
CAC:	Codex Alimentarius Commission
CCPC	Competition and Consumer Protection Commission
CFU:	Coliform Forming Unit
E. coli:	Escherichia coli
FC:	Feacal Coliform
FDA:	Food and Drugs Act
GMP	Good Manufacturing Practices
GRZ	Government of the Republic of Zambia
HACCP	Hazard Analysis Critical Control Points
IBWA	International Bottled Water Association
IEC	Electrotechnical Commission
ISO	International Organization for Standardization
LCC:	Lusaka City Council
MoH	Ministry of Health
SADCAS	Southern Africa Development Community Accreditation Service
TC:	Total Coliform
TNTC:	Too Numerous to Count
UNICEF:	United Nations International Children's Emergency Fund

WARMA	Water Resource Management Authority
WHO:	World Health Organization
ZABS:	Zambia Bureau of Standards
ZCSA	Zambia Compulsory Standards Agency

CHAPTER ONE: INTRODUCTION

1.1 Background

The proportion of the global population with at least basic drinking water services has increased by an average of 49 percent per year between 2000 and 2015. The increase was substantially faster in Eastern and South-eastern Asia and sub-Saharan Africa where the increase was 97 percent and 88 percent respectively. The 844 million people who still lacked basic drinking water service in 2015 either used improved sources with water collection times exceeding 30 minutes due to limited services, used unprotected wells and springs which are unimproved sources, or took water directly from surface water sources (WHO, 2017).

The Joint Monitoring Program (JMP) uses a simple improved/unimproved facility type classification that has been refined over time to describe the type of water sources. Improved sources are those that have the potential to deliver safe water by nature of their design and construction. These include piped supplies such as households with tap water in their dwelling, yard or plot; or public stand-posts and non-piped supplies such as boreholes, protected wells and springs, rainwater and packaged or delivered water. Packaged water and delivered water can potentially be safely managed, but these were previously treated as unimproved due to lack of data on accessibility, availability and quality. For sustainable development goal (SDG) monitoring, the JMP treats packaged water as improved and classifies it as limited, basic or safely managed, based on the criteria outlined above (WHO, 2017).

Due to the increasing demand for access to safe drinking water, the global population has turned to the use of packaged water (Salehi et al., 2014). Packaged water is natural or treated water that reaches the consumer as a packaged product in either a glass or plastic container (Manaia and Nunes, 2017). Choice of packaged water is influenced by social norms, safety and image on consumer choice (Etale et al., 2018).

Three major types of packaged water can be identified: natural mineral water; spring water; and purified water (Ferrier, 2001). Natural mineral water corresponds to an extremely specific product that must meet certain criteria in the European Union. It is microbiologically wholesome water, originating in an underground water table or deposit and emerging from a spring tapped at one or more natural or bore exits. Natural mineral water, whether still or aerated, is very different from other types of packaged water because of its nature. It is characterized by a constant level of minerals and trace elements. Natural mineral water is particularly wholesome and can have health-benefiting effects. It is also characterized by its original state, preserved intact because of the underground origin of the water which is protected from all risks of pollution. Its composition is stable and not affected by possible variations in the rate of flow. Natural mineral waters are not sterile water and can contain natural microflora. It is a raw product that cannot be treated nor have any exogenous element such as additives or flavours put into it. However, some exceptions are admitted, as long as they do not alter the composition of the water, in particular: the separation of unstable elements, such as iron and sulphur compounds; the separation of undesirable constituents, such as manganese or arsenic; and the total or partial elimination of free carbon dioxide by exclusively physical methods (Ferrier, 2001). Spring water is underground water, protected against pollution hazards, microbiologically safe, suitable for human consumption without any additional treatment, except those authorized such as aeration (ibid).

Purified water or drinking water as water taken from rivers, lakes or underground springs and has undergone some form of treatment (Ferrier, 2001). It can be produced by distillation, deionization, reverse osmosis or other suitable processes. It should be noted that a single source of water can be used to produce more than one category of packaged water. For instance, a borehole can be used to produce natural mineral water and purified water.

Packaged water has become very popular for quenching thirst and as a dietary (mineral) supplement. The excess of natural mineral waters precludes any unequivocal system of classification, which makes it difficult for the consumer to choose a water with properties that suits him or her exactly. There is a possibility of misclassification or deception by the companies. The ever-increasing popularity of packaged waters means that it is of the utmost importance to determine not only their mineral content, but above all, the content of possible contaminants (Diduch et al., 2013).

Packaged water production has been a growing industry in Zambia and most people in Zambia perceive packaged water to be better than tap water in terms of quality (Nyundu et al., 2012).

Requirements for processing packaged water are found in the Public Health Act Chapter 295, the Food and Drugs Act Chapter 303 and the Standards Act. Enforcement authorities include local authorities, Ministry of Health, Zambia Bureau of Standards (ZABS), Zambia Compulsory Standards Agency, the Competition and Consumer Protection Commission and the Water Resource Management Authority.

Quality of water is the degree to which the water is portable and is determined by the level of physicochemical and microbial characteristics (Yilkal et al., 2019). The World Health Organization (WHO) standards for drinking water quality indicate that total coliforms and feacal coliforms must be absent in 100ml of water (WHO, 2011). This is similar to the Zambian standards administered by the Zambia Bureau of Standards.

Similarly, both WHO and ZABS standards for drinking water quality indicate that Lead, Chromium and Cadmium concentrations must be <0.001ml/l, <0.05 ml/l and <0.003m/l respectively (WHO, 2011, ZABS, 2000).

This study assessed the bacteriological and chemical quality of packaged water produced in Lusaka and associated quality control measures.

1.2 Statement of the Problem

Globally, 844 million people lacked basic drinking water sources and 12 percent of the population in Zambia relied on untreated water sources in 2015 (WHO, 2017). Unsafe drinking water can lead to spread of water borne diseases. The recent Cholera outbreak in Zambia which started on 6th October 2017 and ended on 18th May 2018 recorded 5, 905 suspected cases of Cholera in the 10 provinces of Zambia (Sinyange et al., 2018). Of these suspected cases, 5,414 (91.7 percent) were recorded in Lusaka with 98 deaths representing a case fatality rate of 1.8 percent. The outbreak was partly attributed to unsafe drinking water.

Packaged water is one of the safe water sources. However, unsafe packaged water can cause water borne diseases. A study in 2014 revealed that 8.9 percent of packaged water sold in Lusaka did not meet ZABS/WHO bacteriological standards for drinking water (Meki et al., 2014). However, the chemical quality of packaged water was not studied. Furthermore, the study by focused on packaged water sold in Lusaka but the current study will be on packaged water produced in registered or licensed companies in Lusaka.

Packaged water is produced by processing raw water from springs, rivers or boreholes and can either be natural or purified. The quality of packaged water is dependent on quality control measures by companies producing packaged water and external monitoring agencies.

This study therefore aimed to assess the bacteriological and chemical quality of packaged water produced in Lusaka and associated quality control measures.

1.3 Rationale

This research provides an insight into the quality of the packaged water produced in Lusaka. Beneficiaries of the research will include consumers, companies producing water, enforcement agencies and the academia.

Consumers may use the study in making informed choices about consumption of packaged water taking into account the safety and health benefits. Information on the quality of the packaged water will also enable production companies improve or sustain quality control measures depending on the quality of their water. This may enable them serve the consumers better.

Enforcement agencies that include Lusaka City Council (LCC) Ministry of Health (MoH), Zambia Compulsory Standards Agency (ZCSA) and the Competition and Consumer Protection Commission (CCPC) will use the results of the study to plan and implement regulation and enforcement programs.

Finally, the research adds to the body of knowledge and also allows academic institutions to research on the gaps identified.

1.4 Conceptual Framework

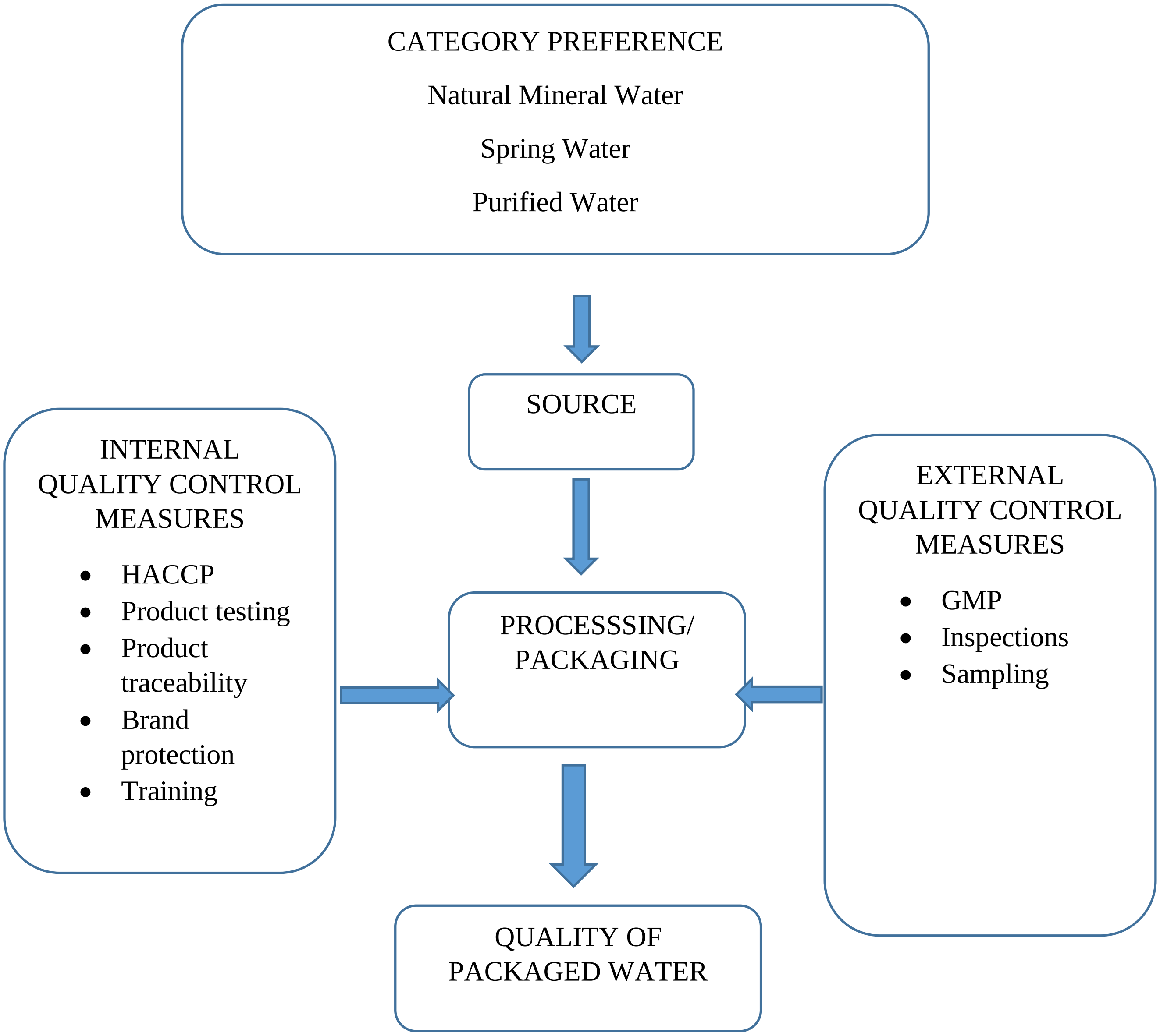

Figure 1: Conceptual Framework

Sources: IBWA, 2000, Meki et al., 2014

The bacteriological and chemical quality of water is dependent on both internal and external quality control measures. Internal quality control measure as activities carried out by companies with the processing plants to ensure production of products of the required standards. External quality control measures are activities conducted by government agencies to monitor compliance to standards.

1.5 Research Questions

1.5.1 What is the bacteriological quality of packaged water produced in Lusaka and associated quality control measures?

1.5.2 What is the bacteriological quality of packaged water produced in Lusaka and associated quality control measures?

1.6 Objectives

1.6.1 General Objective

To assess the bacteriological and chemical quality of packaged water produced in Lusaka and associated quality control measures.

1.6.2 Specific Objectives

1. To determine the bacteriological quality of packaged water produced in Lusaka.
2. To determine the concentrations of Lead, Chromium and Cadmium of packaged water produced in Lusaka.
3. To ascertain quality control measures associated with quality of packaged water produced in Lusaka.

1.7 Working Definitions

Chemical Quality: Concentration levels of Lead, Chromium and Cadmium.

Cleanliness: Absence of litter, stains, dirt, feacal matter or other substances likely to promote disease or become a sight nuisance.

Compliance: In conformity with set standards, rules or regulations.

Packaged Water: Water filled into hermetically sealed containers of various compositions, forms, and capacities that is safe and suitable for direct consumption without necessary further treatment.

Quality Control Measures: Measures employed by companies to ensure production and supply of packaged water in compliance with standards.

Standards: WHO guidelines for drinking water quality and the ZABS standards for drinking water.

CHAPTER TWO: LITERATURE REVIEW

2.1 Bacteriological Quality of Drinking Water

Water must be adequate, safe and accessible in order to support health and protect the public from ill health (WHO, 2011). Diseases related to contaminated water are a major burden on human health and improved quality of drinking-water provide significant health benefits (WHO, 2017). It is further reported that globally, at least 2 billion people use a drinking water source contaminated with feces with an estimation of 502, 000 deaths due to diarrhea each year (WHO, 2017).

Table 2.1 shows the bacteriological quality of packaged water according to the WHO and ZABS standards for drinking water.

Table 2.1: WHO/ ZABS standards for drinking water

	Coliform forming units (CFU) in 100 ml of water	
	Total Coliforms	Feacal Coliforms
WHO	Absent	Absent
ZABS	Absent	Absent

Source: (WHO, 2011, ZABS, 2000)

A study in Dharan municipality in Nepal revealed presence of total coliforms in 25% of bottled water though none of the bottled water samples had feacal coliforms (Pant et al., 2016). In a similar study on the microbiological quality of sachet water sold in Maiduguri metropolis, Nigeria revealed the presence of *coliforms*, *E. coli*, *Pseudomonas* sp. and *Salmonella* sp. Ninety-five percent were not fit for human consumption (Muazu et al., 2012). The study revealed that this could have been as a result of inadequate sanitation and unhygienic practices or ineffective or malfunctioning water treatment processes.

A study conducted in Pretoria, South Africa found that two brands out of eight brands of packaged water did not comply with the South African Bureau of Standards (SABS) guidelines for microbial quality of drinking water (Ehlers et al., 2004). It was further concluded that microbial contamination of packaged natural water is most likely to occur due to improperly cleaned equipment and bottles, failure of zonation or ultraviolet (UV) equipment or due to contamination of the water by workers.

A study in Eretria found that contaminated water caused viral, bacterial and parasitic diseases which were transmitted through consumption and use of water (Demena et al., 2003). A study on the compliance to the bacteriological quality of packaged water sold in Lusaka and revealed that 8.9 percent of analyzed samples were positive for both feacal and total coliforms in every 100ml of water (Meki et al., 2014). The study revealed that the majority of the contaminated packaged water was from the market indicating that contamination could be attributed to processes after treatment and bottling such as transportation and storage.

2.2 Chemical Quality of Drinking Water

Chemicals in drinking water can also cause health problems. High concentrations of heavy metals in drinking water renders the water unfit for consumption. Heavy metals are elements with a weight 4-5 times as much as the weight of water (Fakhri et al., 2015). Heavy metals such as lead, chromium and cadmium are dangerous in man because of toxicity and biological accumulation (WHO, 2011).

Table 2.2 shows the maximum permissible levels of lead, chromium and cadmium according to the WHO and ZABS standards for drinking water.

Table 2.2: Permissible levels for lead, chromium and lead by WHO and ZABS

Element (mg/l)	Permitted
Lead	<0.01
Chromium	<0.05
Cadmium	<0.003

Source: WHO, 2008; ZABS 2000

The maximum acceptable level of lead, chromium and cadmium are 0.01mg/l, 0.05 and 0.003 mg/l respectively (WHO, 2011, ZABS, 2000) A review of heavy metals in drinking water and their effect on human health reported that higher concentrations of heavy metals cause physiological effects on the digestive, circulatory, nervous and other body systems (Priti and Paul, 2016). Lead and Cadmium are potent neurotoxins that accumulate in soft tissues and bone over time and are carcinogenic.

An increased risk of stomach cancer if chromium is ingested in drinking water was documented in a study in Liaoning Province in China (Beaumont et al., 2008). The study found that mortality attributed to stomach cancer in the exposed population was elevated compared with regions without contaminated water (RR = 1.82; CI 1.11–2.91) and compared with the whole province (RR = 1.69; CI 1.12–2.44).

Contamination of drinking water with heavy metals occurs due to both geogenic activities such as weathering and erosion of bedrocks, ore deposits, and volcanic eruptions as well as anthropogenic activities that include agriculture, mining, effluent from industries, waste water irrigation and solid waste disposal (Nawab et al., 2015, Ok et al., 2011). A study on the microbial and physicochemical quality of packaged water produced in Hamadan province of Iran revealed that all measured parameters of packaged water in Hamadan province were within acceptable range of the national and international standards (Salehi et al., 2014).

Lead pollution has been reported to be a serious challenge in mining areas of Zambia (Tirima et al., 2015, Mihaljevič et al., 2011, Yabe et al., 2018). Chromium and cadmium have similar effects but there is scanty information on their occurrence in packaged drinking water in Zambia.

2.3 Water Quality Control Measures

International guidelines for quality control measures of water are provided by the Codex Alimentarius Commission (CAC, 2001). It is recommended that ground water supplies should be tested regularly for constancy of biological, chemical, physical and, where necessary, radiological characteristics. The frequency of testing is determined by the hydrogeological evaluation, the amount of water collected, and the historical constancy pattern of a particular water supply. If contamination is detected, production of packaged water should cease until the water characteristics have returned to established parameters. Any underground supply from which water is collected, should be approved by an official authority having jurisdiction or by a third party with expertise for approving such underground supplies.

Water intended for bottling should be microbiologically, chemically and physically suitable that treatment of that water during processing results in finished packaged drinking water products that are safe and suitable for consumption. Generally, the higher the quality of the water intended for bottling, the less treatment is required to produce safe packaged drinking water products. Surface waters should be tested for safety frequently and treated as necessary. All treatments of water intended for bottling should be carried out under controlled conditions to avoid any type of contamination, including the formation of toxic by-products like bromates and the presence of residues of water treatment chemicals in amounts that raise health concerns in accordance with relevant WHO guidelines (CAC, 2001).

A study on the extent to which drinking water is tested for compliance in sub-Saharan Africa including Zambia revealed that regulated water quality monitoring activities did not achieve testing levels specified by WHO Guidelines or national standards, particularly among smaller water suppliers and surveillance agencies (Peletz et al., 2016). The analysis showed that bureaucratic procedures such as the development of national standards and the creation of independent regulatory bodies are unlikely to solve the problem without parallel commitments to implementation of the policies which include greater resource allocations for monitoring in small towns and focusing on improving the cost-effectiveness of water quality monitoring. Cost-effectiveness of risk-management procedures include applying sanitary surveys to reduce testing of clearly contaminated supplies and prioritizing water quality parameters that represent the greatest risks to public health. Coordination between surveillance agencies and private sector equipment suppliers would improve the supply of testing equipment and consumables. Furthermore, institutions require the resources and skills to act upon testing results to improve water quality. Finally, capacity building of monitoring programs should focus on program sustainability and applying water quality data towards improved water safety.

In Zambia, water quality monitoring for packaged water is conducted by authorities that include local authorities, the Ministry of Health, Zambia Compulsory Standards Agency and the Competition and Consumer Protection Commission.

CHAPTER THREE: METHODS AND MATERIALS

3.1 Study Design

An analytical cross-sectional study design was used to answer the research question. The researcher determined the exposure (quality control measures) and the outcome (quality of packaged water) at the same time in May 2019.

3.2 Study Area

The study was conducted in the Capital City of Zambia, which is Lusaka and it is located by coordinates; 15°25' South of the equator and 28° 17' east of Greenwich. The city has a population of 2,566,758. Lusaka is one of the fastest growing cities in Zambia. It experienced rapid urban growth of about 23 percent increase in the total urban area from 1990 to 2010 (Simwanda and Murayama, 2018). Being a center of commerce, new businesses including water bottling have been emerging.

Most companies producing package water are located in industrial area or areas in close proximity to the industrial area. Groundwater sources within the area are used as sources of the packaged water.

3.3 Study Population

The study population was all companies producing packaged water in Lusaka. There were a total of forty-six (46) companies producing packaged water in Lusaka (ZCSA, 2018).

3.4 Inclusion Criteria

The study included all companies which were producing packaged water in Lusaka.

3.5 Exclusion Criteria

Companies which were closed during the study and those which did not consent to be part of the study were excluded.

3.6 Sample Size

Total enumeration of the forty-six (46) companies producing water in Lusaka was conducted. Nine (9) companies were not operational, six (6) were outside Lusaka District, seven (7) were not traced and seven (8) did not consent to be part of the study leaving eighteen (17) companies which were included in the sample.

3.7 Study Variables

The study had two dependent variables with respective independent variables as shown in table 3.1.

Table 3.1: Study Variables

Variable	**Indicator**	**Scale of Measurement**
Dependent		
Bacteriological quality of packaged water	Total coliforms	▪ Absent in 100ml of water = compliant ▪ Presence in 100ml of water = non-compliant Nominal
	Feacal coliforms	▪ Absent in 100ml of water = compliant ▪ Presence in 100ml of water = non-compliant Nominal
Chemical quality of the packaged water	Concentration of Lead	▪ Less than 0.01mg/l = compliant ▪ More than 0.01mg/l = non-compliant Nominal
	Concentration of Cadmium	▪ Less than 0.003mg/l = compliant ▪ More than 0.003mg/l = non-compliant Nominal

Variable	Indicator	Scale of Measurement
	Concentration of Chromium	▪ Less than 0.05ml/l – compliant ▪ More than 0.05ml/l = compliant Nominal
Independent		
ZABS Registration	Presence or absence of report or certificate	▪ Presence = Compliant ▪ Absence = non-compliant Nominal
LCC Licence	Presence or absence report or certificate	▪ Presence = Compliant ▪ Absence = non-compliant Nominal
Category of packaged water produced	Natural mineral water and purified water	▪ Natural Mineral Water ▪ Purified Water Nominal
Abstraction source of the water intended for packaging	Source of water to be packaged	▪ Spring ▪ Borehole (deep well) ▪ Water utility ▪ Any other Nominal
Presence of chemical Laboratory	Evidence of functional lab Laboratory	▪ Presence ▪ Absence Nominal
Water testing for heavy metals by companies	Presence of laboratory results and frequency of testing	▪ Once a week ▪ Once a month ▪ Once every three months or ▪ Once every six months

Variable	Indicator	Scale of Measurement
		Nominal
Frequency of inspections and water testing by LCC	Records of reports and frequency of inspections	▪ Once every three months ▪ once every six months Nominal
Frequency of inspections and water testing by ZABS/ZCSA	Frequency of inspection	▪ Once every three months or ▪ once every six months Nominal
Heavy metal removal during processing	Being done or not being done	▪ Being Done ▪ Not Being Done Nominal
Evidence of functional bacteriological Laboratory	Present or absent	▪ Presence ▪ Absence Nominal
Frequency of bacteriological water testing by companies	Presence of laboratory results and frequency of testing	▪ After each batch ▪ Once a week ▪ Once a month ▪ Once every three months ▪ Once every six months Categorical

3.8 Data Collection Techniques and Tools

3.8.1 Water Sampling

Data was collected by the Principal Investigator and two trained Research Assistants. Water samples were recorded on a sampling form Annex II. Water samples from the companies were collected from batches ready for distribution. Simple random sampling was used to collect the water samples by conducting a raffle for the last 20 cases of water produced. Pieces of paper with numbers 1 to 20 where put in a bag and the researcher picked a number representing the case where the bottles were to be picked. One bottle or sachet of a minimum of 500ml capacity for each brand was collected for bacteriological analysis. A minimum of 1 litre is required for chemical analysis according to the ZABS guidelines. For some brands of water that were packaged in packages of less than 1 litre, the researcher had to combine two or three bottles or packages to come up with the required quantity of the water.

The samples were kept in a cooler box packed with ice blocks at temperatures from 4^0C to 10^0C and transported to the Zambia Bureau of Standards laboratory in Lusaka within 24 hours of collection for analysis. This was to make sure that the microorganisms that may have been present do not grow and multiply.

3.8.2 Bacteriological Analysis of Water

Membrane filtration method was used for bacteriological analysis of the water because it allows for isolation and enumeration of discrete colonies of bacteria.

After receiving the sample at the laboratory, necessary dilutions were made. The absorbent pad was added to the Petri dish. The pad was soaked with Lactose agar with Tergitol 7. Flamed forceps were used to remove the membrane filter from the sterile package and was placed into the filtration apparatus. The water sample was then added to the filtration apparatus and a vacuum was applied to the suction flask. The filter was then removed with sterile forceps from the funnel and placed in the prepared Petri dish and incubated at 36 degrees Celsius for 24 hours for total coliforms and 44.5 degrees Celsius for feacal coliforms. The colonies were then counted and reported. The term too numerous to count was used to denote colonies which were more than 200 in number.

The laboratory used TEST-1-0013 of the ISO/IEC 17025 SADCAS accredited method to analyze the samples. Measures done to assure quality of the results included replicate testing and replicate evaluation of test results.

3.8.3 Heavy Metal Analysis of water

Analyses for lead, cadmium and chromium were conducted by atomic absorption spectroscopy (AAS). The method is used to determine quantities of trace elements using the absorption of light by free atoms in gaseous state. The samples were placed in graphite tubes in the furnace, evaporated to dryness and charred after which they were atomized at temperatures above 2300 °C. Radiation from metal-specific hollow cathode lamps was passed through the vapor containing ground-state atoms of Lead, Chromium and Cadmium. The atoms were placed in the beam of radiation by increasing the temperature of the furnace which made them to volatilize. The method works on a principle that the intensity of the transmitted radiation decreases in proportion to the amount of the ground-state element in the vapor. The specific wavelengths are 283.3/217 for Lead; 357.5 for Chromium; and 228.8 for Cadmium. A monochromator in the apparatus was used to isolate the characteristic radiation from metal specific hollow cathode lamp and a photosensitive device measured the amounts of the trace elements.

The laboratory used TEST-8 0018 of the ISO/IEC 17025 SADCAS accredited method to analyze the samples. Quality control was assured by calibrating the equipment using an approved calibrant; checking digestion efficiency and system performance; and adhering to internal standards.

3.8.4 Water Quality Control Measures

Observational checklists were used for observations and document reviews for quality control measures. Data on the quality control measures was collected from the companies, LCC and ZCSA. At each company, a senior member of the production staff was interviewed using a structured questionnaire annex III on trading permits, category of the mineral water, abstraction source, presence of laboratories and frequency of water analysis. A checklist annex IV was also used for observations and document review to verify the information. A senior member in the health inspectorate section was interviewed at LCC council as well as a senior member of staff at

ZCSA using the questionnaire annex V for licensing or registration status and frequency of inspection.

3.9 Data Analysis

Stata software version 15 was used for data analysis. Data entry was done in Stata. Frequencies and proportions were used to report descriptive statistics for bacteriological quality and quality control measures implemented by companies. Means and ranges were used to describe the concentrations for Lead, Chromium and Cadmium in comparison with the WHO/ZABS standards.

The Fisher's exact tests were performed to establish associations between the bacteriological quality of packaged water and quality control measures as well as the chemical quality of packaged water and quality control measures. Analyses were done at 0.05 significance level. The results were presented in tables.

3.10 Ethical Consideration

Ethical clearance was sought from the University of Zambia's Biomedical Research Ethics Committee. Thereafter, the researcher acquired an introductory letter from the University of Zambia to LCC, ZCSA and the companies. Written permission given by LCC introducing the researcher to the companies. Lastly the researcher got written or verbal consent from companies which were part of the study.

The research may result in loss of business if the companies are named. Therefore, anonymity was maintained. Companies were not coerced into being part of the research. A written consent annex I was used.

Companies were also advised on measures to take to maintain good internal quality control measures during data collection.

CHAPTER FOUR: PRESENTATION OF RESULTS.

4.1 Characteristics of Companies

Table 4.1: Descriptive Characteristics of Companies that produce packaged water in Lusaka

Variable	Measure	Frequency (n)	Proportion (%)
Licensing by LCC	Licensed	13	76.5
	Not licensed	4	23.5
Registration by ZABS	Registered	16	94.1
	Not Registered	1	5.9
Inspection each Quarter by LCC	Inspected	6	35.3
	Not Inspected	11	64.7
Inspection each Quarter by ZCSA	Inspected	4	23.5
	Not Inspected	13	76.5
Abstraction Source	Spring	1	5.9
	Borehole	16	94.1
Category of Mineral Water	Natural Mineral Water	1	5.9
	Purified Water	16	94.1
Bacteriology Laboratory	Present	11	66.4
	Absent	6	35.3
Bacteriological Testing of each Batch	Tested	9	47.4
	Not Tested	8	47.1
Laboratory for Heavy Metal Analysis	Present	0	0
	Absent	17	100
Heavy metal Extraction during processing	Done	0	0
	Not done	17	100

Table 4.1 shows the characteristics of companies producing packaged water in Lusaka. Out of the 17 companies included in the study, a majority 13 (76.5 percent) were licensed by Lusaka City Council. Most, 16 (94.1 percent) were registered by the Zambia Bureau of Standards. Only

6 (35.3 percent) were inspected at least each quarter by Lusaka City Council and only 4 (23.5 percent) were inspected at least every quarter by the Zambia Compulsory Standards Agency.

Almost all companies 16 (94.1 percent) used boreholes as abstraction sources for the packaged water. Only 1 (5.9 percent) used a spring as the source of the water. Only one company produced Natural Mineral water while the rest 16 (94.1 percent) produced Purified Mineral Water. Most companies (66.4 percent) had laboratories for bacteriological analysis but only 9 (47.4 percent) conducted bacteriological testing of water samples for each batch produced. None of the companies had laboratories for heavy metal analysis nor did they have means of extracting heavy metals from the water during processing.

4.2 Total Coliforms and Fecal Coliforms

Table 4.2: Total Coliforms and Fecal Coliforms in Packaged Water in Lusaka

Water Source	Total Coliforms			Feacal Coliforms		
	Present (%)	Absent (%)	Total (%)	Present (%)	Absent (%)	Total (%)
Borehole	6 (35.3%)	10 (58.8%)	16 (94.1%)	0 (0.00%)	16 (94.1%)	16 (94.1%)
Spring	0 (0.00%)	1 (5.9%)	1 (5.9%)	0 (0.00%)	1 (5.9%)	1 (5.9%)
Total	6 (35.3%)	11 (64.7%)	17 (100%)	0 (0.00%)	17 (100%)	17 (100%)

Table 4.2 shows the bacteriological quality of packaged water for the seventeen (17) companies. Of the 6 (35.3 percent) samples which had presence of total coliforms. None of the samples had presence of feacal coliforms. Compliance to bacteriological standards for drinking water was 64.7 percent.

4.3 Concentrations of Lead, Chromium and Cadmium in Packaged Water

Table 4.3: Concentrations of Lead, Chromium and Cadmium in Packaged Water

Compliance per type abstraction Source	Lead		Chromium		Cadmium	
	Satisfactory (<0.001)	unsatisfactory (>0.001)	Satisfactory (<0.05)	Unsatisfactory (>0.05)	Satisfactory (<0.003)	Unsatisfactory (>0.003)
Borehole	16 (94.1%)	0 (0.0%)	2 (11.8%)	14 (82.4%)	0 (0.00%)	16 (94.1%)
Spring	1 (5.9%)	0 (0.0%)	0 (0.0%)	1 (5.9%)	0 (0.00%)	1 (5.9%)
Total	17 (100%)	0 (0.0%)	2 (11.8%)	15 (88.2%)	0 (0.00%)	17 (100%)

Table 4.3 indicates laboratory results for chemical quality of the water. All the brands of packaged water were not compliant to the ZABS/WHO standards of drinking water as regard to levels of Chromium and Cadmium whereas the levels of lead were within acceptable limits.

4.3.1 Summary for Chemical Quality of Water

Table 4.4: Summary of Chemical Quality of Water

Element (mg/l)	Permitted	Mean	Std. Dev.	Min	Max	Compliance
Lead	<0.01	<0.001	0	<0.001	<0.001	100%
Chromium	<0.05	0.2658	0.0443	0.002	0.62	11.8%
Cadmium	<0.003	0.0264	0.0109	0.009	0.2	0%

Table 4.4 illustrates a summary of the concentrations for Lead, Chromium and Cadmium. The concentrations for Lead were <0.01mg/l in all the 17 samples giving a compliance of 100 percent to standards for drinking water quality. Concentrations for Chromium were as low as 0.002mg/l and as high as 0.62mg/l giving a compliance of 11.8 percent from the borehole source.

Concentrations for Cadmium were as low as 0.009mg/l and as high as 0.2mg/l giving a compliance of zero.

4.4 Quality Control Measures Associated with Quality of Packaged Water

4.4.1 Quality Control Measures Associated with Bacteriological Quality

Table 4.5: Quality Control Measures Associated with Bacteriological Quality

Quality Control Measure		**Bacteriological Quality**		**Fisher's exact**
		Satisfactory	**Unsatisfactory**	**P-values**
LCC Health Permit	Present	8 (47.1%)	4 (23.5%)	1.0
	Absent	3 (17.6%)	2 (11.8%)	
Inspection each quarter by LCC	Inspected	4 (23.5%)	1 (5.9%)	0.6
	Not Inspected	7 (41.2%)	5 (29.5%)	
Inspection each quarter by ZCSA	Inspected	3 (17.6%)	0	0.5
	Not Inspected	8 (47.1%)	6 (35.3%)	
ZABS Registration	Present	11 (64.7%)	5 (29.4%)	0.3
	Absent	0	1 (5.9%)	
Abstraction Source	Spring	1 (5.9%)	0	1.0
	Borehole	10 (58.8%)	6 (35.3%)	
Bacteriological Laboratory	Present	8 (47.1%)	3 (17.6%)	0.6
	Absent	3 (17.3%)	3 (17.6%)	
Bacteriological Testing after each Batch	Tested	8 (47.1%)	3 (17.6%)	0.05
	Not Tested	1 (5.9%)	5 (29.4%)	

Table 4.5 shows the quality control measures associated with the bacteriological quality of package water. About half (41.7 percent) of the packaged water produced by companies with Health Permits from the local authority were satisfactory compared to 3 (17.66 percent) which were satisfactory but from companies without Health Permits. Only 1 (5.9 percent) of the packaged water from companies inspected quarterly by the local authority was unsatisfactory compared to 5 (29.5 percent) from companies which are not inspected every quarter. Packaged water produced by companies that own bacteriological laboratories accounted for 8 (47.1 percent) of satisfactory results while only 3 (17.3 percent) were satisfactory from companies

without bacteriological laboratories. Companies that conducted bacteriological analysis on each batch accounted for 8 (47.1 percent) of satisfactory results while companies that did not conduct bacteriological analysis only accounted for 1 (5.9 percent) of satisfactory results

The Fisher's exact test was used test for association. Only bacteriological testing after each batch was found statistically significant a p-value of 0.05.

CHAPTER FIVE: DISCUSSION OF FINDINGS

The study revealed that not all the packaged water produced in Lusaka adhered to WHO and ZABS bacteriological and chemical standards for drinking water quality. Furthermore, quality control measures were not adequate in some of the water packaging companies.

5.1 Bacteriological Quality of Packaged Water

The World Health Organization and Zambia Bureau of Standards require that treated water for drinking purposes must have zero total coliforms in 100ml of water as well as zero feacal coliforms in 100ml of water. A higher compliance proportion was reported in a similar study where 8.9 percent of bottled water sold in Lusaka was not compliant with the standards for drinking water (Meki et al., 2014). The difference in compliance level could be because the current study focused on water produced in Lusaka while the 2014 study focused on water sold in Lusaka which may have included water produced from other districts.

The total coliforms detected in the water may have been due to inadequate treatment. This also highlights the inability of companies to use methods that can adequately treat the water. Water treatment methods are meant to make the water safe but this was not the case in some companies. For example, three brands had more than 200 total coliforms which were recorded as too numerous to count. The presence of total coliforms do not implies bacterial contamination. Subsequent for fecal coliforms came out negative implying that there was no fecal contamination. However, total coliforms without fecal coliforms is indicative of other sources of contamination that should be analyzed to decide the route the organisms are entering the water system (Ajumobi and Olayinka, 2014). The risk of contracting a water-borne illness is increases when water tests positives for coliforms.

The 35.3 percent non-compliance with the bacteriological quality of drinking water is a serious public health concern as it could lead to diarrheal diseases. Zambia had a serious Cholera outbreak in 2017 which resulted in about 5, 900 cases and 114 deaths a majority of which were recorded in Lusaka (Sinyange et al., 2018). People perceive packaged water as safe but it could contribute to such outbreaks if quality control measures are not implemented well.

5.2 Chemical Quality of Packaged Water

The chemical quality of packaged water depend on many factors that include mineralogy of rocks encountered during abstraction, residence time of groundwater in the aquifer and topology (Ristić et al., 2011). This study revealed that the concentrations of Lead were below 0.01mg/l in all the brands of the packaged water. The compliance on the concentration of lead could be attributed to the geology of the area. The underlying rock may not contain lead therefore the water abstracted show low lead concentrations.

Only 11.8 percent of the brands had Chromium concentrations less than 0.05mg/l. Chronic exposure to chromium has been linked to cancer and other non- carcinogenic health effects such as cardiovascular disease, neurological deficits and hypertension (Chervona et al., 2012). Chromium targets the iron- and 2-oxoglutarate-dependent dioxygenase family enzymes and other histone modifying enzymes to mediate the toxicity and carcinogenicity (Chervona et al., 2012).

None of the brands had Cadmium concentrations below 0.003mg/l. This study does not agree with an earlier study which found that none of the bottled water on the Serbian market had concentrations of trace elements including Cadmium higher than 0.003 mg/l in Serbia (Ristić et al., 2011). The current study does also not agree with the four-year survey from 2010 to 2013 in Iran who found that the concentrations of Lead and Cadmium in the 43 brands of bottled water were within the WHO limits (Hadiani et al., 2015). Different findings could be attributed to hydrogeological characteristics of the regions as well as processing methods.

Contamination of drinking water with heavy metals occurs due to both natural activities such as weathering and erosion of bedrocks, ore deposits, and volcanic eruptions as well as anthropogenic activities that include agriculture, mining, effluent from industries, waste water irrigation and solid waste disposal (Nawab et al., 2015, Ok et al., 2011). The abstraction sources are likely to contain aquifers with rocks that contain Cadmium and Chromium looking at their occurrence in the packaged water in this research. Furthermore, the findings could be from human activities because the companies producing the water are located in or near the industrial area.

High concentrations of Cadmium cause high blood pressure and destroy red blood cells and testicular tissue (Maju-Oyovwikowhe and Shuaib, 2019). Cadmium also has the potential to cause health effect that include vomiting, diarrhea, muscle cramps, sensory disturbances, liver injury, convulsions, shock and renal failure in a short period of time (Ideris, 2008). Exposure for a long period of time at levels exceeding 0.05 mg/l can cause kidney, liver and bone damage (WHO, 2011).

About 50 percent of accumulate dose of Cadmium is stored in the kidneys and cause tubular injury which leads to tubular dysfunction with urinary loss of glucose and amino acids as well as bicarbonate and phosphates (Johri et al., 2010). The loss of vitamin D binding protein in urine also indirectly contribute to osteomalacia in adults and rickets in children.

All three analyses were conducted on each sample implying that the overall compliance in respect of the three heavy metals under the study was zero.

All companies used groundwater as the abstraction source for the water. The season of the year could have also contributed to the observed concentrations as the water levels may be low thereby increasing the concentrations of the elements. The geology of the study area could contain rocks with chromium and cadmium and these are extracted together with the water. Furthermore, all the companies are located in industrial area or areas in close proximity to the industrial area. Boreholes and the spring for companies producing purified and natural mineral water respectively are located in the same area. The pollution of ground water may be from the geology of the areal or industrial effluent (Nawab et al., 2015).

Water is taken daily with most people taking at least one litre a day. Heavy metal bio accumulate and may cause health problems in time. Chromium and Cadmium are neural toxins and may also lead to birth defects (WHO, 2011).

5.3 Quality Control Measures

Quality control measures for production of packaged water are done internally by the companies and externally by government agencies. Licensing and registration by Lusaka City Council and the Zambia Bureau of Standards respectively is dependent on compliance to set standards. For example, compliance to hygiene standards at all times is one of the conditions for issuance of the

Health Permit from the local authority. Companies which implemented the quality control measures considered in the study had most of the brands complying with the standards for drinking water. About half of the packaged water produced by companies with Health Permits from the local authority were satisfactory compared to only 17.6 percent which were satisfactory but from companies without Health Permits. Good hygiene is one of the requirements before issuance of the health permit therefore companies with Health Permits are less likely to have sources of contamination. The frequency of inspections also plays a part in the maintenance of hygiene as can be explained from the 5.9 percent of the packaged water from companies inspected quarterly by the local authority which was unsatisfactory compared to 29.5 percent from companies which are not inspected every quarter.

Presence of a bacteriological laboratory also plays a part as companies become aware of areas of improvement in terms of preventing contamination. Packaged water produced by companies that owned bacteriological laboratories accounted for 47.1 percent of satisfactory results compared to only 17.3 percent from companies without bacteriological laboratories. Furthermore, conducting bacteriological analysis on each batch that is produced influences the quality of the water as companies are able to isolate unfit batches.

Only bacteriological testing after each batch was found statistically significant a borderline p-value of 0.05. The other factors many not have been statistically significant because of the small sample size. However, the explanation given above gives an insight of how they are associated with the bacteriological quality of the packaged water.

All brands had concentrations of Lead within acceptable concentration of <0.01mg/l. On the other hand, none of the brands were compliant to the chemical quality on Cadmium concentrations and only 11.8 percent were complaint on Chromium concentrations. None of the companies use methods or technologies to extract the heavy metals during processing of the water. A 2016 study revealed that many developing countries have a challenge of reducing human exposure to heavy metals, due to inadequate financial capacities to use advanced technologies for heavy metal removal (Chowdhury et al., 2016). Accessibility of these technologies coupled with weak monitoring mechanisms may also exacerbate the problem.

The focus by companies and government agencies has been on measures to ensure acceptable bacteriological quality of the water. Measures to ensure that only sources that do not contain heavy metals are used or measures to remove heavy metals from the water during processing are not taken by both the government agencies and the companies.

5.4 Limitations, Discussion of Methods, Bias and Validity of the Study

The study was a cross-sectional design which only provided data at single point in time. Collection of data over a long period of time would reveal more information of which months or season of the year the quality of water improves or becomes poor. Furthermore, samples were only analyzed at one laboratory without any confirmatory tests at other laboratories.

The data collection tools used in the current study were not validated and prone to affect the quality of the information acquired. To ensure internal validity, the questionnaires and checklists were pretested before use. The principle investigator collected the data himself with assistance of trained assistants. Triangulation of the data was used when collecting certain information by using checklists, document review and observations. For instance, data on frequency of water testing was done by interviews and document review and data on presence of laboratory was collected by interview and observation.

The companies which did not consent would have added value to the study had they participated in the study. Some companies were also not traced during the study because the information on the labels applied on the packages was inadequate or missing. For instance some labels had no physical addresses and some only had postal addresses. This raises the concern of authenticity of the companies on whether they really exist or it is a way of hiding from authorities.

Despite the limitations, the study is valid and can be generalized because of the complete enumeration of companies producing packaged water and random sampling of the water samples.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study revealed that 35.3 percent of packaged drinking water did not comply with the WHO/ZABS standards for drinking water quality of zero total or feacal coliforms in 100ml of water. The minimum number of total coliforms detected was zero and the maximum was more than 200.

All brands of packaged water had concentrations of Lead within acceptable concentration of <0.01mg/l. On the other hand, none of the brands were compliant to the chemical quality on concentration of Cadmium and only 11.8 percent were satisfactory on the concentration of Chromium. The analyses for the three heavy metals were done on each brand and therefore none of the packaged water brands met the standards for chemical quality of drinking water.

Quality control measures associated with the quality of packaged water produced in Lusaka are inadequate as can be seen from the quality of the water. However, measures to ensure bacteriological quality are better implemented than measures meant to ensure chemical quality. Companies and government agencies should ensure that the packaged water produced is safe for consumption.

6.2 Recommendations

6.2.1 Government agencies

- Ensure only safe sources are used for abstraction of water for bottling or adequate measures are employed by companies to remove heavy metals.
- Continued monitoring companies to ensure bacteriological quality.

6.2.2 Companies

- Use technologies to remove heavy metals when processing.

6.2.3 Areas for future research

- Spatial analysis for packaged water companies linking the quality to the location.
- Health risk assessment for consumption of packaged water.
- Traceability of packaged water companies following the information on the labels.

6.2.4 Consumers

- Demand for quality assurance reports from LCC, ZABS and ZCSA.

References

Ajumobi, O. & Olayinka, A. 2014. Implication of coliforms as a major public health problem in Nigeria. *Journal of public health epidemiology,* 6**,** 1-7.

Beaumont, J. J., Sedman, R. M., Reynolds, S. D., Sherman, C. D., Li, L.-H., Howd, R. A., Sandy, M. S., Zeise, L. & Alexeeff, G. V. 2008. Cancer mortality in a Chinese population exposed to hexavalent chromium in drinking water. *Epidemiology***,** 12-23.

CAC, C. A. C. 2001. Code of hygienic practice for bottled/packaged drinking waters (other than natural mineral waters) CAC/RCP 48-2001; Committee on Food Hygiene.

Chervona, Y., Arita, A. & Costa, M. 2012. Carcinogenic metals and the epigenome: understanding the effect of nickel, arsenic, and chromium. *Metallomics,* 4**,** 619-627.

Chowdhury, S., Mazumder, M. J., Al-Attas, O. & Husain, T. J. S. O. T. T. E. 2016. Heavy metals in drinking water: occurrences, implications, and future needs in developing countries. 569**,** 476-488.

Demena, M., Workie, A., Tadesse, E., Mohammed, S. & Gebru, T. 2003. Waterborne disease for the ethiopian health center team. *Modul. Ethiopia: Haramaya University***,** 12-13.

Diduch, M., Polkowska, Ż. & Namieśnik, J. 2013. Factors affecting the quality of bottled water. *Journal of exposure science environmental epidemiology,* 23**,** 111-119.

Ehlers, M. M., Van Zyl, W. B., Pavlov, D. N. & Muller, E. E. 2004. Random survey of the microbial quality of bottled water in South Africa. *Water SA,* 30**,** 203-210.

Etale, A., Jobin, M. & Siegrist, M. 2018. Tap versus bottled water consumption: The influence of social norms, affect and image on consumer choice. *Appetite,* 121**,** 138-146.

Fakhri, Y., Mohseni, S. M., Jafarzadeh, S., Langarizadeh, G., Moradi, B., Zandsalimi, Y., Rahimizadeh, A. & Mirzaei, M. 2015. Assessment of carcinogenic and non-carcinogenic risk lead in bottled water in different age groups in Bandar Abbas Ciry, Iran. *Global journal of health science,* 7**,** 286.

Ferrier, C. A.. 2001. Bottled water: understanding a social phenomenon. *AMBIO: A journal of the Human Environment,* 30**,** 118-119.

Hadiani, M. R., Dezfooli-Manesh, S., Shoeibi, S., Ziarati, P. & Mousavi Khaneghah, A. 2015. Trace elements and heavy metals in mineral and bottled drinking waters on the Iranian market. *Food Additives Contaminants: Part B,* 8**,** 18-24.

Ideris, Z. 2008. *Study of the Quality of Commercial Bottled Mineral Waters in Malaysia.* Jabatan Kimia, Fakulti Sains, Universiti Malaya.

Johri, N., Jacquillet, G. & Unwin, R. 2010. Heavy metal poisoning: the effects of cadmium on the kidney. *Biometals,* 23**,** 783-792.

Maju-Oyovwikowhe, G. & Shuaib, I. 2019. Physiochemical characteristics and heavy metal levels of water from hand dug wells in Ikiran-Ile, Akoko Edo Local Government Area, Edo State, Nigeria. *Journal of Applied Sciences Environmental Management,* 23**,** 283-290.

Manaia, C. & Nunes, O. C. 2017. Microbial diversity and ecology of bottled water. *Quantitative microbiology in food processing: Modeling the microbial ecology***,** 560-580.

Meki, C. D., Mbewe, A. R., Nzala, S. H. & Michelo, C. C. 2014. Compliance to Bacteriological Standards for Bottled Drinking Water Sold in Lusaka District, Zambia. *Journal of Environmental Science Toxicology Research,* 2**,** 223-228.

Mihaljevič, M., Ettler, V., Šebek, O., Sracek, O., Kříbek, B., Kyncl, T., Majer, V. & Veselovský, F. 2011. Lead isotopic and metallic pollution record in tree rings from the Copperbelt mining–smelting area, Zambia. *J Water, Air, Soil Pollution,* 216**,** 657-668.

Muazu, J., Muhammad-Biu, A., Mohammed, G. J. 2012. Microbial quality of packaged sachet water marketed in Maiduguri Metropolis, North Eastern Nigeria. *British Journal of Pharmacology Toxicology* 3**,** 33-38.

Nawab, J., Khan, S., Shah, M. T., Khan, K., Huang, Q. & Ali, R. 2015. Quantification of heavy metals in mining affected soil and their bioaccumulation in native plant species. *International journal of phytoremediation,* 17**,** 801-813.

Nyundu, K., Silembo, O. & Simumba, F. A. 2012. Bottled drinking water in Zambia-does it pose any threat to human safety and health. *Integrated water resources management centre, University of Zambia, Lusaka, Zambia*.

Ok, Y. S., Usman, A. R., Lee, S. S., El-Azeem, S. A. A., Choi, B., Hashimoto, Y. & Yang, J. E. 2011. Effects of rapeseed residue on lead and cadmium availability and uptake by rice plants in heavy metal contaminated paddy soil. *Chemosphere,* 85**,** 677-682.

Pant, N. D., Poudyal, N. & Bhattacharya, S. K. 2016. Bacteriological quality of bottled drinking water versus municipal tap water in Dharan municipality, Nepal. *Journal of Health, Population Nutrition,* 35**,** 17.

Peletz, R., Kumpel, E., Bonham, M., Rahman, Z. & Khush, R. 2016. To what extent is drinking water tested in sub-Saharan Africa? A comparative analysis of regulated water quality monitoring. *International journal of environmental research public health,* 13**,** 275.

Priti, P. & Paul, B. 2016. Assessment of heavy metal pollution in water resources and their impacts: A review. *Journal of Basic Applied Engineering Research,* 3**,** 671-675.

Ristić, M., Popović, I., Pocajt, V., Antanasijević, D. & Perić-Grujić, A. 2011. Concentrations of selected trace elements in mineral and spring bottled waters on the Serbian market. *Food Additives Contaminants,* 4**,** 6-14.

Salehi, I., Ghiasi, M., Rahmani, A., Sepehr, M. N., Kiamanesh, M. & Rafati, L. 2014. Evaluation of microbial and physico-chemical quality of bottled water produced in Hamadan province of Iran. *Journal of food quality hazards control,* 1**,** 21-24.

Simwanda, M. & Murayama, Y. 2018. Spatiotemporal patterns of urban land use change in the rapidly growing city of Lusaka, Zambia: Implications for sustainable urban development. *Sustainable cities society,* 39**,** 262-274.

Sinyange, N., Brunkard, J. M., Kapata, N., Mazaba, M. L., Musonda, K. G., Hamoonga, R., Kapina, M., Kapaya, F., Mutale, L. & Kateule, E. 2018. Cholera epidemic—Lusaka, Zambia, October 2017–May 2018. *Morbidity Mortality Weekly Report,* 67**,** 556.

Tirima, S., Bartrem, C., Von Braun, M. & Von Lindern, I. 2015. Lead Pollution in Nigeria and Zambia: Two different remedial strategies and public health outcomesSimba Tirima. *European Journal of Public Health* 25.

WHO 2011. Guidelines for drinking-water quality. 38**,** 104-8.

WHO 2017. Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines.

Yabe, J., Nakayama, S. M., Ikenaka, Y., Yohannes, Y. B., Bortey-Sam, N., Kabalo, A. N., Ntapisha, J., Mizukawa, H., Umemura, T. & Ishizuka, M. 2018. Lead and cadmium excretion in feces and urine of children from polluted townships near a lead-zinc mine in Kabwe, Zambia. *Chemosphere,* 202**,** 48-55.

Yilkal, E., Zewge, F. & Chandravanshi, B. S. 2019. Assessment of the quality of bottled water marketed in Addis Ababa, Ethiopia. *Bulletin of the Chemical Society of Ethiopia,* 33**,** 21-41.

ZABS 2000. "Zambian Standards Bottled Drinking Water: Specifications", private report, Lusaka, Zambia.

ZCSA 2018. 'List of Water Bottling Companies'. 'Information File', Lusaka, Zambia.

Annex i: Informed Consent Form

THE UNIVERSITY OF ZAMBIA

SCHOOL OF PUBLIC HEALTH

Informed Consent Form to Participate in a Study for Companies Producing Packaged Water

This informed consent form is for companies producing packaged water in Lusaka to participate in a research entitled **"Assessment of Bacteriological and Physicochemical Quality of Packaged Water Produced in Lusaka, Zambia and Associated Quality Control Measures"**

This Informed Consent Form has two parts:

- Information Sheet to share information about the study with you
- Certificate of Consent for signatures if you choose to participate

Part 1:Information Sheet

Introduction

My name is **Rodney Kachikoti Banda**, a student at the University of Zambia school of Public Health. I am conducting this research in partial fulfilment of the Master of Public Health - Environmental Health degree program. My student number is 2017013877 and can be contacted on phone number +260978927392 or email address rodneykb2001@yahoo.com

Purpose of Study

- Water is an important part of our lives. Unsafe water causes many diseases and packaged water is a solution to the problem of unsafe water. There are many categories of packaged water and the quality may differ according to sources of the unpackaged water. The purpose of the study is to determine the quality of packaged water according to the various categories, for instance natural mineral waste, purified water or spring water. The abstraction sources of the water will also be assessed. The internal quality control measures will be assessed as well.

- Ultimately, this research will be presented as a paper in paper in partial fulfilment of the requirements of the Master of Public Health in Environmental Health program. Your company will not be named in any of the documents.

Participant Selection

- You were selected as a possible participant because your company is one of the companies producing packaged water in Lusaka. The study will only focus on water packaged in plastic bottles of not more than one litre and will not include water packed in containers of more than one litre.

- We ask that you read this form and ask any questions that you may have before agreeing to be in the study.

Voluntary Participation

- The decision to participate in this study is entirely up to you. You may refuse to take part in the study at any time without affecting your relationship with the investigators of this study or the University of Zambia. Your decision will not result in any loss or benefits to which you are otherwise entitled. You have the right not to answer any single question, as well as to withdraw completely from the study at any point during the process; additionally, you have the right to request that the interviewer not use any of the information provided.

Description of the Study Procedures

- If you agree to be in this study, you will be asked to allow the investigator to collect samples of the water before packaging and the finished products which will be taken to the laboratory for analysis. The research also involves confirming the categories of the packaged water and assessing the internal quality control measures used by companies to ensure maintenance of the quality of the packaged water. The study procedures will only take two hours of your time and requires any senior staff to accompany the researcher.

Risks/Discomforts of Being in this Study

- There are no reasonable foreseeable risks for the company because the identity of the company will not be revealed.

Benefits of Being in the Study

- The benefits of participation are that detailed inspection reports will be made available indicating findings and recommendations on how to maintain good manufacturing practices. The researcher is an Environmental Health Officer practicing as a Health Inspector with vast knowledge that will benefit the company.

- You will also receive a summary of the study results and get a chance to know the quality of the water produced as well as how effective your quality control measures are.

Confidentiality

- We will not be collecting or retaining any information about your identity. We will not include any information in any report we may publish that would make it possible to identify you.

Payments

- Payments for the packaged water which will be taken for laboratory analysis will be made to the company.

- If the study will be done during lunch time, K85 will be provided for lunch to members of staff who will be attending to the researcher.

Right to Ask Questions and Report Concerns

- You have the right to ask questions about this research study and to have those questions answered by me before, during or after the research. If you have any further questions about the study, at any time feel free to contact me, Rodney Kachikoti Banda at rodneykb2001@yahoo.com or by phone at +260978927392. If you like, a summary of the results of the study will be sent to you. If you have any other concerns about your rights as a research participant that have not been answered by the investigators, you may the Chairperson of the University of Zambia Ethics Committee at +211-256067

- If you have any problems or concerns that occur as a result of your participation, you can report them to the Chairperson of the University of Zambia Ethics Committee at the number above. Alternatively, concerns can be reported by completing a Participant Complaint Form, which can found on the IRB website at http://www.smith.edu/irb

Part II: Certificate of Consent

Participant

I have been invited to participate in a study to assess the quality of packaged water produced in Lusaka and associated quality control measures.

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study

Name of Company:____

Respondent's Name:___________________________Designation: _____________________

Signature:________________________ Thumb Print: ________________________

Date: ________________________________

Researcher

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this Informed Consent Form has been provided to the participant.

Researcher's Name: Rodney Kachikoti Banda

Signature: ___________________ Date: ____________________________

Annex ii: Sampling Form

MF No 206 **FOOD AND DRUGS ACT, 1994**

<table>
<tr><td colspan="3">1. Sample No.</td><td colspan="2">2. Date Collected :</td></tr>
<tr><td colspan="5">3.(a) Product name and description :
(b) Method of collection :
(c) Collector's identification on package and seal :</td></tr>
<tr><td colspan="5">4. Reason for collection:</td></tr>
<tr><td colspan="3">5. Manufacturer:</td><td colspan="2">6. Dealer:</td></tr>
<tr><td colspan="3">7. Size of lot sampled :</td><td colspan="2">8. Date dispatched:</td></tr>
<tr><td colspan="2">9. Delivered to :</td><td colspan="2">10. Date:</td><td>11. Laboratory :</td></tr>
<tr><td rowspan="2">12. Records obtained :</td><td colspan="4">(a) Invoice No and date (b) Shipping record and date</td></tr>
<tr><td colspan="4">(c) Other documents :</td></tr>
<tr><td colspan="5">13. Remarks</td></tr>
<tr><td>14. Sample cost :</td><td colspan="4">15. Collector (printed name & signature)</td></tr>
</table>

Annex iii: Questionnaire for Senior Production Staff in Companies

Instructions

Kindly tick [ ] the appropriate responses in the brackets provided and write down the most suitable responses to questions in the available spaces.

1. What type of packaged water do you produce?
   (a) Natural Mineral Water [ ]
   (b) Purified Water [ ]

2. Does the company have a hydrogeological survey report from the WARMA, Water Affairs Department or any other institution?
   (a) Yes [ ]
   (b) No [ ]
3. Does the plant have a Health Permit from Lusaka City Council?
   (a) Yes [ ]
   (b) No [ ]

4. What is the abstraction source of the packaged water?
   (a) Spring [ ]
   (b) Borehole (Deep well) [ ]
   (c) Artesian well [ ]
   (d) Surface water [ ]

5. How do you test the water?
   (a) Own laboratory [ ]
   (b) Out-sourced laboratory [ ]

6. How often is the water tested?
   (a) Every day [ ]
   (b) Once a week [ ]
   (c) Once a month [ ]
   (d) Once every three months [ ]
   (e) Once every six months [ ]
   (f) Any other? ……………………………………………………………………………………

7. Do you keep control samples of the produced water?
   (a) Yes [ ]
   (b) No [ ]

Thank for your participation!

Annex iv: Checklist for Companies

Subject	Indicator	Observation
ZABS/ZCSA Clearance	Presence or absence	
LCC Health Permit	Presence or absence	
Category of packaged water produced	Natural mineral water or purified water	
Abstraction source of the water intended for bottling	▪ Spring ▪ Borehole (well) ▪ Water utility ▪ Other(Specify)	
Presence of Laboratory	Evidence of functional Laboratory	
Water testing by companies	Presence of laboratory results and frequency of testing ▪ Daily ▪ Once a week ▪ Once a month ▪ Once every three months or ▪ Once every six months	

Annex v: Checklist for Lusaka City Council and the Zambia Compulsory Standards Agency

Subject	**Indicator**	**Observation**
Water Sampling	Presence of laboratory results and frequency of testing ▪ Daily ▪ Once a week ▪ Once a month ▪ Once every three months or ▪ Once every six months	
Laboratory facility	Owned or Out-sourced	
Frequency of inspections	Once a month Every 3 months Every 6 months Irregular interval	

Annex vi: Permission Letter from Lusaka City Council

LUSAKA CITY COUNCIL

OFFICE OF THE TOWN CLERK

P O Box 30077
CIVIC CENTRE
LUSAKA, ZAMBIA 10101

TELEPHONE : 260 01 252997
TELEFAX : 260 01 252141

Our Reference: HK/kk
TCD/7/57/5A

2nd August, 2018.

TO WHOM IT MAY CONCERN

RESEARCH STUDY –BANDA RODNEY KACHIKOTI

The above mentioned is a bona fide student at The University of Zambia currently studying for his Masters in Environment Health.

He is conducting a research on **"an assessment of bacteriological and physicochemical quality of bottled water produced in Lusaka and associated quality control measures."** The Research will be conducted at Companies producing bottled water in Lusaka District.

This study is purely for academic purpose, kindly therefore assist with the needed information for the successful completion of research project.

Yours faithfully,
LUSAKA CITY COUNCIL

Alex Mwansa
TOWN CLERK

Cc: The Director - Human Resource & Administration
The Director - Public Heath
File

Annex vii: Approval from Biomedical Research Ethics Committee

THE UNIVERSITY OF ZAMBIA

BIOMEDICAL RESEARCH ETHICS COMMITTEE

Telephone: 260-1-256067
Telegrams: UNZA, LUSAKA
Telex: UNZALU ZA 44370
Fax: + 260-1-250753
E-mail: unzarec@unza.zm
Assurance No. FWA00000338
IRB00001131 of IORG0000774

Ridgeway Campus
P.O. Box 50110
Lusaka, Zambia

3rd December, 2018.

REF. No. 026-08-18

Mr. Rodney K. Banda,
University of Zambia,
School of Public Health,
P.O Box 50110,
Lusaka.

Dear Mr. Banda,

RE: "ASSESSMENT OF BACTERIOLOGICAL AND PHYSICOCHEMICAL QUALITY OF BOTTLED WATER PRODUCED IN LUSAKA AND ASSOCIATED QUALITY CONTROL MEASURES" (REF. NO. 026-08-18)

The above-mentioned research proposal was presented to the Biomedical Research Ethics Committee (UNZABREC) on 16th November, 2018. The proposal is approved. The approval is based on the following documents that were submitted for review:

a) **Study proposal**
b) **Questionnaires**
c) **Participant Consent Form**

APPROVAL NUMBER : REF. 026-08-18

This number should be used on all correspondence, consent forms and documents as appropriate.

- **APPROVAL DATE : 3rd December, 2018**
- **TYPE OF APPROVAL : Standard**
- **EXPIRATION DATE OF APPROVAL: 2nd December, 2019**
  After this date, this project may only continue upon renewal. For purposes of renewal, a progress report on a standard form obtainable from the UNZABREC Offices should be submitted one month before the expiration date for continuing review.
- **SERIOUS ADVERSE EVENT REPORTING**: All SAEs and any other serious challenges/problems having to do with participant welfare, participant safety and study integrity must be reported to UNZABREC within 3 working days using standard forms obtainable from UNZABREC.
- **MODIFICATIONS**: Prior UNZABREC approval using standard forms obtainable from the UNZABREC Offices is required before implementing any changes in the Protocol (including changes in the consent documents).
- **TERMINATION OF STUDY**: On termination of a study, a report has to be submitted to the UNZABREC using standard forms obtainable from the UNZABREC Offices.
- **NHRA:** Where appropriate, apply in writing to the National Heath Research Authority for permission before you embark on the study.
- **QUESTIONS**: Please contact the UNZABREC on Telephone No.256067 or by e-mail on unzarec@unza.zm.
  Other
- Please be reminded to send in copies of your research findings/results for our records. You're also required to submit electronic copies of your publications in peer-reviewed journals that may emanate from this study.

Yours sincerely,

Dr. S. H. Nzala
VICE-CHAIRPERSON

Annex viii: Approval from National Health Research Authority

THE NATIONAL HEALTH RESEARCH AUTHORITY
Paediatric Centre of Excellence
University Teaching Hospital
P.O. Box 30075
LUSAKA
T: +260 211 250309/+260 95 563276 | **E:** znhrasec@gmail.com | www.nhra.org.zm

12th December, 2018

Rodney Kachikoti Banda
The University of Zambia
School of Public Healh
P.O. Box 50110
LUSAKA

Re: Request for Authority to Conduct Research

The National Health Research Authority is in receipt of your request for authority to conduct research titled **"An Assessment of Bacteriological and Physicochemical Quality of Bottled Water Produced in Lusaka and Associated Quality Control Measures."** I wish to inform you that following submission of your request to the Authority, our review of the same and in view of the ethical clearance, this study has been **approved** on condition that:

1. The relevant Provincial and District Medical Officers where the study is being conducted are fully appraised;
2. Progress updates are provided to NHRA quarterly from the date of commencement of the study;
3. The final study report is cleared by the NHRA before any publication or dissemination within or outside the country;
4. After clearance for publication or dissemination by the NHRA, the final study report is shared with all relevant Provincial and District Directors of Health where the study was being conducted, University leadership, and all key respondents.

Yours sincerely,

Dr. Godfrey Biemba
Director/CEO
National Health Research Authority

All correspondences should be addressed to the Director/CEO National Health Research Authority

Annex ix: Results for bacteriological quality

Bacteriological Quality

Sample ID	Abstraction Source	Category of Mineral Water	Total Coliforms	Feacal Coliforms
1	Borehole	Purified	2	0
2	Borehole	Purified	0	0
3	Borehole	Purified	0	0
4	Borehole	Purified	>200	0
5	Borehole	Purified	6	0
6	Borehole	Purified	0	0
7	Borehole	Purified	0	0
8	Borehole	Purified	0	0
9	Borehole	Purified	3	0
10	Borehole	Purified	0	0
11	Borehole	Purified	0	0
12	Borehole	Purified	>200	0
13	Borehole	Purified	0	0
14	Spring	Natural	0	0
15	Borehole	Purified	0	0
16	Borehole	Purified	0	0
17	Borehole	Purified	>200	0

Annex x: Results for chemical quality

Sample No.	Category	Lead	Chromium	Cadmium
1	Purified	<0.001	0.13	0.01
2	Purified	<0.001	0.2	0.01
3	Purified	<0.001	0.02	0.02
4	Purified	<0.001	0.26	0.02
5	Purified	<0.001	0.18	0.2
6	Purified	<0.001	0.11	0.02
7	Purified	<0.001	0.16	0.02
8	Purified	<0.001	0.009	0.02
9	Purified	<0.001	0.29	0.02
10	Purified	<0.001	0.13	0.02
11	Purified	<0.001	0.31	0.01
12	Purified	<0.001	0.62	0.01
13	Purified	<0.001	0.49	0.01
14	Natural	<0.001	0.43	0.009
15	Purified	<0.001	0.51	0.01
16	Purified	<0.001	0.18	0.02
17	Purified	<0.001	0.49	0.02