

ASSESSMENT OF QUALITY OF SACHET WATER SOLD BY VENDORS IN BLANTYRE CITY, BLANTYRE, MALAWI

GEORGE NGULUBE

WQM-023-18

THYOLO

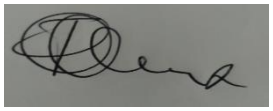
Dissertation submitted to Ndata School of Climate and Earth Sciences of the Malawi University of Science and Technology in partial fulfilment of the requirements for the Bachelor of Science degree in Water Quality and Management

October, 2022

APPROVAL

DISSERTATION APPROVED BY:

SUPERVISOR:

MR F. CHAULUKA Signature: 

ASSESSOR:
Title, Initials, Name Signature: _____

Date: 19th October 2022

Declaration

I George Ngulube declare that 'ASSESSING QUALITY OF SACHET WATER SOLD IN BLANTYRE CITY, BLANTYRE' is my own work and that the sources that I have used or quoted have been indicated and acknowledged by means of complete references

Signature: G Ngulube Date: 18/10/22

DISCLAIMER

This document describes work undertaken as part of a programme of study at Ndata School of Climate and Earth Sciences of the Malawi University of Science and Technology. All views and opinions expressed therein remain the sole responsibility of the author(s), and do not necessarily represent those of the school.

COPYRIGHT STATEMENT:

This copy of the dissertation has been supplied on condition that anyone who consults it is understood to recognize that its copyright rests with its author and that no quotation from the dissertation and no information derived from it may be published without acknowledgement.

ABSTRACT

Sachet water is one of the sources drinking water that are commonly used by people who lack access to piped water. They are commonly used in markets. In Malawi, informal sachet water is common. These sachet waters are not regulated by MBS and the information about the quality of sachet water is questionable. This research aimed at assessing the quality of sachet water that are used in Blantyre city markets. The study used quantitative research to acquire primary data. Five Areas namely (Blantyre market, Limbe, Mapanga, Bangwe and Ndirande) were selected using systematic random sampling methods, 10 vendors were selected using purposive sampling and a total of 30 sachet water packets were purchased randomly from the 10 vendors. The study analyzed the physical, chemical and microbial parameters of the sachet water. The assessed parameters were pH, temperature, salts, TDS, EC, alkalinity, chlorine, nitrate and fecal coliform. Water quality index was used to give general quality of sachet water per vendor and areas. The results indicated that EC, turbidity, salts, pH alkalinity, chlorine and nitrate were below the standard limits set by WHO and MBS. The majority of samples were contaminated with fecal coliform and did not comply with standards set by WHO and MBS standard. The results further showed that most sachet samples did not comply with MS 214 (2013) turbidity maximum limit of 1 NTU. Since these sachet waters are not regulated, this study recommends that the government through Malawi bureau of Standards should engage the stakeholders to civic educate them on the water packaging and other water quality standards that have to be adhered to.

ACKNOWLEDGEMENT

All the praise for my success and accomplishment of my project should go to Almighty God in heaven. Let me also express my special thanks to my supervisor Mr. Chauluka for all the support and motivation for the accomplishment of my research project.

Special thanks and appreciation should also go to my family and friends for all the support they rendered to me during my research and studies both spiritually and financially. I am making this project not only for marks but to also increase my knowledge.

Thanks Again to all who helped me. May good LORD bless you.

Table of Contents

APPROVAL i
Declaration i
DISCLAIMER ii
COPYRIGHT STATEMENT: iii
ABSTRACT iv
ACKNOWLEDGEMENT v
ACRONYMS /ABBREVIATIONS viii
List of figures ix
List of tables x
CHAPTER 1: INTRODUCTION 1
1.1 Background 1
1.2 Problem statement. 2
1.3 Main Objective 3
1.4 Specific Objectives 3
1.5 Research Questions 3
1.6 Significance of the study 4
CHAPTER 2: LITERATURE REVIEW 5
2.1. Overview of Global Access to Drinking Water 5
2.2 Sachet Water Quality and Processes Used in Production 6
2.3 Water Quality Issues and Healthy Impact. 7
2.4 Water Quality Standards 7
2.5 Drinking Water Quality Properties 8
2.5.1 The Power of Hydrogen 8
2.5.2 Electrical conductivity 9
2.5.3 Chlorine 9
2.5.4 Turbidity 9
2.5.5Temperature 10
2.5.6 Alkalinity 10
2.5.7 Nitrate 10

2.6. Microbial assessment of Sachet Water 10
2.6.1 Fecal Coliform 11
2.6 Water Quality Index 11
CHAPTER 3: METHODOLOGY 12
3.1 Study area 12
Figure 2: Map of Malawi and Blantyre City showing sample sampling locations 12
3.2 Research design 13
3.3Sample and data collection 13
3.4 Laboratory analysis 14
3.4.1 Physio-Chemical and Microbial Water Quality Determination 14
3. 5 Assessing Water Quality Using Water Quality Index (WQI) 17
CHAPTER 4: RESULTS AND DISCUSSION 19
Introduction 19
4.1 Descriptive Analysis 19
4.1 Physco-Chemical assessment based on Location 20
4.1.1 pH 21
4.1.2Turbidity 22
4.1.3 EC and TDS 22
4.1.4 Nitrate 24
4.1.5 Chlorine 25
4.1.6 Salts 26
4.2 Evaluating Water Quality of Sachet Water Using Drinking Water Quality Index 29
4.4 Results for Analysis of Variance for Sachet Water Sample 31
4.5 Correlation Analysis 31
CHAPTER 5: CONCLUSION AND RECOMMENDATION 34
5.1 Conclusion 34
5.2 Recommendation 34
6.References 35

ACRONYMS /ABBREVIATIONS

ANOVA analysis of variance

CFU colony forming units

EC electrical conductivity

LV1 vendor 1 in Limbe

MBS Malawi Bureau of Standard

MS Malawi Standards

MV1 vendor number 1 in Mapanga

BV1 vendor number 1 in Blantyre market

BAV1 vendor number 1 in Bangwe

NV1 vendor number 1 in Ndirande

TDS total dissolved solids

WHO world health organization

WQI water quality index

List of figures

Figure 1: example of improved sources example of unimproved sources of water ---------- 6
Figure 2: map of malawi and blantyre city showing sample sampling locations ---------- 12
Figure 3: flow diagram showing methodology ---------- 13
Figure 4: graph of ph for different areas in blantyre city ---------- 21
Figure 5: graph of turbidity for different areas in blantyre city ---------- 22
Figure 6: (1-2) graph of ec and tds in different areas ---------- 24
Figure 7: graph of nitrate for different areas ---------- 24
Figure 8: graph showing chlorine for different areas ---------- 25
Figure 9:graph showing levels of salts in blantyre city ---------- 26
Figure 10: alkalinity graph for different areas ---------- 27
figure 11: some of the petri dishes ---------- 28
Figure 12:graph of fecal coliform ---------- 28

List of tables

Table 1:safety standards set by who and ms for drinking water adapted from msb (2013) and who standards 8
Table 2: grading system for wqi 18
Table 3: summary of physio-chemical parameters and microbial parameters of sachet water 20
Table 4: scores of water samples under wqi 30
Table 5: anova analysis for different areas 31
Table 6: is for correlation analysis 33

CHAPTER 1: INTRODUCTION

1.1 Background

Globally, about 785 million people do not have access to clean water for their homes representing 1 out of 10 on the planet. Water is still collected by hundreds of millions of people from rivers and lakes and open wells (World Vision, 2021). Due to lack of access to safe water, people are forced to drink contaminated with bacteria, viruses and parasites and it is estimated that contaminated water cause 485000 diarrheal deaths each year (WHO, 2019). This year alone about 948 cholera cases were reported in Malawi (Ministry of Health, 2022). Water quality can be determined by analyzing the physical, chemical and biological properties of water. Good water quality should be of odorless, free from contaminants, colorless, and tasteless. Quality of drinking water is also evaluated using chemical components. Two thirds in sub-Saharan Africa rely mostly on surface water of the continents such as rivers, lakes, or wetlands (Rodriguez, 2019). Most surface water is often highly polluted and not considered a reliable and safe source of drinking. Construction of pipe water infrastructure is too expensive in dry areas hence forcing communities to resort dangerous to alternatives.

In Malawi, Ngumbira, (2020) stated that 15% of people do not have access to potable water because they still fetch drinking water from unimproved sources like lakes, rivers, or unprotected wells. People who do not have access to good quality water seek alternative sources like packaged water. Packaged drinking water sold in bottles and plastic bags or informal sachet water is common in low- and middle-income countries, and many low-income urban users in sub–Saharan Africa rely on informal packaged sachet water as their primary source of water consumption (Fisher, et al., 2015). Informal sachet water is sachet water that is produced by unregistered vendors. These sachet waters are mostly consumed by low-income people because it is readily available and cheap (Akinnibosun & Ugbawa, 2018). Sachet water are mostly sold along the roadside and local markets in Malawi. Several studies that were conducted previously indicated that most sachet water that are produced informally does not meet standard limits. Research that was conducted by Akinnibosun & Ugbawa (2018) revealed that most sachet water are not free from microbial contamination. According to Akinnibosun & Ugbawa(2018), sachet water

become contaminated when they are being packaged, transported and not handled properly. In Malawi, some studies that was conducted in the past also reported that most sachet water that are sold in our market are contaminated. Mayinja, Tilley, & Marks, (2019) assessed the microbial quality of sachet water in Mwanza and found that there are not in compliance with MBS and WHO. (Ngumbira, 2020) also conducted research on physco-chemical and microbial properties of sachet water that are sold in Lilongwe and the results of some samples were also not in compliance with MSB and WHO.

In Malawi, most vendors use water from tap and sometimes from boreholes direct to produce sachets water. Blantyre water board, is the one that supplies water services in Blantyre. The board is supplying water to 1.4 million people within its supplying area which include its city and other areas like Bvumbwe, Chileka, Lunzu, Chirazulu, Limbe and Mapanga (Blantyre Water Board, 2018). However, there is little or no studies that have been done to assess the quality of sachet water from these unregistered vendors in Blantyre, Malawi despite being of the major commercial cities in Malawi.

1.2 Problem statement.

In Malawi, about 4 million people still lacks access to safe drinking water (USAID, 2021). Drinking contaminated water can lead to waterborne diseases like diarrhea, cholera, dysentery typhoid and polio. There are rising cases of cholera in Malawi and this year alone about 4223 cholera cases were reported in Malawi as of 9th October 2022. Blantyre district is one of the affected districts with a total of 625 cases and 25 deaths as 9 October 2022 (Ministry of Health, 2022). Most of the cases are mainly due to drinking unsafe water, poor sanitation services and eating contaminated food (Ministry of Health, 2022). Sachet water is one of the sources of water that has gained popularity to low-income people due to its affordability and availability but its quality is questionable. In Blantyre city, some low-income people who do their businesses in this city consume sachet water as their source of water. There are concerns of contamination of sachet water (Mayinja, Tilley, & Marks, 2019). These sachet water can become contaminated due to poor handling practices, questionable sources of water where they collect water, transportation and treatment of sachet water. This raises risk that sachet water may contribute to rise of

cholera cases in this district. Few studies conducted in Malawi on quality of sachet water have shown that they do not follow the standards limits. Mayinja, Tilley, & Marks, (2019) assessed the microbial quality of sachet water in Mwanza and found that they are not in compliance with MBS and WHO standards limits. Ngumbira, (2020) also conducted research on the physco-chemical and microbial properties of sachet water that is sold in Lilongwe and the results of some samples were also not in compliance with MSB and WHO guidelines. However, there are no documented studies that have been done to assess the quality of sachet water from these unregistered vendors in Blantyre, Malawi despite it being the major commercial cities in Malawi. It is for reason this study was carried to assess the quality of the sachet water in Blantyre to bridge the gap. This research was of paramount significance as it hinges on the tenet of life which is water.

1.3 Main Objective

The overall objective of the study was to assess quality of sachet water sold by vendors in Blantyre.

1.4 Specific Objectives

. To determine physical and chemical properties of sachet water sold by vendors in Blantyre.

. To determine the relationship between the physio-chemical parameters and biological properties of water.

. To analyze microbial properties of sachet water sold by vendors in Blantyre

. To examine the quality of sachet water using water quality index.

1.5 Research Questions

. What is physio-chemical properties and biological properties of sachet water sold in Limbe?

. What is the relationship between the parameters?

. What is the quality of sachet water using water quality index?

1.6 Significance of the study

This study will help in improving the quality of water of sachet since vendors in Blantyre will have more knowledge on how to handle and package sachet water hence achieving Sustainable Development goal target 6.1 which calls for universal and equitable access to safe and affordable drinking water (World Health Organization, 2019). The target is tracked with the indicator of safely managed drinking water services, water that is free from fecal and chemical contamination (World Health Organization, 2019). The study will also help government institution and other stakeholders to have more information on sachet water sold in Blantyre City make relevant decisions and regulations on sachet water there by improving the health of people in Blantyre city.

CHAPTER 2: LITERATURE REVIEW

2.1. Overview of Global Access to Drinking Water

Clean water is vital to our community's health and economy. Access to safe drinking water is measured by the percentage of the population having access to using improved drinking water sources (Centers for Diseases Control and Prevention, 2022). Universal access to safe drinking water is a fundamental need and human right. Good access to safe water reduces illness and death due to water borne diseases (UNICEF, 2022).Sustainable Development Goal target 6.1 calls for universal and equitable access to safe and affordable drinking water (WHO, 2019).

Safe drinking water is defined as water from an improved source which include household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater collections (Dinka, 2018). Examples of unimproved drinking water sources are unprotected dug well, unprotected spring, surface water such as river, dam, Lake Pond, stream canal, and irrigation channels, vendor-provided water, bottled water and tanker truck water. Bottled water is not considered improved due to limitations in the potential quantity not quality of the water (Centers for Diseases Control and Prevention, 2022) Although 67% of Malawi's households have access to drinking water, distribution among districts and between urban and rural areas, is uneven. Improved drinking water sources

are more common in urban areas which is at 87% compared to 63% in rural areas (UNICEF, 2022).

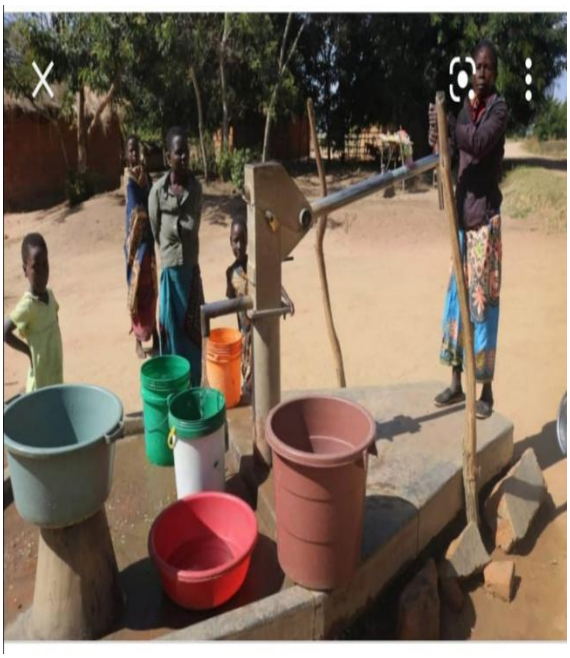




Figure 1: Example of improved sources Example of unimproved sources of water

2.2 Sachet Water Quality and Processes Used in Production

Sachet water has gained widespread use as an alternate to the insufficient provision of water. It is an alternate that is readily available affordable but not without concerns about its purity. In Malawi (Ngumbira, 2020) stated that safe drinking water as one that meets both WHO and Malawi Bureau of Standard guidelines. (Dinka, 2018) described clean/pure water as one that has no minerals and it only contains hydrogen and oxygen. However, some studies that were conducted in some countries in Africa revealed that these sachets drinking water does not meet standard safe of drinking water. Yusuf, Jimoh, Onaolapo, & Dabo (2015) did research in kaduna state in Nigeria and they found that sachet water that is being sold was of relatively good quality for human consumption but there is need to improve in biological treatment. In Malawi, for example, 62% of sachet water samples did not meet the guidelines (Mayinja, Tilley, & Marks, 2019). Production of sachet water in Malawi is somehow worrisome too because they are not regulated by any organizations (Ngumbira, 2020). Poor manufacturing and handling practices such as production of the

water under unhygienic environment, poor hygiene of vendors and non-adherence to WHO or MBS regulations can lead to production of unsafe sachet water (Mohammed, Badau, Igwegbe, & Maina, 2020). The health impact of drinking unsafe sachet water is that people get exposed to water borne diseases like cholera, typhoid, diarrhea just to mention a few. The studies that were also conducted revealed that sachet water is increasing the cases of cholera and other water borne diseases (Miner, Tagurum, & Hassan, 2015). Sachet water industry mostly use tap water as main source of production of sachet water (Ngumbira, 2020).

2.3 Water Quality Issues and Healthy Impact.

Contaminated water can cause a lot of problems to the health of human. It can cause gastrointestinal illness, nervous system or reproductive chronic and diseases such as cancer (US EPA, 2021). Presence of microbes in drinking water can cause life threatening diseases such cholera and typhoid. Viruses, bacteria's and parasites can also lead to stomach pain, vomiting, diarrhoea, polio, headache, fever and kidney failure ((US EPA, 2021).

2.4 Water Quality Standards

The drinking water quality standards are applicable to all water intended for human consumption. Drinking water from public water supply systems, tanks supplies and bottled water companies uses drinking water quality standards. The World Health Organisation (WHO) provide general guidelines for making water quality. In Malawi, the Malawi Bureau of Standards (MBS) formulates national standards for drinking water and other fields of interest (Chidya, Singano, Chiteze , & Mourad, 2019). The table 1 below shows some of the drinking water quality set by MSB

Parameter	MS (214) Standards	WHO
Ph	5.0-9.5	6.5-8.5
Turbidity	0.1-1 NTU	<5 NTU
Conductivity	<1000 μS/cm	<1500 μs/cm
Chlorine		2 mg/l
Alkalinity		200 mg/l
TDS	1000 ppm	1000ppm
Salts	200	200 ppm
Nitrate	5-10 mg/l	<50
Fecal coliform	0 cfu/100 ml	0 cfu/100ml

Table 1:Safety standards set by WHO and MS for drinking water adapted from MSB (2013) and WHO Standards

2.5 Drinking Water Quality Properties

Water quality properties include chemical, physical and biological properties and can be tested based on the desired water parameters of concern (YSI, 2022). Parameters that are frequently monitored for water quality include temperature, dissolved oxygen, pH, turbidity electrical conductivity, total dissolved solutes, fluoride, chloride alkalinity, hardness and fecal coliform. Sachet water is in a group of packaged water which include packaged cans, laminated boxes and glasses and plastic bags. Physio-chemical and microbial indicators of packaged drinking water quality are:

2.5.1 The Power of Hydrogen

pH is a measure of how acidic/ basic water is. The range goes from 0 to 14, with 7 being neutral. pH of less than 7 indicate acidity where a pH of greater than 7 indicates a base. pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water (Water Science School, 2019). Excessively high and low pH can be detrimental for the use of water. High pH causes a bitter taste, water pipes and water using appliance become encrusted with deposits and it affect the effectiveness of chlorine, thereby causing

the need for addition of chlorine when pH is high. Low-pH water will corrode metals and other substances. Due to the utilization of city piped water for the manufacturing of sachet products, it might increase the risk of contamination from copper and lead that can leach from appropriate pipes (Ngumbira, 2020). The Ph for packaged water ranges from 6.5 to 8.5.

2.5.2 Electrical conductivity

Electrical conductivity is the measure of the ability of water to pass an electrical current. Because dissolved salts and other inorganic chemicals conductivity electrical current, conductivity increases as salinity. Organic compounds like oil do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature, the warmer the water, the higher the conductivity (Regan , 2022). Conductivity is useful as a general measure of water quality. The EC for raw water and potable water ranges between 50-500 μs/cm.

2.5.3 Chlorine

Most packaged water is tap water which means, depending on where it was sourced from directly, it could have been disinfected with chlorine. Depending on the levels of chlorine used for drinking water disinfection, chlorinated water is generally safe to drink and Chlorine is not harmful but when reacted with Na it has negative effects to consumers like kidney problem and heart diseases. Small amount is needed for ordinary cell functioning. (WHO, 2006).

2.5.4 Turbidity

Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is a measurement of the amount of light that is scattered by materials in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity (Water Science School , 2018). Turbidity has no health effects but can interfere with disinfection and provide a medium for microbial growth. High turbidity in drinking may indicate the presence of disease-causing organisms. These organisms include bacteria, viruses and parasites which can cause symptoms like nausea, cramps

diarrhea and associated headaches. People with severely compromised immune systems, infants and some elderly may be at increased (Crosby, 2021).

2.5.5Temperature

In any system the water temperature controls the rate of all reactions, this affects the growth of fish and other aquatic organisms. It also has a role in determining the survival of microorganisms in the water body (Zuane, 1990). Palatability, viscosity, solubility, odors and chemical reactions are influenced by temperature. Most people find water at temperatures of 10-15 °c most palatable.

2.5.6 Alkalinity

Alkalinity is the measure of the ability of the water body to neutralize acids and bases and thus maintaining a fairly stable pH. It is not chemical in water but, rather, it is a property of water certain chemical in the water such as bicarbonates, carbonates and hydroxides. In more simple terms, water with alkalinity will experience less of a change in its own acidity (Water Science School, 2018). If the alkalinity is too high, the water can have a salt, soda like or chalky taste (Water Science School, 2018).

2.5.7 Nitrate

Nitrate is a compound that naturally occurs and has many human-made sources. Natural processes can cause low levels of nitrate in drinking water – usually less than 3 mg/l. The health concern is with levels of nitrate over 10 mg/l (MINNESOTA, n.d.) . Consuming too much nitrate can affect how blood carries carries oxygen and can cause methemoglobinemia also known as blue baby syndrome. Bottle-fed babies under six months old are at the highest risk of getting blue baby syndrome (MINNESOTA, n.d.).

2.6. Microbial assessment of Sachet Water

Microbial assessment of water is a method of analyzing water to estimate the numbers of bacteria present measure in water. It is the most important aspect of drinking water in relation to waterborne diseases (Yassin, 2006).

2.6.1 Fecal Coliform

Fecal coliforms are types of total coliform that are considered to be present specifically in the gut and feces of warm-blooded animals. Because the origins of fecal coliforms are more specific than the origins of the more general total coliform group of bacteria, fecal coliforms are considered a more accurate indication of animal or human waste than other coliforms. Fecal contamination is a serious problem due to the potential for contracting diseases from pathogens (New York State Department of Health, 2017).

2.6 Water Quality Index

Water quality index (WQI) provide a single number that expresses the overall water quality at certain location and time, based on several water quality parameters (Godwin, Etim, & Adelegun, 2021). The objective of WQI is to turn complex water quality data into information that is understandable and usable by the public (Godwin, Etim, & Adelegun, 2021). Water Quality index is calculated by averaging the individual index values of some or all parameters within five water quality parameters categories. It is a scale from 0-100. The higher, the value the better the quality of water. The WQI ranges between 0 to 100. zero represent a best water quality and 100 represent worst water quality (Godwin, Etim, & Adelegun, 2021). Application of WQI is useful method in assessing the suitability of water for various beneficial users.

CHAPTER 3: METHODOLOGY

3.1 Study area

The study was conducted in Blantyre one of the cities in Malawi (figure 2). It is located in the southern region of Malawi, in Blantyre district. 2018 census reveals that Blantyre district has a population of approximately 800246. Blantyre water board is the one who supplies water in this city.

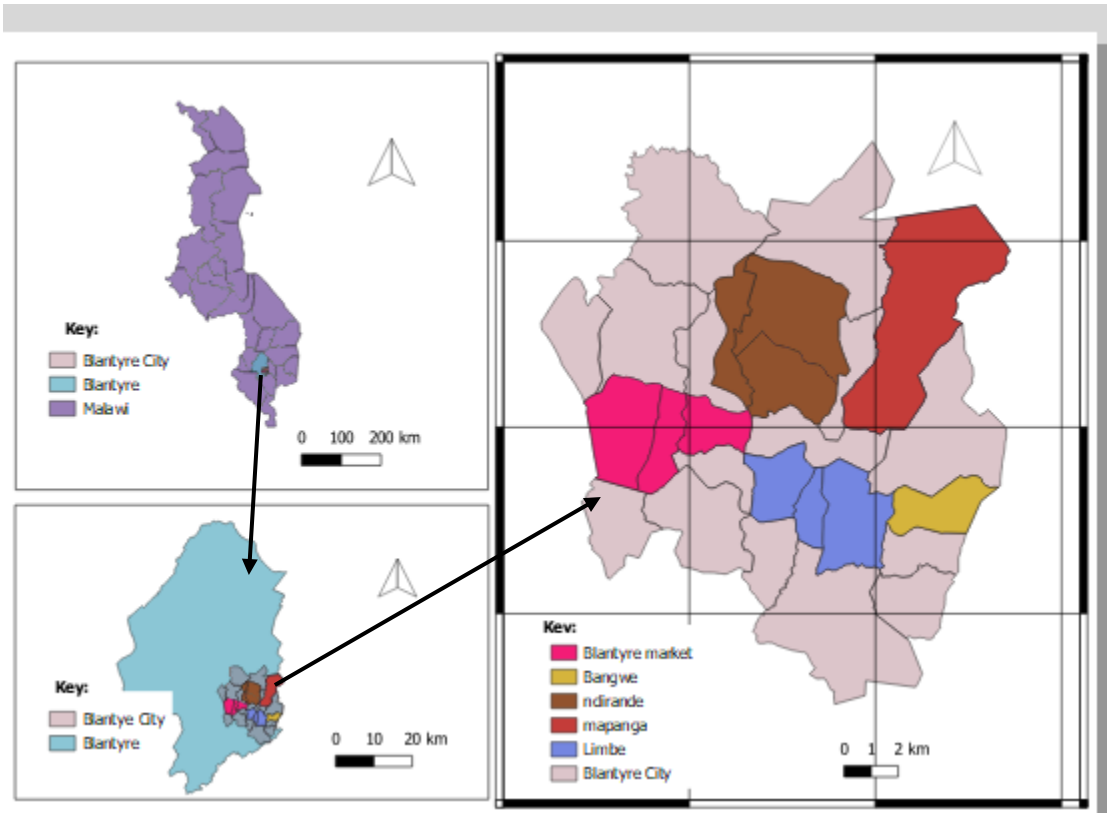


Figure 2: Map of Malawi and Blantyre City showing sample sampling locations

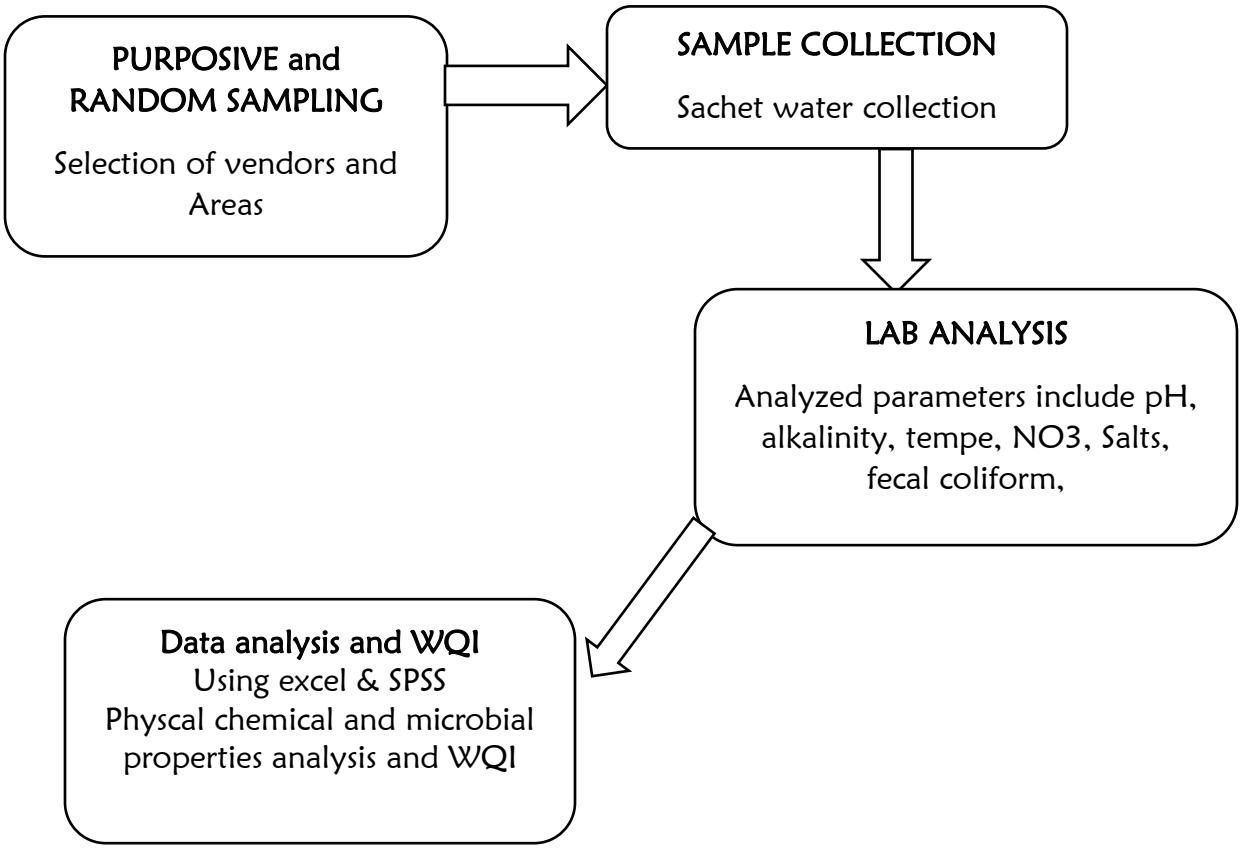


Figure 3: Flow Diagram showing Methodology

3.2 Research design

figure 3 above shows a flow diagram of methodology. The study involved quantitative research. Primary data was collected by doing a laboratory test in order to determine the physical, microbial and chemical properties of sachet water. Secondary data were collected from different websites, government publications and journal articles.

3.3Sample and data collection

purposive sampling technique was used to target 10 producers who were selling their sachet water in these markets. The targeted vendors were vendors who produce and go around the market and sell on their own. A total 30 sachet were selected randomly from the

markets. Three replicate samples from each vendor. After purchasing, samples from each vendor were labeled and stored under the same conditions in a cooler box. Then, water vendors were interviewed on sources where these sachets drinking water are collected and processes used in production of sachet water. The interviews were only for those sachet water have been purchased. Then samples were stored in a cooler box with ice to prevent contamination and then transported to MUST water Lab for analysis. Upon arrival to lab, samples were analyzed within recommended hours and microbiological evaluation was done immediately after arrival to lab.

3.4 Laboratory analysis

3.4.1 Physio-Chemical and Microbial Water Quality Determination

3.4.1.1 Microbial water quality analysis

The membrane filtration method was used to analyze fecal coliforms. Firstly, the area that was used and all materials used like petri dishes, filtration apparatus and forceps were sterilized using alcohol. Then absorbed pads were added onto the petri dishes. The pads were then soaked in the nutrient medium called Lauryl Sulphate and Broth. Then using forceps, the membrane filters were removed from the packages with a pair of forceps and placed on the filtration apparatus. Using suction flask, water was drawn through a special porous membrane designed to trap microorganisms larger than 0.45μm. Water from each sample was filtered through a special cellulose nitrate filter. Petri dishes containing filter membranes and selective nutrient media for fecal coliform was be incubated at 44°c for 24 hours. This temperature is known to be ideal for the development of bacteria. The analysis for fecal coliforms organisms per water sample were reported in terms of cfu/ml. Counting was done using physical method with the help of colony counter. Colonies representation formed were picked for microscope test to confirm their identity. The presence of fecal coliform in any water sources gives an indication of fecal contamination and the presence of disease-causing microorganisms. After incubation the colonies were counted using the following formula:

No of colonies per volume= [no of colonies on the membrane /volume filtered] × factor.

3.4.1 .2 Determination of PH

PH meter was used to measure pH values of the sachet water sample. A sample volume of 50 ml was taken from each sample and filled into a glass beaker. Then, these water samples were mixed properly and stirred using a glass rod. Next into the water sample, the electrodes were inserted. The beaker was turned and adjusted so that there was good contact between the electrodes and the water. Once the pH meter was steady, pH of the sample was collected. The probe of the meter was rinsed with distilled water and scrubbed with clean tissue paper after every determination. This was done to avoid cross contamination.

3.4.1.3 How turbidity will be determined.

Hydro test HT1000 was used to measure to measure turbidity values of the sachet water sample. Firstly, a clean vial was filled with a 10 ml of deionized water and closed tight with a cap and then the vial was placed on the hydro tester chamber and the zero key was pressed setting the meter to give turbidity values. Samples to be measured were then poured in the vial and the vial was placed on the chamber to give the values of turbidity by pressing the test key. Hydrotest HT100 utilize a light and photo detector to measure light scatter, and read out in units of turbidity FAU. 1 FAU is the same as 1 NTU

3.4.1.4 Determination of electrical conductivity, Salts, Temperature and TDS

CD 90 Salt meter was used to determine was used to determined TDS, Temperature salts and electrical conductivity. The meter was first calibrated. 50 ml 0f water samples were place in a beaker. Then the electrode was dipped into beaker. The readings for salt, temperature EC and TDS were recorded on a results sheet after two minutes when the meter had stabilized. Next, the electrodes will be rinsed thoroughly with distilled water and wiped with a clean tissue paper in order to avoid cross **contamination** of samples, then introduced directly into the samples. The value for each sample will be taken (Sheshe & Magashi, 2014).

3.4.1.5 Determination of Chlorine

Chlorine was determined using hydro test HT1000. Firstly, a clean vial was filled with 10 ml of deionized water and closed tightly with a cap and then the vial was placed on the photometer chamber aligning the marks and the zero key was pressed setting the photometer to give total chlorine values. The vial was then removed from chamber, another vial was 10 ml of water samples, one chlorine tablet no 1 was added straight from the foil to the water sample in a vial and the tablet crushed using a clean stirring rod, another tablet labeled chlorine no 2 was added straight was added straight from the foil to the same water and it was crushed using a clean stirring rod, the vial was tightly closed with cap and swirled several times until the tablets got dissolved, the vial was placed on the photometer aligning the mark, then the test key was pressed to begin the analysis and after 2 minutes of waiting of waiting, the reaction was finished and the values were provided on the photometer screen and recorded.

3.4.1.6 Determination of Nitrates

Nitrate was determined using hydro test HT1000. A clean vial was filled with 10 ml of deionized water and it was closed tightly with a cap and then placed in the sample chamber by aligning the marks. The zero key was pressed to set the photometer to give nitrates reading. The vial was emptied. A nitrate test tube was filled with 20 ml of the water sample, then a one level spoon of nitrate test powder was added. Then, the tube was tightly closed with a cap and the sample was shake for a minute and the tube was left to stand upright for the reagents to settle. The tube was gently inverted for three times and was left again to stand upright for 2 minutes. Then 10 ml of the prepared sample was poured into the clean vial, then one nitrite tablet was added straight from the foil to the water sample and was crushed using a clean stirring rod. The vial was then placed on the photometer chamber and the test key was pressed. After 10 minutes of waiting for the reaction period, the photometer gave the nitrate reading and it was recorded.

3.4.1.7 Determination of alkalinity

Alkalinity was determined using hydro test HT1000. Firstly, a clean vial was filled with 10 ml of deionized water and closed tightly with a cap and then the vial was placed on the photometer chamber aligning the marks and the zero key was pressed setting the photometer to give total chlorine values. The vial was then removed from chamber, another vial was 10 ml of water samples, one alkalinity tablet was added straight from the foil to the water sample in a vial and the tablet crushed using a clean stirring rod, the vial was tightly closed with cap and swirled several times until the tablets got dissolved, the vial was placed on the photometer aligning the mark, then the test key was pressed to begin the analysis and after 2 minutes of waiting of waiting, the reaction was finished and the values were provided on the photometer screen and recorded.

3. 5 Assessing Water Quality Using Water Quality Index (WQI)

After laboratory analysis, the WQI of the different water samples will be assessed using online water quality index. This will be performed taking into account of 6 important parameters which are pH, turbidity, TDS, TSS, total hardness, electrical conductivity, chloride, nitrates, calcium and magnesium. The calculations were made using weighed arithmetic index method using the following steps (Adelagun, Etim, & Godwin, 2021). Using n water quality parameters and quality rating q_n corresponding to nth parameter is a number reflecting relative value of this parameter in the polluted water with respect to its standard permissible. Quality rating values were given by the relationship

$q_n = 100(Vn-Vi)/(Vs-Vi)$

Vs= Standard value, Vn= observed value and Vi = ideal value.

In most cases Vi=0 except in certain parameters like pH, and Dissolved oxygen. Therefore, quality ratings for pH and DO (Vi≠0) were calculated using the following

$q_{pH} = 100(VpH-7)/Vs-7$ & $q_{DO} = 100(V_{DO} - 14.6)/ Vs-14.6$.

Calculation of unit weight : the weight unit Wn to various water quality parameters are inversely proportion to the recommended standards for the corresponding parameters

$Wn=k/s_n$. where Wn = unit weight for nth parameter

Sn= standard permissible value for nth parameter

K =proportionality constant

WQI is calculated was calculated using the following equation

$WQI= \sum qn* wn$

The suitability of WQI values for human were rated as follows

Value	Grading	Rating
0-25	A	Excellent
26-50	B	Good
51-75	C	Poor
76-100	D	Very Poor
>100	E	Unfit Quality

Table 2: Grading system for WQI

CHAPTER 4: RESULTS AND DISCUSSION

Introduction

This chapter presents the results of the study and provide a thorough discussion with reference to the aim of the study, which was to assess the quality of sachet water sold in Blantyre.

4.1 Descriptive Analysis

The table 3 below shows the results of parameters that were assessed. Due to the absence of sachet water standards in Malawi, the results were compared to WHO and MS 214 (2013) which are drinking water standards used in Malawi.

	Units	Minimum	Maximum	Mean	Std. Deviation
Ph	NA	7.5567	8.4333	7.974667	.2764645
Ecoli	CFU/100ml	.0000	92.3333	24.63333	28.2114809
Alkalinity	Mg/l	94.3333	141.000	121.20667	16.0213577
Salt	Ppm	56.6667	100.000	79.33333	12.6491106
Tempe	℃	15.3333	19.6667	17.966667	1.2905162
Ec	μS/cm	133.87	210.17	183.36	27.92
Turbidity	NTU	2.0000	5.3333	4.110000	1.0201731
Tds	Ppm	60.1667	108.000	91.759334	13.6170558
Chlorine	Mg/l	.0367	.0667	.051000	.0096928
Nitrate	Mg/l	.0400	.8000	.259000	.2620199

Table 3: summary of physio-chemical parameters and microbial parameters of sachet water

The results table shows that the mean pH of 7.975 and the standard deviation of 0.276 showing that the results for pH were not out from the average pH. The maximum pH was 8.4333 and minimum pH were 7.5567. The mean value for electrical conductivity were 183.36 μS/cm. The maximum and minimum EC were 210.1667 μS/cm and 133.8667 μS/cm. The standard deviation for EC is 28.21 indicating that the results were largely spread out from the mean value. The summary of the results further indicates the mean TDS of 91.76 ppm and the standard deviation were 13.62. The same trend was also found on alkalinity. The mean value for alkalinity was 121.20 with a standard deviation of 16.02.

The results table also indicate the mean result for salts, chlorine temperature and nitrate which were 79.33ppm, 0.051mg/l 17.97°c and 0.259 mg/l and the standard deviation were 12.64, 0.0097, 1.29 and 0.262 respectively. The STD deviation for salt shows that the data points were spread out from the mean.

The summary also indicates the mean for fecal coliform which was 24.633. The standard deviation was 28.411 indicating the results were also largely spread out from the mean. The maximum and minimum coliform were 92.3 and 0 cfu/100ml respectively

4.1 Physco-Chemical assessment based on Location

Figures 4-12 below show the results on the physico-chemical water quality compared and plotted to Malawi standards (MS) 214 (2013) and the WHO guidelines for drinking water quality. The results generally showed that the sachet water from the different vendors and areas had different characteristics and chemical compositions attributed to several factors such as sources of water used to collect water, handling practices when producing sachet and storage that is used before and after production.

4.1.1 pH

The limits for both WHO 2011 standards and MS 214 drinking water have pH ranges of 6.5 to 8.5 respectively (USEPA, 1992). In All samples (n=10) registered pH within recommended ranges of 6.5 to 8.5 and 6.0 to 9.5 set by WHO (2011) and MBS (2013) for drinking purposes respectively. The lowest mean pH (7.5567) was recorded in Ndirande at vendor number 9 and the highest pH was recorded in Bangwe at vendor number 7. There was significant difference for pH ($p<0.05$) between the areas. Although, pH has no negative effects to consumers but to sensitive people it may cause irritation to the eyes, skin and mucous membrane for humans (Chidya, Singano, Chitedze, & Mourad, 2019). Heavy metals such as cadmium, Lead and Chromium dissolve more easily in high acidic water. So, pH should be considered because many heavy metals become much more toxic when dissolved in water (Water Science School, 2019). The figure 4 below shows the pH for different vendor and areas compared to MBS and WHO 2011 standards.

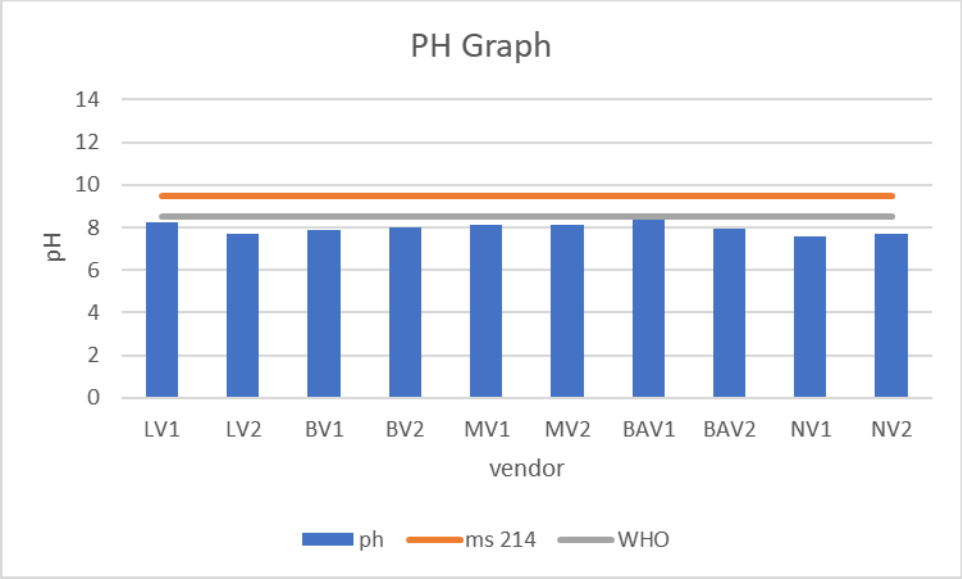


Figure 4: Graph of PH for Different Areas in Blantyre City

4.1.2Turbidity

Turbidity ranged from 2.00 to 5.33 NTU and all of the sachet water samples scores above MS standards with 1 NTU and 1 sample from Ndirande vendor number 1 was above WHO standards. There was no significant difference for (ANOVA, P< 0.05). Although most of these uses tap water which is treated, it is evident that the processes of storage and handling practices used in the production affect the quality of water. Sachet water packets from Ndirande vendor 1 were above the WHO (2011) standards which is 5. Though turbidity has less impacts on the health at the level it is found in the drinking water. Turbidity is a good indicator of presence of bacteria, pathogens or harmful particles during the disinfection process (Chidya, Singano, Chitedze, & Mourad, 2019). Mann, Tam, & Rodrigues (2007) did research on association of turbidity and gastrointestinal illness and concluded that association exists in some setting or over a certain range of turbidity. The higher concentration that had been found in this study should give a worry to the health of consumers. Figure 5 below shows the graph of turbidity against vendor

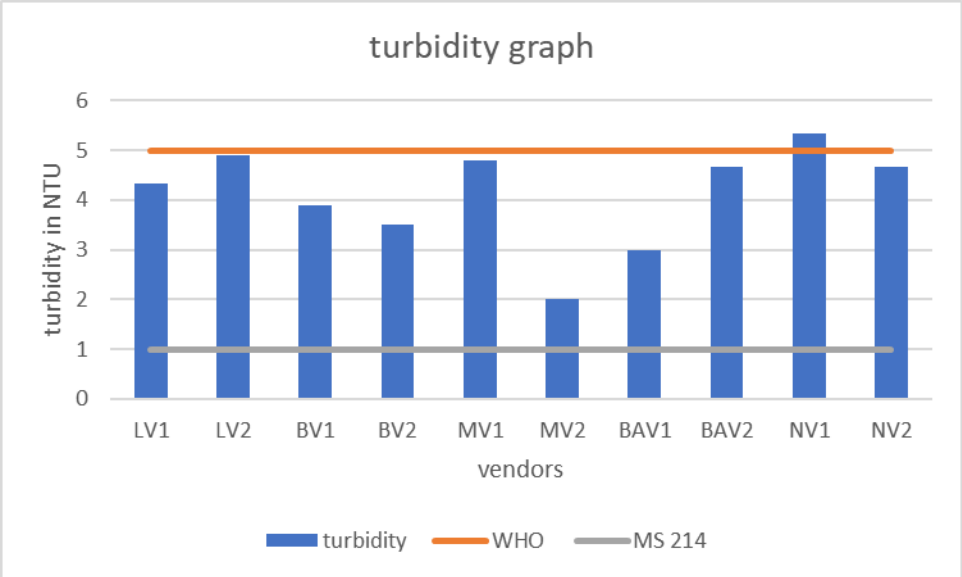
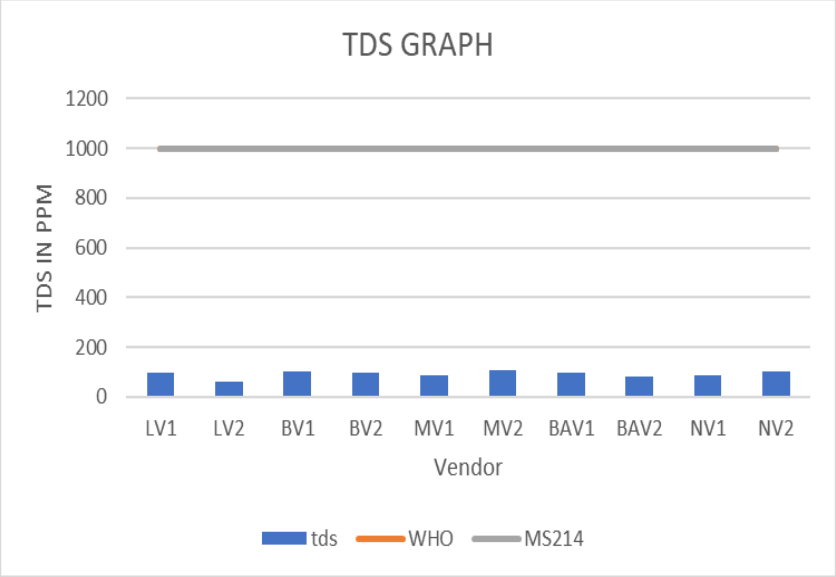


Figure 5: Graph of Turbidity for Different Areas in Blantyre City

4.1.3 EC and TDS

The results for EC and TDS show that both are complying WHO (2011) and MS 214 (2013). The highest EC was recorded in Mbayani vendor 2 (210. 2μs/cm) and the lowest EC was recorded in Bangwe vendor number 2 (133.9 μs/cm). For TDS, the lowest value was recorded in Limbe vendor 2(LV2) 60.and the highest value was recorded and in Ndirande vendor number 2 (NV2) which was 108 ppm. The most important aspect of TDS with respect to drinking water quality is its effect on taste (Health Canada, 2009). The palatability of drinking water with a TDS level less than 600 mg/l is generally considered to be good. Drinking water with TDS levels greater than 1200mg/l are unpalatable to most consumers (Health Canada, 2009). So, in this study all the sachet water packets were found to be palatable since were below 600ppm. The results showed that there was significant difference for EC and TDS (ANOVA, $P<0.05$) between the areas. Figure 6(1-2) shows the graph of EC and TDS



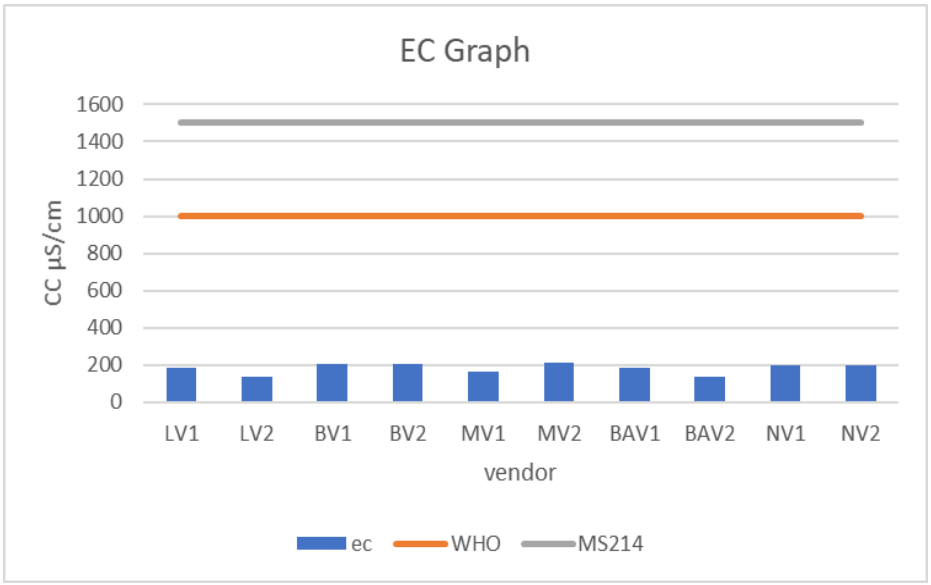


Figure 6: (1-2) Graph of EC and TDS in different areas

4.1.4 Nitrate

The results for nitrate indicated that it was below the standard set by WHO and the results were very small as shown in figure 7 below. The results ranged between 0.04 to 0.8 with the highest number. This shows that in the study area there are no any risk of blue baby syndrome which is caused by nitrates.

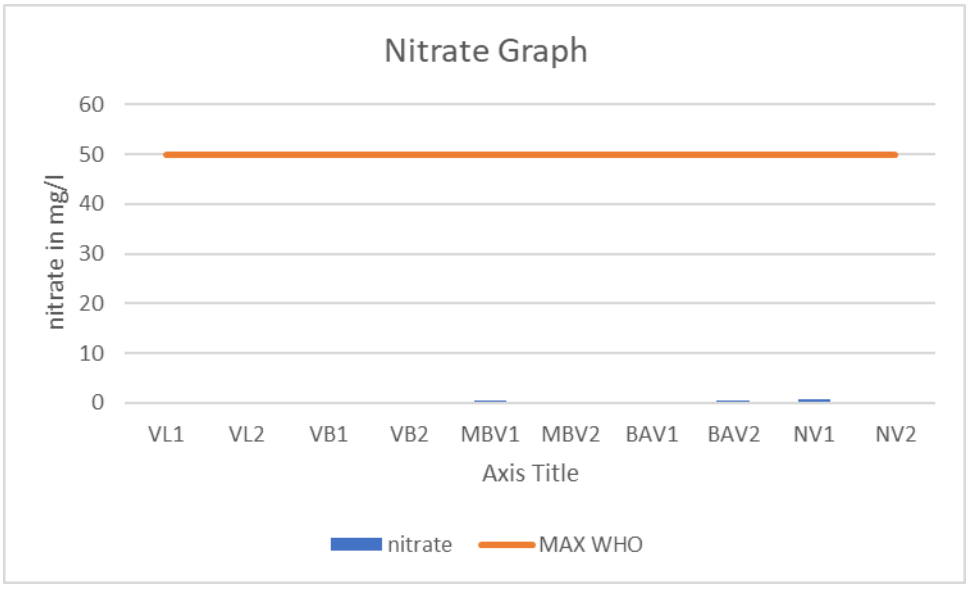


Figure 7: Graph of Nitrate for different Areas

4.1.5 Chlorine

During the determination of chlorine, residual chlorine was not being detected it was under range. This means that the residual chlorine was used up so the hydro tester detected the total chlorine which symbolize the presence of combine chlorine which means that the water had some contaminants which was reacting with the residual chlorine (Walensky, 2022). The results for chlorine ranged from 0.0367mg/l to 0.0667 and the maximum total chlorine was registered in Bangwe vendor number 2 and the lowest chlorine levels were registered in Mapanga vendor number 1. Chlorine levels in the sample were compared to WHO (2011) standards and was found to be below the limit's standards.

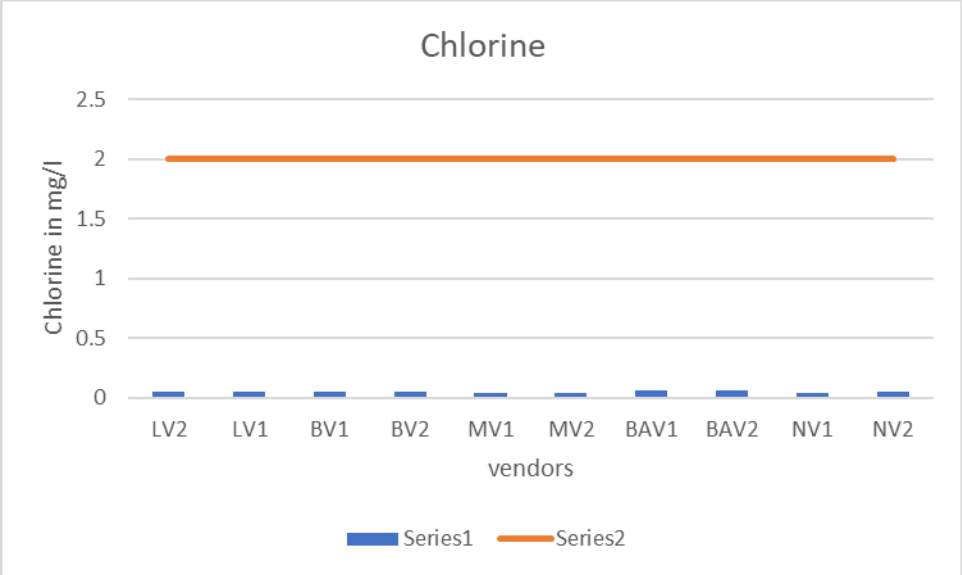


Figure 8: Graph Showing Chlorine for Different Areas

4.1.6 Salts

Due to the absence of MBS standards, the results were just compared to the WHO standards. The recommended standard for salt in drinking water for WHO is 200 mg/l. The maximum concentration levels and minimum concentration of salts in the sachets was 100 mg/l and 56 mg/l. This shows that the results were within the recommended standards. Sodium is not generally considered harmful at the normal levels of intake from drinking water sources. High salt will give drinking water a salty taste at a concentration greater than recommended standards hence changing the palatability of water (Western Australia Department of Health , 2016).

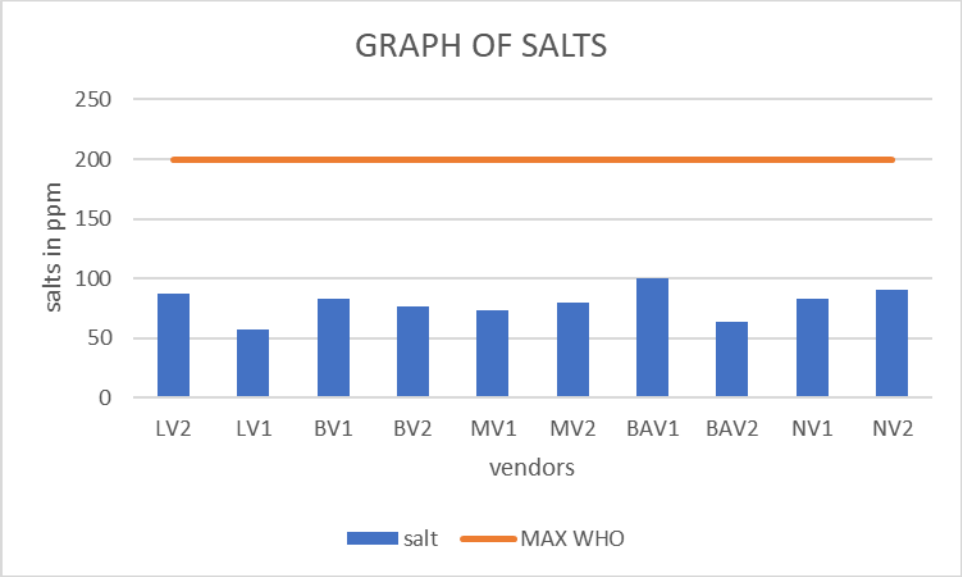


Figure 9:Graph showing levels of Salts in Blantyre city

4.1.7 Alkalinity

The graph number 10 below shows the mean value for alkalinities for different areas vendors and areas in Blantyre. The maximum and minimum alkalinity were 141 and 94 mg/l. The highest alkalinity was found in ndirande at vendor number 1 and lowest alkalinity was also found in Ndirande again at vendor number 2. The results were below the standard limits for WHO (2011). When total alkalinity is too high, the elevated

alkalinity may cause the pH to rise and this can reduce the effectiveness of the chlorine in water.

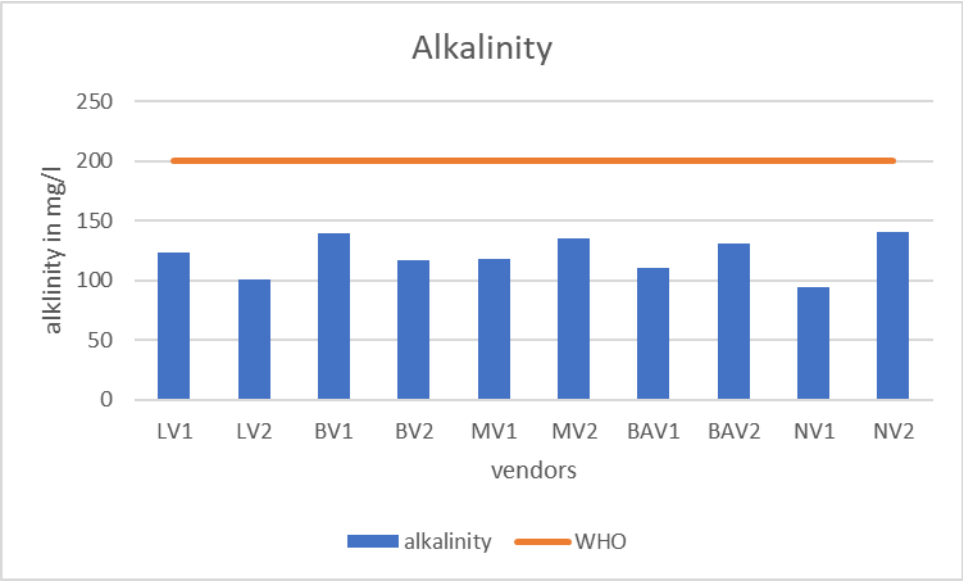


Figure 10: Alkalinity Graph for different areas

4.2 Microbial Assessment of Sachet Water.

The presence of fecal coliform in drinking water sample often indicates recent fecal contamination, meaning there is a greater risk that pathogens are present than if only total coliform bacteria is detected. Ecoli is a sub-group pf the fecal coliform group (Mahmud & Ahmed, 2019). The WHO (2011) and MS 214 (2013) recommend that 0 colony counts/100 ml of fecal coliform for drinking water. From the results, fecal coliform was detected in 80% (n=8) of the samples hence the results were above the recommended standard of MBS and WHO. Only 2 sample complied the recommended standard. In this study, the other microorganisms were not analyzed due to financial and time problems. The contamination ranged from 0 to 92 cfu/100 ml. The mean value for Fecal coliform were of significant different (ANOVA, $p<0.05$). Although the vendors claimed that they use tap water as their source the water were still contaminated with fecal contamination. Through the interview that was done with the vendors and the observation, the contamination could be as a result of lack of hygiene practices during water production. Possibilities are

also there the water from the tap may also be contaminated before the sachet water is produced other sources done in Malawi also showed that sachet water is contaminated with microorganisms. Manjaya (2019) and Ngumbira (2020) did research in Mwanza and Lilongwe found that some of these sachet waters are contaminated with fecal matter. Figures 11 and 12 below show some Petri dishes and a graph of fecal coliforms across the areas and vendors. On figure 11, the yellow dots indicate the presence of fecal coliform.



Figure 11: some of the petri dishes

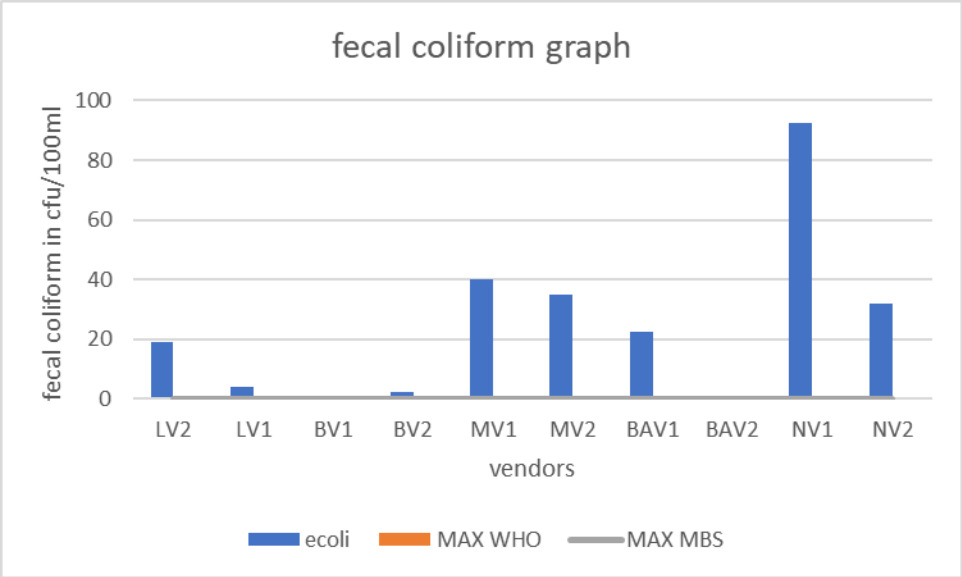


Figure 12:graph of fecal coliform

4.2 Evaluating Water Quality of Sachet Water Using Drinking Water Quality Index

The water quality index was calculated to the overall quality of the sachet water sold in Blantyre. Water quality parameters that were used include pH, turbidity, alkalinity, salts fecal coliform, EC, TDS nitrate and chlorine. When choosing the parameters in the index, microbial assessments were included they are important predictor of water quality. However, the WHO and MS standard is 0 CFU/100 ml for fecal coliform which makes it difficult to be calculated in the index. Due to stringent guidelines for fecal coliform, some countries use suggested guideline in water quality index. For example, the government of Swaziland set a guideline of 100 counts/100 ml for untreated water in rural areas (Rickwood & Carr, 2007). Since microbial assessment is considered too important in predicting suitability of water, a guideline of 10 counts/ 100ml were suggested and used in this calculation.

vendor	Scores based on vendors	Status	Grading	Scores based on areas	Status	Grading
Lv1	50.99291	Poor	C			
Lv2	32.70442	Good	B	41.84866	Good	B
Bv1	25.71749	Good	B			
Bv2	24.69366	Excellent	A	25.20557	Excellent	A
Mv1	73.67972	Very poor	D			
Mv2	56.12876	Poor	C	64.90424	Poor	C
Bav1	50.25394	Good	B			
Bav2	29.84403	Good	B	40.04898	GOOD	B
Nv1	124.5035	Unfit quality	E			
Nv2	60.62319	Poor	C	92.56336	Very poor	D
∑WQI	52.91416				POOR	B

Table 4: Scores of water samples under WQI

The table 4 above show the results of water samples under the water quality index. The quality of 10 samples of sachet water sold in Blantyre were evaluated to assess the suitability for drinking. Based on vendors, only one sample from vendor number 1 in Blantyre market (BV1) were rated excellent and scored a grade of 24 and sample from 1 vendor from Ndirande (NV1) were rated unsafe for drinking and scored a grade of 124. This be because of insufficient, unhygienic practices in production of sachet water and storage used when selling these sachet water. Despite that many vendors claimed that tap water is the only source of water used in production of sachet water, some might use other sources that are untreated. Based on areas, Blantyre market scored 25 and were rated excellent. Based on areas sachet water sold in Ndirande market were rated poor for drinking. In general, sachet water sold by vendor in Blantyre city were not of good quality and it scored 52 on water quality index.

4.4 Results for Analysis of Variance for Sachet Water Sample

Table 5 below shows the results for ANOVA analysis of sachet water samples. The results show that turbidity, salts, alkalinity and temperature were not significantly different while rest of the parameters were significant.

Parameter	p-value
ph	0.008664
turbidity	0.27315
ec	0.000886
tds	0.028223
nitrate	0.000302
Salt	0.532333
Ecoli	0.043748
Chlorine	0.001836
Alkalinity	0.411682
temperature	0.087377

Table 5: ANOVA analysis for different areas

4.5 CORRELATION ANALYSIS

Correlation analysis in research is used to measures the relationship between two variables and compute their association. The correlation can be negative or positive. Table 6 below shows the relationship between different parameters in this study. There was strong positive relationship between total dissolved solids and electrical conductivity (r=

0.83787). According to, Tuc, (2019) the total amount of dissolved solids (TDS) is directly proportion to its electrical conductivity, so high solids, conductivity will also be high. this concurs with the previous studies which also found that these parameters correlate each other (Ngumbira, 2020). In this study, there was also strong relation of salts with EC and TDS (r> 0.7). This relationship shows that salts is a contributor of EC and TDS. Another significant positive relationship is between turbidity and nitrate (r=0.531). This also show that nitrate is contributor of turbidity Chlorine showed a negative significant relationship with fecal coliform (r=-0.6717), this show that chlorine that was in water were being used with the microorganisms hence negative relationship (Karikari & Ampofo, 2012).

	ph	feacal	alkalinity	salt	tempe	ec	turb	tds	chlorine	nitra
Ph	1									
Feacal	-0.3	1								
alkalinity	0.16	-0.4	1							
Salt	0.37	0.31	0.17	1						
Tempe	0.15	0.11	0.19	0.18	1					
Ec	0.05	0.3	0.27	0.72	-0.4	1				
Turb	-0.6	0.26	-0.4	-0.4	0.41	-0.5	1			
Tds	0.37	0.07	0.62	0.73	-0.1	0.84	-0.6	1		
chlorine	0.27	-0.7	0.09	-0.1	0.28	-0.5	-0.1	-0.2	1	
nitrate	-0.4	0.75	-0.3	-0.1	0.36	-0.2	0.53	-0.2	-0.4	1

Table 6: is for Correlation analysis

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Sachet water plays an important in providing drinking water to people who do their businesses in Blantyre. The aim of this study was to assess the quality of sachet water sold in Blantyre. This was done by determining the physical, chemical and biological parameters of sachet water, finding the relationship between the physiochemical and biological parameters and evaluating the overall quality of water using WQI. After assessing the sachet water, most physical and chemical parameters of sachet water were in compliance with WHO and MBS standards except turbidity which were above the limits set by MBS. The report also revealed that, 80% of the sachet water indicated that are contaminated with fecal coliforms. Using WQI, the results showed that only most sachet water that were purchased were of poor quality. The results also showed both positive and negative relationship between the parameters after doing statistical analysis. The presence of contaminated sachet water sold in Blantyre increases the risk for waterborne diseases contributing to the already prevailing cases in the city.

5.2 Recommendation

Based on the research findings, the following recommendations have been made;

1. Due to presence of the fecal coliforms in sachet, consumers should be informed about the risks of drinking informal sachet water
2. Sachet water vendors should ensure that proper personal hygiene so that there is no contamination during the handling process
3. Sachet water should be stored in good condition like away from the sun and in very hygienic conditions
4. MBS and other relevant authorities should start monitoring of sachet water quality and production practices
5. Since these are informal sachet water, government should make laws, regulations and policies on quality of sachet water.
6. Factory based sachet water should be introduced so that the government and other stakeholders should easily monitor them.

6.References

Adelagun, R. A., Etim, E. E., & Godwin, E. (2021). Application of Water Quality Index for the Assessment of Water from Different Sources in Nigeria. In A. I. Moujdin , & J. K. Summers, *Promising Techniques for WastewaterTreatment and Water Quality Assessment.* Intechopen. doi:10.5772/intechopen.98696

Akinnibosun, F. L., & Ugbawa, L. A. (2018, December). Comparative Analysis of Bottled and Sachet Water in Urban and Rural Areas of Edo State, Nigeria. *Sierra Leone Journal of Biomedical Research.* Retrieved November 4, 2022, from http://www.sljbr.org/index.php

Alfa Chemistry. (n.d.). *Determination of Hardness of Water by EDTA Titrimetric Method*. Retrieved from Biocyclopedia: https://biocyclopedia.com>index

Auriga Research Private Limited. (n.d.). *Nitrate testing In Water*. Retrieved from Auriga Research: https://aurigaresearch.com>nitrate

Blantyre Water Board. (2018, April). *View/Download Customer service Charter (April, 2018)*. Retrieved from BWB: https://www.bwb,mw

Centers for Diseases Control and Prevention. (2022, October). *Assessing Access to Water & Sanitation*. Retrieved December 22, 2021, from Global Water Sanitation & Hygiene: https://www.cdc.gov/healthywater/global/assessing.html

Chidya, C. G., Singano, L., Chitedze, I., & Mourad, K. (2019, March). Standards Compliance and Health Implications of Bottled Water in Malawi. *Environmental Research and Public Health*. doi:10.3390/ijerph16060951

Crosby, J. (2021, May). *Drinking Water High Turbidity Boil Advisory Template*. Retrieved from EPA: https://www.epa.gov>files

Dinka, M. O. (2018). Safe Drinking Water: Concepts, Benefits, Principles and Standards. In M. Glavan, *Water Challenges of an Urbanizing World.* IntechOpen. doi:DOI:10.5772/intechopen.71352

Fisher, M. B., Williams, A. R., Jalloh, M. F., Saquee, G., Bain, R. E., & Bartram, J. K. (2015, July). Microbial & Chemical Quality of Packaged Sachet Water and Household Stored Drinking Water in Freetown, Sierra Leone. *PLos ONE.* doi:10.1371/journal.pone,0131772

Godwin, O. E., Etim, E. E., & Adelegun, A. R. (2021, August). *Application of Water Quality Index for the Assessment of Water from Different sources in Nigeria.* doi:10.5772/intechopen.98696

Health Canada. (2009, August). *Guidelines for Canadian Drinking Water Drinking Water Quality: Guideline Technical Document-Total Dissolved Solids TDS.* Retrieved from Government of Canada : https://www.canada.ca>publication

Mahmud, Z. H., & Ahmed, N. (2019). *Ocurrence of Escherichia Coli and FecalColiforms in Drinking Water at Source and Household Point of use in Rohingya Camps, Bangladesh.* doi:10.1186/s130099-0333-6

Mann, A. G., Tam , C. C., & Rodrigues, L. C. (2007). The Association Between Drinking Water Turbidity and Gastrointestinal Illness:a Systematic Review. *BMC Public Health.* doi:101186/1471-2458-7-256

Mayinja, D., Tilley, E., & Marks, S. J. (2019, April). Informally Vended Sachet Water: Handling Practices and Microbial Water Quality. *Water.* doi:10:3390/w11040800

Miner, C., Tagurum, Y., & Hassan, Z. (2015). Sachet Water: Prevalence pf Use, Perception and Quality in A Community of Jos South Local Government Area of Plateau State. *Jos Journal of Medicine.* Retrieved from 2015: https://www.ajol.info>article>view

Ministry of Health. (2022). *Malawi Cholera Situation Update.* Lilongwe. Retrieved from https://m.facebook.com>malawimoh

MINNESOTA. (n.d.). *Nitrate in Drinking Water*. Retrieved from Department of Health: https://www.health.state.mn.us>water

Mishra, M., & Sinha, A. (2018, March 22). *World Water Day 2020:Importance of Water & How to Save Water*. Retrieved from Doconline: https://www.doconline.com>blog

Mohammed, M., Badau, M. H., Igwegbe, A. O., & Maina, F. J. (2020, April). Assessing Physcochemical and Microbialogical Quality of Sachet Water Sold in Kumbotso LGA, Kano State, Nigeria. *Agricultural Research & Technology Open Access Journal, 24*(1). doi:10.19080/ARTOAJ2020.24.556256

New York State Department of Health. (2017). *Coliform Bacteria in Drinking Water Supplies*. Retrieved from Department of Health: https://www.health.ny.gov

Ngumbira, K. S. (2020). *An Analysis of the Physico-Chemical and Microbial Quality of Sachet Water in Lilongwe, Malawi:Implication on Public Health and WASH policies.* Masters Dissertation , PAN-AFRICAN UNIVERSITY, Institute For Water and Energy Sciences, Lilongwe. Retrieved November 8, 2021

Regan , M. (2022, April). *Indicators: Conductivity*. Retrieved from United States Environment Protection Agency: https//www.epa.gov>indicators

Rickwood, C., & Carr, G. M. (2007). *Global Drinking Water Quality Index Development and Sensitivity Analysis Report.* GEMS.

Rodriguez, L. (2019). *Factors Driving the Water & Sanitation Crisis in Africa*. Retrieved from Global Citizen: http://www.globalcitizen.org>water

Sheshe, M. U., & Magashi, A. m. (2014, August). Assessment of Physicochemical Quality of Sachet Water Produced in Selected Local Government Areas of Kano Metropolis, Kano State - Nigeria. *Bayero Journal of Pure and Applied Sciences, 7*(2), 31-35. doi:10.4314/bajopas.v7i2.7

UNICEF. (2022). *Water, Sanitation & Hygiene*. Retrieved from UNICEF: http://www.unicef.org/malawi/water-sanitaion-and-hygiene

US EPA. (2021, September). *Drinking Water*. Retrieved from Report on Environment: https://www.epa.gov>drinkingwater

USAID. (2021, December). *Water, Sanitation and Hygiene*. Retrieved from US Agency: https://www.usaid.gov>wash

USAID. (2022, August). *Water, Sanitation and Hygiene.* Retrieved from USAID: https://www.usaid.gov>wash

USEPA. (1992). *United States Environmental Protection Agency (USEPA).* Retrieved from secondary drinking water regulation: Guidance for Nuisance Chemicals: http://www.epa.gov/safewater/consumer/2ndstandard.html

Walensky, R. P. (2022, January 10). *Free Chlorine Testing| The Safe Water System*. Retrieved from CDC: https://www.cdc.gov>global>chlorine

Water Science School . (2018, June). *Turbidity and Water*. Retrieved from USGS: https://www.usgs.gov>science >turbidity

Water Science School. (2018, August). *Alakalinity and Water*. Retrieved from Water Science School: https://www.usgs.gov.science>alkalinity

Water Science School. (2018, June 5). *Biological Oxygen Demand and Water*. Retrieved from USGS: http://www.usgs.gov/special

Water Science School. (2019, October 22). *pH and Water*. Retrieved from USGS: https://www.usgs.gov>water-science-school>science

Western Australia Department of Health . (2016, June 24). *Salt In Drinking Water*. Retrieved from https://ww2.health.wa.gov.au

WHO. (2011). *Guiidilines For Drinking Water.* Gutenberg: Malta.

WHO. (2019, June). *Drinking-Water*. Retrieved from World Health Organization.: https://www.who.int/news-room/fact

World Health Organization. (2019, June 19). *Drinking Water*. Retrieved December 7, 2021, from WHO: https://www.who.int

World Vision. (2021, April). *Global Water Crisis: Facts, FAQs, and How to Help*. Retrieved November 28, 2021, from World Vision: http://www.worldvision.org/clean-water

Yassin, M. M. (2006, December). Assessment of Microbiabiological Water Quality and its Relation to Human Health in Gaza Governarate, Gaza Strip. *Public Health*. doi:10.1016/j.puhe.2006.07.026

YSI. (2022). *Water Quality Parameters*. Retrieved from Water Quality Parameters and Measurement Methods: https://www.ysi.com>parameters