ASSESSING WATER QUALITY FOR UNPROTECTED SHALLOW WELLS AT CHISINKHA VILLAGE IN MULANJE DISTRICT.

BRIGHT CHIYEMBEKEZO ZINYONGO, ESC-032-15

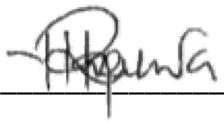
THYOLO, MALAWI

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JULY, 2021.

DISSERTATION APPROVED BY:

SUPERVISOR:

MR. H. YAPUWA Signature: 

ASSESSOR:

Title, Initials, Name Signature: _____

DECLARATION

I BRIGHT CHIYEMBEKEZO ZINYONGO declare that this research project represents my own work and that it has never been submitted to this institution or any other institution for any academic purpose. All sources of information have been appropriately acknowledged.



Signature_____

Date 19TH JULY, 2021

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ABSTRACT

The provision of safe drinking water is a fundamental right of basic health and an extremely high priority of the Malawi Poverty Strategy. Mulanje is one of the districts in Malawi where limited resources and services are facing relentless pressure due to rapid population growth and water as a resource is of no exception. Sixty seven cases were reported at Mulanje District Hospital in the year of 2020 for the people of Chisinkha Village affected by gastrointestinal diseases. The main objective of the present study was to assess the water quality for unprotected shallow wells in Chisinkha village and compare the water quality parameters result with World Health Organization (WHO) and Malawi Bureau of standards drinking water standards. Water samples were obtained from 5 selected unprotected shallow wells distributed in Chisinkha village. The water quality parameters analyzed were: pH, temperature, Total Dissolved Solids (TDS), turbidity, total hardness, Electrical Conductivity (EC), Escherichia Coliform, Faecal Coliform and Total Coliform. The data was analyzed using Microsoft Excel, Statistic Package for Social Science (SPSS) and a one-way Analysis of Variance (ANOVA). Water Quality Index (WQI) was used as a tool to communicate information on the quality of water status to the concerned citizens and the public. Water Quality Index for all Shallow unprotected wells indicates that the water quality status for Chisinkha Village was bad and badly affected according to water quality status and E.I.A status. The water quality for unprotected Shallow Well 1 was 41.7, unprotected Shallow Well 2 was 36.76, unprotected Shallow well 3 were 30.56, unprotected Shallow Well 4 was 47.89 and unprotected Shallow Well 5 was 46.1 hence according to Water Quality Status, the quality of Shallow Unprotected Wells of Chisinkha Village was bad and badly affected. The study recommends for interventions in Chisinkha Village that focus on household water treatment like chlorination, provide more safe water facilities supply and emphasis on water education in this study area. The study recommends the citizens to observing the distance between the well and the pit latrines and cattle kraal.

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TABLE OF CONTENTS

1.0 CHAPTER ONE: 11

1.1. INTRODUCTION 11

1.2. BACKGROUND INFORMATION.....13

1.3. PROBLEM STATEMENT 14

1.4. RESEARCH QUESTIONS 14

1.5. MAIN AND SPECIFIC OBJECTIVE 15

1.6. SIGNIFICANCE OF THE STUDY 15

2.0 CHAPTER TWO: 16

LITERATURE REVIEW 16

3.0 CHAPTER THREE: METHODOLOGY 20

3.1. RESEARCH DESIGN 20

3.2. STUDY AREA 21

3.3.0 MATERIALS AND METHODS 21

3.3.1. DATA COLLECTION 21

3.3.2. SAMPLE SIZE 22

3.3.3. DATA ANALYSIS 22

3.3.4. DATA ANALYSIS METHODS.....23

4.0 **CHAPTER FOUR**: RESULTS AND DISCUSSIONs 24

5.0 **CHAPTER FIVE**: CONCLUSSIONS AND RECOMMENDATIONS.....35

6.0 **REFERENCES**.....36

7.**0 APPENDIX**.....38

LIST OF FIGURES

Figure1: Shows the study area of Chisinkha village 21

Figure 2: Shows the graph of pH with MBS and WHO Standards.....26

Figure 3: Shows the graph of TDS with MBS and WHO Standards.....27

Figure 4: Shows the graph of turbidity with MBS and WHO Standards.....28

Figure 5: Shows the graph of EC with MBS and WHO Standards.....29

Figure 6: Shows the graph of Total Hardness with MBS and WHO Standards.....29

Figure 7: Shows the graph of Escherichia Coliforms with MBS and WHO Standards.....30

Figure 8: Shows the graph of Faecal Coliforms with MBS and WHO Standards.....31

Figure 9: Shows the graph of Total Coliforms with MBS and WHO Standards.....32

Figure 10: Shows sample analysis at Chisinkha village.....38

Figure 11: Shows sample analysis at MUBAS Laboratory.....40

Figure 12: Shows sample analysis at MUBAS Laboratory.....41

Figure 13: Shows Equipment collection at MUST Laboratory.....42

LIST OF TABLES

Table 1: shows water quality standards……17

Table 2: shows data analysis methods……23

Table 3: shows different water parameter average values and Result….24

Table 4: shows a descriptive statistic……25

Table 5: shows results comparison with MBS, WHO and Remarks……..25

Table 6: shows measured average value of water parameters……32

Table 7: shows calculated value of WQI……33

Table 8: shows calculated value of WQI……33

Table 9: shows Water Quality Index Legend……34

Table 10: shows the concentration of shallow unprotected wells……..34

Table 11: shows coordinates for sample collection sites……39

Table 10: shows all sample analysis of the water parameter……43

ACRONYMS/ABBREVIATIONS

E-COLI	Escherichia Coliform
EC	Electrical Conductivity
F. Coliform	Fecal Coliform
MBS	Malawi Bureau of Standards
Mg/l	milligrams per litre
NTU	Nephelometric Turbidity Units
Recc	Recommendation
pH	Power of Hydrogen
SW	Shallow Wells
TDS	Total Dissolved Solids
T. Hardness	Total Hardness
TURB	Turbidity
WHO	World Health Organization
WQI	Water Quality Index
μS	micro siemens

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION TO THE STUDY

"Water is Life", "Health is Wealth" and "Waste to Wealth" are the popular saying related to life and wealth. However, waste that is not popular managed in the vicinity of surface water and groundwater can be detrimental to life, health and wealth.

Access to clean domestic water is a basic human right but only 65 % of the total population has an access to safe domestic water (Pritchard et al, 2008). Previous research has shown that many Africa communities obtain their domestic water supplies from unprotected water sources (Adelekan, 2010; Dorice et al.,2010; Olaniran et al.,2009) which are prime to contamination by Faecal materials from human and non-human sources (latrines and cattle kraal). Persistent diarrhea in Children is a common problem in low and middle income countries due mainly to inadequate supply of portable drinking water (Cabral, 2010; Abba et al., 2009; Fawell and Nieuwenhuijsen, 2003). In Less Economical Developed Countries, grossly contaminated water is also a major source of exposure to Faecal contamination and diarrhea pathogens (Moe et al, 1991).

In Africa and Asia, most people in rural areas depend on ground and surface water for sustenance (Kwame, 2021). Malawi is one of the countries in the sub-Saharan region that has made a fair progress in provision of safe and portable water by 67% (WHO/UNICEF JMP report, 2015). The increasing population in Malawi has made the available boreholes and other water sources inadequate hence a lot of people are using water from the streams or rivers and shallow unprotected wells.

Malawi faces a number of public health challenges that are currently leading to a lot of premature death of which diarrhea rank highly due to a number of factors including the use of contaminated water, poor sanitation, improper waste management and unhygienic practices in food preparation (Clasen, 2008).

Water quality is a consequence of the natural physical and chemical state of the water as well as any alteration that may have occurred as a consequence of human activity (fetter C.W, 2014). Water quality analysis is a process of determining the true nature of water by estimating the presence of parameters and its limits by various experiments available (Andreadakis et al., 2003). Contamination of groundwater is a major widespread issue around the world and the water quality is highly dependent on the geology set up of the area as well as anthropogenic interventions in the area. Geology plays a great role for the contamination of water. The process of weathering (breaking down of rocks into

small particles) leads to contamination of water in the sense that water can carry the small unit of rocks as it passes through the weathered rocks. When the water flow through the geology unit (rocks) it dissolves the materials in the rock because water is the best solvent in the process called dissolution. Carbonate rocks for example dissolves in water and the molecules are carried together with the water. The excess present of the minerals or metals in water cause a lot of risk to the human healthy. Chisinkha village located in Mulanje district the southern part of Malawi is an example where people use untreated water from shallow wells and nearby Likhumbula River due to the presence of few boreholes catering a lot of people in a big community. There are a lot of cases reported at Mulanje District Hospital of gastrointestinal diseases like diarrhea because the water which the Chisinkha villagers use is unprotected. This study will assess the water quality for unprotected shallow wells for the Chisinkha village. By definition shallow well is a hole which has been dug, bored, driven or drilled into the ground for the purpose of extracting water (king's country et al., 2021). This study will help to improve the well heath living of Chisinkha villagers and surrounding community and other areas in Malawi. The assessing water quality for unprotected shallow wells involves collecting of water samples from the 5 randomly selected wells. The laboratory test involves analyzing the pH, Total Dissolved Solids, Electrical Conductivity (EC), Total Hardness, Turbidity, Escherichia COliform, Faecal Coliform and Total Coliform levels that were present in the water. The expected results were presented in statistical tables, graphs and charts. This study helps to provide ways of treating contaminated water in order to have clean water and improves the standard of living for the human.

1.2 BACKGROUND TO THE STUDY AREA

Malawi is situated in east-central Africa between latitudes 9 22' and 17 08' S and longitudes 32 40' and 35 55' E. The greatest part of Malawi is underlain by crystalline rocks of Precambrian to lower Paleozoic age referred to the Malawi Basement Complex. Malawi's water resources cover 21% of its territory and include Lake Malawi. Malawi has a total area of 118,484 square Kilometer and Malawi is approximately 860 km in length from north to south and 250 km wide at its broadest point. Malawi has 94,080 square Kilometer land and 24,404 square kilometer water. Clean water is vital for a healthy population. In Malawi about 80% of the population has an access to an improved source of drinking water but about 4 million people continue to lack access to safe water (Water Sanitary and Hygiene, 2010). Mulanje district is a district in the Southern Region of Malawi. The capital is Mulanje. Mulanje district has an area of 2,005 km2 and a density of 341.2/km2, Mulanje district has a population of 684,107 (National Statistical Office of Malawi, 2018). The Chisinkha village depends much on water from the stream, river, boreholes and wells. Chisinkha village has a lot of people hence water

supply from the boreholes does not meet the demand for water hence a lot of people depend on shallow unprotected wells and nearby river.

1.3 PROBLEM STATEMENT

Sixty seven people from Chisinkha village are affected by gastrointestinal disease like diarrhea due to the use of water from shallow unprotected wells (Mulanje District Hospital, 2020). Although these unprotected shallow wells are backbone of water used for drinking and irrigation in rural areas including Mulanje district, there are a lot of studies that focusses on groundwater than studies on assessing water quality of shallow subsurface water (shallow wells) hence this study is important as it bridges the gap.

1.4 RESEARCH QUESTIONS

- What were the main physical and chemical parameters of shallow unprotected wells that lead to more cases at Mulanje District Hospital for Chisinkha villagers?
- What were the biological parameters of shallow unprotected wells that lead to the gastrointestinal diseases for people of Chisinkha Village?

1.5 MAIN OBJECTIVE

- The main objective of this study was to assess the water quality for unprotected shallow wells in Chisinkha village, Mulanje district the southern part Malawi.

1.5.0 SPECIFIC OBJECTIVES

2.1 To determine the physio-chemical parameters characteristics of water like Turbidity, Temperature, pH, Hardness, Total Dissolved Solids (TDS) and Electrical Conductivity (EC).

2.2 To determine the biological parameters characteristics of water like Escherichia Coliform (E-Coli), Faecal Coliform (F-Coli) and Total Coliforms.

2.3. To develop the Water Quality Index (WQI), WQI help to provide easy and simple way of classify the water quality of Chisinkha Village.

1.6 SIGNIFICANCE OF THE STUDY

The area of study has a lot of people that uses unprotected shallow wells due to insufficient boreholes hence the main source of water for drinking and domestic purposes is shallow unprotected wells. This study is important because it will assess the water quality for unprotected shallow wells of Chisinkha Village hence improving human health and the economy of the country since people from Chisinkha Village work in different tea estates like Esparanza tea estate and Chitakale tea estates.

The study of assess water quality for unprotected shallow wells for Chisinkha Village provides information that some students, organisation and government can use to treat the similar problem in different locations. If the area has the similar problem of gastrointestinal diseases, using the same approach (objectives, methodology and analysis) the problem can be assessed.

The study is also in line with the Sustainable Development Goal number six which states that Everyone should have an access to clean water and sanitation by the year of 2030.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

SHALLOW WELLS WATER SOURCES

Shallow well is a hole which has been dug, bored, driven or drilled into the ground for the purpose of extracting water. Most people use shallow well as an alternative source of water for drinking and other domestic purpose which is not monitored and well protected. Shallow well water is mostly prone to contamination and pollution when are not protected although most of the people ignore and only focus on the color of the water as a major indicator for contamination which is not the fact.

Water quality is a consequence of the natural physical and chemical state of the water as well as any alteration that may have occurred as a consequence of human activity (fetter C.W, 2014). Water quality analysis is a process of determining the true nature of water by estimating the presence of parameters and its limits by various experiments available (Andreadakis et al., 2003). Contamination of groundwater is a major widespread issue around the world and the water quality is highly dependent on the geology set up of the area as well as anthropogenic interventions in the area.

It is in this view that the World Health Organization (WHO) put in place standards for drinking water to serve as technical guidance to the health administrators of countries wishing to establish or revise their regulations on drinking water quality control (Gower A.M, 1980). Thus drinking water standards vary country to another on social-economic factors, levels of tolerance and types and extent of pollution. In Malawi, Malawi Bureau of Standards (MBS) set the maximum limits on the level of contaminants permitted in drinking water and to enforce those standards. The water quality standards recommended by WHO and MBS are presented in Table 1.

Table 1 below shows water quality standards

PARAMETERS	WHO		MBS(for Boreholes and Shallow Wells)	UNITS
	RECOM	MAL		
pH	7.0-8.5	6.5-8.5	6.0-9.0	pH units
TDS	500	1500	2000	Mg/l
TURBIDITY	5	5	25	NTU
E.C	1000	1000	3500	μScm^-1 @20°C
HARDNESS	1000	1000	800	mg/l CaCO-3
E-COLI	0	0	0	Number/100ml
TOTAL COLIFORM	0	0	50	Number/100ml
FAECAL COLIFORMS	0	0	50	Number/100ml

2.2 WATER QUALITIES PARAMETERS

2.2.1 PH

Water pH is the measure of the acidity or alkalinity of the water. pH is one of the most important parameters of water quality and normal pH of pure water is about 7.0 (neutral) but may be lowered by addition of some organic as well as inorganic acids, or raised by the addition of basic compounds such as lime. It is measured by the instrument called Multiprobe parameter. It is therefore essential to know the pH of the water in question before the development of any community water supply is affected. MBS and WHO recommends pH for untreated water supply such from the wells, the pH should be between 6.5 and 8.5.

2.2.2 TOTAL DISSOLVED SOLIDS

Total dissolved solids (TDS) is when a portion of water sample is filtered to get rid of suspended solids, some solids dissolved in it will still remain. TDS is measured by the instrument called Conductivity and TDS Meter with the units of mg/L. Nkambulane (2006) recounts the essence of measuring the amount of these dissolved particles, thus" High levels of (TDS) in drinking water can cause objectionable taste and have laxative effects. The major dissolved substances include Chlorides, Sulphates, Nitrates, Bicarbonates, and Phosphates of Sodium, Potassium, Calcium, Magnesium, Iron and Manganese, and some of the fluorides (Nkambulane, 2006). These dissolved solids may produce aesthetically displeasing color and taste and odor. Besides, some chemicals may be toxic and some organic constituents may be carcinogenic. Although many of these

substances are on the other hand not harmful, prolonged exposure to small amounts of them can be detrimental to health. The Malawi Bureau of Standard recommends a maximum value of 2000mg/l for untreated water while WHO recommends a value of 1500mg/l (WHO, 2003).

2.2.3 TURBIDITY

Turbidity is a measure of the cloudiness or opaqueness of the water and is measured in Nephelometric Turbidity Units (NTU) (ePa, 2014). The turbidity is influenced by the amount and nature of suspended organic and inorganic material in water. The source of turbidity could be fine sand, silt and clay, organic material, particles of iron and manganese or other metal oxides, rust from corroding piping or carbonate precipitates. It is recommended that for the water to be disinfected the turbidity should be consistently less than 5 NTU. (Nayla, 2019) argues that turbidity more than 5 NTU can be visible to the average person while turbidity in muddy water, it exceeds 100 NTU and groundwater normally has very low turbidity because of the naturally filtration that occurs as the water penetrates through the soil.

2.2.4 TOTAL HARDNESS

Hardness in water is caused by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations. Total Hardness is measured by an instrument called EDTA Titrimetric method and usually expressed as milligrams of calcium carbonate per liter. Hardness is the traditional measure of the capacity of water to react with soap, hard water requiring considerably more soap to produce lather. Mineral consumption from drinking water and cooking water depends upon location, treatment and water source consumers should be informed of the mineral composition of their water whether or not it is modified. Nayla, 2019 argues that Calcium and Magnesium ions cause the greatest portion of hardness in naturally occurring waters and they enter water mainly from the contact with soil and rock particularly limestone deposits.

2.2.5 ELECTRICAL CONDUCTIVITY (EC)

Conductivity is a materials ability to conduct an electric current (WHO, 1996). EC is measured by the instrument called Conductivity and TDS Meter and it is expressed in μScm ^ -1. The conductivity of water depends on the quantity of dissolved salts present and for the dilute solutions (Tebbutt, 1999). The geology of the environment may result in the presence of EC level counts. Drinking water quality should not have high levels of EC concentration. The study conducted in Visakhapatnam shows all samples had greater

Electrical Conductivity compared by permissible value recommended due to problem of scale formation in the study area (Sarada P et al., 2016).

2.2.6 BIOLOGICAL PARAMETERS

A very important biological indicator of water and pollution is the group of bacteria called Coliforms. Pathogens coliforms always exist in the intestinal system of human and millions are excreted with body waste (Nayla, 2019). Total Coliform bacteria are a group of bacteria that are regularly present in environmental waters. Total Coliform bacteria include a wide range of aerobic and facultative anaerobic, grown negative, non-spore-forming bacilli capable of growing in the presence of relatively high concentrations of bile salts with the fermentation of lactose and production of acid or aldehyde within 24 hours at 35°C - 37°C. Fecal Coliform, Escherichia Coliform and thermotolerant coliforms are a subset of the total coliform group that can ferment lactose at higher temperature. It is proposed that total coliform could be used as a disinfection indicator. These occur in both sewage and natural water. Some of these bacteria are excreted in the faeces of humans and animals but many coliforms are heterotrophic and able to multiply in water and soil environments. Total Coliforms are measured using Membrane Filtration method.

Total Coliforms are measured in 100 Ml samples of water. The procedure include membrane filtration followed by incubation of the membrane on selective media at 35°C - 37°C and counting of colonies after 24 hours. Alternative methods include most probable number procedures using tubes or microttre plates and presence/absence tests. The study conducted in Bangwe Township, the faecal Coliform was in the range of 2 CFU/100 Ml to 1400 CFU/ 100 ML, the high level of Faecal Coliform was due to the additional contamination at household result from contamination of household utensils and water storage facilities (Kaonga C, 2013).

2.3 WATER QUALITY INDEX

Water Quality Index is a simple and easy way to understand for decision maker about quality and possible users of any water body (Jacinta et al., 2016). Water Quality Index (WQI) is widely used tool in evaluation of water quality: it summarizes a number of water quality parameters into a meaningful single numerical value (Singh et al., 2013a and Stambuk-Giljanovik, 2003). The Weighted Arithmetic Water Quality Index (WAWQI) method was applied to assess water quality suitability for drinking purposes in Chisinkha Village.

CHAPTER THREE

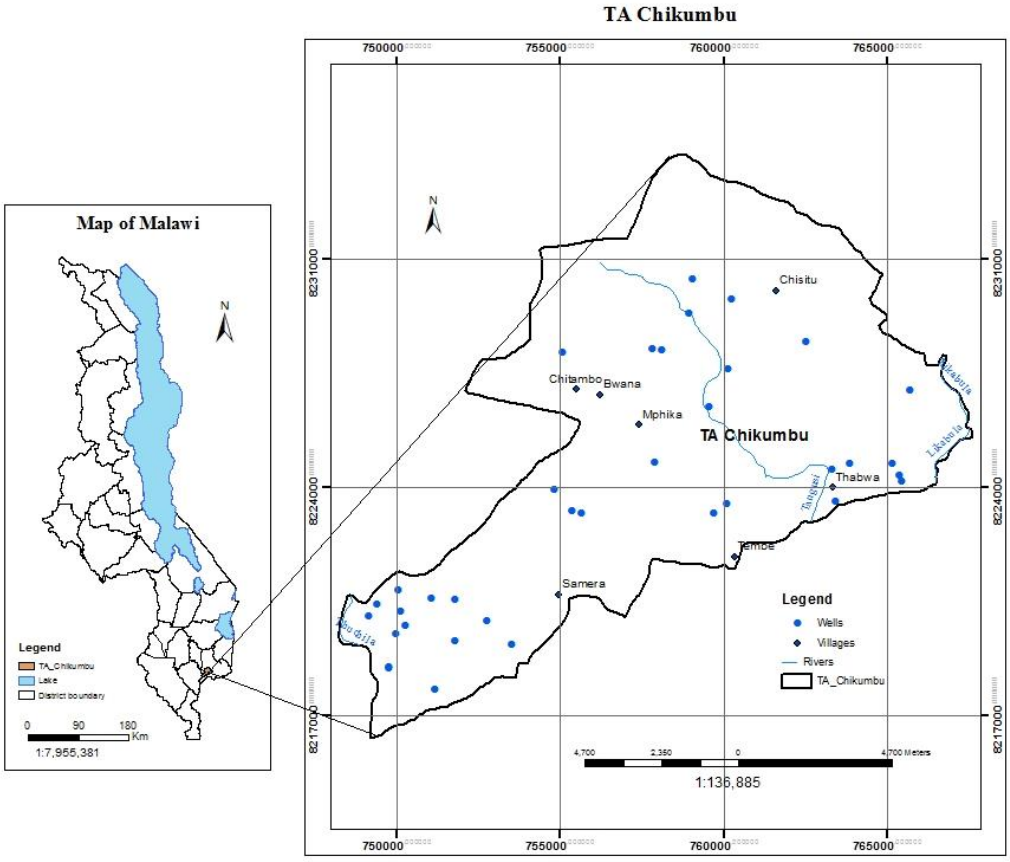
3.0 METHODOLOGY

3.1 RESEARCH DESIGN

This study of assessing the water quality for unprotected shallow wells at Chisinkha Village was an experimental that involves laboratory analysis. The study involved consulting the villages through the Chisinkha Village Headman before collecting the water samples from unprotected shallow wells. Global Positioning System (GPS) was used to locate the places for the wells. The physio-chemical water parameters analyzed were pH, temperature, turbidity, total hardness, Total Dissolved Solids (TDS) and Electrical Conductivity (EC). Temperature and pH were analyzed onsite using Multiprobe parameter. Electrical Conductivity (EC), Total Dissolved Solids (TDS), turbidity and total hardness were analyzed in environmental laboratory at Malawi University of Business and Applied Science (MUBAS). The biological parameters such as Escherichia Coliform, Fecal Coliform and Total Coliform were analyzed at biological laboratory at Malawi University of Business and Applied Science (MUBAS). The results were compared with the Malawi Bureau of Standard (MBS) and World Health Organization (WHO) Regulations. The analysis of the results was done by the means of descriptive statistics using Microsoft Office excel software, the Statistical Package for Social Science (SPSS) and a one way Analysis of Variance (ANOVA) .

3.2 STUDY AREA

Figure 1 show a map of Chisinkha village



3.3.0 MATERIALS AND METHODS

3.3.1 DATA COLLECTION

The data collection involves collecting water samples in triplicate from 5 unprotected shallow wells of Chisinkha village in Mulanje district in order to see if there is any variation with the sample analysis. Three sets of water samples were collected at each shallow unprotected well. The standard sampling procedure of American Public Health Association (APHA, 2005) was used for sample collection. PH and temperature was analyzed using a clean bucket at the field. The water samples were collected using 1 Litre clean water plastic bottles for physical and chemical parameters and 250 millimeter glass bottles for biological parameter and a cooler box with ice blocks was used to collect the samples from the wells to the laboratory to avoid biodegradation. The stratified sampling system was used to collect 5 selected unprotected shallow wells from the Chisinkha village.

3.3.2 SAMPLING SIZE

The water collection involves collecting three samples at each shallow unprotected well (triplicate) in order to see if there is any variation in the analysis of the physical, chemical and biological parameters.

Stratified sampling system was used to collect the water samples from 5 selected unprotected shallow wells because the Chisinkha village is highly populated and the study area has a lot of shallow unprotected wells.

3.3.3 DATA ANALYSIS

The GPS was used to locate the points of shallow unprotected wells. Water samples were collected from the 5 selected shallow unprotected wells and onsite analysis involves measuring Temperature and pH using a SD50 pH Meter at the field. The water samples were kept in the cooler box with ice blocks for further laboratory analyses of the other parameters to avoid biodegradation at Malawi University of Business and Applied Sciences laboratory. The laboratory involves testing the water parameters and the water parameters analyzed are Total Dissolved Solids (TDS) and Electrical Conductivity (EC) using conductivity/TDS meter. Turbidity was measured using LP2000 turbidity meter. Total hardness was measured using EDTA. Total Coliform, Fecal Coliform and Escherichia Coliform were analyzed using a membrane filtration. Results of laboratory analysis were subjected to data analysis using Statistical Package for Social Science (SPSS) and one-way Analysis of Variance (ANOVA) at 0.05 significance level was used to analyses the changes in the levels of physical, chemical and biological parameters.

Water Quality Index is a simple and easy way to understand for decision maker about quality and possible users of any water body (Jacinta et al., 2016). Water Quality Index (WQI) is widely used tool in evaluation of water quality: it summarizes a number of water quality parameters into a meaningful single numerical value (Singh et al., 2013a and Stambuk-Giljanovik, 2003). The Weighted Arithmetic Water Quality Index (WAWQI) method was applied to assess water quality suitability for drinking purposes in Chisinkha Village. Water quality rating scale, relative weight and the overall WQI will be calculated using the following formula:

$$Qi = 100 \times [(Vi - Vio) \div (Si - Sio)]$$

Where Qi indicates quality rating scale, Vi indicates estimated value of the I th parameter, Vio indicates ideal value of the I th parameter, Si indicates standard permissible value of the I th parameter.

Hence Vio=0 for all parameters except for pH=7 and DO=14.6 mg/L.

Relative weight will be calculated using:

$$Wi = K/Si$$

Where the standard value of the I parameter is inversely proportional to the relative weight.

$$K = 1/ (\sum 1/Si)$$

Overall WQI was calculated using:

$$WQI = \sum qiwi/ \sum wi$$

NOTE: Escherichia Coliform has no health guideline values (zero value) hence it is not used in calculation of WQI.

3.3.5 DATA ANALYSIS METHODS

Table 2 below shows data analysis methods

PARAMETERS	UNITS	METHODS USED
pH	pH values	Multiprobe parameter (Aqua-Read AM2000)
TDS	mg/L	Conductivity and TDS meter # company
TURBIDITY	NTU	LP 2000 Turbidity meter
EC	μScm ^ -1	Conductivity and TDS Meter (AUTO)
HARDNESS	mg/L CaCO_3	EDTA Titrimetric method
E-COLI	CFU/100 mL	Membrane filtration Method
TOTAL COLIFORM	CFU/100 mL	Membrane filtration Method
TEMPERATURE	°C	Multiprobe parameter (Aqua-Read AM2000)

3.3.6 ANALYSES OF WATER PARAMETERS

DETERMINATION OF PH

The pH was determined using multiprobe parameter method and calibrated with buffer solution of pH 4 and 7.

DETERMINATION OF TDS AND EC

TDS and EC was determined using auto Conductivity and TDS meter which was calibrated using potassium chloride solution.

DETERMINATION OF TURBIDITY

The turbidity of water was determined using a Turbidity Meter which was calibrated using distilled water, Hexamethylenethylenetetramine and hydrazine sulphate.

DETERMINATION OF TOTAL HARDNESS

AIM: To determine the total hardness of shallow unprotected well.

METHOD: EDTA Titrimetric method

MATERIALS: Tripod stand, burette, pipette, Erlenmeyer flasks, measuring cylinder

REAGENTS:

a) Buffer solution: 16.9g ammonium chloride was dissolved in 143mL concentrated ammonia solution. 1.25g magnesium salts of EDTA was added and diluted to 250mL with distilled water. The solution was stored in a plastic container and the container was tightly closed to prevent the loss of NH_3 or picking up of carbon dioxide.

b) Indicator: Eriochrome Black T indicator. 200mg of powdered dye and 100mg of solid NaCl was grinded together in a mortar to 40 to 50 mesh. The mixture was stored in a tightly stoppered bottle. 0.2g of this ground mixture was used for titration.

c) Standard EDTA titrant, 0.01M: 3.723g analytical reagent grade disodium EDTA dehydrate was weighed, dissolved in distilled water and diluted to 1000mL. The solution was then standardized against standard calcium solution.

d) Standard Calcium Solution: To prepare this, 1.000g anhydrous $CaCo_3$ powder (primary standard) was weighed and placed into a 500mL Erlenmeyer flask. The funnel was placed in the flask neck and little by little, 1+1 HCL was added until all the $CACO_3$ dissolved. 200mL distilled water was added to it and the foil boiled for a few minutes to expel CO_2.

e) After cooling, a few drops of methyl red indicator was added and adjusted to intermediate orange color by adding 1+1 HCl. The mixture was transferred quantitatively and diluted with distilled water to 1000mL (1mL=1.00mg $CaCO_3$)

f) Sodium hydroxide, NaOH, 0.01N

PROCEDURE:

Titration of sample: 25.0mL of sample was diluted with distilled water up to 50mL. 1mL of buffer solution was added to the sample.

Half a scoop of dry powder indicator formulation was then added to the sample. The sample was titrated against standard EDTA slowly until reddish tinge disappeared.

CALCULATION:

Total hardness (EDTA) as mg $CaCO_3$/L = $\frac{\text{AxBx1000}}{\text{mL sample}}$

Where A = mL titration for sample and

B = mg $CaCO_3$ equivalent to 1.00mL EDTA

DETERMINATION OF BIOLOGICAL PARAMETERS

AIM: To determine the biological parameters of shallow unprotected wells

METHOD*:* Membrane Filtration Method

MATERIALS: Incubator, a stainless steel 47 mm filter holder assembly, vacuum syringe with tubing, stainless steel forceps, stainless steel graduated sampling cup, plastic bottles (for alcohol and rinse water), Pre-sterilized filters, petri dishes, Membrane Filtration coliform Broth (MFC), and Disposable pipettes.

PREPARATION*:* A phosphate buffer dilution and rinse waters were prepared prior to sample collection at the water quality laboratory.

PROCEDURE*:*

The numbers of total coliforms and E.coli were determined using membrane filtration technique. A measured volume of water (100ml) was filtered through a membrane. Bacteria were retained on the membrane and incubated at 37^0C for total coliforms and 44^0C for E.coli for 24 hours.

When bacteria were present, they grew into visible colonies that were counted manually. Each test was duplicated for consistency. The results were presented as count per 100ml. All supplies were sterilized to ensure sterile conditions.

Samples were analyzed using membrane filtration method and were analyzed in triplicate. E.coli samples were incubated at 44^0C while for total coliforms, the samples were incubated at 37^0C. All samples were analyzed in triplicate for both E.coli and total coliforms.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

The study findings indicate that many respondents rely on Shallow Wells that are unprotected for their household uses like drinking purpose. The water quality results from unprotected shallow wells were compared to WHO and MBS guidelines to assess if the quality of the water were within the drinking water quality standards. The results of the onsite and laboratory analysis carried out on water samples are shown in Table 3 while the results of the descriptive data analysis are shown in Table 4.

Table 3 below shows different analysis of average water parameters and results

PARAMETERS	SW 1	SW 2	SW 3	SW 4	SW 5
TEMPERATURE	26.5±0.25	27.3±0.4	26.6±0.2	27.5±0.31	27.4±0.41
PH	7.1±0.31	6.6±0.31	7.3±0.2	7.6±0.2	7.5±0.25
TDS	527.7±0.76	716.3±0.4	651±1.16	535±4.45	648.5±0.31
EC	795±0.32	1064.3±1.13	837.2±0.2	809.4±0.51	968.1±0.2
TURBIDITY	0.5±0.12	0.8±0.06	0.4±0.06	0.6±0.06	1.2±0.15
T. HARDNESS	26.5±0.26	32.8±0.4	43±0.81	28.5±0.1	34.3±0.35
E-COLI	30±1	24±1	18±0	22±1	35±1
F. COLIFORMS	61±2	31±1	27±1	45±1	31±1
T. COLIFORMS	122±2	87±1	76±0	98±1	118±0

Table 4 below shows a descriptive statistics of water parameters

PARAMETERS	NUMBER OF WATER SAMPLES	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION	P VALUE
pH	15	6.6	7.6	7.22	0.39623	0.080
TDS	15	527.7	716.3	615.7	75.65341	0.000
Turbidity	15	0.4	1.1	0.7	0.238647	0.071
T. Hardness	15	26.5	43	33.02	5.918977	0.000
EC	15	795	1064.3	894.8	108.2401	0.000
E-COLI	15	114.67	271.33	25.8	6.394194	0.044
F. COLIFOM	15	27	61	39	12.86746	0.000
T. Coliform	15	76	122	100.0667	18.33991	0.000
TEMPERATURE	15	26.5	27.5	27.06	0.47223	0.083

Table 5 below shows the results Comparison with MBS & WHO and Remark

PARAMETERS	MEAN VALUES	MBS RECOM VALUES(SW)	WHO RECOM VALUES	REMARKS
pH	7.22	6.5-9.0	6.5-8.5	Within Good
TDS	615.7	2000	1000	Within Good
TURBIDITY	0.7	25	5	Within Good
HARDNESS	33.02	800	1000	Within Good
EC	894.8	3500	1000	Within Good
E-COLIFORM	25.8	0	0	Outside
F.COLIFORM	39	50	0	Within Good
T.COLIFORM	100.07	50	0	Outside

Within good- within recommended standard of drinking water

Outside- outside the recommended standard of drinking water

The total mean values of pH was 7.22±0.4, TDS was 615.7±75.65, turbidity was 0.7±0.2, Total hardness was 33.02±5.92, Electrical Conductivity was 894.8±108.24 and faecal Coliform was 39±13 of Chisinkha Village, which were all within the recommended standard of drinking water for MBS and WHO. The mean values of Escherichia Coliform and Total Coliform were 25.8±6 and 100.07±18 respectively, which exceed the recommended standard of drinking water for MBS and WHO.

WATER QUALITY PARAMETERS

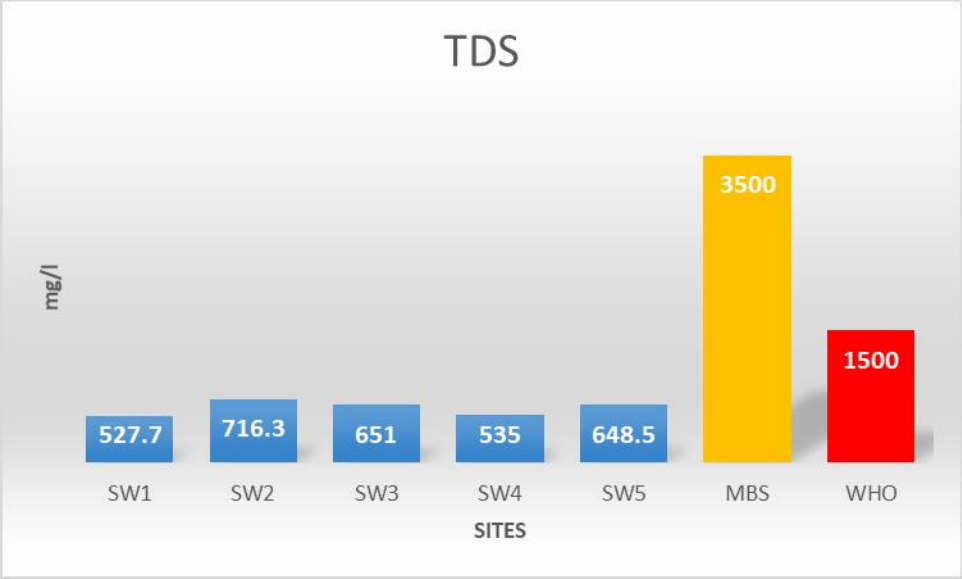
The results show that there were no significant differences ($p>0.080$) in the number of pH counts of 5 shallow unprotected wells. The pH values were in the ranges of 6.6±0.31 to 7.6±0.2 with a total mean of 7.22±0.04. The lowest level of pH was registered at Shallow Well 2 with 6.6±0.31 values and the highest level of pH was registered at Shallow Well 4 with 7.6±0.2 values. All Shallow Wells pH where within the recommended standards of MBS and WHO. pH less than 7 is acidic and pH greater than 7 is alkaline (Nelson, 2002). Shallow unprotected well 1, 3, 4 and 5 of Chisinkha Village show alkaline condition while shallow unprotected well 2 show an acidic condition.

Figure 2 below shows a plot of concentration of pH for Shallow unprotected Wells and the comparison with MBS and WHO standards



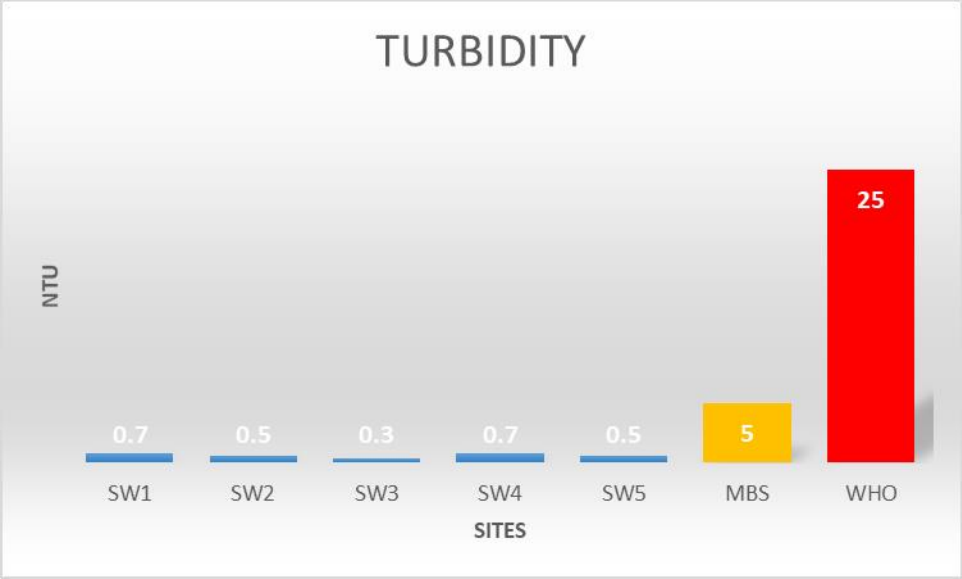
The results show that there were significant differences ($p<0.000$) in the number of TDS counts of 5 unprotected shallow wells. TDS values were in the range of 527.7±0.76 mg/L and 716.3±0.4 mg/L with the total mean of 615.7±75.65. The lowest value of TDS was registered at Shallow Well 1 with 527.7±0.76 mg/L and the highest level was registered at Shallow Well 2 with 716.3±0.4 mg/L. The TDS value of all Shallow Wells where within the recommended standards of MBS and WHO. . Nkambule (2006) recounts the essence of measuring the amount of these dissolved particles, thus" High levels of (TDS) in drinking water can cause objectionable taste and have laxative effects. The highest value of TDS at shallow unprotected well 2 was due to the leaching of salts and domestic sewage percolation from the Esparanza Tea Estate into the well.

Figure 3 below shows a plot of concentration of TDS for Shallow Unprotected Wells and the comparison with MBS and WHO standards



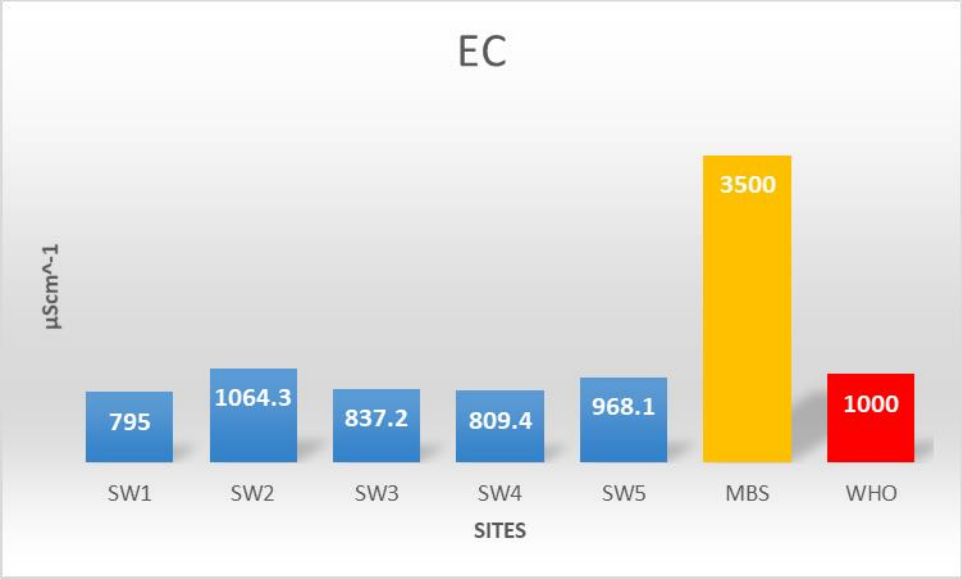
The results show that there were no significant differences ($p>0.071$) in the number of Turbidity counts of 5 unprotected shallow wells. The Turbidity levels were in the range of 0.4±0.06 NTU to 1.1±0.15 NTU with the mean of 0.7±0.2. The lowest level of turbidity value was registered at Shallow Well 3 with 0.4±0.06 NTU and the highest level of turbidity value was registered at Shallow Well 5 with 1.1±0.15 NTU. The turbidity values of all Shallow Wells were within the recommended standards of MBS and WHO. (Nozaic, 2002) argues that apart from the displeasing appearance, the particles which create turbidity also provide adsorption site for chemical that may be harmful or cause undesirable taste and odor. The highest value of shallow unprotected well 5 was due to the presence of clay, silt, very tiny inorganic and organic matter, algae and dissolved colored organic compounds.

Figure 4 below shows a plot of concentration of turbidity of Shallow Wells and the comparison with MBS and WHO standards



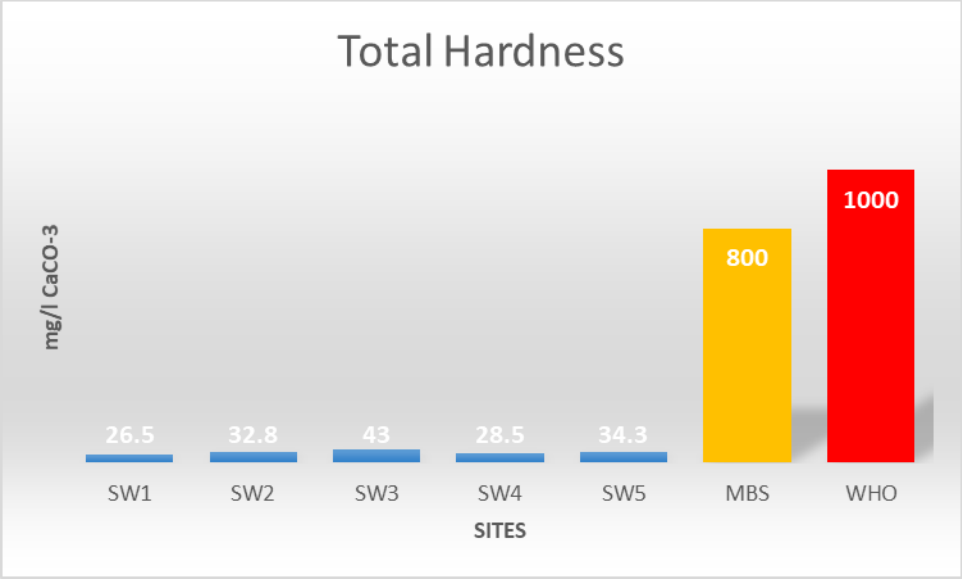
The results show that there were significant differences ($p<0.000$) in the number of EC counts of 5 unprotected shallow wells. The lowest level of EC was registered at Shallow Well 1 with 795±0.32 μScm^-1 and the highest level of EC was registered at Shallow Well 2 with 1064.3±1.14 μScm^-1 with the total mean of 894.8±108.24. Shallow Well 2 has EC value of 1064.3±1.14 μScm^-1 that is above the recommended standard of WHO but other Shallow Wells values were within the recommended standards of MBS and WHO. The study conducted in Karonga shows that EC values for shallow wells were in the range of 252 μS/cm to 1380 μS/cm that indicate below the MBS drinking standard (Wanda et al., 2017). The highest value of EC was registered at shallow unprotected well 2 because of presence of concentration of dissolved ions and temperature of the solution that increases the concentration of ions.

Figure 5 below shows a plot of concentration of EC for Shallow Wells and the comparison with MBS and WHO standards



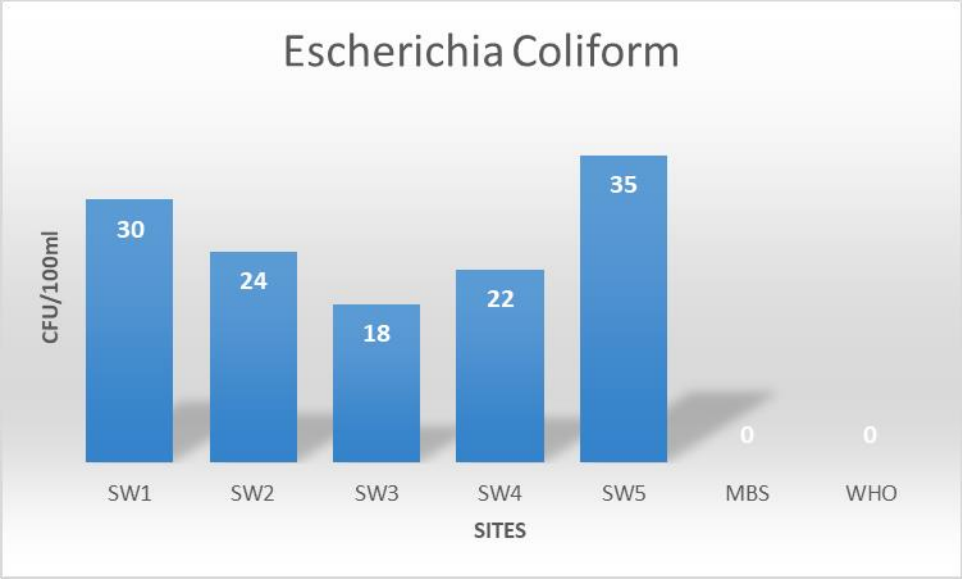
The results show that there were significant differences ($p<0.000$) in the number of Total Hardness counts of 5 unprotected shallow wells. The Total Hardness levels were in the range of 26.5±0.26 mg/L CaCO_3 to 43±0.81 mg/L CaCO_3 with the total mean of 33±5.92. The lowest level of Total Hardness was registered at Shallow Well 1 with 26.5±0.26 mg/l CaCO_3 and the highest level of Total Hardness was registered high at Shallow Well 3 with 43±0.81 mg/L CaCO_3 due to the presence of dissolved calcium and magnesium that enter the water mainly from contact with soil and rock particularly limestone deposit. The Total Hardness of all Shallow unprotected Wells values were within the recommended standards of MBS and WHO.

Figure 6 below shows a plot of concentration of Total Hardness of Shallow Wells and the comparison of with MBS and WHO standards



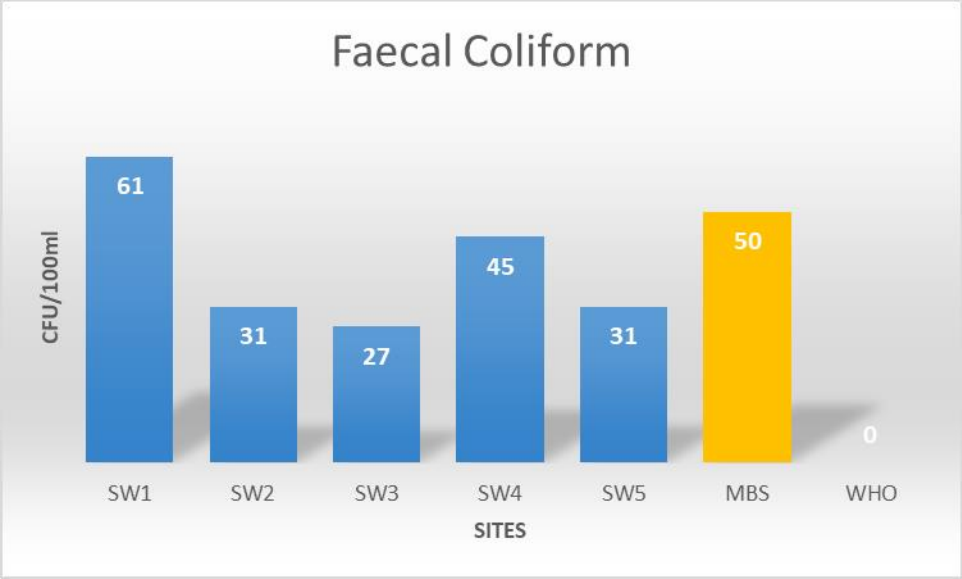
The results show that there were significant differences ($p<0.044$) in the number of Escherichia Coliform counts of 5 unprotected shallow wells. The Escherichia Coliform values were in the range of 18±0 to 35±1 (CFU/100ml) with the mean value of 25.8±6. The lowest value of Escherichia Coliform was registered at Shallow Well 3 with 18±0 CFU/100ml and the highest value was registered at Shallow Well 5 with 35±1 CFU/100ml. The Escherichia Coliform of all Shallow wells was outside the recommended standards of MBS and WHO. The presence of high level of Escherichia Coliform in all shallow unprotected wells was due to the feces of people and warm blooded animals. The absence of E-coli in this water source could imply that the total coliform that were detected could be naturally occurring bacteria that do not necessarily reflect fecal contamination of the groundwater (Kamanula et al., 2014).

Figure 7 below shows a plot of concentration of Escherichia Coliform of Shallow Wells and the comparison with MBS and WHO standards



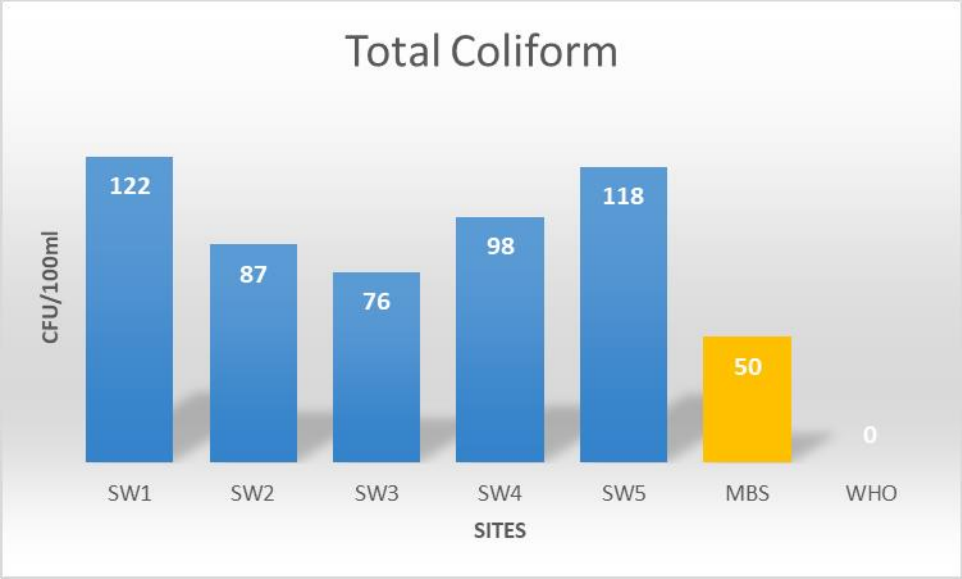
The results show that there were significant differences ($p<0.000$) in the number of Faecal Coliform counts of 5 unprotected shallow wells. The Faecal Coliform values were in the range of 27±1 to 61±1 (CFU/100ml) with the total mean value of 39±13. The lowest value was registered at Shallow Well 3 with 27±1 CFU/100ml and the highest value was registered at Shallow Well 1 with 61±1 CFU/100ml. The Faecal Coliform values were outside the recommended standards of WHO while Shallow Well 1 was outside the recommended standard of MBS but the other Shallow Wells were within the recommended standard of MBS. The highest level of Faecal Coliform was registered at shallow unprotected well 1 due to the short distance between the pit latrines and cattle kraal to the well hence there is a lot of feces from human and animals. The study conducted in Bangwe Township, the faecal Coliform was in the range of 2 CFU/100 Ml to 1400 CFU/ 100 ML, the high level of Faecal Coliform was due to the additional contamination at household result from contamination of household utensils and water storage facilities (Kaonga et al., 2013).

Figure 8 below shows a plot of concentration of Faecal Coliform of Shallow Wells and the comparison with MBS and WHO standards



The results show that there were significant differences ($p<0.000$) in the number of Total Coliform counts of 5 unprotected shallow wells. The Total Coliform values were in the range of 76±0 to 122±2 with the mean of 100.2. The lowest value of Total Coliform was registered at Shallow Well 3 with 76±0 CFU/100ml and the highest value of Total Coliform was registered at Shallow Well 1 with 122±2 CFU/100ml. The Total Coliform of all Shallow unprotected Wells values were outside the recommended standards of MBS and WHO. The presence of high level of Total Coliform was due to the human and warm blooded animals feces from pit latrines and kraals respectively. Environmental Technology verification program argues that if the sample result shows Total Coliform positive, then the sample must be further tested for the presence of fecal coliform and E-Coli that indicates the presence of water borne diseases.

Figure 9 below shows a plot of concentration of Total Coliform of Shallow Wells and the comparison with MBS and WHO standards



WATER QUALITY INDEX (WQI)

Table 6 below shows a measured average value of water parameters

PARAMETER	SW1	SW2	SW3	SW4	SW5
TEMPERATURE	26.5	27.3	26.6	27.5	27.4
pH	7.1	6.6	7.3	7.6	7.5
TDS	527.7	716.3	651	535	648.5
EC	795	1064.3	837.2	809.4	968.1
TURBIDITY	0.7	0.5	0.3	0.7	0.5
T.HARDNESS	26.5	32.8	43	28.5	34.3
E-COLI	30	24	18	22	35
F.COLIFORM	61	31	27	45	31
T.COLIFORM	122	87	76	98	118

Table 7 below shows a calculated value of WQI

PARAMETERS	Si	1/Si	Wi	SW1 Qi	SW2 Qi	SW3 Qi	SW4 Qi	SW5 Qi
pH	9	0.11	0.58	5.0	20	15	30	25
TDS	2000	0.0005	0.003	26.4	35.8	32.6	26.8	32.4
EC	3500	0.0003	0.002	22.7	30.4	23.9	23.1	27.7
TURBIDITY	25	0.04	0.21	2.8	2.0	1.2	2.8	2
T.HARDNESS	800	0.00125	0.007	3.3	4.1	5.4	3.6	4.3
F.COLIFORM	50	0.02	0.104	122	62	54	90	62
T.COLIFORM	50	0.02	0.104	244	174	152	196	234

Si= Standard permissible value

Wi= Relative unit weight (K/Si)

Qi= Quality rating of water parameters

Table 8 below shows Calculation of WQI

PARAMETERS	SW1 Qi.Wi	SW2 Qi.Wi	SW3 Qi.Wi	SW4 Qi.Wi	SW5 Qi.Wi
pH	2.9	11.6	8.7	17.4	14.5
TDS	0.08	0.1	0.1	0.08	0.1
EC	0.05	0.06	0.05	0.05	0.06
TURBIDITY	0.59	0.42	0.25	0.59	0.42
T.HARDNESS	0.02	0.03	0.04	0.03	0.03
F.COLIFORM	12.68	6.45	5.61	9.36	6.45
T.COLIFORM	25.38	18.10	15.81	20.38	24.54

WQI (SW1) = $(\sum Qi.Wi)/\sum Wi$ = 41.7

WQI (SW2) = $(\sum Qi.Wi)/\sum Wi$ = 36.76

WQI (SW3) = $(\sum Qi.Wi)/\sum Wi$ = 30.56

WQI (SW4) = $(\sum Qi.Wi)/\sum Wi$ = 47.89

WQI (SW5) = $(\sum Qi.Wi)/\sum Wi$ = 46.1

Table 9: below shows Water Quality Index Legend

CONCENTRATION	QUALITY	E.I.A
90-100	Excellent	Excellent
80-90	Good	Healthy
50-80	Medium	Alarming
25-50	Bad	Badly Affected
0-25	Very Bad	Very Badly Affected

Table 10: below shows the concentration of the Shallow unprotected well calculated against the water quality status and E.I.A status.

LOCATION	CONCENTRATION	QUALITY	E.I.A
SHALLOW WELL 1	41.7	Bad	Badly Affected
SHALLOW WELL 2	36.76	Bad	Badly Affected
SHALLOW WELL 3	30.56	Bad	Badly Affected
SHALLOW WELL 4	47.89	Bad	Badly Affected
SHALOW WELL 5	46.10	Bad	Badly Affected

According to the calculated values of Water Quality Index (WQI), Water quality of Shallow unprotected Well 1 was 41.7 which are bad and badly affected according to the water quality and E.I.A status respectively. The water quality of Shallow unprotected Well 2 was 36.76 which is bad and badly affected according to the water quality and E.I.A status respectively. The water quality of Shallow unprotected Well 3 was 30.56 which are bad and badly affected according to the water quality and E.I.A status respectively. The water quality of Shallow unprotected Well 4 was 47.89 which are bad and badly affected according to the water quality and E.I.A status respectively. The water quality of Shallow unprotected Well 5 was 46.1 which are bad and badly affected according to the water quality and E.I.A status.

CHAPTER FIVE

CONCLUSSIONS AND RECOMMENDATIONS

The study has shown that water quality of Chisinkha Village from Shallow unprotected wells is bad. The WQI of all shallow unprotected wells has a concentration values which were within 30.56 to 47.89 hence the water quality status is bad and according to the Environment Impact Assessment (E.I.A) the water quality are badly affected (Almeida and Schwarzbold, 2003).

The water quality from unprotected shallow wells of Chisinkha Village is contaminated with fecal matter from humans and warm blooded animals. The presence of fecal matter in drinking water shows that water is not safe for human consumption without any treatment. A lot of people from Chisinkha Village are affected by gastrointestinal diseases due to the use of bad and badly affected water.

The study recommends for interventions in Chisinkha Village that focus on household water treatment like chlorination, heating and provide more safe water facilities supply.

The study also recommends that the citizen should always observe the distance between a shallow well and a pit latrine or animal kraal in order to avoid contamination of shallow wells by human and animal faeces.

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THE APPENDIX

FIGURE 10 shows sample analysis in Chisinkha Village.



TABLE 11 shows coordinates for sample collection

SITE	NORTHINGS	EASTINGS	ALTITUDE(M)
WELL 1	8222402	767193	608
WELL 2	8222306	767219	605
WELL 3	8222304	767146	599
WELL 4	8222157	767323	604
WELL 5	8222452	767676	605

FIGURE 11 shows a sample analysis at Malawi University of Business and Applied Sciences



FIGURE 12 below shows sample analysis at MUBAS



FIGURE 13 below equipment collection at MUST



TABLE 12 below shows all sample analysis

LOCATION	SW1	SW2	SW3	SW4	SW5
TEMPERATURE A1	26.7	27.7	26.8	27.4	27.5
TEMPERATURE A2	26.5	26.9	26.6	27.8	26.9
TEMPERATURE A3	26.2	27.3	26.4	27.2	27.7
PH A1	7.2	6.7	7.3	7.4	7.2
PH A2	6.8	6.9	7.5	7.8	7.5
PH A 3	7.4	6.3	7.1	7.6	7.7
TDS A1	528	716.7	650.8	537.4	648.4
TDS A2	526.8	715.9	652.2	529.9	648.2
TDS A3	528.2	716.3	649.9	537.8	648.8
EC A1	795.4	1063	837.4	809.5	968.3
EC A2	794.8	1064.8	837	809.8	968.1
EC A3	794.9	1065.1	837.2	808.8	967.9
HARDNESS A1	26.7	32.4	42.2	28.5	34.3
HARDNESS A2	26.6	33.2	43.8	28.6	34.6
HARDNESS A3	26.2	32.8	42.8	28.4	33.9
TURBIDITY A1	0.6	0.8	0.4	0.7	1.2
TURBIDITY A2	0.6	0.9	0.5	0.7	0.9
TURBIDITY A3	0.4	0.8	0.5	0.6	1.1
E-COLI A1	30	24	18	22	36

E-COLI A2	29	23	18	21	36
E-COLI A3	31	24	18	23	34
F. COLI A1	60	32	28	46	30
F. COLI A2	62	32	27	45	31
F. COLI A3	60	30	27	44	31
T. COLI A 1	124	87	76	98	118
T. COLI A2	121	87	76	97	118
T. COLI A3	121	86	76	98	118

A1 = Analysis 1, A2 = Analysis 2 and A3 = Analysis 3.