BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF NATURAL RESOURCES

ASSESSING PHYSICO-CHEMICAL AND MICROBIOLOGICAL GROUNDWATER QUALITY OF KITSIYATOTA CATCHMENT AREA IN BINDURA, ZIMBABWE

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The undersigned certify that they have read and recommended to the Department of Natural Resource Management for acceptance, this research project entitled

Assessment of physio-chemical and Microbiology groundwater quality within Kitsiyatota catchment area.

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DEDICATION

This work is a testament to the unwavering support and guidance of my family - my parents who made my education possible, my brothers who motivated me, and my sister who stood by me throughout. Their contributions have made this achievement possible.

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ABSTRACT

This study was undertaken to assess the physico-chemical and microbiological ground water quality within Kitsiyatota catchment area in Bindura, by comparing the water parameters with the WHO guideline standards. The study period was from February 2024 to April 2024.Data were collected using a strategic sampling location and the water samples were collected from five sampling points including tap-water, boreholes, and wells in different locations . A total of 5 sampling points were collected and each point replicated three times after every 10 minutes to obtain accurate data and each sampling site was analyzed for 11 parameters. Test kits were calibrated using WHO guidelines and the water collection and water testing was done according to the recommended procedures. The data were entered and analyzed using the Statistical Packages for Social Science (SPSS) version 20 of 2011.T-test was used for statistical differences within the tested parameters of the sampling points. The results of physicochemical and microbiological analyses were compared with the WHO standards for drinking water and the P-value <0.05 was considered to show the significant differences of the mean. The coefficient of variation (% CV) was used for the determination of the significances of difference within the water samples at 95% confidence interval. The general findings clearly shows that the physicochemical and microbiological properties of the water analyzed from the Kitsiyatota catchment area in Bindura, exceed the recommended standards for drinking water quality. The study further recommends the drilling of recommended depths of boreholes so that the water cannot be easily contaminated within the Kitsiyatota catchment area. The researcher suggests using chlorine and ultraviolet light treatment to remove or reduce the concentration of E. coli in the water and the use of water softeners, such as tetra-sodium diphosphate and calcium hydroxide.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA……………………………………….Analysis of Variance

BUSE………………………………………….Bindura University of Science Education

CBD……………………………………….....Central Business District

DPD……………………………………….....Diethyl-phenylene diamaine

DWQ…………………………………………Drinking Water Quality Guidelines

EC…………………………………………....Electrical Conductivity

EMA………………………………………...Environmental Management Agency

EPA……………………………………………Environmental Protection Agency

Goz……………………………………………Government of Zimbabwe

RADWQ……………………………………Rapid Assessment of Drinking Water Quality

JMP……………………………………………Joint Monitoring Program

IBI…………………………………………....Index of Biological Integrity

NTU…………………………………………...Nephelometric Turbidity Units

SES…………………………………………….Sanitary Epidemiological Services

SPSS…………………………………………...Statistical Packages for Social Sciences

TDS……………………………………………Total Dissolved Solids

UN………………………………………………United Nation

UNICEF…………………………………….....United Nations Children's Fund

UWSSR……………………………………….Urgent Water Supply and Rehabilitation Project

WHO…………………………………………...World Health Organization

WSR…………………………………………….Water Safety P

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Ground water quality is the primary driver that enables the proper stewardship and deployment of water resources in a way that is sustainable over the long-term. Maintaining high ground water quality is essential for supporting human health, the environment, and economic development in a sustainable fashion globally (Roy, 2018). In the past, the assessment of ground water quality has been a critical aspect for observation, collecting and analyzing of the environmental aspect (Polevoi *et al*., 2019). Physicochemical and microbiological parameters are essential users that determines which water can be used for drinking, irrigation and industrial purposes (WHO, 2011). The assessment of groundwater parameters involves the observation of different impacts affecting the quality of water (Obilonu *et al.*, 2013). Unfortunately, physico-chemical and microbiological ground water quality assessment usually gives a well detailed information and is considered as controlling instruments in all living things (Kazi *et al.*, 2009).The assessment of physicochemical and microbiological parameters focus on the quality and safety of substances used in water treatment (Lohit, 2019). The analyzing of ground water parameters helps in making decisions and identifying bacteria present in water leaving a room for control measures (AI-Khatib *et al*., 2023).

Water is a very important aspect for all living organisms as it provides an essential benefits to plants, organisms, and animals (Mwanza *et al*., 2022). The health and economic status of the people in most African countries is at risk due to the contamination of water bodies, for instant in Ghana and Zimbabwe (Bruce and Limin, 2021). Studies has it that some of the communities prohibits the use of water from the water points due to poor water quality in many rural districts in Zimbabwe (Offat and Kamuzungu, 2009).Ground water quality analyses have been conducted by so many groups across the country and microbiological parameters such as E.coli and fecal coliform contamination are the major coliform usually noticed in water (Satihals *et al.*, 2014).

The assessment of ground water quality includes the water parameters which provide detailed information about its quality (AI-Khatib *et al*., 2023). These parameters include physical properties such as pH, conductivity, and turbidity, as well as chemical properties like dissolved oxygen, hydrogen carbonates, chlorides, sulphate and nitrates (Lohit, 2019). Monitoring these parameters provides us with a meaningful information on the health and contamination levels of water sources (Polevoi *et al*., 2019). Furthermore, microbiological parameters such as total coliforms, fecal coliforms, and E. coli are analyzed to determine the presence of harmful bacteria contamination in the water (Gerritsen *et al.*, 2017). This information on water quality is used in the formulation of management practices that improves the water quality (Satihals *et al.*, 2014).

In the previous studies of ground water quality assessment in Mashonaland Province of Zimbabwe, shows the evidence that a number of boreholes have been prohibited for domestic purposes after the results outcomes which shows that the water was contaminated (Hoko, 2005). Therefore, water quality monitoring according to the WHO standards for adequate results is well recommended (Hoko, 2008; WHO, 2011). Water sources recommends forecasting in the planning of ground water quality assessment, and a model known as the ANN model has been used in forecasting the levels of water quality mostly in advance (Gupta *et al.*,2019).Therefore, the study seek to assess the physicochemical and microbiological groundwater quality within the Kitsiyatota catchment area.

1.2 PROBLEM STATEMENT

The people living in Kitsiyatota catchment area are sitting at a time bomb due to water quality issues. The improper handling and disposal of waste from human activities and livestock, as well as informal mining operations and overexploitation of natural resources, might be the cause of groundwater quality problems. As a result, the local population has experienced an increase in waterborne illnesses such as cholera, diarrhea, typhoid, and other diseases caused by pathogens. Therefore the study seeks to justify the groundwater quality issues with the catchment area of Kitsiyatota.

1.3 JUSTIFICATION

The research aimed to generate more comprehensive physico-chemical and microbiological data that can be readily utilized to analyze and manage the water supply. This information will help identify and predict future water quality problems. The findings are also intended to inform guidelines aligned with WHO standards for protecting boreholes and wells within the Kitsiyatota catchment area. A key objective of the study is to assess the extent of bacterial contamination in the groundwater sources. The results can then be used to develop guidelines and measures for purifying water before it is used for various purposes. The study hopes to promote extension services and improved sanitation practices within the target community, based on the research outcomes.

1.4 AIM

The study aimed to assess physico-chemical and microbiological groundwater quality parameters with WHO standards during the month of February to April 2024 within the Kitsiyatota catchment area.

1.5 OBJECTIVES

1.5.1 To assess the selected physico-chemical and microbiological ground water quality parameters

1.5.2 To compare whether the ground water quality parameters vary across different selected sites

1.6 HYPOTHESES

1.6.1 There is no significant difference in the concentration of selected physico-chemical and microbiological ground water parameters.

1.6.2 There is no significant difference in means that vary across different selected sites of groundwater sources.

CHAPTER TWO: LITERATURE REVIEW

2.1 WATER QUALITY STANDARDS

The guidelines that controls and manages the physicochemical and microbiological parameters are known as water quality standards (Dhopte, 2021). World Health Organization (WHO) water quality standards monitors the water quality for drinking purposes within the sets of guidelines (WHO, 2020). These guidelines for World Health Organization (WHO) state that microbiological contamination of drinking water is a serious threat to human health (WHO, 2020) Water quality standards involve monitoring and evaluation of the assessment of water quality that meets the guidelines (Patil *et al.*, 2015). The available water for different purposes must be included in analyzing water quality standards and the WHO Drinking Water Quality Guidelines (DWQG) are considered as a useful tool in the making of national drinking water quality standards in so many countries(Goodman, 2012).

Ground water quality standards shows the level of bacteria that can pose a problem to human life and the users (Satihals *et al.*, 2014). The water quality standards serve to provide information about the substances present in drinking water and help minimize the concentrations of these substances (WHO, 2020). There are various levels of water quality standards such as safety of drinking water and water quality for industrial uses. (Anesthesia *et al.*, 2010). The regulatory standards such as mandatory monitoring were recommended to confirm if the water quality meets the required standards and if the water does not meet the standard as required, accurate measures are implemented so that the guidelines can be accomplished (Goodman, 2012). The establishment of water standards require a proper regular check-up to see if these standards are properly enforced for adequate monitoring (Dhopte, 2021).

TABLE 2.1: WHO GUIDELINE STANDARDS (WHO, 2011)

Parameter	Guidelines
pH	9.2
Conductivity	400
TDS	100
Hardness	1500
Alkalinity	500
Hydrogen Carbonates	0.1
Sulphate	500
Chlorides	250
T. coli	0
E.coli	0
Total Veacal Count	100

2.2 EFFECTS OF DRINKING WATER QUALITY

Bahir Dar City, northwest Ethiopia was involved in a study of assessing the drinking water quality (DWQ) where waterborne diseases have been a pandemic (Sitotaw *et al.*, 2023). A study was carried out from January to mid June 2022 to evaluate the level of coliform bacteria and physicochemical parameters from the selected sites which includes the urban, peri-urban and rural location of Bahir Dar City (Sitotaw *et al.*, 2023). A total of 180 drinking water samples were collected and analyzed as part of the study. The water quality test outcomes were evaluated using the standards set by the World Health Organization (WHO) (WHO, 2020). According to the findings of the study, it was noticed that only 16.7 and 73.88% of the samples met the (WHO) guidelines standards for total coliform and fecal coliform. However, 95.4 and 43% of the bacteria were not according to the required standards. Educational activities was supposed to be in place as a way to manage drinking water handling capacity and treatment to reduce the water quality effect (WHO, 2022).

2.2.1 EFFECTS OF WATER QUALITY FOR RESIDENCE HEALTH

Nagia Chadi village in India was involved in a case study on the effects of water quality of groundwater on residence health from April 14 to 18, 2022. The water was collected in a 1L water bottle from the two selected water sampling points and then send for analysis in the laboratories. The water parameters of this study were compared with the required guidelines of the Indian Standards (IS) 10500:2012.The results shows that the water from the handpumb exceeded the required standards, therefore regarded as unsafe for use (Kanyagui *et al.*, 2024). On the residence health issues within the village, a number of water-borne disease which have pose a problem includes diarrhea, skin problems and yellowing teeth. According to the results of the study, the high iron content in the water was causing the health issues among the people within the village of Nagia Chadi (Kanyagui *et al.*, 2024).

2.3 RAPID ASSESSMENT OF WATER QUALITY

Rapid Assessment of Drinking Water Quality (RADWQ) is a process which takes time for planning and it includes fieldwork and data analysis. Six countries were involved in a pilot project on the rapid assessment of water quality from the 2004 to 2005 (WHO/UNICEF, 2011).The best method which was used in Tajikistan during the assessing of water quality is known as the rapid, low-cost field based approach (Aliev *et al.*, 2010). The Rapid Assessment of Drinking Water Quality in Tajikistan was formed by the Sanitary Epidemiological Services (SES) (WHO/UNICEF 2010).Water samples from 160 households were taken for analyses and the parameters used for the assessment include pH, thermo-tolerant, coliform levels, conductivity, and turbidity levels of arsenic, fluoride, nitrate, and iron and the sanitary inspections was carried out by the field team (WHO, 2011). This study indicates contamination risks in drinking water and the results were not in the range with the WHO guidelines standards so rapid assessment of water quality was necessary for the study (Aliev *et al.*, 2010).

2.4 WATER QUALITY AND SANITATION PROJECTS

The World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) played a significant role in the Joint Monitoring Program (JMP) at the end of the International Drinking Water Supply and Proper Sanitation activities (WHO/UNICEF, 2010).In the year 2015, the N'gar vision was adopted by the AfricaSan conference. The goal of this initiative was to achieve water and sanitation-related targets and objectives in various African countries (WHO, 2020). Meeting the SDG targets for water management and sanitation improvements was in the hands of the N'gar declaration. Zimbabwe was recorded among the top countries in managing water supply and sanitation services in the late 1990s (ZINWA, 2012). Factors such as limited resources in Zimbabwe from the year 2008 contributed to the country's resources decline which resulted in the outbreak of the cholera which leads to the death of many people(WHO, 2020). The (Zim-Fund) Zimbabwe Multi-Donor Trust Fund was formed in 2010 and managed by the African Development Bank (AFDB).The agreement was on water supply and sanitation infrastructural development for the benefit of water quality and the restoration of water sources areas leading to problems of water diseases (WHO, 2020). To complement the Zim-Fund, the Urgent Water Supply and Sanitation Rehabilitation (UWSSR) project was formed. The goal of this project was to enhance water management and sanitation services in several Zimbabwean municipalities, including Chegutu, Chitungwiza, Masvingo, and Mutare. This initiative helped to reduce water pollution activities in these areas (ZINWA, 2012).

2.5 WATER QUALITY MANAGEMENT POLICIES AND INSTITUTIONS

The management of water resources in Zimbabwe is governed by the Water Act, which aligns closely with various other related Acts and policies (Makoni and Smits, 2007).The monitoring of water quality assessment is performed at a national level with regulations that are the responsibility for water management (GoZ, 2002). These frameworks include the Water Act (Chapter 20:24) of 1998, the Environmental Management Act (Chapter 20:27, 2002) and the Statutory instruments (Gandidzanwa and Mawonde, 2024). The environmental management regulation was published in 2007 with the legislation of the Environmental Management Act (SI 6, 2007).Therefore, water quality management in Zimbabwe requires the regulations and institutions to set the basic framework (Jaspers, 2001).

2.6 ASSESSING GROUNDWATER QUALITY

A study of assessing ground water quality was done in Sargodha city, Pakistan. The study was carried out between June and July 2013 and twelve water samples were collected haphazardly from different places (Riaz *et al.,* 2016).1L of polyethylene bottles were used from water collection and the bottles were washed with distilled water to remove impurities

(Patil *et al*, 2015). In the process of collecting the water, it was recommended to first pump the water for about 5 minutes before collection to obtain good results (Riaz *et al.*, 2016). The water analysis was done with the Hi-Tech instrumental Lab at the Sargodha University. The parameters that were used for assessing groundwater quality includes pH ,conductivity, TDS , calcium, chloride, potassium, sodium ,copper, sulphate, iron, magnesium and nitrates. The results of the analysis showed that the groundwater was highly concentrated with elevated levels of these various water quality parameters. However, the study found that the pH and calcium values were within the permissible limits set by the World Health Organization (WHO) guidelines for drinking water standards. (WHO, 2020). Therefore, the groundwater of the area studied was not recommended for drinking water activities (Riaz *et al*., 2016).

2.7 MICROBIOLOGICAL ASSESSMENT OF WATER QUALITY

The rural communities in Ethiopia faced a major issue of fecal contamination in their water sources, which prompted a case study aimed at assessing the microbiological safety of the water resources (Edessa *et al.,* 2017). The water samples were collected following the guidelines set by the World Health Organization (WHO, 2020), and the most probable number method was used to evaluate the levels of total coliforms and fecal coliforms present. The study findings revealed that the water samples contained significantly higher levels of total coliforms and fecal coliforms compared to the drinking water standards (Edessa *et al*., 2017). In fact, the bacteriological parameters were found to exceed the WHO guidelines, which do not allow any detection of fecal coliforms or E.coli (Satihals *et al*., 2014) .The study found out that about 92.6% of the well water was observed with fecal coliforms with 54.1% of the surface water being contaminated with E.coli. The management of water and proper sanitation was recommended through proper waste disposal and health educational activities within the rural community in Ethiopia (Edessa *et al*., 2017).

2.8 BIOLOGICAL MONITORING IN WATER QUALITY

2.8.1 THE NERVOUS APPROACH

A theoretical framework for the modelling norovirus in surface water for Quantitative Microbial Risk Assessment (QMRA) that has fecal contamination was done in Glomma River, Norway in 2016. The purpose of the project was to monitor fecal indicator organisms which includes E.coli for the protection of public health on drinking water (Petterson *et al*., 2016). The Risk Based Approach was the best method to be used in the project as it provides the correct information of fecal contamination (Mclarnan and Mclarnan, 2019) .The main goal of the case study was to build a model for estimating norovirus contamination in water resources and was observed that the contamination of sewage materials into the river has contributed to fecal contamination (Petterson *et al*., 2016). The results of the study shows that the area with low population contributes less to the contamination as compared to areas with high population. Also the seasonal patterns also contributed in the sense that, the fecal contamination is high during winter but fall during summer time. The norovirus was best in the sense that it would help in assisting the best time to collect the samples and it foresee water bacteria contaminations in the absence of the pathogen data (Petterson *et al*.,2016).

CHAPTER 3: MATERIALS AND METHODS

3.1 DESCRIPTION OF THE STUDY AREA

The study was conducted in the Bindura catchment area of Kitsiyatota, located approximately 88 km northeast of Harare in the Mazowe Valley (Figure 3.1). Bindura is situated between latitudes 16°45' and 17°35' and longitudes 31°25' and 31°45', at an elevation of 1,100m above sea level. The catchment area covers around 1,000 square kilometers and features a diverse range of land cover types. The climate in the region is subtropical, characterized by hot summers and mild winters, with an average annual rainfall of nearly 800 millimeters. The soils in the study area are fertile, consisting of dark clay and loam. The catchment is also rich in mineral deposits, particularly gold, which has been extracted from the region for many years.

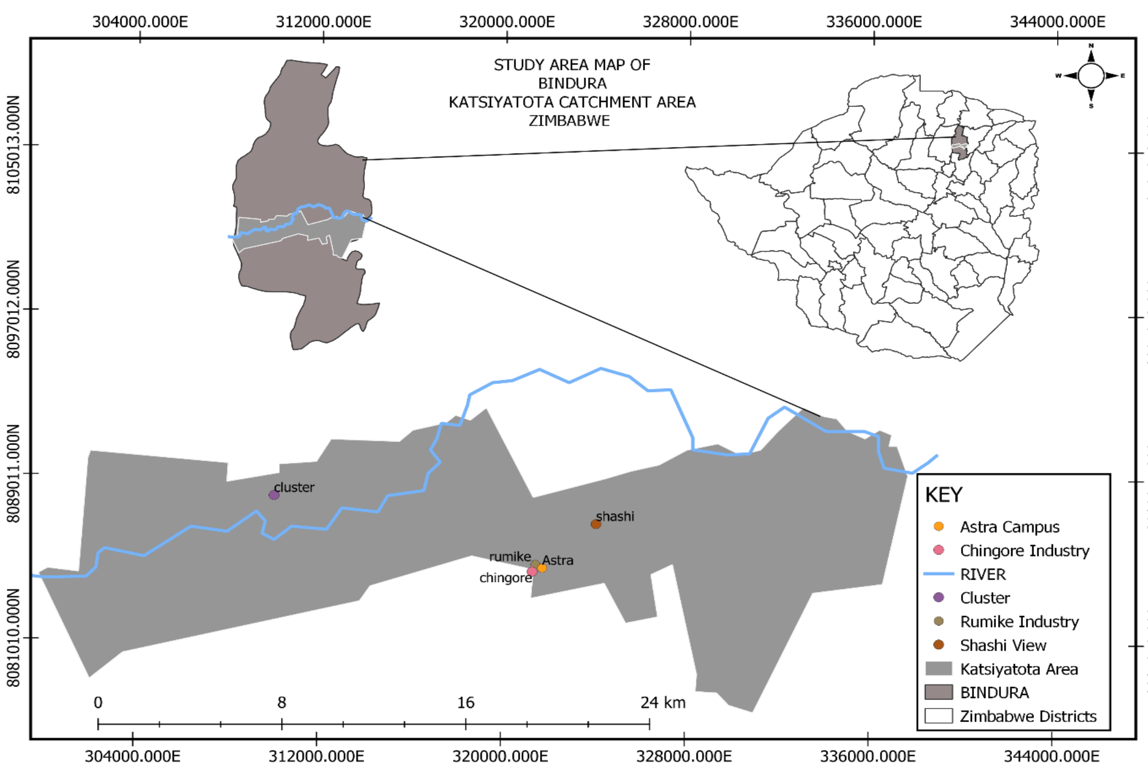

Figure 3.1: Map of Bindura showing the Kitsiyatota catchment area.

3.2 RESEARCH DESIGN

Prior to the main study, a pre-survey was conducted in order to gain a better understanding and overview of the study area, including the five sampling points. The purpose of this pre-survey was to assist with a visual analysis of the site area. This allowed the researcher to identify and select the appropriate groundwater sources within the Kitsiyatota catchment from which to collect water samples.

3.3 SAMPLE COLLECTION

Water from the five randomly selected sites were collected in the month of February 2024. Clean polyethylene bottles of 500ml were used to collect water samples from the boreholes and wells and tap water in replicates (Patil et al., 2015). According to the WHO guidelines, containers were first washed with tap water and chromic acid solution for about 10 minutes to remove impurities (WHO, 2011). The container were rinsed with deionized distilled water in the chemistry lab and then taken for sample collection and the water samples were replicated from each borehole and well (United States Environmental Protection Agency, 2016). Thereafter, the water samples were collected for laboratory analysis and then transported in ice cold room at about 4 C at Bindura University lab (Myers, 2002).

3.4 MATERIAL AND ANALYTICAL CHEMISTRY

Table 3.1: Water quality test methods and test units (Patil et al., 2015)

Sampling Parameter	Analytical method	Unit	Number of samples
Ph	pH-Ion meter	1 – 14	5
Turbidity	2100P Turbid meter	NTU	5
Conductivity	EC and TDS and Temperature meter	µS/cm	5
Chlorine	Diethyl-p-phenylenediamine	Milligrams per liter	5
TDS	TDS meter	Mg/L-Milligrams per liter	5
Total Hardness	Handicap reagent on a photometer	Mg/L	5
Hydrogen carbonates	pH meter	HCO^{-}_{3}	5
Sulphate	Bench top photometers	Mg/L-milligrams per liter	5

3.5 PHYSICO-CHEMICAL ANALYSIS

The water samples collected were analyzed for physico-chemical parameters such as pH, conductivity, total dissolved solid, total hardness, alkalinity, hydrogen carbonates, sulphate and chlorides in replicates (Satihals *et al.,* 2014).This was done according to the procedures given by the WHO guideline standards and the results from these water samples were presented as means (WH0, 2011).

3.5.1 TESTING FOR PH

Material – 10ml vial containing 2 pH test strips, 5ml vial containing Ph7 Buffer, pH scale card and 10ml disposable beakers.

3.5.2 TURBIDITY

Materials – 2100p Turbid meter, 10ml disposal beakers, electric source (battery).

3.5.3 CONDUCTIVITY

Materials – conductivity sensor, 100ml of drinking water, test tube, recording instruments, source of electrical energy.

3.5.4 TESTING FOR CHLORINE

Materials – 10ml water containing standard chlorine, (DPD) Diethyl-phenylene-diamine tablets, DPD 1 tablet and DPD 3 tablets.

3.6 MICROBIOLOGICAL ANALYSIS

For the microbiological testing, water samples were collected in 500 mL sterile containers. Multiple replicates of the water samples were taken to ensure reliable and representative data. The MacConkey broth media and Eosin Methylene Blue (EMB) Agar were used to analyze E.coli content in the water samples. The testing procedure involved using 0.1 mL aliquots of the water samples and spreading them on EMB agar plates using the spread plate technique. This spread plate method allowed for the even distribution of the water sample across the agar surface, enabling the growth and enumeration of the E. coli colonies on the selective EMB media. The use of both the confirmatory MacConkey broth and the selective EMB agar provided a robust approach to detect and quantify the E. coli bacteria present in the collected water samples (Satihals *et al*, 2014). The MacConkey broth agar was used to detect total coliform count and a mathematical tool known as the Most Probable Number – multiple tube technique was used to determine total fecal coliforms (Ashfaq and Ahmad, 2014). All these plates were incubated at 37 C for 24 - 48 hours and each plate was given a positive or negative score and the biochemical reaction and the gram staining confirmed the presumptive colonies (Lake *et al.*, 2014).

3.7 METHODS OF DATA ANALYSIS

The data were entered and analyzed using the Statistical Package for Social Science (SPSS) software, version 20.0 of 2011. T- Test method was used to test statistical differences in the water quality parameters measured across the five selected sampling as shown in appendix 1 and 2. The use of the T-Test allowed the researcher to rigorously analyze and compare the water parameter data collected from the different sampling points, providing insights into how the water quality may have differed between locations (Al-Khatib *et al*, 2023).The purpose of using this statistical software was to determine the mean values across the selected sampling sites, shown in appendix 1 and 2 (Patil *et al*., 2015). The results of physicochemical and microbiological water parameters were analyzed using the WHO guidelines principles (WHO, 2017). The researcher employed the coefficient of variation (% CV) to evaluate the statistical significance of any differences observed in the water quality parameters across the sampled locations.(Satihals *et al.*, 2014).

CHAPTER 4: RESULTS

4.1 PHYSICO-CHEMICAL ANALYSIS OF WATER QUALITY

4.1.1 PHYSICAL ANALYSIS

4.1.2 TOTAL HARDNESS

The total mean of total hardness that comes from all the five sites was 58.4mg (Figure 4.1).There was a significant difference that varies across selected sites (P=0.00) The water in different five sites were within the WHO standards guidelines (WHO≤500).

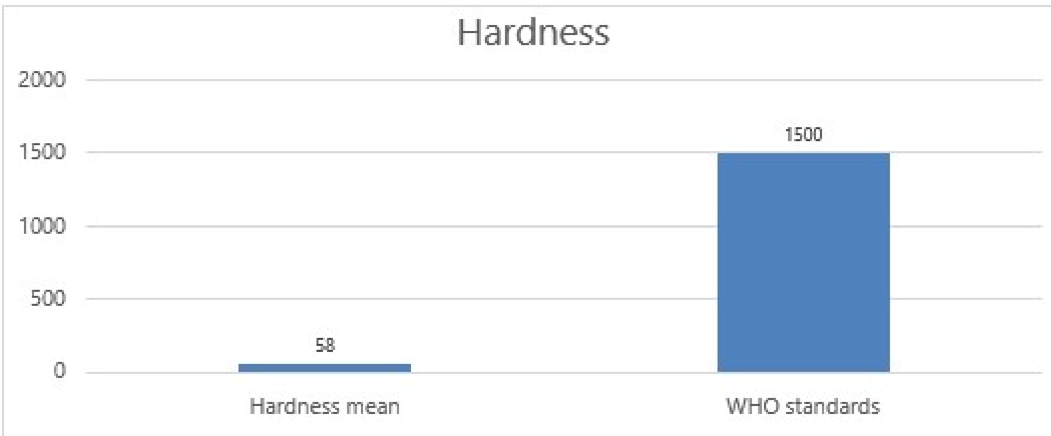

Figure 4.1: Total Hardness of well, boreholes and trap water.

4.1.3 CONDUCTIVITY

There was no significant difference across selected sites (P=0.81) and the total mean of conductivity recorded for all the five sites was 374.18µS/cm which is within the guideline standards (WHO≤400) (Figure 4.2).

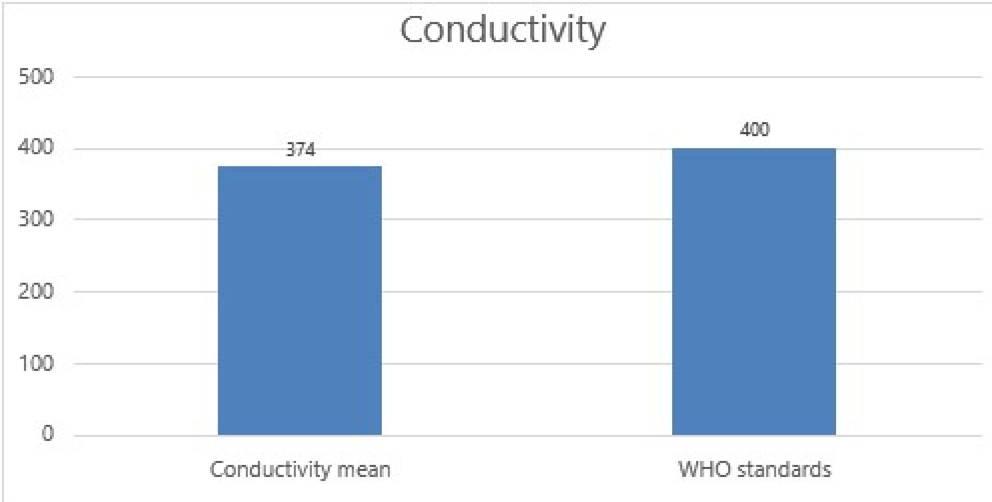

Figure 4.2: Conductivity of well, boreholes and tap water.

4.1.4 TDS

The significant difference in the mean of Total Dissolved Solids of the five selected sites were noticed (P=0.00). The total average mean of all the five sites was 271.67mg/L (Figure 4.3). The TDS mean values were above the range recommended by (WHO≤100).

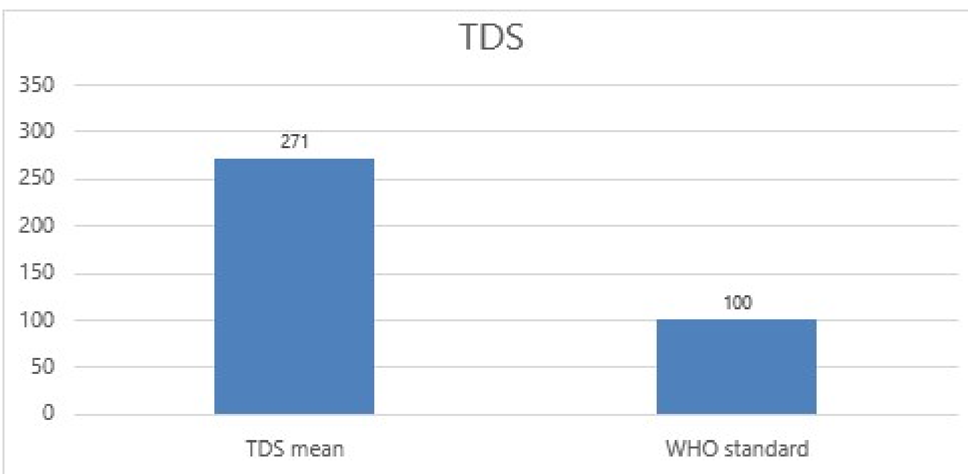

Figure 4.3: TDS of well, boreholes and tap water.

4.2 PHYSICOCHEMICAL ANALYSES

4.2.1 CHEMICAL ANALYSIS OF WATER QUALITY

4.2.2 PH

The measured pH values vary from the five sites in Kitsiyatota catchment area. The total average mean of all the five sites was 7.0 with a significant difference that varies across groundwater sites (P=0.00) (Figure 4.4). All the values within the selected sites were within the range recommended by (WHO≤9.2).

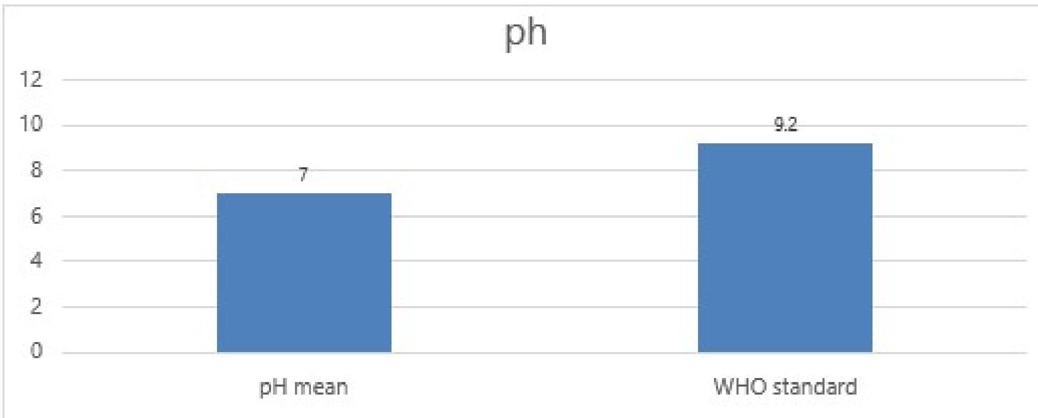

Figure 4.4: pH of well, boreholes and tap water.

4.2.3 HYDROGEN CARBONATES

Hydrogen carbonates was observed in all the five selected sites tested. The total mean of hydrogen carbonates in all 5 sites was 0.79 HCO^{-}_{3} (Figure 4.5).There was a significant difference that vary across selected sites (P=0.00).The carbonates results exceeded the required recommendation of (WHO≤0.1).

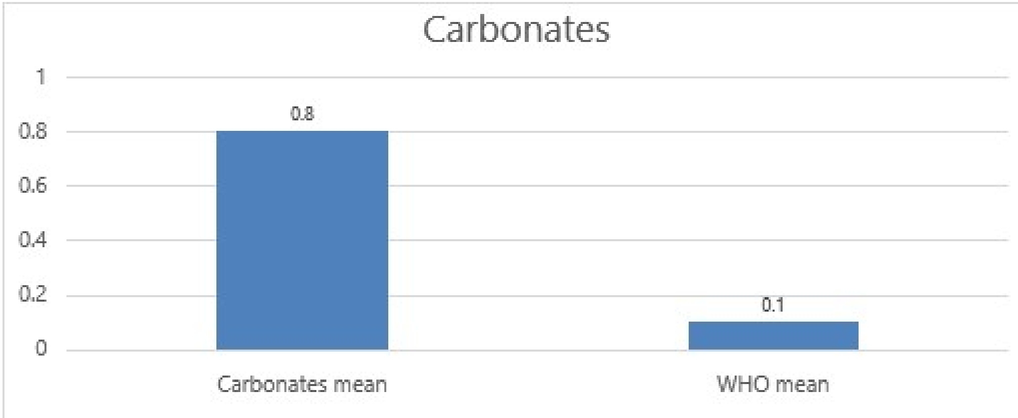

Figure 4.5: Carbonates of well, boreholes and tap water.

4.2.4 ALKALINITY

Total Alkalinity were observed in all the five selected sites within the Kitsiyatota catchment area. The total average mean of all the five sites was 1373 and a significant difference across sites (P=0.00).These results shows that the values of total alkalinity of the selected sites exceeded the required standards of (WHO≤500) (Figure 4.6).

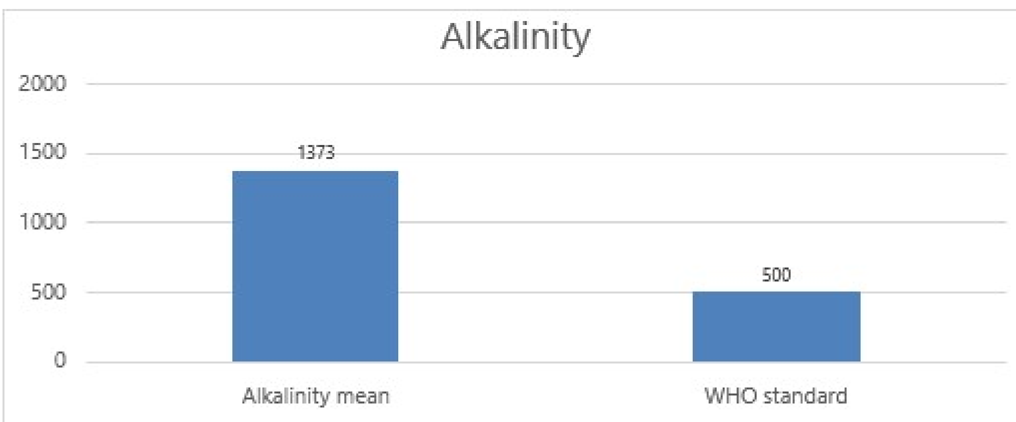

Figure 4.6: Alkalinity of well, boreholes and tap water.

4.2.5 SULPHATE

The water tested from the different sites during the study shows the presence of sulphate. The total average mean of the five tested sites was 150.60mg/L (Figure 4.7). There was a significant difference that varies across sites (P=0.00) and the evident that all the five sites tested for sulphate concentration fell in the range recommended by WH0 (≤500) for drinking water.

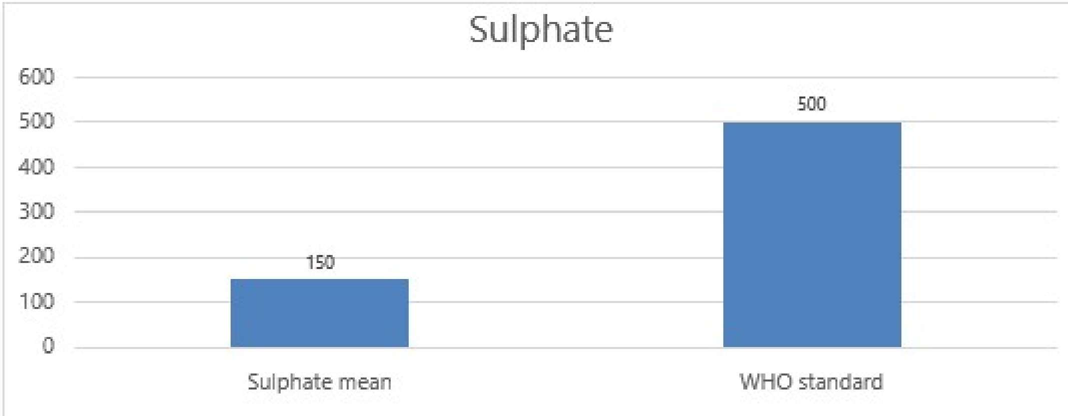

Figure 4.7: Sulphate in well, boreholes and tap water.

4.2.6 CHLORIDES

Chlorides were also noticed in the five sites tested within the Kitsiyatota catchment area. The total mean value of all the five selected sites was 15.84mg/L and there was a significant difference across selected sites (P=0.00). The values of chloride concentration were in the range of the recommended guideline standards of WHO (≤ 250) (Figure 4.8).

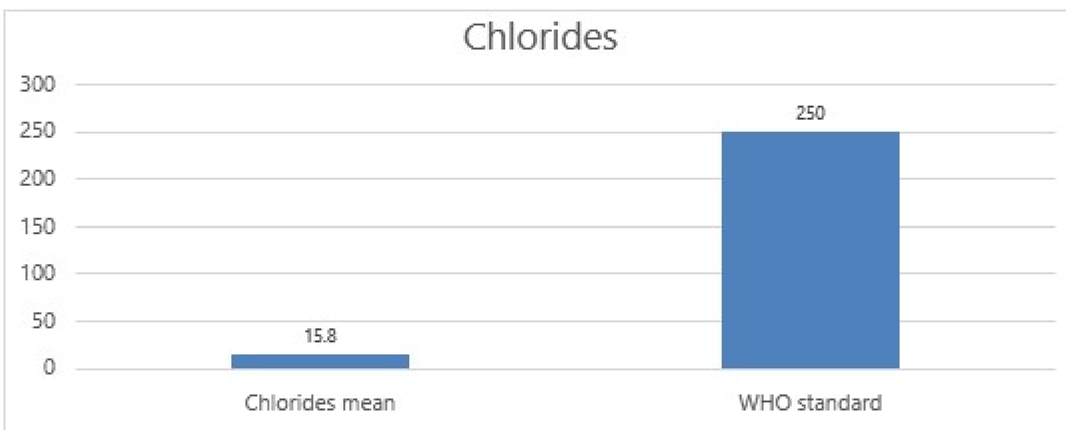

Figure 4.8: Chlorides in well, boreholes and tap water.

4.3 MICROBIOLOGICAL ANALYSES OF WATER QUALITY

4.3.1 MICROBIAL ANALYSES

4.3.2 ESCHERICHIA COLI

The water from the selected five sites revealed both the present and absent of E.coli. The total average mean of all the five selected sites was 0.89cfu/ml and there was a significant difference vary across sites (P=0.02). The mean value across sites exceeded the limit value expected from the WHO guideline standards (Figure 4.9).

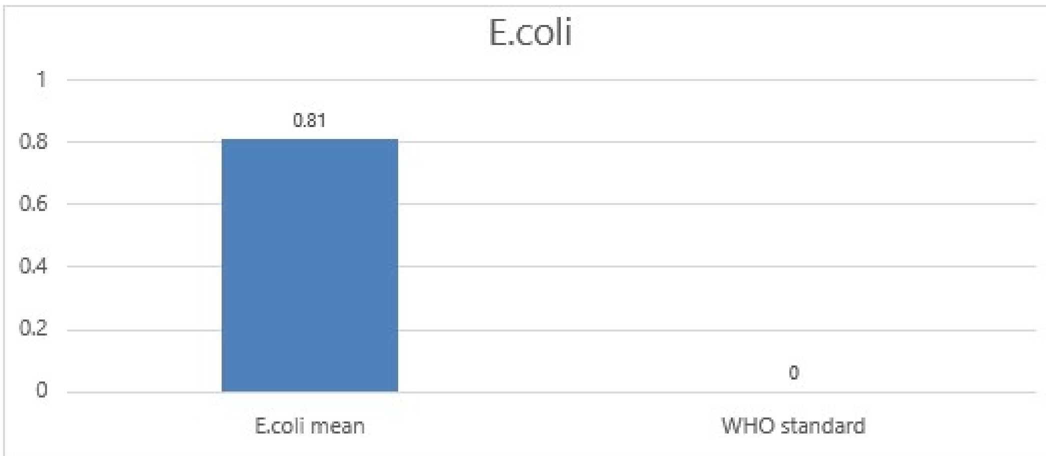

Figure 4.9: E.coli in well, boreholes and tap water.

4.3.2 TOTAL FECAL COLIFORM

Water points obtained from the Kitsiyatota catchment area contains fecal coliform. The total average mean of all the five sites was 1.There was a significant difference between values of the selected sites (P=0.00). The mean of the five sites exceeded the expected range of WHO guideline standards (≤ 0) (Figure 4.10).

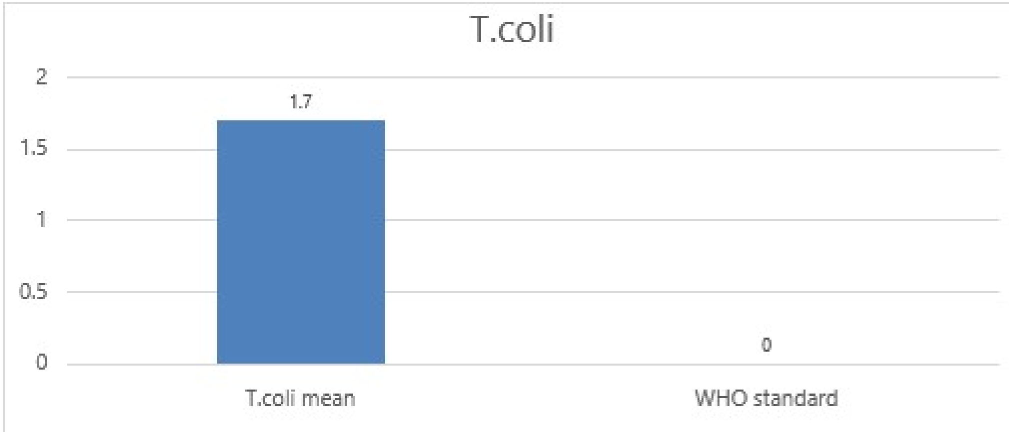

Figure 4.10: T.coli in well, boreholes and tap water.

4.3.3 TOTAL VIABLE COUNTS (TVC)

The total average mean of the total viable counts was 45.40/ml and there was a significant difference in measured values across site (P=0.00). The values from the five sites in Kistiyatota were within the range recommended by (WHO ≤ 100) (Figure 4.11).

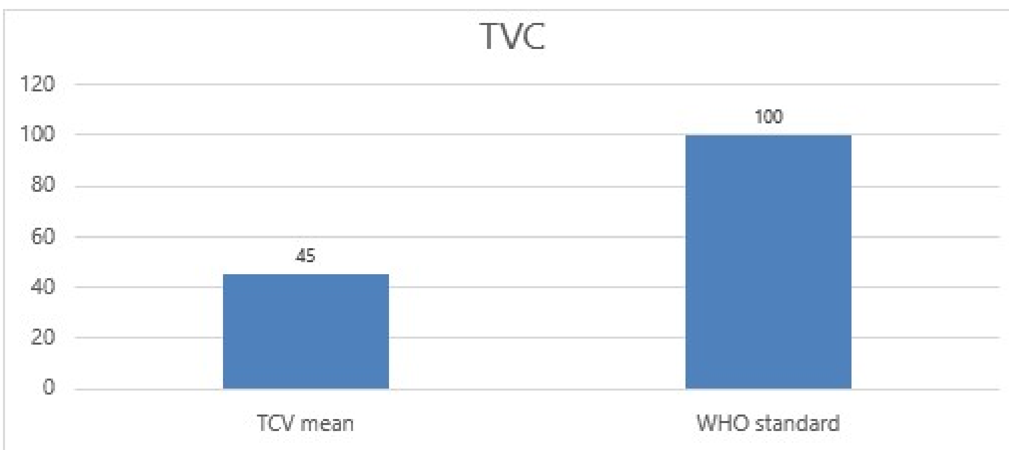

Figure 4.11: TVC in well, boreholes and tap water.

CHAPTER FIVE: DISCUSSION

5.1 PHYSICO-CHEMICAL WATER QUALITY IN KITSIYATOTA CATCHMENT AREA

5.1.1 TOTAL HARDNESS

The total hardness in groundwater quality is caused by the presence of dissolved calcium and magnesium in water. A similar study shows that the water samples tested for total hardness were within the recommended line of 300 -600 mg/l for drinking water and the fact that hardness is not harmful to health but can contribute in heart problems (Ashfaq and Ahmad, 2014).

5.1.2 ELECTRICAL CONDUCTIVITY

Literature tell us that ions with negative charges and positive charge such as calcium and sulfate affects the conductivity in water and also temperature in the sense that, the warmer the water the higher the conductivity. Another similar study shows that the electrical conductivity was above the recommended standards (Riaz *et al.,* 2016).

5.1.3 TOTAL DISSOLVED SOLIDS

The total dissolved solids in groundwater quality is due to nature cause and human activities within Kitsiyatota catchment area. The observations from a similar study shows that the large amounts of TDS in drinking water makes it unsuitable for use because it reduces the amount of dissolved oxygen in water(Mohammad *et al*., 2017).

5.1.4 PH

The pH levels in groundwater quality is influenced by water treatment processes, geological composition and mostly by human activities. According to Cameroon (2011), rock materials that are capable to buffer acids from the oxidation reaction can be an idea for pH in water quality. Another study found that the pH and calcium values were within the permissible limits set by the World Health Organization (WHO) (Riaz *et al*., 2016).

5.1.5 HYDROGEN CARBONATES

The hydrogen carbonates in groundwater quality is caused by bicarbonates and carbonates and also the anthropogenic activities. The results from a similar study indicates contamination risks in drinking water and the results exceeds the WHO guidelines standards (Aliev *et al*., 2010).

5.1.6 ALKALINITY

Total alkalinity is due to the capacity of water's buffering in the basic pH range. A similar study shows that the values of alkalinity in the tested water samples were 203-659mg/L (Ashfaq and Ahmad, 2014).

5.1.7 SULPHATE

The sulphate concentration in ground water quality is caused by natural factors such as mineral found in the earth's crust and human activities such as mining. Other scholars such as Cameron (2011) argues that the high levels of sulphate can lead to a bitter and water taste.

5.1.8 CHLORIDES

The high concentration of chlorides contributes to a salty taste in water (WHO, 2011). Another similar study shows that natural water contains chlorides and natural factors such as chloride rich rocks and human factors such as agriculture and industry leads to chlorides in water (Jha and Verma, 2000).The degree of contaminants in water quality determines the concentration of chlorides (Yogendra and Puttaiah, 2008).

5.2 MICROBIOLOGICAL WATER QUALITY OF GROUNDWATER

5.2.1 E.COLI

E.coli concentration in groundwater quality is caused by inadequate waste disposal and sewage systems. Osot (2000) argues that, there are pathogens that causes diarrheal symptoms such as E.coli 0157:H7. A study reveal that E.coli in infant leads to hemolytic uremic syndrome which affects the red blood cells which further contribute to kidney failure problems (Bettelheim and Goldwater, 2015). Another similar study reveal that the E.coli in tested water samples were absence, therefore no fecal contamination can be detected.

5.2.2 TOTAL FAECAL COLIFORM

Sewage discharges have contributed to high levels of total fecal coliform in ground water quality. Total fecal coliform does not cause any health risk factors and it's good to note that, their presence indicates fecal contamination (Kativhu, 2013).Bacteria impurities are the major threats to public health in drinking water quality, according to WHO (2011).A similar study shows that the total coliform was noticed to be higher than the WHO recommended values for drinking water. A scholar, Adetuga emphases on the similar finding expressing the fact that, the increase in water concentration and drinking water from animals can cause high total coliforms. The study findings revealed that the water samples contained significantly higher levels of total coliforms and fecal coliforms compared to the drinking water standards (Edessa *et al*., 2017).

5.2.3 TOTAL VIABLE COUNTS

Total Viable Counts indicates the presence of a wide range of microorganisms in groundwater quality. Another similar study shows the presence of bacterial pathogen in drinking water quality (Edessa *et al*., 2017). The water sources for the Kitsiyatota catchment area proved to be well below the acceptable standards for drinking water quality.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The study findings demonstrate that the water samples collected from the Kitsiyatota catchment exhibited statistically significant differences in their physicochemical and microbiological properties across the sampling locations examined.

The results of the conducted study indicate that the general boreholes, tap water and well water samples collected from the Kitsiyatota catchment area exceed the drinking water quality guidelines set by the World Health Organization (WHO).Specifically, the high values observed for certain measured water quality parameters, such as conductivity, total dissolved solids (TDS), carbonates, alkalinity, E. coli, and total coliforms, exceeded the recommended standards for domestic use or drinking purposes. These elevated levels of the analyzed parameters suggest that the water from the boreholes and wells in the Kitsiyatota catchment is of poor quality and does not meet the WHO standards for safe drinking water. However, the study also shows that other water quality parameters, including total hardness, pH, chlorides, sulfates, and total viable count, did fall within the recommended ranges specified by the WHO guidelines, though they still exhibited significant differences across the different sampling sites within the catchment.

The study generally shows that the physico-chemical and microbiological properties of the water analyzed from the Kitsiyatota catchment area in Bindura, exceed the recommended standards for drinking water quality.

6.2 RECOMMENDATIONS

6.2.1 RECOMMENDATIONS TO THE COMMUNITY

The researcher recommends the private water sources like boreholes or wells to use chlorine and ultraviolet light treatment to remove or reduce the concentration of E. coli in the water. The use of water softeners, such as tetra-sodium diphosphate and calcium hydroxide, is well-recommended for people living within the Kitsiyatota catchment area as an ideal method for water treatment and waste management. Cheaper and more affordable pre-treatment methods, such as boiling the water, are recommended as they can help remove hardness and improve the overall water quality for the local community.

6.2.2 RECOMMENDATIONS TO THE DISCIPLINE OF ENVIRONMENTAL SCIENCE

The researcher recommends that the department provide backup power sources to maintain laboratory operations during electricity outages. The researcher work was hindered by power breakdowns, which the department should address. The researcher had to independently seek funding to purchase materials and test kits that were not available in the laboratory. This suggests the department does not adequately consider the availability and accessibility of necessary lab equipment and supplies. The researcher recommends the department improve the provisioning of required test kits and materials. Due to the limitations of the existing laboratory facilities, the researcher was unable to test all the desired water quality parameters. The researcher therefore recommends that the department upgrade and expand their laboratory capabilities to enable comprehensive water quality analysis.

6.2.3 RECOMMENDATIONS FOR POLICY

The researcher recommends that the government should improve the water supply systems to ensure residents have access to clean, portable drinking water. The current water sources do not meet quality standards. The researcher suggests prohibiting the use of illegal groundwater sources and informal mining activities within the Kitsiyatota catchment area, as these are likely contributing to the contamination of the water sources used for domestic purposes. For residents living in the Kitsiyatota catchment, the researcher recommends providing them with water treatment chemicals to enable them to effectively treat the contaminated water before using it for domestic purposes. The researcher also advises that the drilling of boreholes should be done to the recommended depth, to prevent the groundwater from becoming easily contaminated.

REFERENCES

Aliev, S. . (2010) 'Rapid assessment of drinking-water quality in the republic of tajikistan. Country report of the pilot project implementation in 2004-2005', p. 82.

Anesthesia, N. . (2010) *Guidelines for, Resuscitation*.

Ashfaq, A. and Ahmad, F. (2014) 'Case Study Assessment of Drinking Water Quality: A Case Study', *Int.J.Curr.Microbiol.App.Sci*, 3(9), pp. 608–611. Available at: http://www.ijcmas.com.

Bettelheim, K.A. and Goldwater, P.N. (2015) 'Escherichia coli and sudden infant death syndrome', *Frontiers in Immunology*, 6(JUL). Available at: https://doi.org/10.3389/fimmu.2015.00343.

Bruce, M. and Limin, M. (2021) 'Recent Advances on Water Pollution Research in Africa: A Critical Review', *International Journal Of Scientific Advances*, 2(3). Available at: https://doi.org/10.51542/ijscia.v2i3.23.

Dhopte, D.N. (2021) 'IRJET- Assessment of Quality of Water through Physicochemical Parameters- A Review', *Irjet*, 8(9), pp. 945–951.

Edessa, N., Geritu, N. and Mulugeta, K. (2017) 'Microbiological assessment of drinking water with reference to diarrheagenic bacterial pathogens in Shashemane Rural District, Ethiopia', *African Journal of Microbiology Research*, 11(6), pp. 254–263. Available at: https://doi.org/10.5897/ajmr2016.8362.

Gandidzanwa, C.P. and Mawonde, A. (2024) 'Uncorrected Proof Water – energy network provisioning services in Harare , Zimbabwe Uncorrected Proof', 00(0), pp. 1–16. Available at: https://doi.org/10.2166/ws.2024.073.

Gangwar, S.K. (2020) 'Analysis of antibacterial and antifungal activity of Terminalia brownii upon Escherichia coli and Candida albicans ANALYSIS OF ANTIBACTERIAL AND ANTIFUNGAL ACTIVITY OF TERMINALIA', (June 2018).

Gerritsen, J. (2017) 'Calibration of the biological condition gradient in Minnesota streams: A quantitative expert-based decision system', *Freshwater Science*, 36(2), pp.

427–451. Available at: https://doi.org/10.1086/691712.

Goodman, T.M. (2012) ‘International standards for colour’, *Colour Design: Theories and Applications: Second Edition*, pp. 417–452. Available at: https://doi.org/10.1016/B978-0-08-101270-3.00018-7.

GoZ (2002) ‘Water Resource Management , Supply and Sanitation’, *Zimbabwe Report*, pp. 1–50.

Gupta, R., Singh, A.N. and Singhal, A. (2019) ‘Application of ANN for water quality index’, *International Journal of Machine Learning and Computing*, 9(5), pp. 688–693. Available at: https://doi.org/10.18178/ijmlc.2019.9.5.859.

Jaspers, F.G.W. (2001) ‘The New Water Legislation of Zimbabwe and South Africa - Comparison of Legal and Institutional Refor’, *International Environmental Agreements : Politics, Law and Economics Jul*, 1(3), pp. 305–325. Available at: https://search-proquest-com.ezproxy.lib.monash.edu.au/docview/195502370?OpenUrlRefId=info:xri/sid:primo&accountid=12528.

Kanyagui, M.K. (2024) ‘Assessment of health impacts of quality water provisioning from groundwater sources: a micro-level study in India’, *Water Policy*, 26(1), pp. 111–130. Available at: https://doi.org/10.2166/wp.2023.206.

Lake, K. (2014) ‘Original Research Article Assessment of physico-chemical and microbiological parameters of’, 3(2), pp. 88–96.

Lohit, U. (2019) ‘Assessment of Physical and Chemical Water Quality Parameters at NH-11’, *International Journal of Engineering Research & Technology*, 8(May), p. 77. Available at: https://www.researchgate.net/publication/351945393%0AAssessment.

Makoni, F. and Smits, S. (2007) ‘Policies and institutional framework for multiple use of water in Zimbabwe’.

Mclarnan, S.M. and Mclarnan, S. (2019) ‘Escherichia coli as a Water Quality Indicator Organism : A Case for Responsive , Science-Based Policy Escherichia coli as Water Quality Indicator Organism : A Case for’, (2017), pp. 2016–2019.

Mohammad, A.H., Abdullat, G. and Alzughoul, K. (2017) ‘Changes in Total Dissolved Solids Concentration during Infiltration through Soils (Rain, Fresh Groundwater and Treated Wastewater)’, *Journal of Environmental Protection*, 08(01), pp. 34–41. Available at: https://doi.org/10.4236/jep.2017.81004.

Myers, M.D. (2002) ‘Burgmann-gruppe übernimmt die vertriebsorganisation von Beldam Crossley’, *VGB PowerTech*, 82(1).

Obilonu, A.N.. (2013) ‘Water Quality Challenges and Impact’, *International Letters of Natural Sciences*, 4, pp. 44–53. Available at: https://doi.org/10.18052/www.scipress.com/ilns.4.44.

Offat, I. and Kamuzungu, T. (2009) ‘Access To Safe Drinking Water By Rural Communities in Zimbabwe: a Case of Mundenda Village in Mutasa District of Manicaland Province’, *Journal of Sustainable Development in Africa*, 11(1), pp. 113–127.

Patil P.N (2015) ‘Physico-chemical parameters for testing of water, a review paper’, *International Journal of Chemical Studies*, 3(4), pp. 24–28.

Petterson, S.R., Stenström, T.A. and Ottoson, J. (2016) ‘A theoretical approach to using faecal indicator data to model norovirus concentration in surface water for QMRA: Glomma River, Norway’, *Water Research*, 91, pp. 31–37. Available at: https://doi.org/10.1016/j.watres.2015.12.037.

Riaz, O. (2016) ‘Assesment of Ground Water Quality: a Case Study in Sargodha City, Pakistan’, *Researchgate.Net* [Preprint], (November). Available at: https://www.researchgate.net/profile/Omar-Riaz/publication/310694454_Assessment_of_Ground_Water_Quality_A_Case_Study_in_Sargodha_City_Pakistan/links/5835631308aef19cb8221c07/Assessment-of-Ground-Water-Quality-A-Case-Study-in-Sargodha-City-Pakistan.pdf.

Roy, R. (2018) ‘An Introduction to water quality analysis’, *ESSENCE – International Journal for Environmental Rehabilitation and Conservation*, (July), pp. 94–100. Available at: https://doi.org/10.31786/09756272.18.9.2.214.

Satihals, S. (2014) ‘Assessment of Bacteriological and Physicochemical Analysis of Water’, 4(3), pp. 466–469.

Sitotaw, B. (2023) ‘Drinking water quality and associated factors in Bahir Dar City and the surrounding rural areas, Northwest Ethiopia: a community-based cross-sectional study’, *Journal of Water Sanitation and Hygiene for Development*, 13(8), pp. 584–594. Available at: https://doi.org/10.2166/washdev.2023.049.

United States Environmental Protection Agency (2016) ‘Quick Guide To Drinking Water Sample Collection’, *U.S. Environmental Protection Agency*, 2(September), pp. 1–20. Available at: https://www.epa.gov/sites/production/files/2015-11/documents/drinking_water_sample_collection.pdf.

WHO (2020) *WHO global water, sanitation and hygiene annual report 2018*. Available at: https://www.who.int/water_sanitation_health/publications/global-water-sanitation-and-hygiene-annual-report-2018/en/.

APPENDIX 1: T-TEST

PHYSICOCHEMICAL OUTPUTS

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Ph	15	7.047	.1552	.0401

One-Sample Test

	Test Value = 9.2					
					95% Confidence Interval of the Difference	
	T	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Ph	-53.727	14	.000	-2.1533	-2.239	-2.067

One-Sample Effect Sizes

				95% Confidence Interval	
		Standardizer[a]	Point Estimate	Lower	Upper
Ph	Cohen's d	.1552	-13.872	-18.971	-8.768
	Hedges' correction	.1642	-13.113	-17.933	-8.288

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation.

Hedges' correction uses the sample standard deviation, plus a correction factor.

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Conductivity	15	374.1853	259.54060	67.01309

One-Sample Test

Test Value = 500

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of Difference	
					Lower	Uppe
Conductivity	-1.877	14	.081	-125.81467	-269.5435	17

One-Sample Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
Conductivity	Cohen's d	259.54060	-.485	-1.014	.059
	Hedges' correction	274.56254	-.458	-.958	.056

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation.

Hedges' correction uses the sample standard deviation, plus a correction factor.

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Alkalinity	15	1373.00	377.216	97.397

One-Sample Test

	Test Value = 500					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Alkalinity	8.963	14	.000	873.000	664.10	1081

One-Sample Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
Alkalinity	Cohen's d	377.216	2.314	1.316	3.291
	Hedges' correction	399.049	2.188	1.244	3.111

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation.

Hedges' correction uses the sample standard deviation, plus a correction factor.

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Carbonates	15	.7920	.34884	.09007

One-Sample Test

	Test Value = 0.1					
					95% Confidence Interval o Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Uppe
Carbonates	7.683	14	.000	.69200	.4988	

One-Sample Effect Sizes

				95% Confidence Interval	
		Standardizer[a]	Point Estimate	Lower	Upper
Carbonates	Cohen's d	.34884	1.984	1.086	2.858
	Hedges' correction	.36903	1.875	1.027	2.702

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation.

Hedges' correction uses the sample standard deviation, plus a correction factor.

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Sulphate	15	150.60	198.327	51.208

One-Sample Test

	Test Value = 500					
					95% Confidence Interval of th Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Sulphate	-6.823	14	.000	-349.400	-459.23	-239

One-Sample Effect Sizes

				95% Confidence Interval	
		Standardizer[a]	Point Estimate	Lower	Upper
Sulphate	Cohen's d	198.327	-1.762	-2.570	-.929
	Hedges' correction	209.806	-1.665	-2.430	-.879

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation.

Hedges' correction uses the sample standard deviation, plus a correction factor.

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Chlorides	15	15.8433	8.94353	2.30921

One-Sample Test

	Test Value = 250					
					95% Confidence Interval of t Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Chlorides	-101.401	14	.000	-234.15667	-239.1094	-229.:

One-Sample Effect Sizes

				95% Confidence Interval	
		Standardizer[a]	Point Estimate	Lower	Upper
Chlorides	Cohen's d	8.94353	-26.182	-35.773	-16.586
	Hedges' correction	9.46117	-24.749	-33.816	-15.679

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation.

Hedges' correction uses the sample standard deviation, plus a correction factor.

APPENDEX 2: T-TEST

MICROBIOLOGICAL INPUTS

	N	Mean	Std. Deviation	Std. Error Mean
T.Coli	15	1.73	.704	.182

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
T.Coli	9.539	14	.000	1.733	1.34	2.12

One-Sample Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
T.Coli	Cohen's d	.704	2.463	1.418	3.487
	Hedges' correction	.744	2.328	1.340	3.296

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation.

Hedges' correction uses the sample standard deviation, plus a correction factor.

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
E.Coli	15	.8100	.80246	.20719

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
E.Coli	3.909	14	.002	.81000	.3656	1.2544

One-Sample Effect Sizes

				95% Confidence Interval	
		Standardizer[a]	Point Estimate	Lower	Upper
E.Coli	Cohen's d	.80246	1.009	.371	1.625
	Hedges' correction	.84891	.954	.350	1.536

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation.

Hedges' correction uses the sample standard deviation, plus a correction factor.

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
TVC	15	45.40	21.553	5.565

One-Sample Test

	Test Value = 100					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
TVC	-9.811	14	.000	-54.600	-66.54	-42.66

One-Sample Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
TVC	Cohen's d	21.553	-2.533	-3.580	-1.466
	Hedges' correction	22.801	-2.395	-3.384	-1.386

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation.

Hedges' correction uses the sample standard deviation, plus a correction factor.