

ANALYSIS AND MAPPING OF GROUNDWATER SALINITY IN SHALLOW HAND-DUG WELLS IN T/A CHIMALIRO AREAS OF THYOLO, MALAWI

Thyolo, Malawi

FLORENCE CHIRWA

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

DATE

18th, July 2021

DECLARATION

I FLORENCE CHIRWA declare that this research project represents my 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 18-07-2021

DISSERTATION APPROVED BY

E.C Mabedi Signature:

ASSESSOR:

Title, Initial, Name Signature:

DISCLAIMER

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

COPYRIGHT STATEMENT:

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

ABSTRACT

Access to portable water sources in rural and urban areas remains a serious challenge in many developing countries like Malawi. The present study was undertaken to analyze and

map groundwater salinity in shallow hand-dug well in thyolo district T/A chimaliro. The purpose of the study

ACKNOWLEDGEMENT

First and foremost I would like to thank the Lord God Almighty for His blessings and protection throughout the journey.

Special thanks to my supervisor Miss Esther Mabedi of the department of earth sciences for her tremendous supervision, valuable insights, comments, advice, and experience shared throughout the writing of this paper.

I would also wish to extend my gratitude to the Ndata School of climate and earth sciences at Malawi University of science and technology for allowing me to research this topic in the study area

It would be incomplete not to express my acknowledgments to Victor Nyambi. I appreciate your able hands to assist in various aspects of my research.

And my acknowledgments go to all village participants who took part during the study for providing necessary comments on issues of pollution and solid wastes disposal in the area

Finally, I thank my family for always being there for me with support and inspiration, especially in difficult times.

TABLE OF CONTENTS

Abstract.....6

Acknowledgments.....7

List of abbreviations.....10

List of figures.....11

List of tables.....11

1.0. CHAPTER ONE: INTRODUCTION..... 12

1.1. Background..... 12

1.2. Problem of Statement..... 13

1.3. Research Question..... 13

1.4. Objectives..... 14

1.4.1. Specific Objectives..... 14

1.4.2. Hypothesis.....14

1.5. Significance of the Study..... 14

2.0. CHAPTER TWO: LITERITURE REVIEW..... 14

2.1. Gis application on mapping hand dug wells in Malawi..... 14

2.2. Hand dug well contamination.....15

2.3. Ground water quality.....15

2.4. Groundwater quality parameter analysis.....15

2.4.1 temperature ……..……15
2.4.2. Total dissolved solids TDS ……15
2.4.3. Electrical conductivity ……...15
3.0. CHAPTER THREE: MATERIALS AND METHODS..... 17
3.1. Study Area..... 17
3.2. Sample Collection..... 18
3.2.1. Determination of Physio-Chemical Parameters ……18
3.2.1 PH, Temperature, TDS AND EC ……18
3.3. Data Analysis..... 20
3.4. Ethical considerations ……..20
4.0. CHAPTERFOUR: RESULTS AND DISCUSSION..... 21
4.1. Hand dug wells-water point facilities ……..……....22
4.2. Groundwater flow ……..……..22
4.3. Chemical composition of ground water salinity and their correlation levels ……..22
4.3.1. Temperature..... 26
4.3.2 PH ….……..26
4.3.3 Total dissolved solids TDS ……..26
4.3.4. Electrical conductivity EC ……26
4.3.5. Distribution of the major solutes.....….....26
5.0 CHAPTER FIVE: CONCLUSION AND RECOMMENDATION ……..30
REFERENCES ……...33

APPENDIX……33

ACRONYMS/ABBREVIATIONS

µS/M: Microseconds Per Meter, Unit Measure for Electrical Conductivity

ANOVA: Analysis Of Variance

CI: Confidence Interval

DO: Dissolved Oxygen

EC: Electrical Conductivity, Best Measure of Salinity

GIS: Geographical Information Systems

MBS: Malawi Bureau of Standards

Mg/L: Milligrams per Litre

PH: Hydrogen Ion Activity

SPSS: Statistical Package for Social Scientists

TDS: Total Dissolved Solids

WHO: World Health Organization

LIST OF FIGURES

Figure 1; scope of the research..... 20
Figure 2; Map of study area TA Chimaliro, Thyolo district..... 21
Figure 3: Piper diagram showing major ions compositions of the groundwater samples..... 23
Figure 4; shows the hand-dug wells where the physio-chemical properties of water were measured..... 25
Figure 5: Groundwater flow in the study area..... 27
Figure 6; showing the temperature of water samples in wells compared to WHO standards 30
Figure 7; showing Ph. for wells in the study area compared to WHO standards..... 31
Figure 8; Plot of concentrations of Electrical Conductivity for hand-dug wells in Chimaliro area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentrations in drinking water (WHO 2008)..... 32
Figure 9; Plot of concentrations of total dissolved solids (TDS) for hand-dug wells in Chimaliro area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration..... 33
Figure 10; spatial variations on levels of total dissolved solids..... 34
Figure 11; Box and Whisker plot showing the variation of major ion..... 35
Figure 12; piper diagram showing major ion composition of the groundwater samples, classified into three groups..... 36

LIST OF TABLES

Table 1: Depth statistics for the hand-dug wells..... 26
Table 2: Summary of results of physical of the hand-dug Wells water samples. All values are in mg/L except pH, temperature (°C), electrical conductivity (EC) (µS/cm), TDS (mg/l).....28
Table 3; Summary statistics of the physical parameters and compositions of groundwater samples from wells..... 29
Table 4; Summary of results of the chemical composition of the hand-dug Wells water samples..... 29
Table 5; Summary statistics of the Chemical compositions of wells water samples.....29

1.0. CHAPTER ONE: INTRODUCTION

1.1. Background

Groundwater constitutes the largest readily available freshwater reserve on earth. Unfortunately, in many countries around the world, including Malawi, water has become a scarce commodity as only a small proportion of the population has access to treated water with a large population depending on hand-dug wells. A Well is an excavation or a structure created in the ground by digging, driving, boring, or drilling to access groundwater in underground aquifers,(Philip victor mintah, 2011). Shallow dug wells are constructed in places where possibilities of high groundwater recharge are available at shallow depth. These wells get recharged from the available seepage. all peoples, whatever their stage of development and social and economic condition, have the right to have access to drinking water in quantities and of a quality equal to their basic needs (WHO, 1997a).

A challenging problem which arises in the rural areas heightens the issue of water supply concerning available water quantity and quality, (Molden et al., 2000). While hand-dug wells have been used as a household water supply source for many years, consequently, there is an alarming gap between consumption and potentially available safe water resources (O & Peace, 2015). A recent theoretical development in Malawi by Jabulani Matsimbe, (Matsimbe, 2020) has revealed that residents in Bangwe Township use water from hand-dug wells for consumption which has coliforms that exceeded the recommended guideline values for drinking water according to the World Health organization and Malawi Bureau of standards. Again, water access is measured by the percentage of the population with access to safely managed water service by the rural population where the term “safely managed” implies

protecting supplies from excreta and other forms of contamination that's ensuring water is safe to drink (MW

The concentrations of major solutes vary widely, suggesting that the water chemistry is controlled by normal water-rock interaction and mixing with the saline groundwater. This means that the presence of highly mineralized groundwater renders groundwater resources in large areas unsuitable for domestic and irrigation purposes,(Monjerezi & Ngongondo, 2012). According to (Philip victor mintah, 2011), there is a growing appeal that the quality of the well water can be significantly increased by following common technique of lining the Well, sealing the wellhead, fitting a self-priming hand pump, constructing an apron, ensuring the area is kept clean and free from stagnant water and animals. These techniques have potential to solve contemporary problems in preventing surface contaminates effecting the wells. During this study, some physicochemical properties and parameters of water from hand-dug wells were determined and evaluated. The purpose of this study was to analyze and map groundwater salinity in shallow hand-dug wells in areas of thyolo district, Malawi

1.2. Problem of Statement

The quality of drinking water has become a major concern in Malawi,(Matsimbe, 2020). Most of the people living in villages are becoming increasingly dependent on wells, which have doubtful water quality, especially during the dry or rainy season. The villages have no standard treated piped water supply system but depend on the hand-dug wells. Due to this limited water supply, most people depend on rainwater or hand-dug Wells constructed in the villages as alternatives. These hand-dug wells are even spatially distributed. The hand-dug well sources are to a large extent exposed to contaminants such as bacteria, viruses, metals, nitrates, and salts that have polluted water supplies because of inadequate treatment and disposal of waste of humans and livestock, (Nkansah et al., 2010). The inhabitants of the villages also rely on agricultural activities such as tea, maize, and tobacco with high possibilities of using chemicals such as pesticides and fertilizers in the agricultural land. There is no literature on the water quality of the hand-dug wells in villages of the T/A Chimaliro area. To add to that, this topic has been selected to understand the levels of salinity in wells in the study area as most inhabitants in the area think hand dug wells are a source of portable water.

1.3. Research Question

The research answered the following questions;

i. What is the depth and elevation of the water table on each water point facility?
ii. What is the direction of groundwater and contaminants flow?
iii. What is the chemical composition of groundwater salinity in the study area?

1.4. Objectives

To analyze and map groundwater salinity in shallow hand-dug wells in villages of traditional authority Chimaliro.

1.4.1. Specific Objectives

- To map the hand-dug wells in the study area
- To determine the groundwater flow direction in the area
- To analyze the Physio-chemical composition of groundwater salinity

1.4.2. Hypothesis

- Ho: Salinity levels on wells in the T/A Chimaliro area in Thyolo District do exceed permissible drinking standards set by the Malawi Bureau of Standards (MBS) or WHO.
- Ho1: There is no significant salinity difference across the hand-dug wells

1.5. Significance of the Study

The knowledge generated from this study will provide useful data for effective groundwater quality monitoring programs in Malawi and it will render service to others exploring similar groundwater studies. Furthermore, the study will provide useful data for sustainable land use planning, agricultural strategies and crop selection, water supply management, and water security.

2.0. CHAPTER TWO: LITERATURE REVIEW

2.1. Gis application on mapping hand-dug wells in Malawi

A large number of existing studies in the broader literature have examined the application of geographical information systems (GIS). Lately, it has become increasingly in use during water samples collections in shallow hand-dug wells, which means the locations of the hand-dug wells are recorded by using a hand-held Global Positioning System (GPS). In realization

of this significant role, groundwater flow direction, recharge, and discharge zones are being geo-referenced

2.1.1 General Groundwater flow mapping

The groundwater flow direction of the catchment is identified by using groundwater level maps. According to groundwater flow lines and contour maps, groundwater flows from the highland part of the catchment towards the plain areas or lower areas direction, (Messene et al., 2017). Generally, aquifers in Malawi have a limited lateral extent with a lenticular shape. Messene et al., (2017), documented that groundwater recharge, discharge, and intermediate zones of the catchment are mapped based on different indicators, are; topography, groundwater flow pattern, and static groundwater levels. (Nilawar, 2015), also articulated that among these indicators, topographic elevation is the simplest to tell the water flow direction. This is suggesting that topography is a major factor that has to be considered for delineating the recharge and discharge zone, as this tells that high land areas are an indicator of recharge areas.

The divergence and convergence of vector flow lines is an indicator of the recharge and discharge areas respectively in general. This statement is in agreement with what (Oborie & Nwankwoala, 2017) stated that three wells are needed for triangulation. The hydraulic head of the three well locations are joined through straight lines and differences in hydraulic head between the wells are determined. Furthermore (S Suganthi1, 2013) stated that the elevation differences are divided into equal increments by adding the initial water level to each increment of the topographic contours. Straight lines connecting the areas of increments on the contours which have the same values are drawn.

Generally, this knowledge has been used in this research when doing map visualization of the spatial location of the hand-dug wells and the groundwater flow in the areas of traditional authority Chimaliro to represent the water table contours. Therefore, groundwater would flow from higher elevation to lower elevation in the direction of maximum change in elevation contour. This study is in agreement with previous studies that the line perpendicular to the straight lines which connect the elevation increments indicates the direction that the groundwater flows (Oborie & Nwankwoala, 2017). To add on that, some authors, (Twumasi & Kwang, 2017) have noted that a preferred site for hand-dug wells would be on the level

ground in the middle of the plain and suggesting that the worst location would be on the top of a steep narro

2.2. Hand-dug well contamination

Any addition of undesirable substances to groundwater by human activities or natural sources is considered to be contamination. Most of the bacteria, viruses, parasites, and fungi that contaminate well water come from fecal material from humans and other animals, (Philip victor mintah, 2011). Consuming such waters could cause intestinal infections, dysentery, typhoid fever, cholera, and other illnesses. According to (Philip victor mintah, 2011) Contamination of the wells increases during the rainy seasons where the aquifer or water table rises more rapidly hence both vertical and horizontal migrations of water are accelerated. Furthermore, old wells, which are constructed by hand and cased with rocks or bricks usually have large openings. This makes it easier for some surface excreta's coming from flood water to get or fall in that well. This amount of water acts as a transport vehicle to carry contaminants to the groundwater,

2.3. Groundwater quality

In Malawi, the circumstances of the water supplies of the rural areas of Malawi are derived from shallow hand-dug wells or hand-pumped boreholes. According to a study made by (Hellens, 2013), little documentation on the chemical parameters of aquifer groundwater has been done. Determination of physical and chemical quality serves to provide a guide on the quality of groundwater for all purposes. In the case of poor quality, the results help in identifying and prescribing the water-borne health implications in an area,(Mapoma & Xie, 2014). Groundwater compositions appear to be spatially variable and highly dependent on aquifer lithology. Some shallow wells dry up in the dry season forcing people to use surface water (e.g. rivers) which are grossly contaminated. Contamination of shallow wells is due to sanitation facilities being close to the wells (Molden et al., 2000). Contaminants such as bacteria, viruses, heavy metals, nitrates, and salt have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-use of limited water resources,(Nkansah et al., 2010).

Groundwater has excellent natural microbiological quality and generally adequate chemical quality for most uses. Nine major chemical constituents (Na, Ca, Mg, KHCO3, Cl, SO4, NO3, and Si) make up 99% of the solute content of natural groundwaters. The proportion of these

constituents reflects the geology and history of the groundwater (A M MacDonald, 2002). This means that M

2.4. Groundwater quality parameter analysis

2.4.1. Temperature

Temperature is the measure of how much heat is in the water. Temperature is important because it influences water chemistry. In general, temperatures of shallow groundwater show some seasonal fluctuation whereas temperatures of groundwater from moderate depths remain near or slightly above the mean annual air temperature of the area. As the temperature increases, the density of water molecules also increases. As the density increases, the amount of salts in the water also increases (Gibbs, 2000). Groundwater with higher temperatures can dissolve more minerals from the Surrounding rock and will therefore have high electrical conductivity. Higher water temperatures are not recommended mainly because they make drinking difficult.

2.4.2. PH

PH is a measure of the degree of acidity or alkalinity of a solution. PH influences chemical processes within the water bodies. Most substances have a pH range between 0 and 14, (WHO, 2008). Some extremely acidic or basic solutions can have a pH < 0 or pH > 14. pH is considered to be neutral when the activity of H+ ions is equal to that of OH- ions, and that is at pH=7. Low values of pH (pH<4), indicate the corrosive water that will tend to dissolve metals and other substances that it contacts. High values of pH, (pH>8 .5) indicate alkaline water that, on heating, will tend to form scale (WHO, 1997b). The pH affects the treatment and use of water.

2.4.3. TDS

TDS is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. TDS originate from natural sources, sewage, urban And agricultural run-off, and industrial wastewater, Salts used for road deicing can also contribute to the TDS loading of water supplies (WHO, 1997b). The principal Constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, chloride, sulfate, and nitrate anions. The presence of dissolved solids in water may affect its taste and hardness, (Ravikumar et al., 2015).

2.4.4. EC

Conductivity is a measure of the ability of water to pass an electrical current. When salts and other inorgani

3.0. CHAPTER THREE: MATERIALS AND METHODS

3.1. Research design

A field study was conducted in thyolo district, tradition authority Chimaliro which mainly focused on the experiment of the water quality and quantifying well locations and the ground water flow in the villages of Nantheleza, Mina, Mitabali, and Mangaazi. This involved collection of water samples, coordinates capture (using GPS) from the shallow hand-dug wells in the villages. The water samples were later taken to the lab for test. The test results were compared with both the MBS and WHO standards for drinking water while the coordinates captured were used for map visualization of the spatial location of the wells and groundwater flow. At last, the following software's the gw_chart, QGIS, and SPSS for analysis to produce the results.

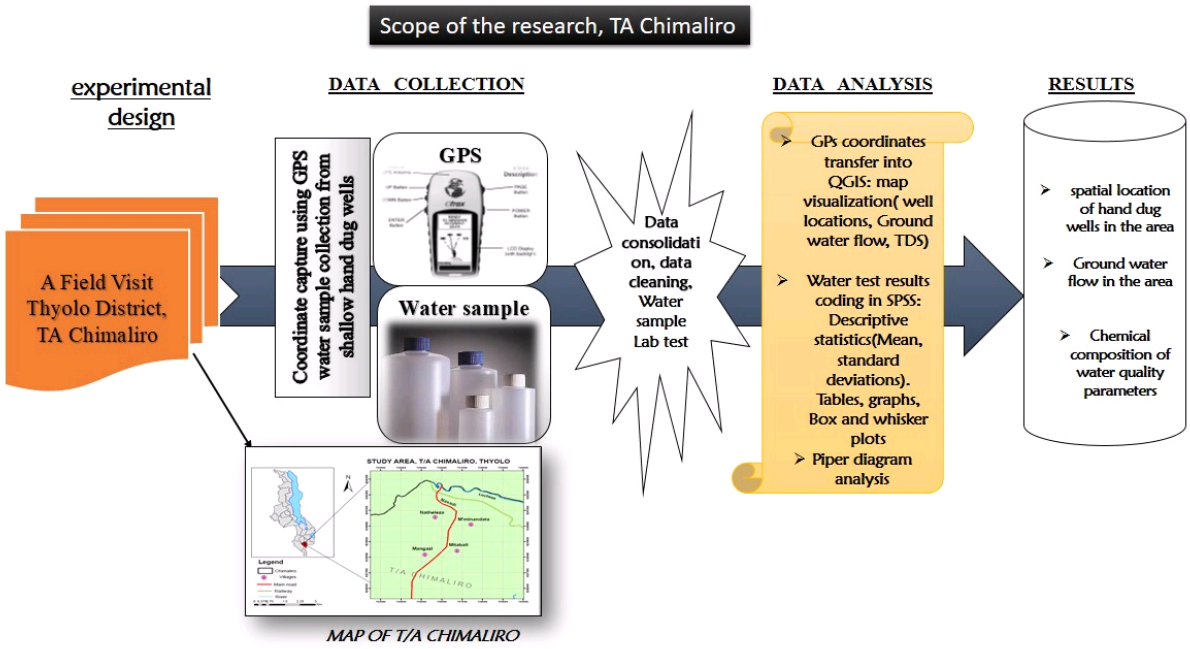


Figure 1; scope of the research

3.2. Study Area

The study was conducted in Thyolo district T/A Chimaliro in the following villages Nantheleza, Mina, Mitabali, and Mangaazi. Thyolo district is located in the southern region of Malawi. The greater part of thyolo district is underlined by what is referred to as the Malawi Basement Complex,(Habgood et.al., 1973). The Basement complex of thyolo is composed of the high-grade magmatic gneisses and granulite's which lie in the Precambrian to Lower Paleozoic Mozambique Belt. The Biotitic hornblende gneisses and Charnokitic granulite's are the dominant rock types in this area. Thyolo is also filled with a swarm of dolerite dykes which cuts the basement complex rocks on a NE – SW (north-east to south-west) trend. These

alkaline dykes of the late Jurassic to early cretaceous are assigned to the Chirwa alkaline province and thes

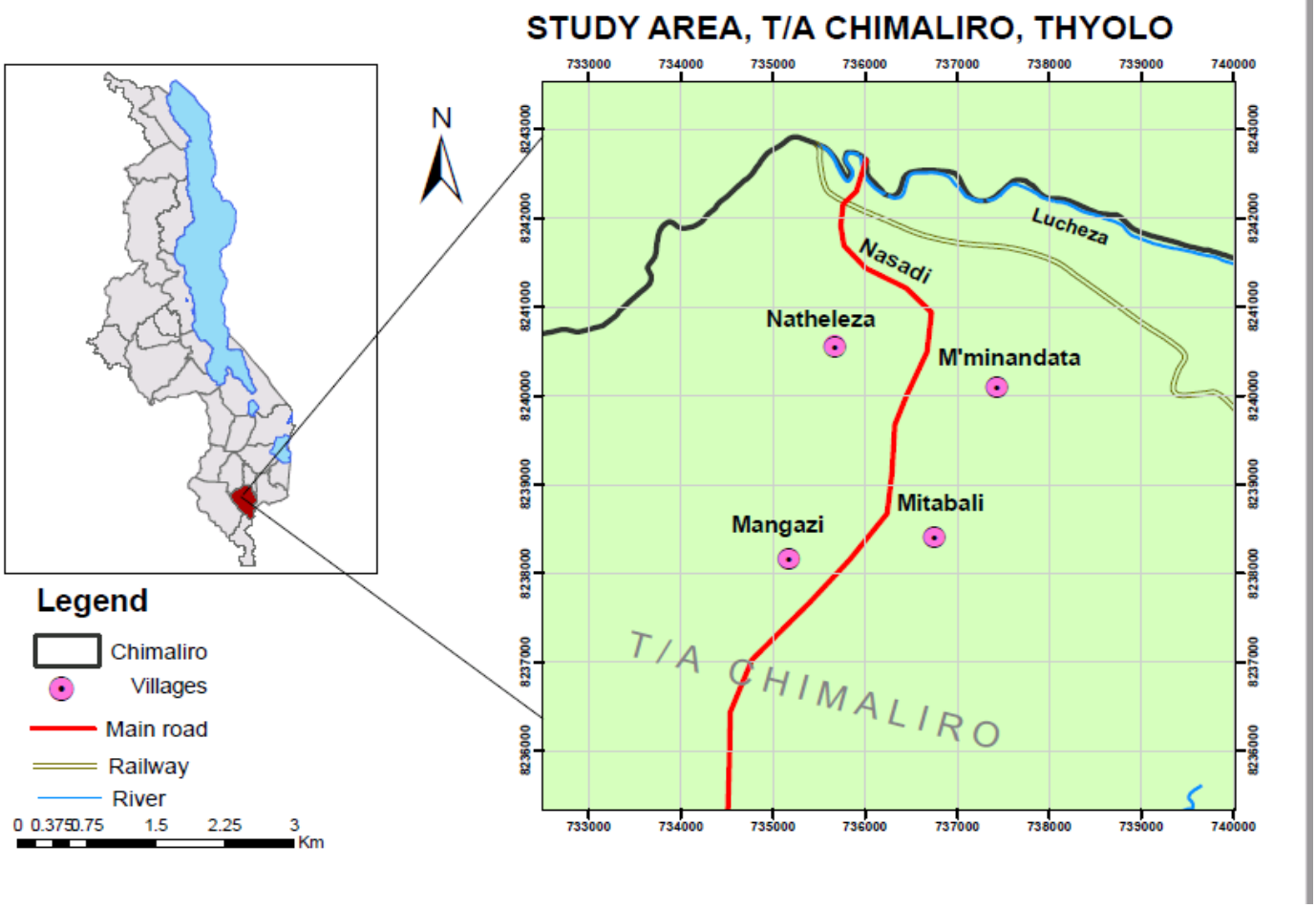


Figure 2; Map of study area TA Chimaliro, Thyolo district

3.3. Sample Collection

Fieldwork: a total of 12 groundwater Samples were purposively collected from five shallow

wells and in the following villages: M'minaNdata, Nanthereza, Mitabali, and mangazi. Sample collection was

The second sample set was collected in 250ml sterilized glass bottles for further chemical analysis of inorganic ions. The glass bottles were first rinsed with distilled water and then rinsed three times with the sampled water at the sites before sample collection. Immediately after drawing water in the glass bottles, drops of Nitric acid (HNO3) to pH < 2 were poured to fix metals in the water. The bottles were labeled with unique identification numbers using a permanent marker. Then the samples were stored in a hard cartoon to protect them during transportation. The samples were sent to Blantyre central water lab for chemical analysis.

Lab work: the samples were filtered through 0.45µm membrane filters and later on stored at 4^{o}C before chemical analysis. The samples for major cations were acidified. All the acidified samples were transferred into 2 unused HDPE bottles for major cation and analyses using the flame atomic absorption spectrophotometer method. The major cations include magnesium, calcium, sodium, potassium. The un-acidified samples were also transferred into 125ml unused HDPE bottles for analyses of major anions using ion-exchange chromatography (IC). The major anions include sulfate, chloride, carbonate, bicarbonate: All these analyses were to determine the concentration of each element in the sampled groundwater. The coordinates of the water point facilities were recorded using the handheld GPS device. The depth (m) of the water table was measured using the measuring tape.

3.2.1. **Determination of Physio-Chemical Parameters**

3.2.1 PH, Temperature, TDS, AND EC

Water quality parameters including pH, TDS, and electrical conductivity (EC) were recorded at each water point to see if concentration changes with time. Immediately after drawing groundwater samples, pH, temperature (0C), total dissolved solids (TDS) in mg/L, and electrical conductivity (EC) in Ns/cm were determined using a Multi-probe meter. A Multi-probe meter was inserted in the groundwater sample and the Reading was recorded after 3 minutes when the readings stabilized.

3.4. Data Analysis

To make sense out of the data collected, the results of measured water quality parameters during the exper

Piper diagram analysis

The piper diagram analysis, also called the trilinear diagram is a combination of plotted proportions (in meq/l Or mg/L) of anion and cation triangles that lie on a common baseline, (Aboulhassan & Amhamdi, 2017). This diagram shows similarities and differences among the water samples. For example, those with similar qualities will tend to fall into the same group, (Saha et al., 2019). This graphical way of presenting the water analysis is significant for several factors; first for the researcher to make proper conclusions and recommendations about the origin of water samples, again for the researcher to identify the mixings between the two end-members hence displaying the type of hydro chemical facies. See figure below

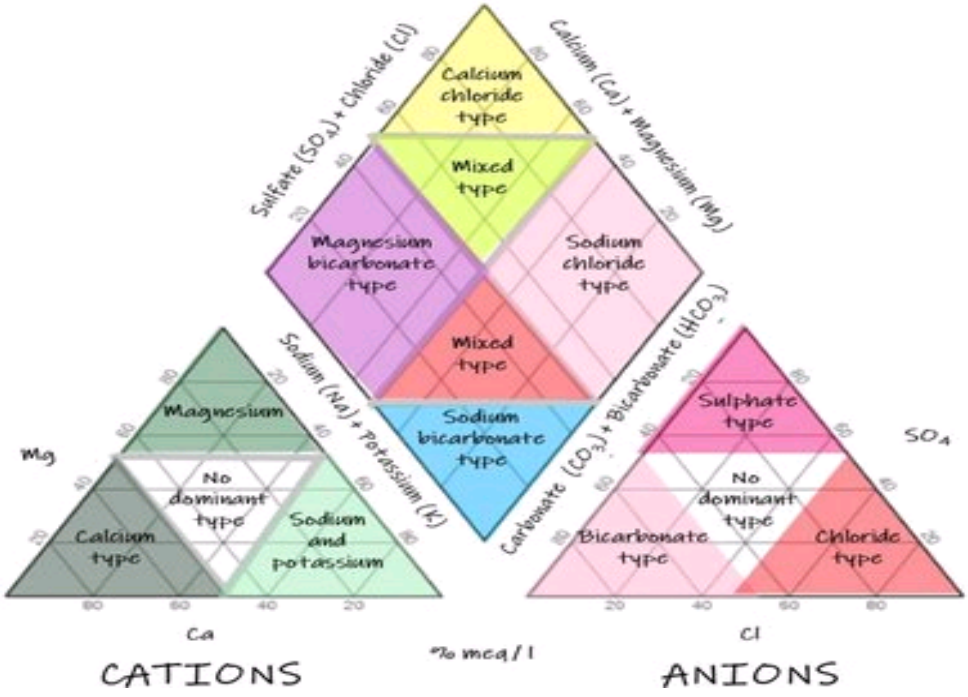


Figure 3: Piper diagram showing major ions compositions of the groundwater samples (https://hatarilabs.co

ArcGIS 10.5 software was used to generate all maps, that's, sample location of the study area, groundwater flow contour map, and total dissolved solids map

3.5. **Ethical considerations**

Before the field visit was conducted, ethical clearance was obtained from the Malawi University of Science and Technology Research Ethics Committee (MUSTREC). The purpose of the study was explained to the study respondents living around the water point facilities (shallow and hand-dug wells). The study respondents were told that the information they provided will be kept confidential and that their identities would not be revealed in connection with the information they provide. Permission from the chiefs of the area was obtained. For this research, all subjects were informed verbally about the nature and benefits of the study. Respondents were encouraged to participate freely and voluntarily. This is because in some cases, human involvement may cause physical, psychological, social, or economic harm to the participants. This served the purpose of building trust and understanding, honoring the rights and dignity of the study respondents.

4.0. CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. Hand-dug wells-water point facilities

The study was conducted in Traditional Authority Chimaliro in thyolo district in Malawi. The samples were collected from four villages (Nantheleza, Mina, Mitabali, and Mangaazi). Six shallow wells were identified and mapped. The collected spatial information was generated into layers to create a GIS water point map to show the spatial distribution of the hand-dug wells. s with some part of the village's location having two water points compared to other villages having one hand-dug well, which are relatively drier.

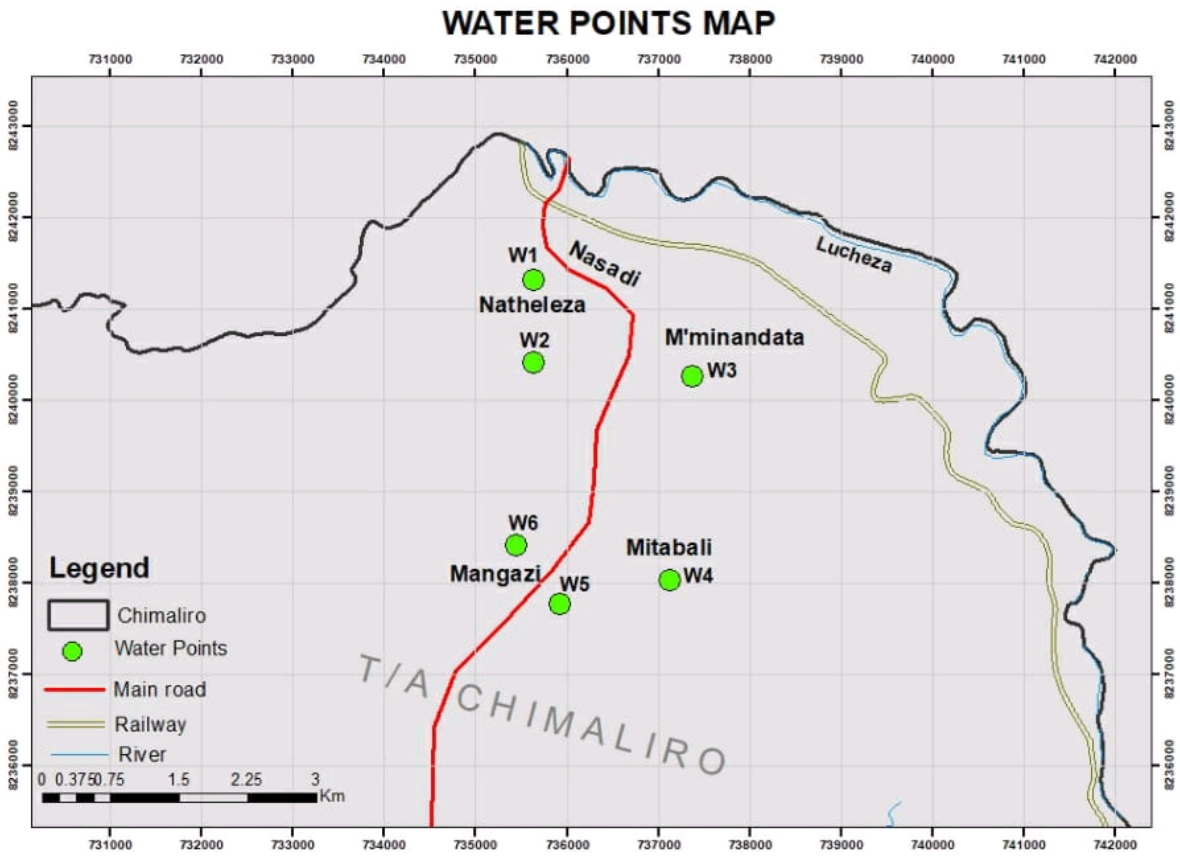


Figure 4; shows the hand-dug wells where the physio-chemical properties of water were measured

From the short review above, the study considered the depth of the hand-dug wells. Key

findings emerging indicated variation in-depth for wells. Some water wells were too shallow and normally so

Table 1; Depth statistics for the hand-dug wells

Well code (water point)		well depth (m)
	w1	2.7
	w2	3.0
	w3	1.3
	w4	1.5
	w5	1.8
	w6	3.6
Mean		2.31667

The general findings indicate that in well W1, W3, W4, W5 with a water depth of 2.7m, 1.3m, 1.5m, 1.8m respectively, these wells would be most susceptible to contaminations by anthropogenic activities which include the use of fertilizers, manures, and pesticides. This is contrary to the wells on W2, W6 with a depth of 3m, 3.6m, respectively, these wells are susceptible to contaminations by geological processes.

Among the reported factors that influence the depth of wells is the level of the water table, the existence of hard rock beneath makes it difficult to dig the ground. It is therefore advised that siting and developing wells in shallow sand and gravel deposits with water tables less than 3 meters below the surface be avoided, (Twumasi & Kwang, 2017).

4.2. GROUNDWATER FLOW

Three-point methods of interpolation were used to create groundwater table contours in a GIS software for the selected hand-dug wells. The digital elevation model (DEM) was used to create

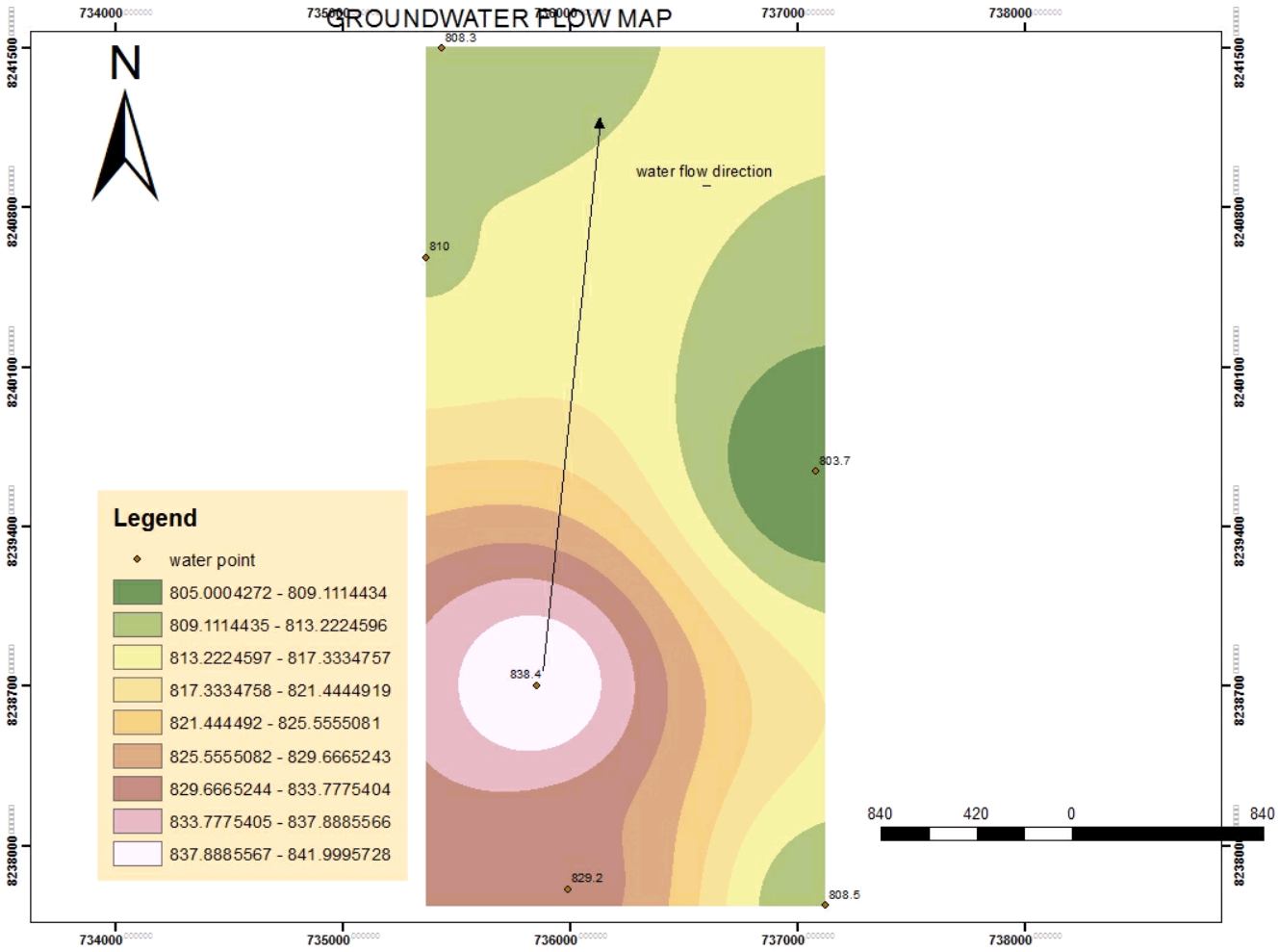


Figure 5; Groundwater flow in the study area

Surface elevation contours. The groundwater in the area flows in different directions (figure5). This is because the area is surrounded by the Lichenza River. Groundwater would

flow from higher water table elevation to lower water table elevation in the direction of maximum change in

4.3. Physio-Chemical composition of groundwater salinity

Results of measured water quality parameters during the analysis are summarized in the tables below. The results of Sulphate, Chloride, bicarbonates, carbonates, calcium, potassium, and sodium in (table 4) for a shallow hand-dug wells (W1, W2, W3, W4, W5, W6) indicates that all groundwater samples were below as they did not exceed standards as prescribed by, (WHO, 2008). The low presence of such chemicals in groundwater and surface water is usually attributed to low atmospheric sources, decomposition of organic matter, and trace impurities in rocks and minerals (Aboulhassan & Amhamdi, 2017).

Table 2: Summary of results of physical of the hand-dug Wells water samples. All values are in mg/L except pH, temperature (°C), electrical conductivity (EC) (µS/cm), TDS (mg/l)

Well code (water point)	EC (s/m)	TDS (mg/l)	PH values	Temperature
	.	.	.	.
WP1	296.0	197.0	6.900	25.35
WP2	583.5	378.5	7.510	25.20
WP3	880.0	638.0	6.735	24.25
WP4	813.0	515.0	6.645	26.85
WP5	838.0	544.5	6.755	25.65
WP6	1794.0	1231.0	7.000	26.75
WHO STDS	400.0	1000.0	7.500	25.00

Table 3; Summary statistics of the physical parameters and compositions of groundwater samples from wells

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation

Temperature	12	24.25	26.85	25.6750	.98982
PH values	12	6.6450	7.5100	6.924167	.3136466
TDS (mg/l)	12	197.0	1231.0	584.000	352.0925
EC (s/m)	12	296.0	1794.0	867.417	503.9181
Valid N (list wise)	12				

Table 4; Summary of results of the chemical composition of the hand-dug Wells water samples

	SULPHATE	CHLORIDE	BICARBONATE	CARBONATE	MAGNESIUM	CALCIUM	POTASSIUM	SODIUM
WP1	56	36	284	6	18	79	.6	32
WP2	44	31	220	4	12	64	.3	28
WP3	32	24	156	2	8	54	.8	22
WP4	18	27	179	13	10	48	.6	24
WP5	13	32	184	8	8	54	.9	28
WP6	38	74	462	6	2	102	.4	68
WHO	800	750	600	250	200	250	200	500

Table 5; Summary statistics of the Chemical compositions of wells water samples

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
SODIUM	6	22	68	33.67	17.178
POTASSIUM	6	.3	.9	.600	.2280
CALCIUM	6	48	102	66.83	20.381

MAGNESIUM	6	2	18	9.67	5.279
CARBONATE	6	2	13	6.50	3.782
BICARBONATE	6	156	462	247.50	114.189
CHLORIDE	6	24	74	37.33	18.435
SULPHATE	6	13	56	33.50	16.121
Valid N (listwise)	6				

4.3.1. Temperature

The measured temperature values of water samples from all the water points ranged from 24.25-26.85^{0}C refer (to table 3). The average temperature for all water points was 25.65^{0}C. The results also indicated that W4, w5, and w6 had higher temperatures. Higher temperatures are not recommended for drinking purposes.

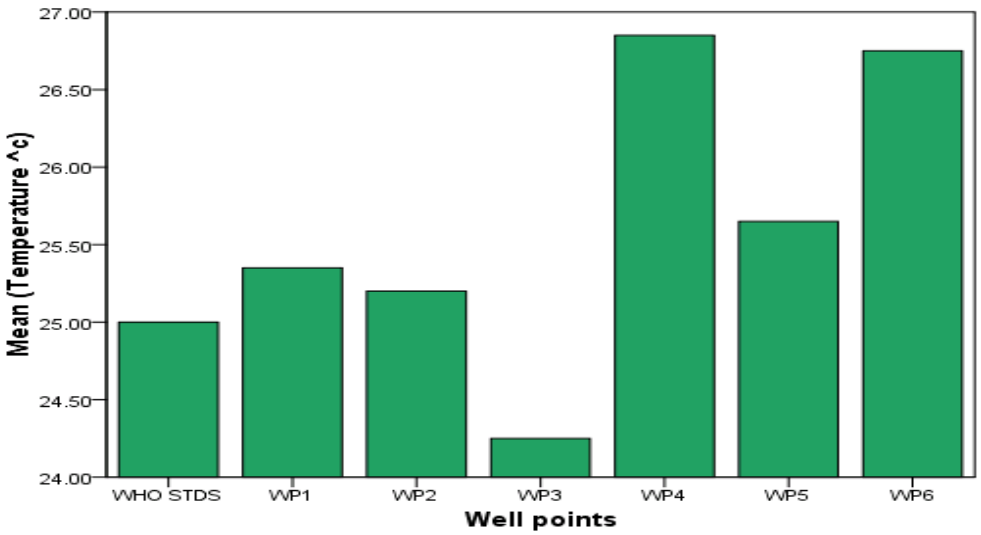


Figure 6; showing the temperature of water samples in wells compared to WHO standards

4.3.2. PH

The results in (Table 3) show that the water pH ranged from 6.735-7.51 for all the water points. The averag

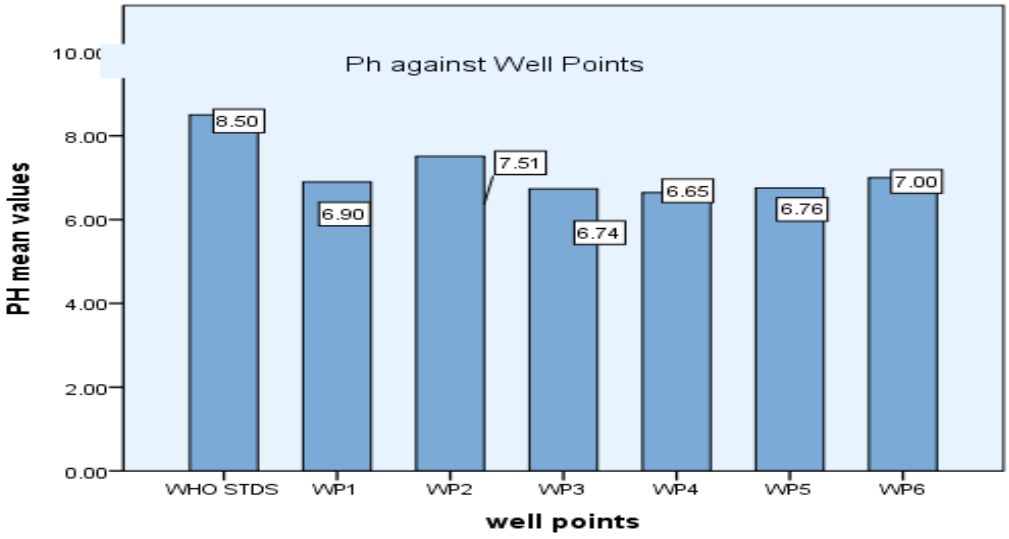


Figure 7; showing Ph. for wells in the study area compared to WHO standards

4.3.3. EC

According to (table 3) above, the study recorded a maximum EC value of 1794 µS/m and a minimum of 296 µS/m. The results show that w1 had EC of 296 µS/m, w2: 583.5 µS/m, w3: 880 µS/m, w4:813 µS/m, w5: 838.5 µS/m, w6: 1794 µS/m. Therefore, the average EC of water from all water points was 867 µS/m. The results show that the values of EC w6, were not within the allowable limit of 70-150 µS/m (Malawi Standard214, 2005) and 400 µS/m by WHO for drinking water. As reported in the literature (ErnestA.,2013), high EC values imply that the Water sources had a lot of inorganic dissolved solids like nitrate, sulfate, and Phosphate anions or cations like sodium, potassium, magnesium, and iron. The causes of the increase in the EC values in the study area are attributed to the geological factors of the area because Statistics do not show any correlation of EC values with values of pH, and Temperature. The area has weathered, and unconsolidated alluvial aquifers surrounded by dolerite dykes. Dissolution of a large amount of Calcium and Sodium into groundwater hence

increasing the TDS and EC

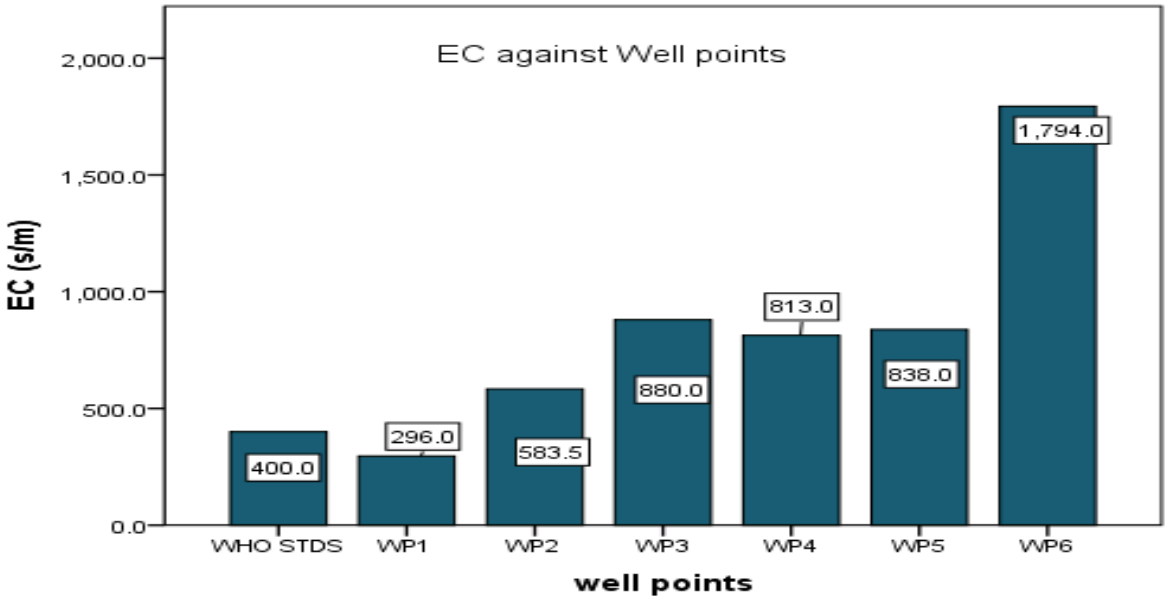


Figure 8; Plot of concentrations of Electrical Conductivity for hand-dug wells in Chimaliro area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentrations in drinking water (WHO 2008)

4.3.4. Total dissolved solids (TDS)

About tables 2 and 3, the results show that TDS for w1 was 197 mg/L, w2: 378 mg/L.5, w3: 638 mg/L, w4: 515 mg/L, w5: 544.5 mg/L, w6: 1231 mg/L. The average TDS of water was 584.08 mg/L. Based on the results, the TDS for groundwater in w1, w2, w3, w4, and w5 were within the recommended range by WHO from 500-1000mg/L (WHO, 2008) and 450-1000mg/L by MBS (MBS, 2017) for drinking water and this indicates freshwater. W6 water is Brackish with slight saline Based on the TDS concentration allowed for drinking water, w6 exceeds the prescribed limit of 1000 mg/L.

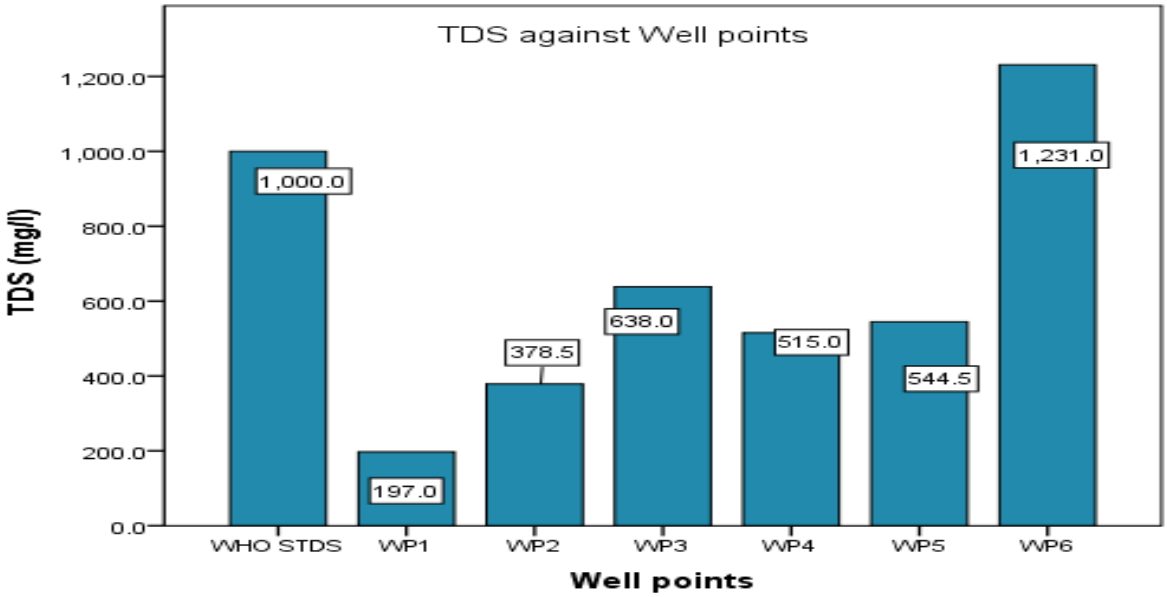


Figure 9; Plot of concentrations of total dissolved solids (TDS) for hand-dug wells in Chimaliro area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration

The figure below shows the distribution of total dissolved solids (TDS) over the distribution of salinity in the area. The TDS distribution suggests that groundwater chemistry is controlled by several mixing processes. This indicates that some samples with high salinity (and high major ion content) can be attributed to those whose chemistry was locally affected by saline groundwater mixing and others (Monjerezi & Ngongondo, 2012). In line with that particular study, this study reveals that a cumulative distribution of TDS is being examined to group the water Well samples based on salinity. Results for TDS (table above) were then used to group the Well samples into three major populations. Group I samples from wells (W1, W2,) was characterized as low saline water, representing 33.3% of all samples. Group two samples from well (W3, W4, W5) were characterized as medium salinity representing 50% of all

samples, and group 3 samples from wells (W6) were characterized as high saline water fresh groundwater

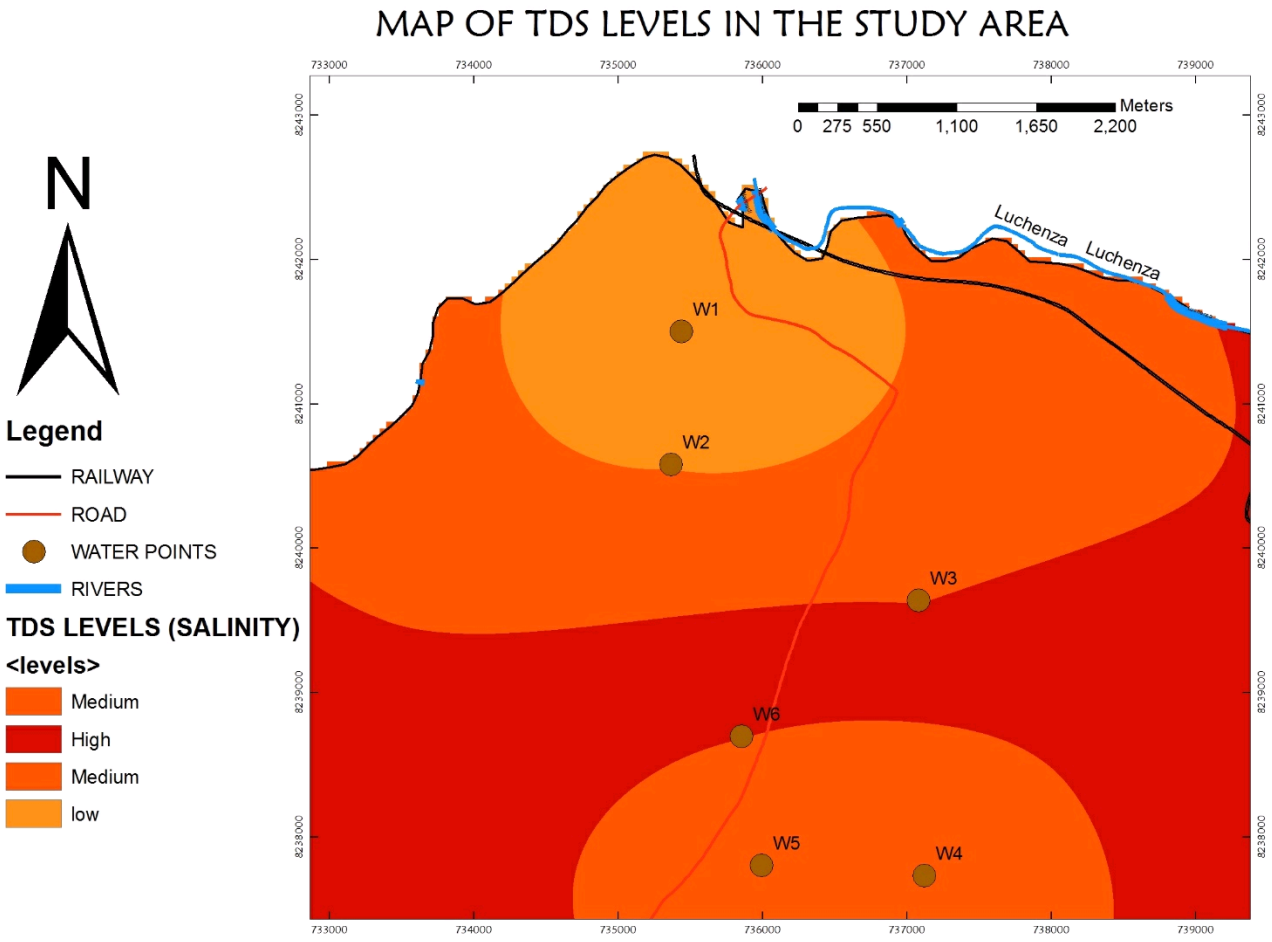


Figure 10; spatial variations on levels of total dissolved solids

4.3.5. Distribution of the Major ions

The distribution of concentrations of the analyzed solutes is shown as box plots, Figure 11.

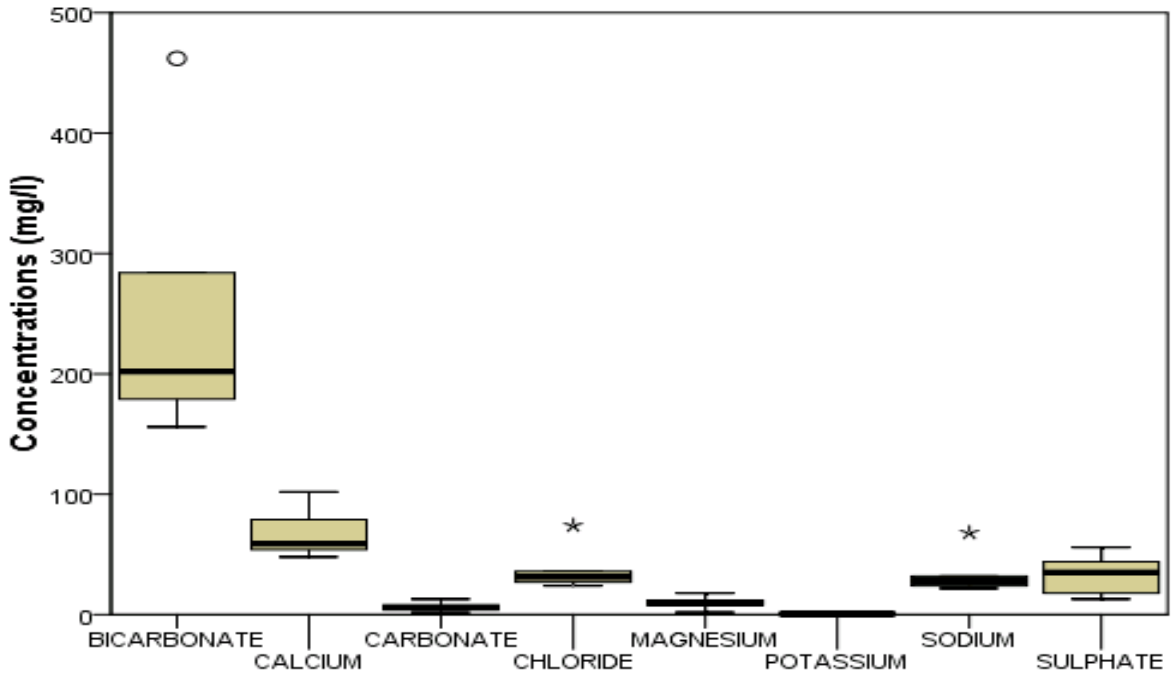


Figure 11; Box and Whisker plot showing the variation of major ion

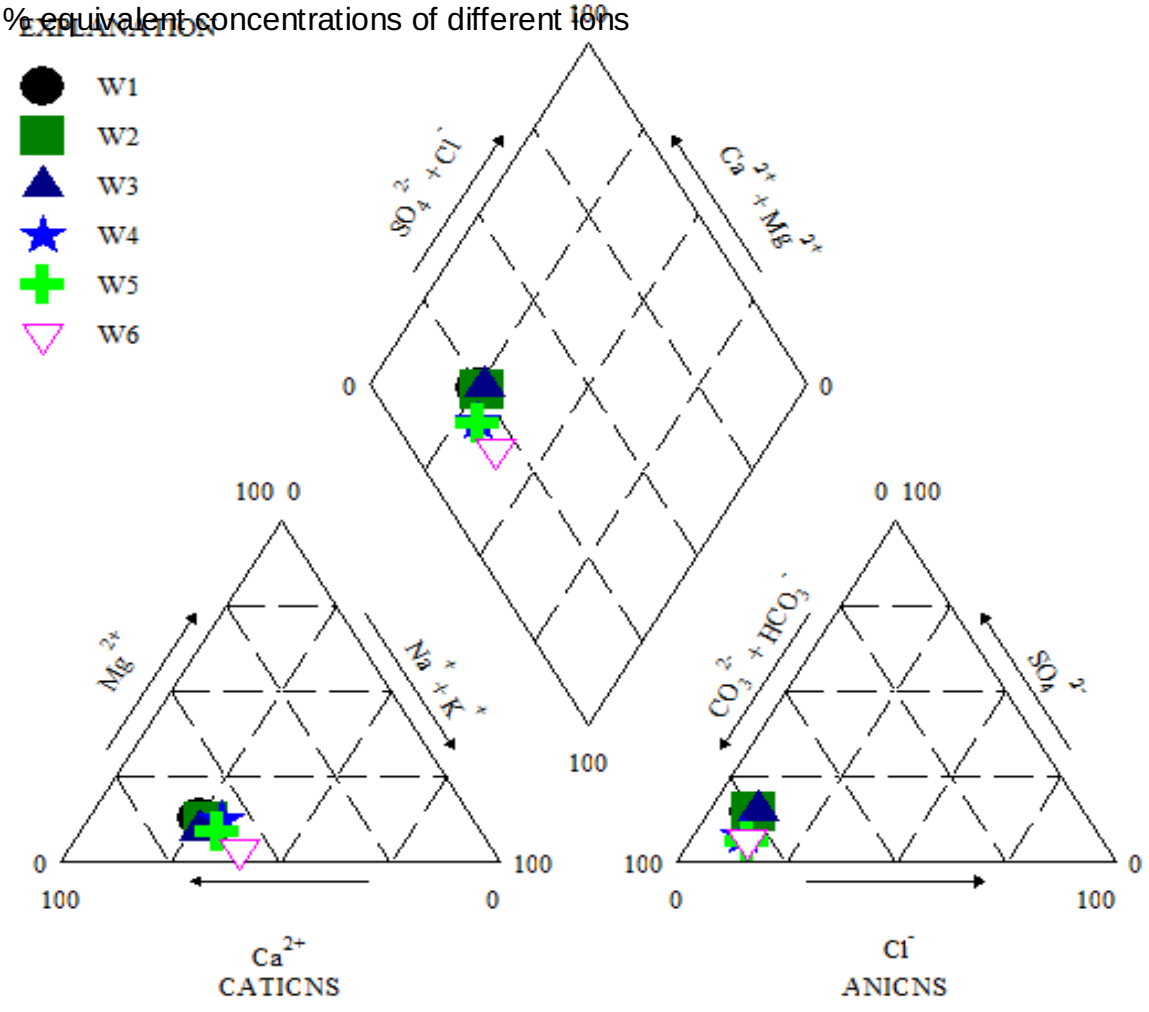
The ranges of sodium (Na+) and Chloride (Cl−) ions were from 22 mg/l to 68 mg/l (mean: 33.67mg/l), and 24 mg/l to 74 mg/l (mean: 37.33 mg/l), respectively. The concentration of Sulphate SO42− also varied widely from 13 mg/l to 56 mg/l (mean: 33.50 mg/l). The ranges of Calcium (Ca2+) and Magnesium (Mg2+) ions were from 48 mg/l to 102 mg/l (mean: 66.83 mg/l), and 2 mg/l to 18 mg/l (mean: 9.67 mg/l), respectively. The concentration of Bicarbonates HCO3−, and Carbonates (CO3−) also widely varied from 156 mg/l to 462 mg/l

(mean: 247.50 mg/l), and 2mg/l to 13mg/l (mean: 6.50). Such ranges of solute concentrations suggest that

4.3.6 Groundwater type

The proportions of major solutes in natural water provide the basis for naming the water type. The concentrations of major ions measured in the studied water samples are presented in the Piper plot, (Figure 12) below. Groundwater is classified into different types according to the percentage of chemical constituents present in it. This difference in groundwater rose mainly from different kinds of rock water interaction. Groundwater samples in the study area were separated into hydro chemical fancies according to the ions which make up 50% of the total ionic charge. All samples (100%) were classified as calcium magnesium bicarbonate type. This type of water is associated with medium salinity,(Rivert et. al, 2018). This groundwater composition is derived from the mixture of rock weathering (dolerite), evaporation, and dissolution into the aquifer. The rocks from which this groundwater type comes are Charnokitic granulites and hornblende-biotite gneiss, these are salt-rich minerals that characterize the alluvial and weathered basement aquifers and thyolo has a weathered basement aquifer(Saha et al., 2019). The plotted figure below indicates that bicarbonate is the dominant anion for most groundwater types. Compositional types of water were identified based on % equivalent concentrations of different ions

PIPER PLOT



5.0. CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

In summary, six (6) functional wells were mapped which were used as models to assess the variation of Physio-chemical parameters that affect the hand-dug well's water salinity. More generally, the water is flowing from southwest going towards the northeast in the study area. This aspect suggested that contaminants are also flowing in the same directions. In addition, the people in the area depend on the wells as a source of potable water as there is no piped water where the people can draw clean water. The salinity levels between the six wells in the area were compared using SPSS in order to test whether this is equivalent across the well points. By using that we tested the hypothesis which revealed that there were no significant differences in salinity levels within most of the wells despite one well having a higher value.

The data reveals significant differences in a concentration of EC, TDS in some wells which exceeded the ac

With that conclusion, this research recommends that:

- Geochemical analysis of the soils should be done to determine pollution sources of groundwater salinity in the hand-dug wells
- Siting and developing hand-dug wells in shallow waters with a water tables less than 3 meters below the surface be avoided, because wastewater can easily infiltrate back down to the water table near the well and contaminate the drinking water supply. The management of the hand-dug wells should take into consideration planting grass and trees around them as a remedial measure of countering erosion and the subsequent siltation.
- Equipping and building capacity in the District Water Office for assessing the rural water situation, and storing such information for development purposes
- Ways of purifying high-level saline water should be made available as soon as possible and the ways to avoid the saline water impacts should be implemented
- More studies on assessment of groundwater quality prioritizing on salinity should be undertaken in other districts of Malawi, especially rural areas.

Limitation of the Study

- The parameters measured were limited by financial constraints and time of the study was smaller
- During the time of this study, the country was facing a healthy problem of the Covid 19, hence government restrictions were being enforced that resulted in several callbacks as some offices which were intended to get assistant were closed.

REFERENCES

A M MacDonald, J. D. and B. É. Ó. D. (2002). *Simple methods for assessing groundwater resources in low permeability areas of Africa*.

Aboulhassan, M. A., & Amhamdi, H. (2017). *Impact of anthropogenic activities on water quality in Ajdir commune (Al Hoceima , Morocco)*. *2*(Fig 1), 4724–4733.

Gibbs, S. (2000). *Salinity Note 4: How do I Test Water Salinity? 4*, 5–6.

Habgood et.al. (1973). *The geology of the thyolo area*. *22*.

Hellens, A. Von. (2013). *Groundwater quality of Malawi – fluoride and nitrate of the Zomba-Phalombe plain*.

Mapoma, H. W. T., & Xie, X. (2014). *Basement and alluvial aquifers of Malawi : An overview of groundwater quality and policies*. *8*(March), 190–202. https://doi.org/10.5897/AJEST2013.1639

Matsimbe, J. (2020). *Engineering and Technology Quarterly Reviews*. *September*. https://doi.org/10.5281/zenodo.4026763

MBS, O. F. (2017). *CATALOGUE OF*.

Messene, G. M., Core, S., & Ababa, A. (2017). *Groundwater Flow Direction , Recharge and Discharge Zones Identification in Lower Gidabo Catchment , Rift Valley Basin ,*. *7*(2), 32–39.

Molden, D., Sakthivadivel, R., & Seckler, D. (2000). *The Global Groundwater Situation : Overview of Opportunities and Challenges*.

Monjerezi, M., & Ngongondo, C. (2012). *Quality of Groundwater Resources in Chikhwawa , Lower Shire Valley , Malawi Quality of Groundwater Resources in Chikhwawa , Lower Shire Valley , Malawi*. *March*. https://doi.org/10.1007/s12403-012-0064-0

Mwamaso, A. A. (2015). *Measuring and mapping citizens ' access to rural water supply in Tanzania Measur*

Nilawar, A. (2015). *Identification of Groundwater Potential Zone using Remote Sensing and GIS Technique*. *May 2014*.

Nkansah, M. A., Boadi, N., & Badu, M. (2010). *Assessment of the Quality of Water from Hand-Dug Wells in Ghana*. *April*.

O, O. A., & Peace, J. K. (2015). *Mapping the Spatial Distribution of Water Borehole Facilities in Part of Rivers State using Geographical Information System (GIS) Techniques Mapping the Spatial Distribution of Water Borehole Facilities in Part of Rivers State using Geographical Informa*. *May 2015*, 17–21.

Oborie, E., & Nwankwoala, H. O. (2017). *Determination of Groundwater Flow Direction in Yenagoa , Bayelsa State , Nigeria*. *November*.

PHILIP VICTOR MINTAH. (2011). *DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY THE QUALITY OF WATER FROM HAND DUG WELLS IN THE AKIM ODA TOWNSHIP THE QUALITY OF WATER FROM HAND DUG WELLS IN*.

Ravikumar, P., Somashekar, R. K., & Prakash, K. (2015). *A comparative study on usage of Durov and Piper diagrams to interpret hydrochemical processes in groundwater from SRLIS river basin , Karnataka , A comparative study on usage of Durov and Piper diagrams to interpret hydrochemical processes in groundwater from SRLIS river basin , Karnataka , India*. *March*.

Rivert et. al. (2018). *A conceptual model based framework for pragmatic groundwater- quality monitoring network design in the developing world : Application to the Chikwawa District , Malawi*.

S Suganthi1, L. E. and S. K. S. (2013). *Groundwater potential zonation by Remote Sensing and GIS techniques and its relation to the Groundwater level in the Coastal part of the Arani and Koratalai River Basin , Southern India*. *17*(2), 87–95.

Saha, S., Reza, A. H. M. S., & Roy, M. K. (2019). Hydrochemical evaluation of groundwater quality of the Tista floodplain , Rangpur , Bangladesh. *Applied Water Science*, *October*. https://doi.org/10.1007/s13201-019-1085-7

Twumasi, Y. D., & Kwang, C. (2017). *GIS Aided Prospect Siting of Boreholes for Maximum Yield*. *1*(9), 4–8.

WHO. (1997a). *Guidelines for drinking-water quality*. *3*.

WHO. (1997b). *Guidelines for drinking water quality*. 51–72.

WHO. (2008). *Guidelines for Drinking-water Quality*. *1*.

APPENDICES

- Supplementary data associated with the pipe diagram analysis can be found, in the online version, at https://hatarilabs.com/ih-en/what-is-a-piper-diagram-and-how-to-create-one

Appendix 1: well water points (using a tape meter to measure the water depth and recording the results)





