ASSESSMENT OF GROUNDWATER QUALITY AND URBAN WATER PROVISION: A CASE OF TAIFA TOWNSHIP IN THE GA-EAST DISTRICT OF THE GREATER ACCRA REGION, GHANA

By

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DECLARATION

I hereby declare that this submission is my own work towards the M.Sc and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of another degree of the University, except due acknowledgement has been made in the text.

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ABSTRACT

Population growth and industrialisation have put a lot of pressure on water resources the world over. Accra, the capital city of the country, is overpopulated due to the influx of people from the various regions to seek greener pastures. The conventional water treatment facility thus, cannot meet the potable water demands of residents. Individuals have resorted therefore to managing their own water supplies and one of such resorts is to develop and harness groundwater resources through drilling of individual boreholes. The study, conducted between December 2007 and January 2008, determined the extent to which groundwater is being used as domestic water supply in Taifa, Ga-East District, Greater Accra region and also assessed the quality of the water. One hundred and twenty heads of households were interviewed using a structured questionnaire and information on demographic characteristics and the use of the ground water were recorded. Twenty two out of the 120 respondents (18.3%) had boreholes in their houses. Houses with boreholes were identified and noted. A hand-held Global Positioning System (GPS) device was used to pick the locations of the boreholes. Samples of groundwater were taken from twenty-two sites and analysed for physico-chemical parameters (namely calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulphate, chloride, total iron, manganese, fluoride, zinc , lead ,pH , total alkalinity , conductivity , total dissolved solids, nitrate ,nitrite, turbidity, phosphate) and indicators for faecal contamination (total coliforms and faecal coliforms).The groundwater was found to be acidic (pH 3.89 to 6.80) . High levels of sodium and chloride were detected at one site (270mg/l and 516mg/l respectively). Conductivity and total dissolved solids were also

high at the same site (2210μs/cm and 1216mg/l) respectively. Lead and carbonate were not present in any of the water samples, upon analyses, whereas potassium, calcium and magnesium concentrations were within their respective World Health Organisation guideline limits (30mg/l, 200mg/l and 150mg/l respectively). Total coliforms and faecal coliforms were present in 27.3% of samples. Residents generally did not know when they would get access to pipe-borne water but they however believed it was the government's responsibility to provide pipe-borne water. All respondents indicated that they used the water for cooking, bathing and washing clothes whereas 54% drank the water; the remaining 46% did not drink the water. Groundwater in the area is of varying levels of quality in terms of physico-chemical and bacteriological quality. It should therefore be regularly monitored for water quality.

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LIST OF ABBREVIATIONS

APHA	-	American Public Health Association
CSIR	-	Council for Scientific and Industrial Research
DA	-	District Assembly
DANIDA	-	Danish Development Agency
DHMT	-	District Health Management Team
EDTA	-	Ethylenediaminetetraaceticacid
EPA	-	Environmental Protection Agency
GIS	-	Geographical Information System
GMA	-	Ghana Meteorological Agency
GNWP	-	Ghana National Water Policy
GOG	-	Government of Ghana
GPRS	-	Ghana Poverty Reduction Strategy
GPRSII	-	Growth and Poverty Reduction Strategy
GPS	-	Global Positioning System
GWCL	-	Ghana Water Company Limited
GWSC	-	Ghana Water and Sewerage Corporation
LI	-	Legislative Instrument
MDGs	-	Millennium Development Goals
MWRWH	-	Ministry of Water Resources, Works and Housing
NEPAD	-	New Partnership for African Development
SPSS	-	Statistical Package for the Social Sciences
TDS	-	Total Dissolved Solids
U.S.A	-	United States of America
UNEP	-	United Nations Environment Programme
UNESCO	-	United Nations Educational, Scientific and Cultural Organisation
WHO	-	World Health Organisation
WRC	-	Water Resources Commission
WRI	-	Water Research Institute

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And to all who helped me in diverse ways to produce this work, I say, thank you.

DEDICATION

To Abbie and Kofi. You make it all worthwhile.

CHAPTER ONE - INTRODUCTION

1.1 Introduction

Population growth and urbanisation have put a lot of pressure on water resources the world over. Both surface and ground water resources are in high demand in order to meet the needs of the ever-growing population. This has resulted in public water provision being woefully inadequate, especially, with the rapid expansion of new housing developments, often, far ahead of utility services, especially in the urban areas. Individuals have therefore resorted to various means of gaining access to and managing their own water supply such as drilling of individual boreholes and rainfall harvesting. In Ghana, due to rural-urban migration, the urban communities are highly populated (GOG, 2007). This has made the potable water supply inadequate to meet the high demand for water by the populace. Cost of potable water supply is also an issue worth considering in the choice of water supply option of the individual.

Accra (in the Greater Accra region), the capital of Ghana, is overpopulated due to the influx of people from the various regions to seek greener pastures. Out of the ten regions of Ghana, Greater Accra Region has the highest annual growth rate of 4.4%, as compared with the average growth rate of 2.7% for the whole country (GSS, 2000). The conventional water treatment facility thus, cannot meet the potable water requirement of the city. In Accra, individuals have resorted to providing their own water supplies by harnessing groundwater resources through drilling of boreholes. Groundwater has been an essential source of drinking water for the rural and urban communities.

Groundwater can be contaminated naturally or through human activity. Residential, municipal, commercial, industrial and agricultural activities can all affect groundwater quality (US EPA, 1993).

1.2 Problem Statement

Population explosion in Accra has led to limited supply of potable water supply provided by the Ghana Water Company. Only few suburbs have access to this pipe-borne water (GOG, 2007). Some do not even have service lines in their area, especially, the peri-urban communities. This has resulted in individuals drilling boreholes to gain access to potable water. Those who cannot afford the cost of drilling boreholes tend to buy water from those who have it. People now build on small pieces of land and mostly there is not much space left to accommodate both a borehole and a septic tank. The siting of these boreholes close to septic tanks can cause contamination of the water. This is because seeping of septic tank effluent into the ground water may cause diseases such as cholera when the water is used for drinking purposes.

In developing countries, the incidence of diarrhoeal diseases attributed to water consumption varies substantially between communities because of varying water quality and other behavioural and socio-economic factors (Esrey *et al*. 1991).

The geology of the area also determines the type of mineral elements and the physico-chemical parameters that may characterise the ground water quality in the area.

Taifa, a suburb of Accra, lacks pipe-borne water. The inhabitants have resorted to the use of groundwater abstractions from boreholes.

1.3 Significance of the study

The results of the study will serve as baseline information on groundwater quality in terms of some selected physico-chemical parameters and microbiological parameters. The data obtained may also assist in advising government on policy regarding regulation for private groundwater provision in the country and also advise on monitoring of groundwater quality for both domestic and commercial use in the country.

1.4 Objectives

Main objective

To determine the groundwater quality in Taifa, Ga-East District and assess the extent to which groundwater is being used as domestic water supply.

Specific objectives:

The Specific objectives were to:

1. Spatially locate the boreholes using a Global Positioning Service device and relate some selected water quality indicators to the geology of the study area.
2. Assess the microbiological quality of the groundwater.
3. Determine the concentrations of the chemical parameters of groundwater and values of the physical parameters.
4. Compare the water quality indicators obtained with their respective World Health Organisation guidelines and discuss their importance to public health.
5. To assess the extent to which ground water is used for domestic purposes and make recommendations on urban water provision.

CHAPTER TWO - LITERATURE REVIEW

2.1 Introduction

Groundwater is increasingly becoming the source of drinking water for inhabitants of both rural and urban settlements due to intermittent water shortage which has been hitting most parts of cities. The United Nations declared 1981-1990 a water-and-sanitation decade (WHO, 1987). It has been estimated that lack of clean drinking water and sanitation services leads to water-related diseases globally and between five to ten million deaths occur annually, primarily of small children (Snyder and Merson, 1982).

In Accra, the Ghana Water Company Limited (GWCL), which is mandated to provide potable water for the inhabitants of city and urban areas, is unable to supply adequate quantities due to the ever-increasing population accentuated by inability to expand the infrastructure to cater for the requirement of potable water.

Most places do not have pipelines and those who have do not have water flowing through their taps for years. This has led to the people resorting to alternative means of getting water, such as drilling boreholes.

2.2 Water Policy

The Ghana Water Company Limited is responsible for overall planning, managing and implementation of urban water supply. However, only 41.4 % of people living in the urban areas have piped water in their homes whilst 42.6% purchase water from a public tap or neighbour's residence (GOG, 2007). This shows that urban water supply by GWCL is insufficient for the urban community and there must be adjustments in policy implementation of urban water supply to ensure sustainable development as spelt out in Growth and Poverty Reduction Strategy II, New Partnership for African Development and the Millennium Development Goals, to which Ghana is signatory.

2.3 Groundwater

Groundwater occurs in many different geological formations. Nearly all rocks in the upper part of the Earth's crust possess openings called pores or voids. In unconsolidated, granular materials the voids are the spaces between the grains which may become reduced by compaction and cementation. In consolidated rocks, the only voids may be the fractures or fissures, which are generally restricted but may be enlarged by solution.

The volume of water contained in the rock depends on the percentage of these openings or pores in a given volume of the rock. This is termed the porosity of the rock. More pore spaces result in higher porosity and more stored water (UNESCO/WHO/UNEP, 1996).

A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a significant quantity of water. In Ghana, a rock unit or unconsolidated medium which can yield up to 13 litres per minute constitutes an aquifer (Harvey, 2004). The limit to which soil pore spaces or fractures and voids in rock become fully saturated with water is called the water table.

The phenomenon by which water seeps down from the land surface adding to the ground water is called recharge. Ground water is recharged from rain water and snowmelt or from water that leaks through the bottom of lakes and rivers. Ground water may be obtained by drilling or digging wells and may also appear on the surface as spring. A well is usually an opening created to be able to gain access to groundwater. This may be in the form of a tube or bore lined with protective material or a shaft created by digging into the earth until the water table is reached. This water can then be brought to the land surface by a pump or a bucket and a rope.

Ground water can run out if more water is discharged than recharged. For example, during periods of dry weather, recharge to the aquifers decreases. If too much ground water is abstracted during these times, the water table can fall and wells may go dry.

2.4 Ground water quality

Groundwater is actually a complex, generally dilute, chemical solution. The chemical composition is derived mainly from the dissolution of minerals in the soil and rocks with which it is or has been in contact. The type and extent of chemical contamination of the groundwater is largely dependent on the geochemistry of the soil through which the water flows prior to reaching the Aquifers (Zuane, 1990). The chemical alteration of the groundwater depends on several factors, such as interaction with solid phases, residence time of groundwater, seepage of polluted runoff water, mixing of groundwater with pockets of saline water and anthropogenic impacts (Stallord and Edmond, 1983; Dethier, 1988; Faure, 1998; Umar and Absar 2003; Umar *et al*., 2006).

Groundwater in its natural state is generally of good quality. This is because rocks and their derivatives such as soils act as filters. However, not all soils are equally effective in this respect and therefore pathogens contained in human excreta such as bacteria and viruses are likely to be small enough to be transmitted through the soil and aquifer matrix to groundwater bodies (Lewis *et al.,* 1982).

Rainfall is a dilute chemical solution and contributes significant proportions to some constituents in groundwater, especially in regions with little soil cover where hard compact rocks occur at or near the surface. As water flows through the ground the dissolution of minerals continues and the concentration of dissolved constituents tends to increase with the length of the flow path. At great depths, where the rate of flow is extremely slow, groundwater is saline, with concentrations ranging up to ten times the salinity of the sea.

Groundwater can become unpotable if it becomes polluted and is no longer safe to drink. In areas where the material above the aquifer is permeable, pollutants can seep into groundwater. This is particularly so in a fractured aquifer.

2.5 Physico-chemical indicators for water quality

The dissolved constituents in groundwater, including calcium, magnesium, sodium, potassium, bicarbonate, nitrite, sulphate and chloride occur in the form of electrically charged ions. Many other minor constituents such as iron, manganese and fluoride. Zinc and Lead are trace elements which may be found in groundwater.

The pH measures the acidity or alkalinity of the water while the conductivity is the ability of the groundwater to conduct an electrical current. Conductivity is a function of temperature, types of ions present and the concentrations of the ions. The total dissolved solids, (TDS) an index of conductivity, has a direct relationship to salinity and high total dissolved solids limits the suitability of water for potable use (Davis and DeWiest, 1966).

Fluoride, when present in drinking water at a concentration of about 1 milligram per litre (mg/l), helps prevent dental cavities. However, exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis (WHO, 2006).

Generally, chemicals occurring in drinking-water are of health concern only after extended exposure for years. The only exception is nitrate. Nitrate and nitrite in water has been associated with methaemoglobinaemia, especially in bottle-fed infants. With a methaemoglobin level of 3-15%, skin can turn to a pale gray or blue. Nitrate may arise from the excessive application of fertilizers or from leaching of wastewater or other organic wastes into surface water and groundwater (WHO, 2006). The nitrite ion contains nitrogen in a relatively unstable oxidation state. Chemical and biological processes can further reduce nitrite to various compounds or oxidize it to nitrate (Anon, 1987). Because of its solubility and its anionic form, nitrate is very mobile in groundwater (Fytianos and Christophoridis, 2003). It tends not to adsorb or precipitate on aquifer solids (Hem, 1985)

High chloride and sodium contents may impart saline taste, which may affect its acceptability for potable purposes. High concentration of sulphate may give bitter taste and also cause laxative effect.

Calcium is obtained mainly from rocks containing limestone and gypsum. Small amounts come from igneous and metamorphic rocks while potassium occurs essentially in rock-salt deposits. Wastewater from industries and agricultural practices through excessive use of potash-rich fertilizers can also increase the potassium levels in groundwater.

Changes in water quality occur progressively, except for those substances that are discharged or leach intermittently to flowing surface waters or groundwater supplies, such as, contaminated landfill sites.

Hardness is a property of water that determines its ability to easily form lather with soap. Total hardness is directly related to the concentrations of calcium and magnesium.

Iron and manganese in ground water originate when water gets into contact with mineral groups and the weathering product that contain iron or manganese. Their concentrations can also be affected by wastewater from chemical industries. Excessive amount of iron and manganese are objectionable for both domestic and industrial water supplies because of their tendency to stain laundry and plumbing fixtures.

In areas with aggressive or acidic waters, the use of lead pipes and fittings or solder can result in elevated lead levels in drinking-water, which cause adverse neurological effects (WHO, 2006).

Guideline values are derived for many chemical constituents of drinking-water. A guideline value normally represents the concentration of a constituent that does not result in any significant risk to health over a lifetime of consumption.

2.6 Bacteriological indicators for water quality

The greatest risk from microbes in water is associated with consumption of drinking-water that is contaminated with human and animal excreta, although other sources and routes of exposure may also be significant. Groundwater from a shallow origin is particularly susceptible to contamination from a combination of point and diffuse sources (Fuest *et al*, 1998; Nolan and Stoner, 2000).

Faecal indicator bacteria, including *E. coli*, are important parameters for verification of microbial quality. Analysis for faecal indicator bacteria provides a sensitive, although not the most rapid, indication of pollution of drinking-water supplies.

Total coliforms are generally measured in 100-ml samples of water. A variety of relatively simple procedures are available based on the production of acid from lactose or the production of the enzyme β-galactosidase. The procedures include membrane filtration followed by incubation of the membranes on selective media at 35–37 °C and counting of colony forming units after 24 hours (WHO, 2006).

2.7 Geographical Information Systems and Water Quality

Geographical Information System (GIS) is a powerful tool and has great promise for use in environmental problem solving. Most environmental problems have an obvious spatial dimension and spatially distributed models can interact with GIS (Goodchild *et al*, 1993). A study by Troge (1994) showed that this computer-based tool was successful in integrating water quality variables into a comprehensible format. In Texas, USA, Hudak, (1999) demonstrated the distribution of nitrate and chloride in wells by the use of ArcView GIS software to map, query, and analyse the data. GIS helps identify and map critical areas of land use and reveal trends that affect water quality, thereby aiding in mitigating potential threats to water quality.

CHAPTER THREE - MATERIALS AND METHODS

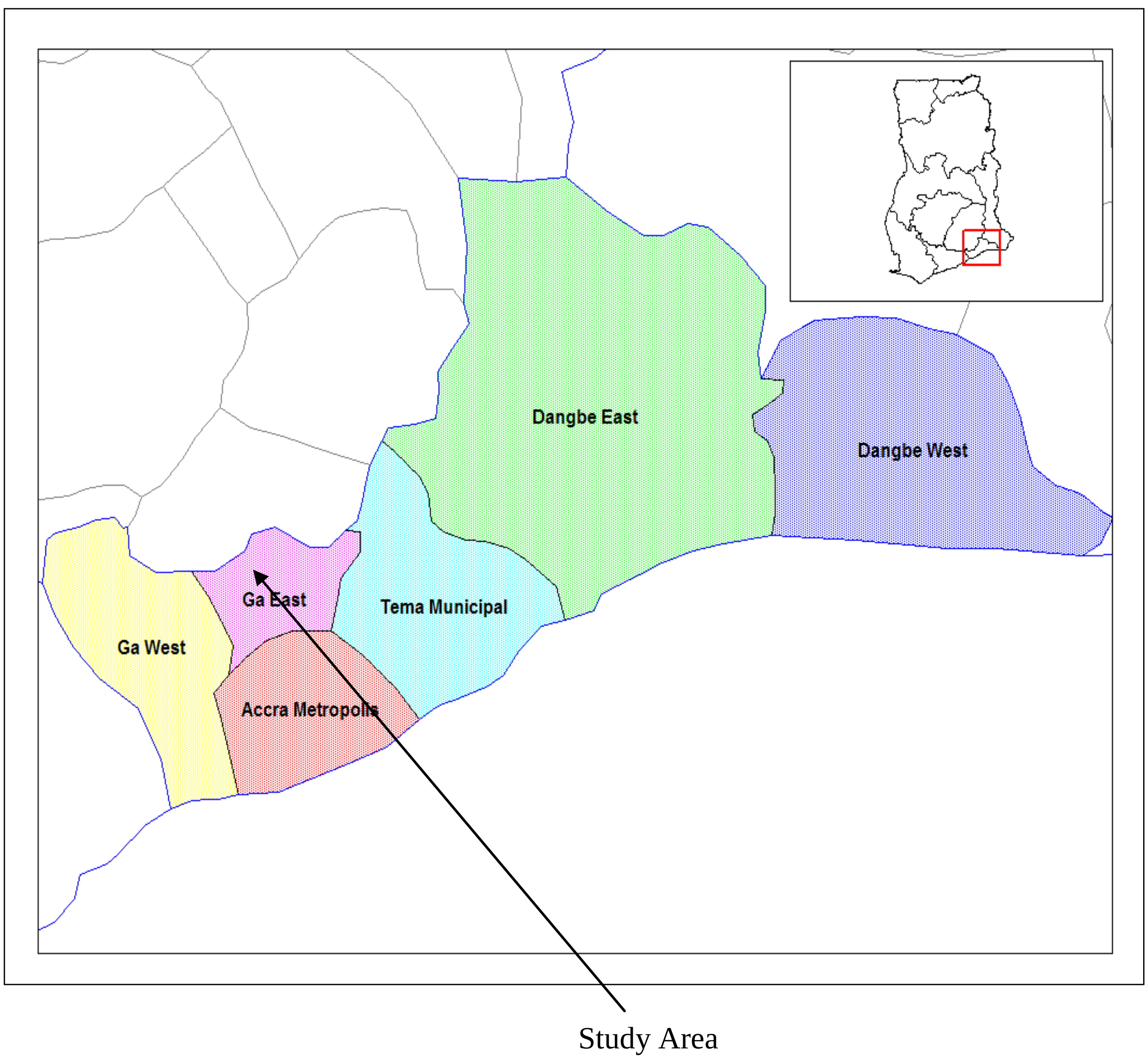
3.1 Study Area

The study area, Taifa, is located in the Ga East District in Greater Accra region. The Ga East district used to be part of the Ga District which was sub-divided into Ga East and Ga West by an Act of Parliament (LI 1589) in 2004.

The district is located in the North-eastern part of Greater Accra region. It is bounded to the north by Akwapim South district, to the west by the Ga West district, to the east by the Tema municipality and to the south by Accra Metropolis. The district has a population of 281, 724 and a growth rate of 4.5%. The district is made up of four sub-districts namely Madina, Danfa, Taifa and Dome. The population of Taifa is estimated to be about 65,000 (DA, 2006).

Figure 1: Map Showing the Study area (Ga East District) of the Greater Accra Region (Inset is the map of Ghana showing position of the study area)

Scale (1:10)



3.2 Climate

The district falls in the coastal-savannah agro-ecological zone and experiences two wet seasons. The first rainy season begins in May and peaks in July while the second rainy season is from September to October. The annual rainfall ranges between 740-890 mm and the mean annual temperature is about 27^{o}C. (DA, 2006).The highest rainfall of166mm for Accra in 2007 was in June whilst the lowest for the season was 66.1mm in October (GMA, 2007).The highest temperature of 33^{o}C was attained April 2007 whilst the lowest temperature of 28.5ºC was recorded in July (GMA, 2007).The average relative humidity for Accra is 77%. The highest relative humidity of 83% for Accra was obtained in July 2007 with a value of 83% whilst the lowest was in January with a value of 57% (GMA, 2007).

3.3 Water Supply Situation

Danfa sub-district has water from its groundwater resource (mechanized borehole) provided by the Community Water and Sanitation Agency through financial support from DANIDA. This water is provided to the whole Danfa Community through a pipe system which delivers the water to each household.

The other sub-districts, namely, Madina, Dome and Taifa do not have access to such a facility and most inhabitants buy water from water vendors via tanker services. However in Taifa, (the study area), most inhabitants have drilled boreholes in their houses which serve as their source of water and those who do not have boreholes buy water from their neighbours who have installed such facilities.

3.4 Health

The district has a District Health Management Team which oversees health services in the district. Diarrhoeal diseases and skin diseases, which are water-related, are among the top five diseases in the area (DHMT, 2006).

3.5 Geological and hydro-geological background

The bedrock geology of the study area is the acidic Dahomeyan. The main rock types include crystalline gneiss, schist and migmattite (Kesse, 1985).

Generally, the Acidic Dahomeyan formation is massive rocks with few joints. These rocks weather into clay and clayey sand, which is usually impervious, however intense weathering along fractures and veins permit water percolation to form ground water reservoirs. Studies conducted by Darko *et a*l., (1995) in the Dahomeyan formation in the Greater Accra region had a mean borehole yield of 1.9m^3/h. A similar study conducted by Dapaah-Siakwan and Gyau-Boakye, (2000) had a yields range of between 1-3m^3 /h.

3.6 Study Population

The study population were homes in Taifa, Ga East district. It was estimated from the 2000 population census that there are 3,264 houses in Taifa and 5,448 households (GSS, 2000).

3.7 Sample Size

The sample size was estimated to achieve a 95% confidence level, with an expected frequency of borehole in houses being 20% and at 7% margin of error.

Using the formula for sample size, $n = \frac{Z^2 pq}{d^2}$

For 95% Confidence level, the value of Z = 1.96

The proportion of boreholes in houses, p = 0.2

$q = 1 - p$ = 1- 0.2 = 0.8

Margin of error, d = 0.07

Sample size, $n = \frac{(1.96)^2 (0.2)(0.8)}{(0.07)^2}$ = **126**

A total of 120 out of 126 responded, giving a rate of response of 95.2%.

22 out of the 120, that is 18.3%, had borehole in their houses.

3.8 Procedure

3.8.1 Location of houses and administration of questionnaire

Houses were chosen for the study by systematic random sampling to ensure that there was equal likelihood of choosing the houses for the study in the study area. The selection interval was determined by dividing the total number of houses (3,264) by the estimated sample size (126), giving an interval of 25. A random start point was selected by spinning a pen in the centre of Taifa and the direction of pen dictated the choice of house to be visited first. We then went to the nearest house in the direction of the spun pen and administered the questionnaire and subsequently, likewise for every 25th house in the right direction. A structured questionnaire was administered to heads of houses, after they had consented to the study, to collect variables on demographic characteristics and the use of groundwater for domestic purposes. One hundred and twenty people were interviewed out of which twenty two had boreholes in their houses.

3.8.2 Geographical Information Systems (GIS) Approach

Locations of the boreholes were picked by a Garmin eTrex hand-held Global Positioning System (GPS) receiver and the coordinates were recorded

3.8.3 Pre-sampling preparations

i) Physicochemical Parameters

The sample bottles of volume 1500ml were thoroughly rinsed with distilled water. Upon reaching the sampling site, each bottle was rinsed with water from the respective borehole, thrice, before actual sample collection was undertaken.

ii) Microbiological Parameters

Glass sample bottles of volume 500ml for bacteriological analyses were washed thoroughly with soap and hot water and then rinsed with hot water to remove traces of washing compound and finally rinsed with distilled water. The bottles were then sterilized in the Gallenkamp autoclave at a temperature of 170^{o}C for three (3) hours, with an Aluminum foil placed around the cover. An indicator tape was placed across the foil. A black strip on the indicator tape signified proper sterilization of the bottle.

3.8.4 Data collection

Two samples of groundwater were collected at each site into two types of clearly labeled bottles, one for physico-chemical analyses (1500ml) and the other for bacteriological analyses (500ml). The samples were collected directly from the groundwater source, without going through the overhead tank.

Each sample collected was preserved in a light-proof insulated box containing ice-packs to prevent possible alteration of parameters by light and also to ensure that the microorganisms remained viable though dormant. Samples were then transported to the Water Research Institute laboratory in Accra, for analyses.

3.8.5 Physico-chemical analyses

i) Field Analyses

Turbidity, pH and conductivity were measured on the field.Turbidity was detected by means of the HACH model: 2100P turbidimeter, whereas pH and conductivity were analysed for with the portable Eijkeljamp 18.21 Multiparameter Analyser.

Turbidity

Nephelometric method

A turbidimeter with sample cells, HACH model: 2100P. Samples in 1500ml plastic bottles were analyzed on the field. The meter was calibrated and the knob was adjusted to read 0.1 before use.

The sample was shaken vigorously and poured into the cell to at least two-thirds full. The appropriate range was selected, when the red light came on, the knob was moved to the next range till it was stable, and then the turbidity value was read.

pH

The pH was measured by a pH meter and a combination electrode (a set of glass electrode and a reference electrode). The electrode was first calibrated against a pH buffer 7 and 9 at a temperature of 25^{o}C to adjust to the response of the glass electrode.

The electrode was then immersed in the sample and stirred gently and stopped, allowing for 1-2 minutes for a stable reading to be obtained and recorded.

Conductivity

The conductivity was determined by means of a Field conductivity meter. The conductivity cells and beaker were rinsed with a portion of the sample. Then the beaker was filled completely. The cell was then inserted into the beaker. The temperature control was adjusted to that of the sample and the probe was then inserted into the vessel and the conductance read.

The conductance was equilibrated to 25^{o}C before the sample measurement (APHA 1998).

ii) Laboratory Analyses

All Laboratory analyses were carried out at the Water Research Institute Microbiology and Water Quality Laboratories of the CSIR in Accra.

Sodium

Flame Photometric method

Twenty milligrammes per litre (20 mg/l) NaCl standard was prepared for standardization of the flame photometer.

The filter selector of the photometer was used to select Sodium after the photometer was switched on and the 20 mg/l standard was set. The machine was calibrated to ensure the standard concentration of 20mg/l set was obtained.

Sample readings were then taken, ensuring that after every ten sample readings, the machine was re-calibrated to ensure readings within the 20 mg/l range.

Chloride

Argentometric Method

Fifty millilitres (50 ml) of sample was taken and one millilitre (1 ml) of K_2CrO_4 indicator solution was added and titrated with standard $AgNO_3$ titrant to a pinkish yellow end point.

Reagent blank value was established by titrating 50ml of distilled water with 1ml of K_2CrO_4 dropped in it, against standard $AgNO_3$.

The value was calculated using the following formula:

$$Cl^- \text{ (mg/l)} = \frac{(A-B) \times M \times 35{,}450}{\text{ml of sample}}$$

Where A = ml titration of sample

B = ml titration of blank

M= Molarity of $AgNO_3$

Calcium

EDTA Titration Method (APHA, 1995)

Two millilitres (2.0 ml) of 1M NaOH was added to 50 ml of sample. The mixture was stirred and 0.1g of the murexide indicator was added to it. Titration was done immediately after the addition of the indicator.

EDTA titrant was slowly added with continuous stirring until the colour changed from Salmon to orchid purple. The end point was checked by adding 2 drops of titrant in excess to make sure that no further colour change occurred.

The value was calculated using the formula:

$$\textbf{Ca (mg/l)} = \frac{\mathbf{A \times B \times 400.8}}{\textbf{ml of sample}}$$

Where A = ml of EDTA titrant used

$$B = \frac{\text{ml of standard calcium solution}}{\text{ml of EDTA titrant}}$$

Total hardness

EDTA titrimetric method

Fifty millilitres (50 ml) of sample was pipetted into a conical flask and 1ml of a buffer solution was added to it to produce a pH of 10. One gram of Eriochrome Black T indicator was also added to it. It was then mixed constantly and titrated with a standard 0.01M EDTA until the last trace of purple disappeared and the colour turned bright blue.

Total hardness was then calculated using the formula:

$$\text{Total Hardness} = \frac{\text{ml EDTA x B x 1000}}{\text{ml of sample}}$$

Where B = mg of $CaCO_3$ equivalent to 1ml of EDTA titrant.

Magnesium

Calcium and total hardness were determined by EDTA titration method. Magnesium hardness was calculated from the difference between the total hardness and the calcium hardness which is expressed in mg/l. The magnesium concentration was obtained by multiplying magnesium hardness by 0.243.

Mg (mg/l) = magnesium hardness x 0.243

Total Suspended Solids

Absorbance Method

The Spectrometer was set to a wavelength of 630 nm.

The sample was shaken to ensure even distribution of dissolved solids and 25 ml aliquot was taken and put in the sample holder. The results were displayed digitally in mg/l.

Nitrite Concentration

Diazotization method

The sample was filtered in the field through a 0.45 μm membrane filter and preserved at 4^{o}C. The sample aliquot was reacted with sulphanilamide to form a diazo compound. This compound was then reacted with N-(1-naphthyl) ethylenediamine dihydrochloride to form an azo dye. The azo dye intensity, proportional to the nitrite concentration, was determined colourimetrically at 540 nm with the aid of an Ultra Violet Spectrophotometer (Wagtech, Jenway 6505) and compared to identically-prepared was 0.001 mg/l. standard and blank solutions (Environment Canada, 1974). The method detection limit was 0.001mg/l.

Nitrate Concentration

Hydrazine reduction method

The sample was filtered in the field through a 0.45 μm membrane filter and stored at $4^{o}C$. Nitrates, from the sample aliquot were reduced to nitrites with hydrazine sulphate. The resulting nitrites, together with the original nitrites, were then reacted with sulphanilamide to form a diazo compound. This compound was then reacted with N-(1-naphthyl) ethylenediamine dihydrochloride to form an azo dye. The azo dye colour intensity, proportional to the nitrate + nitrite concentration, was determined colourimetrically at 520 nm and compared to identically-prepared standard and blank solutions. The nitrate concentration was obtained by subtracting the original nitrite concentration, determined from a duplicate sample (Environment Canada, 1979). The method detection limit was 0.005 mg/l.

Manganese Concentration

Atomic Absorption Spectrometry – Direct Aspiration

The sample was preserved in the field with nitric acid. The sample aliquot was then digested with nitric acid. The solution was aspirated and the absorbance measured spectrometrically at 279.8 nm with the aid of a UNICAM 969 SOLAAR 32 Atomic

Absorption Spectrophotometer and compared to identically-prepared standard and blank solutions, using an air-acetylene oxidizing flame (Environment Canada 1974). Instrument's detection limit was 0.005 mg/l.

Sulphate

Turbidimetric method

One hundred millilitres (100ml) of water sample was measured into a 250 ml Erlenmeyer flask. Five millilitres (5 ml) of conditioning reagent was added and mixed by stirring. One gramme (1g) of barium chloride crystals was added while stirring and timed for 60 seconds. The Absorbance was then determined at 420 nm on the spectrophotometer within 5 minutes. The concentration was then read directly from the calibration curve on the computer screen.

Phosphate

Stannous chloride method

One drop of phenolphthalein indicator was added to 100 ml of sample. The sample was discharged by adding an acid, drop wise until it turned pink. 4 ml of molybdate reagent I and 10 drops of stannous chloride reagent I was added and mixed thoroughly. Absorbance was then read after 10 minutes at a wavelength of 690 nm on a spectrometer.

Fluoride Concentration

SPADNS method

SPADNS (sodium 2-(parasulphophenylazo)-1,8-dihydroxy-3,6-naphthalene disulphonate) was mixed with zirconyl-acid reagent and added to the sample. The absorbance was read at 570 nm and compared to identically-prepared standard and blank solutions (APHA 1995).

Detection limit was 0.001 mg/l.

Iron Concentration

Atomic Absorption Spectrometry – Direct Aspiration

The sample aliquot was digested in nitric acid, diluted appropriately, then aspirated and the absorbance was measured spectrometrically at 248.3 nm with the aid of a UNICAM 969 SOLAAR 32 Atomic Absorption Spectrophotometer and compared to identically-prepared standard and blank solutions, using an air-acetylene oxidizing flame (Environment Canada 1974).

Lead Concentration

Atomic Absorption Spectrometry – Direct Aspiration

The sample was preserved in the field with nitric acid. The sample aliquot was then digested in nitric acid. The digest was aspirated and the absorbance measured spectrometrically at 283.3 nm with the aid of a UNICAM 969 SOLAAR 32 Atomic Absorption Spectrophotometer and compared to identically-prepared standard and blank solutions, using an air-acetylene oxidizing flame (Environment Canada 1974).

Instrument’s detection limit was 0.05 mg/l.

Zinc Concentration

Atomic Absorption Spectrometry – Direct Aspiration

The sample was preserved in the field with nitric acid. The sample aliquot was then digested in nitric acid. The digest was aspirated and the absorbance measured spectrometrically at 213.8 nm with the aid of a UNICAM 969 SOLAAR 32 Atomic Absorption Spectrophotometer and compared to identically-prepared standard and blank solutions, using an air-propane oxidizing flame (Environment Canada 1974).

Instrument's detection limit was 0.005 mg/l.

3.8.6 Bacteriological analyses

The membrane filtration method was used in the determination of two parameters, namely; Total Coliform and Faecal Coliform.

i) Total Coliform determination

A one hundred millilitre (100ml) portion of the groundwater sample was filtered through 47 mm membrane filters of 0.45μm pore size. The membrane filter was incubated on M-Endo agar (Wagtech Int.) and alternatively on Mac Conkey Agar at 37^{o}C for 24 hours. Total coliform was detected as dark-red colonies with a metallic (golden) sheen on the M-Endo agar; and also as all bacteria colonies with yellow ring around them on the Mac Conkey Agar. The total number of colonies appearing were counted for each plate.

ii) Faecal Coliform determination

100 ml portion of the groundwater sample was filtered through 47 mm membrane filters of 0.45μm pore size. The membrane filter was incubated on M-FC agar at 44°C for 24 hours. Faecal coliform was detected as blue colonies on the M-FC agar. The total number of colonies appearing were counted for each plate.

iii) Procedure for bacteriological analyses

The samples were removed from storage and allowed to cool to room temperature and the incubation chamber for the analyses was cleaned with ethanol to prevent contamination. The porous plate of the membrane filtration unit and the membrane filter forceps were sterilised by being applied with 98% alcohol which was burnt off in a Bunsen flame. The sterile forceps were then used to transfer the sterile membrane filter onto the porous plate of the membrane filtration unit with the grid side up and a sterile meshed funnel placed over the receptacle and locked in place. The required volume of groundwater sample (100ml) was added to the membrane filtration unit using the funnel measure. The flame from the Bunsen burner was kept on throughout the whole analyses and the forceps was flamed intermittently to keep it sterile. The sample was filtered through the membrane filter under partial pressure created by a syringe fitted to the filtration unit. The filtrate was discarded and the funnel unlocked and removed. The sterile forceps were then used to transfer the membrane filter onto a sterile labelled Petri dish containing the appropriate growth medium (M. F.C agar for Faecal coliform and M. Endo agar for Total coliform). The membrane filter was placed on the medium by rolling action to prevent air bubbles from forming at the membrane-medium interface. The Petri dishes were incubated upside down at the appropriate temperatures, (37^{o}C for total coliforms and 44^{o}C for faecal coliforms) for 24 hours. After incubation, typical colonies were identified and counted. The colonies were counted three times with the aid of a colony counter and the mean was recorded.

Plate 1: Membrane filtration unit. (Scale: ×0.25)

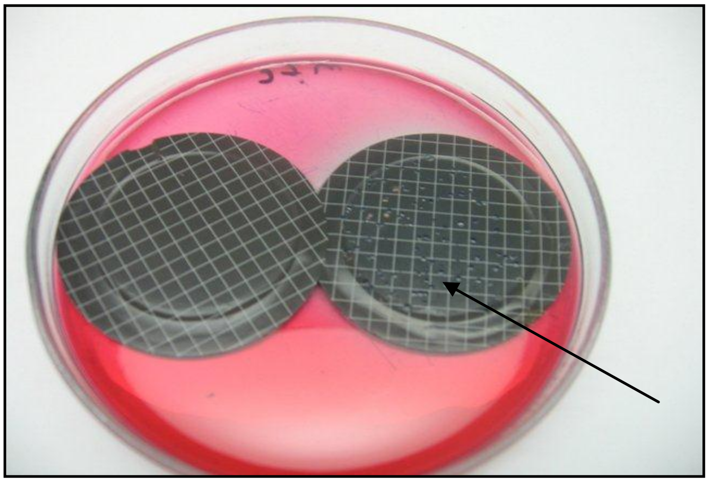


Plate 2: Faecal coliforms on M-FC Agar showing as blue colonies .Growth is seen on the right membrane disc. (Two membrane discs placed on same plate for purpose of illustration). Scale: ×0.75

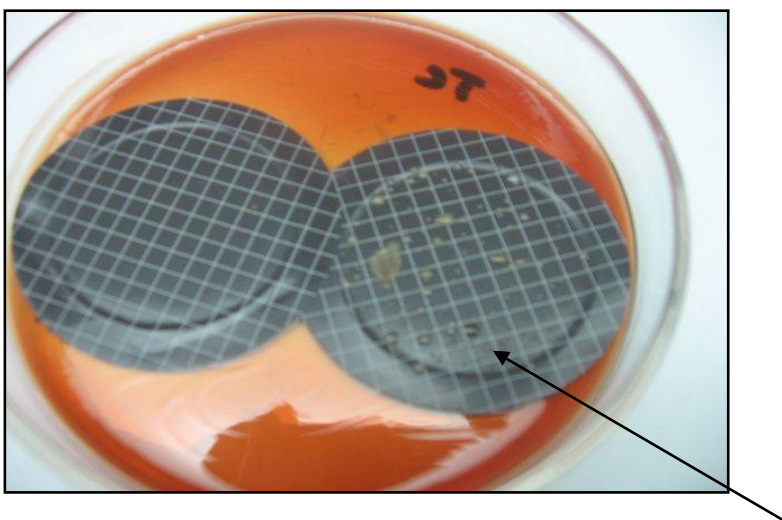


Plate 3: Total coliforms on Mac Conkey Agar showing as yellow rings around the colonies .Growth is seen on the right membrane disc. (Two membrane discs placed on same plate for purpose of illustration). Scale: ×0.75

3.10 Ethical Consideration

The study was explained to the borehole owners and the other participants. They were informed that the study was voluntary and that they could refuse or withdraw from the study without any consequences. The purpose and procedure for the study were fully explained to them and that they would be respected by protecting privacy through confidentiality and also respondents would be informed about the results of the study.

3.11 Preparation of Maps

Hydro-geological and hydrochemical maps were prepared using ARCVIEW 8.3 software and GIS-based techniques. The parameters are presented in the form of contours, density colours and symbols on the map.

To express local trends in the data, the Inverse Distance to a Power gridding method was used to contour the irregularly spaced data. The gridding system is a weighted average interpolator, where the data are weighted during interpolation such that the influence of one point related to another declines with distance from the grid node. Weighting is assigned to the data by a weighting power that controls how the weighting factor drops off as distance from a grid node increases (Franke, 1982; ESRI, 1999).

To offset the possibility of not honoring original data points, a large number of gridlines were generated. This increased the likelihood that the data points were applied directly to the grid file. One characteristic of the inverse distance to a power is the generation of bull's eye surrounding the position of observation within the gridded area, thus enhancing the delineation of the distinct zones.

Thematic maps of size A4 (included in the text) were then prepared.

3.12 Data Analyses

The data was entered in Microsoft Excel and transported to SPSS 12.0 for analyses. The Summary statistics such as mean, range and standard deviation were generated. The patterns of the variation of the water quality parameters in relation to the borehole sites were also generated.

CHAPTER FOUR – RESULTS

4.1 Chemistry and Bacteriology of Groundwater Samples

The results of the field and bacteriological analyses are presented in Table 1

Table 1: Summary Statistics of the analytical data of the physical and bacteriological parameters in Taifa, Ga East District

Parameters	n	Minimum	Maximum	Mean	Std. Deviation (±)
TURBIDITY (NTU)	22	0.54	1.59	0.93	0.29
pH	22	3.89	6.80	5.11	0.79
CONDUCTIVITY (µs/cm)	22	950.00	2210.00	1137.23	261.08
TOTAL COLIFORMS/100ml	22	0.00	651.00	107.68	207.63
FAECAL COLIFORMS/100ml	22	0.00	444.00	42.50	113.13

Physical parameters

The turbidity value for groundwater ranged from 0.54 to 1.59 NTU with an average value of 0.93 NTU and all were below the WHO safety guideline value of 5.0 NTU. The pH values were acidic and were in the range of 3.89 to 6.80 with a mean value of 5.11. The concentration of salinity (TDS) ranged from (523 to 1216) mg/l with a mean of 625. The WHO guideline for TDS is 1000 mg/l. The conductivity of the ground water also ranged from 950 µs/cm to 2210 µs/cm. Total hardness ranged from 66.7 to 390 mg/l with mean value of 132.62 mg/l while WHO guideline value is 500 mg/l.

Microbiological parameters

The bacteriological analyses showed total coliforms range of 0 to 651 with a mean value of 107.68. The WHO safety guideline value is zero (0) counts per 100ml. Faecal coliforms ranged between 0 to 444 with a mean value of 42; WHO safety guideline value is zero (0) counts per 100 ml.

The results of the chemical analyses are presented in Table 2

Table 2: Summary Statistics of the analytical data of the chemical parameters in Taifa, Ga East District

Chemical Parameters (mg/l)	n	Minimum	Maximum	Mean	Std. Deviation (±)
TOTAL DISSOLVED SOLIDS	22	523.00	1216.00	625.05	143.95
SODIUM	22	27.60	270.00	137.71	58.88
POTASSIUM	22	2.40	6.70	4.68	1.47
CALCIUM	22	6.70	80.20	21.49	19.48
MAGNESIUM	22	7.70	47.80	19.09	10.71
TOTAL IRON	22	0.00	0.39	0.05	0.083
CHLORIDE	22	132.00	516.00	249.73	92.64
SULPHATE	22	1.64	113.00	27.79	23.96
PHOSPHATE	22	0.00	1.08	0.15	0.25
MANGANESE	22	0.00	1.08	0.39	0.29
NITRITE	22	0.00	0.15	0.01	0.03
NITRATE	22	0.00	39.00	10.08	8.18
TOTAL ALKALINITY	22	6.00	274.00	39.18	70.81
CALCIUM HARDNESS	22	16.70	200.00	53.71	48.55
TOTAL HARDNESS	22	66.70	390.00	132.62	82.46
FLUORIDE	22	0.00	1.97	0.79	0.56
BICARBONATE	22	7.30	334.00	47.80	86.34
CARBONATE	22	0.00	0.00	0.00	0.00
LEAD	22	0.00	0.00	0.00	0.00
ZINC	22	0.00	0.25	0.07	0.06

Cations

The concentrations of the major cations namely sodium, potassium, calcium, magnesium and manganese ranged from 27.60 to 270.00; 2.40 to 6.70; 6.70 to 80.20; 7.70 to 47.80 and 0 to 1.08 mg/l with a mean of 137.71, 4.68, 21.49, 19.09 and 0.39 mg/l respectively.

Anions

The anions chloride, sulphate, phosphate, nitrate, nitrite and bicarbonate had the following range of concentrations: 132 to 516; 1.64 to 113; 0 to 1.08; 0 to 39; 0 to 0.15; 7.3 to 334 with means of 249.73, 27.79, 0.15, 10.08, 0.01, 47.8mg/l respectively. Carbonate was detected in any of the water samples.

Trace metals

Iron and zinc concentrations in the groundwater ranged from 0 to 0.39; and 0 to 0.29 mg/l with mean values of 0.05 and 0.07 mg/l respectively. Lead was not detected in any of the water samples.

4.2 Comparative Analyses of the Groundwater Sample Parameter Values and their respective W.H.O guideline values

Figure 2 shows the comparison of turbidity at the twenty-two sampling sites. The WHO limit for turbidity is also indicated. All the values were within the WHO safety guideline. The pH values which are shown in Figure 3 show that all the water samples tested were acidic except for sampling sites 4, 12 and 17 which are even on the border line of acidic. Site 4 had a very high level of total dissolved solids as shown in figure 4. Site 4 also had a high concentration of sodium and chloride as shown in Figure 5 and Figure 10 respectively.

Potassium, calcium and magnesium concentrations were within the WHO guideline values as shown in Figs.6-8 respectively.

Total iron concentration in groundwater was within the WHO limit except site 12 which was marginally high (Figure 9).

Nitrite concentrations were within normal WHO limits as shown in figure 13. Some sites, namely, 10, 11, 13, 14, 16 and 19 had concentrations of nitrate being higher than the WHO limit (figure 14).

The level of hardness was within normal limits of 500mg/l. Manganese showed varying degrees of concentration with some within the WHO limits, while others depicted marginal increases. Yet still, some sites registered very high values, such as Sites 7 and 21 (figure12) with values of 1.5mg/l and 0.9mg/l respectively..

Fluoride concentrations were within normal limits except for two sites, namely, site 8 and 17 which is a marginal increase compared to WHO limit is 1.5mg/l (figure 16).

Six sites namely 1, 4, 6, 17, 19 and 20 had both total and fecal coliform counts to be above the WHO limit of zero counts per 100ml of sample (figure 17 and figure 18).

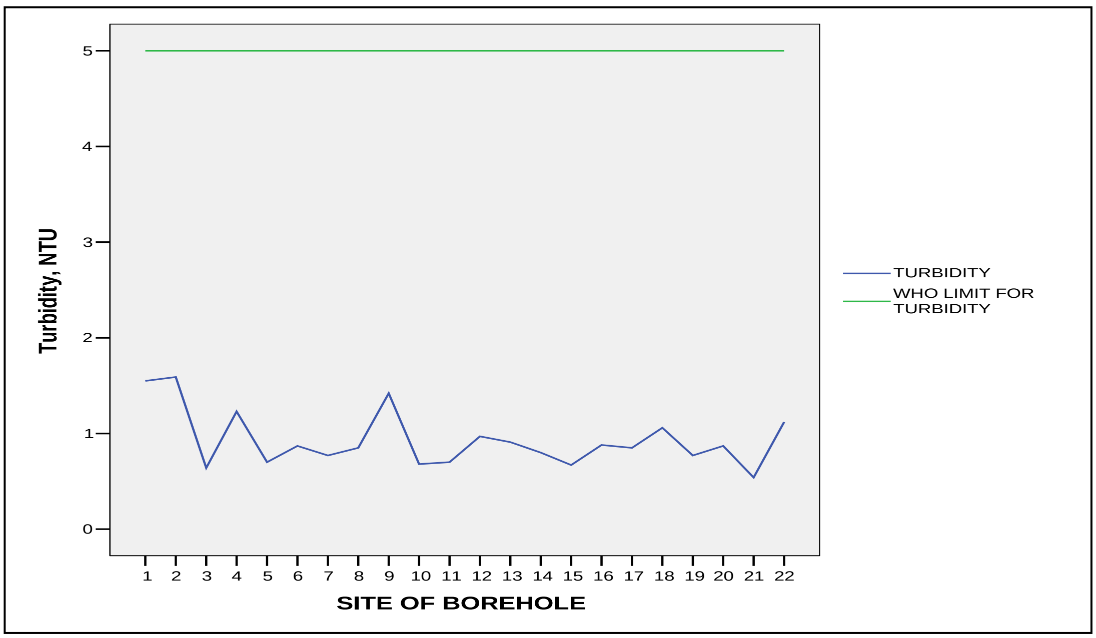


Figure 2: Comparative turbidity values and the WHO limit of the water sampling sites

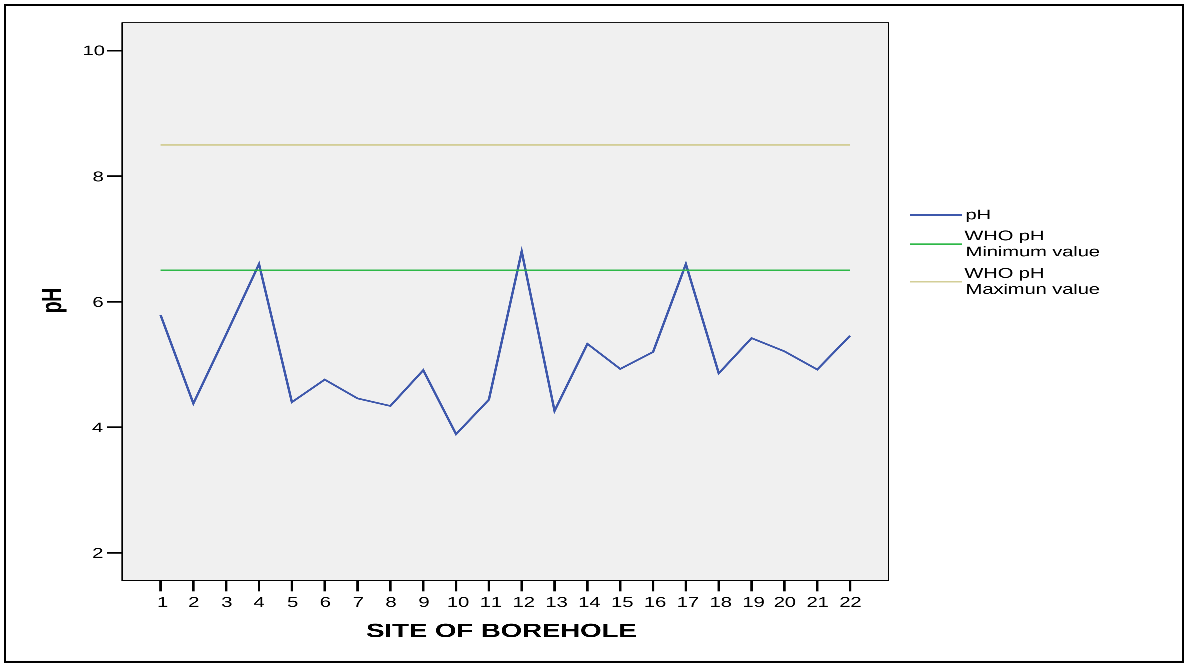


Figure 3: Comparative pH values and WHO minimum and maximum levels of the water from borehole sites at the indicated sampling sites (1-22)

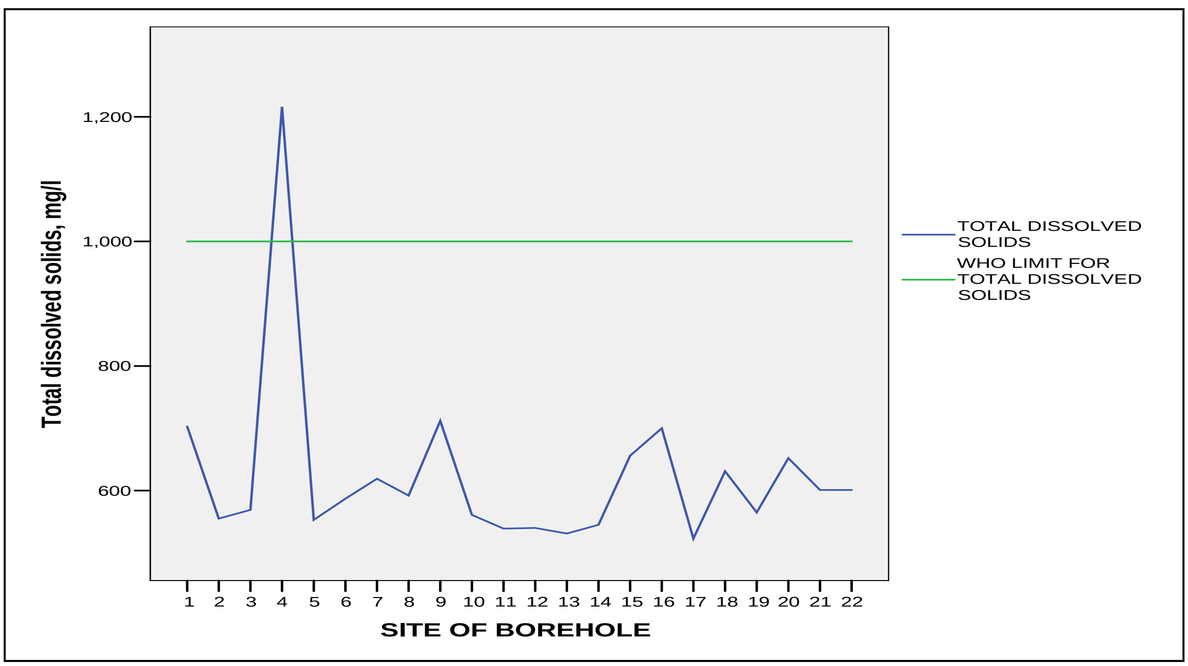


Figure 4: Comparative total dissolved solids and WHO limits of the water from boreholes at the indicated sites

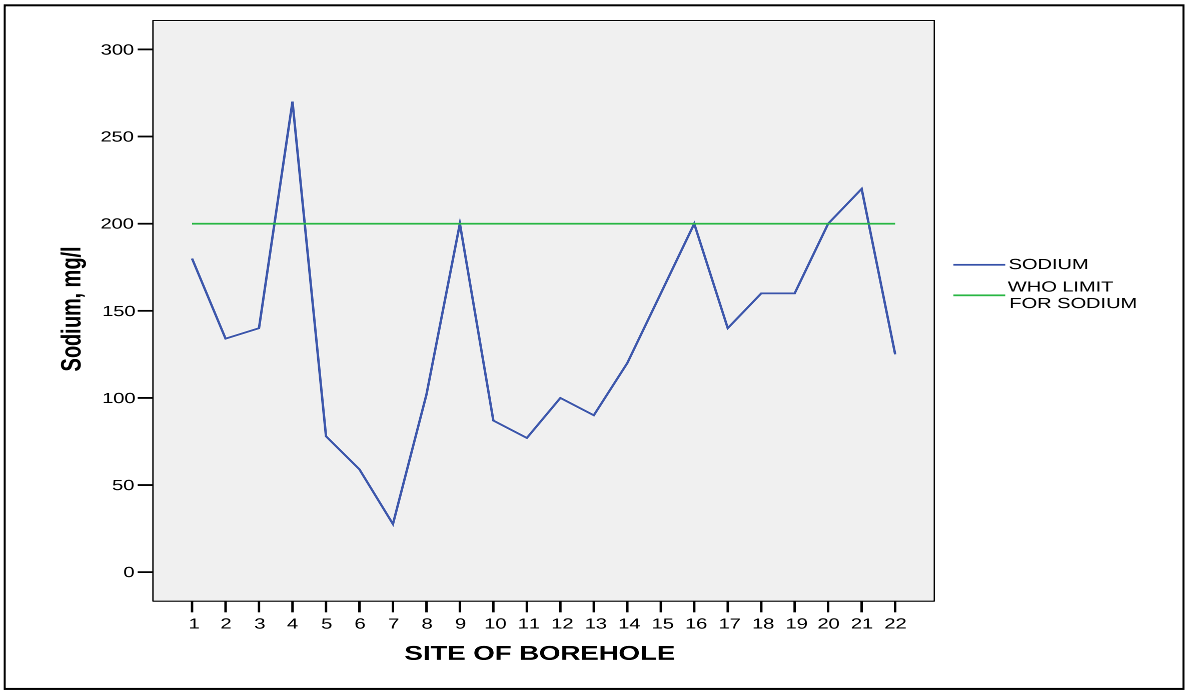


Figure 5: Changes in Sodium Concentration in Borehole water from one sampling site to another compared with the WHO acceptable limit

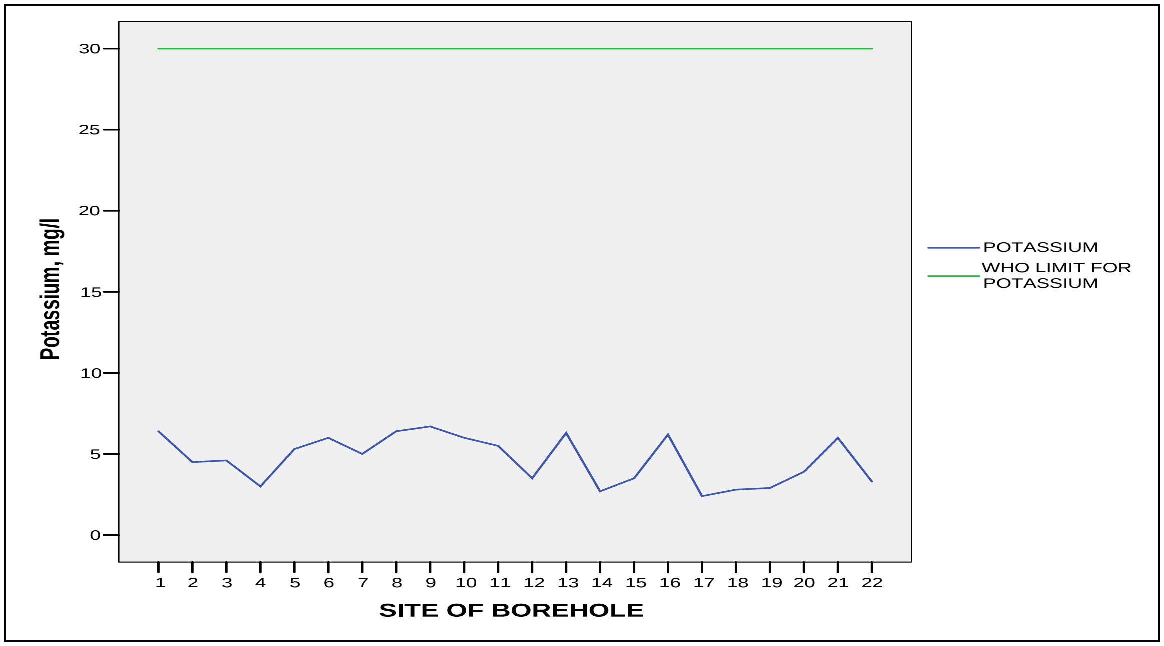


Figure 6: Changes in Potassium Concentration of Borehole water from one sampling site to another compared with the WHO acceptable limit

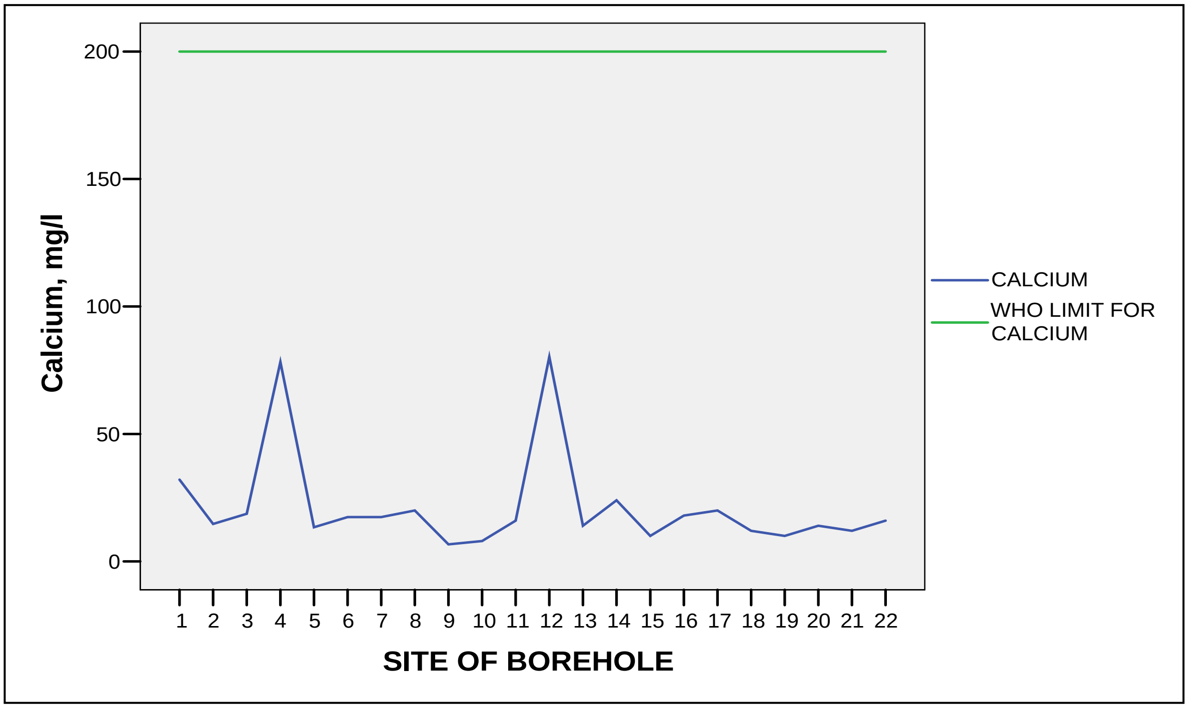


Figure 7: Variation in Calcium concentrations of Borehole water samples from one site to another as compared with the WHO acceptable limit

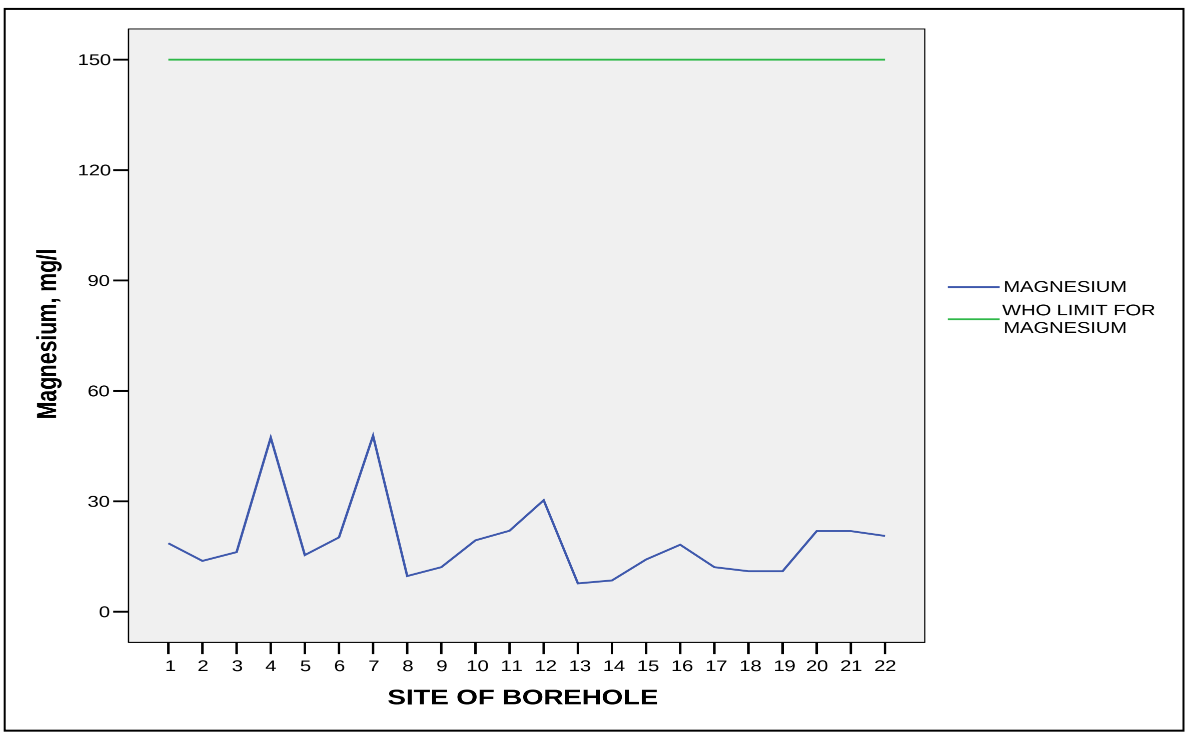


Figure 8: Variation in Magnesium concentrations of Borehole water samples from one site to another as compared to the WHO acceptable limit

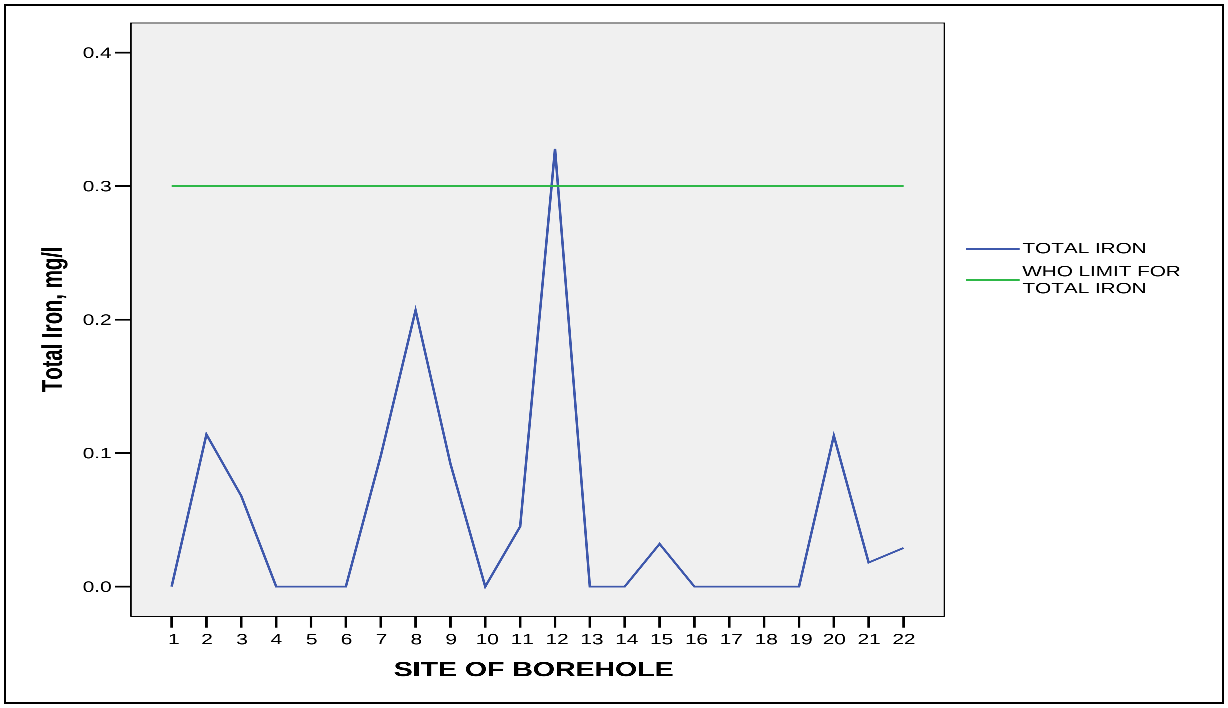


Figure 9: Total iron concentrations of the water from the boreholes at the indicated sampling sites as compared to the WHO acceptable value

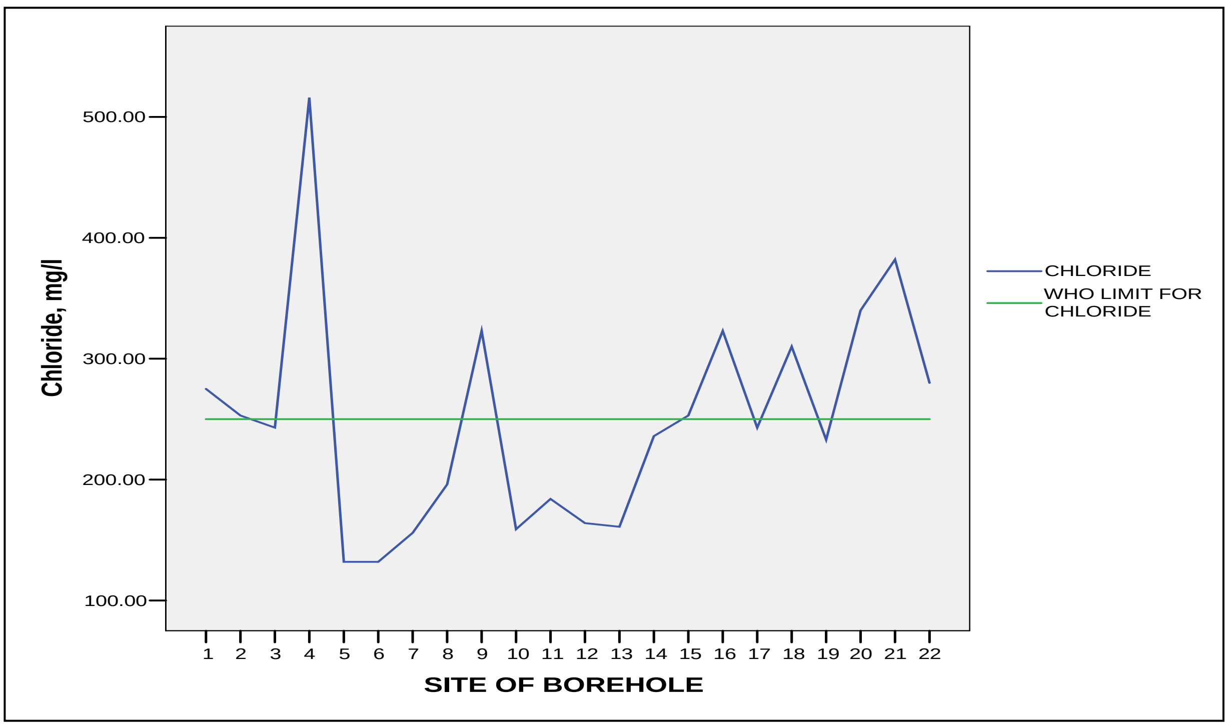


Figure 10: Chloride concentrations of water samples from the indicated borehole sites as compared to the WHO acceptable value

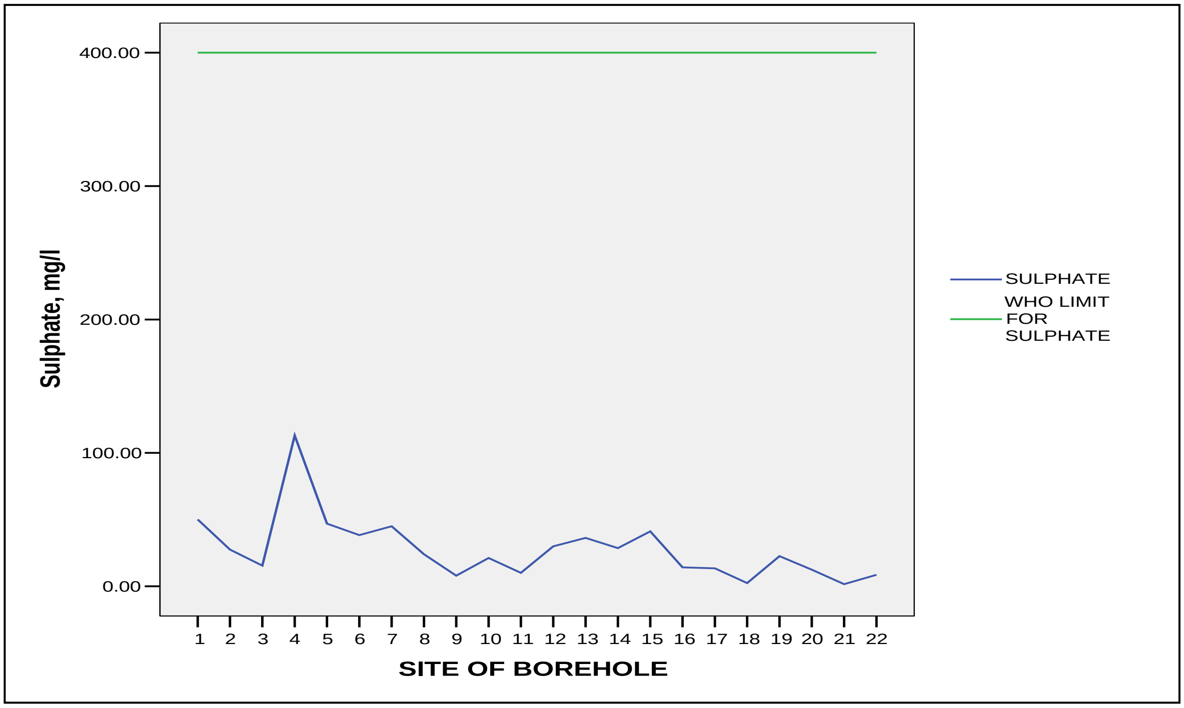


Figure 11: Sulphate concentrations of water samples from the indicated borehole sites as compared to the WHO acceptable level value

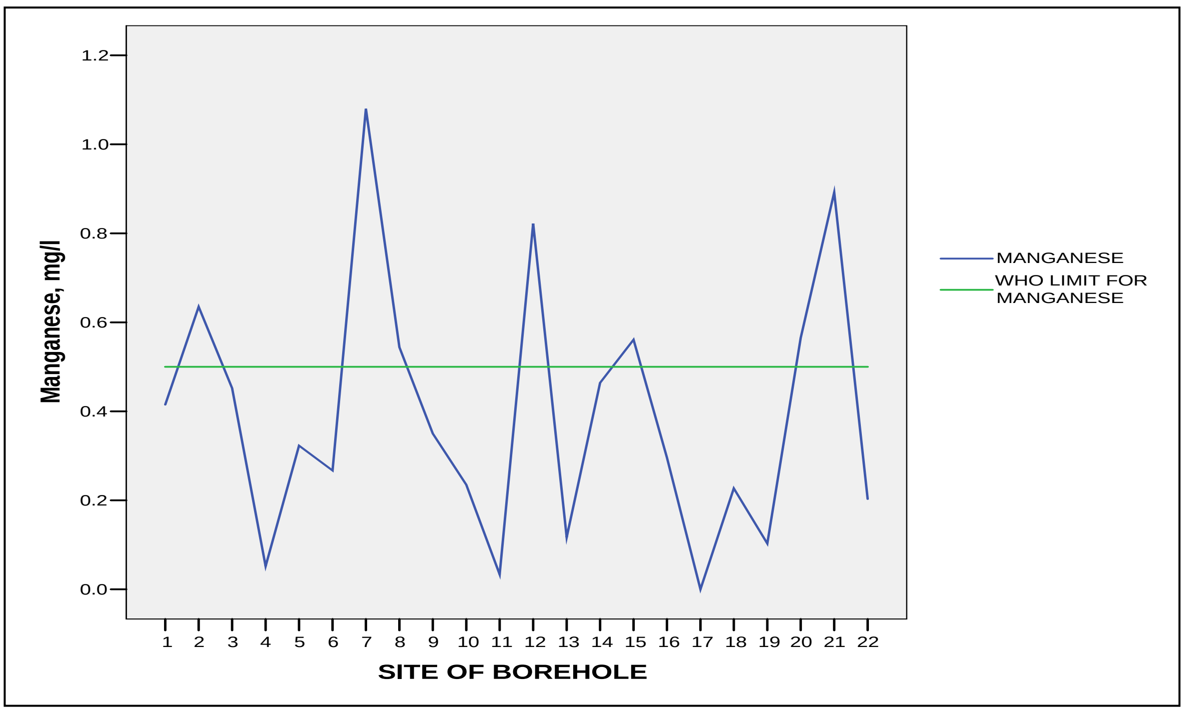


Figure 12: Manganese concentrations of water samples from the indicated borehole sites as compared to the WHO acceptable level value

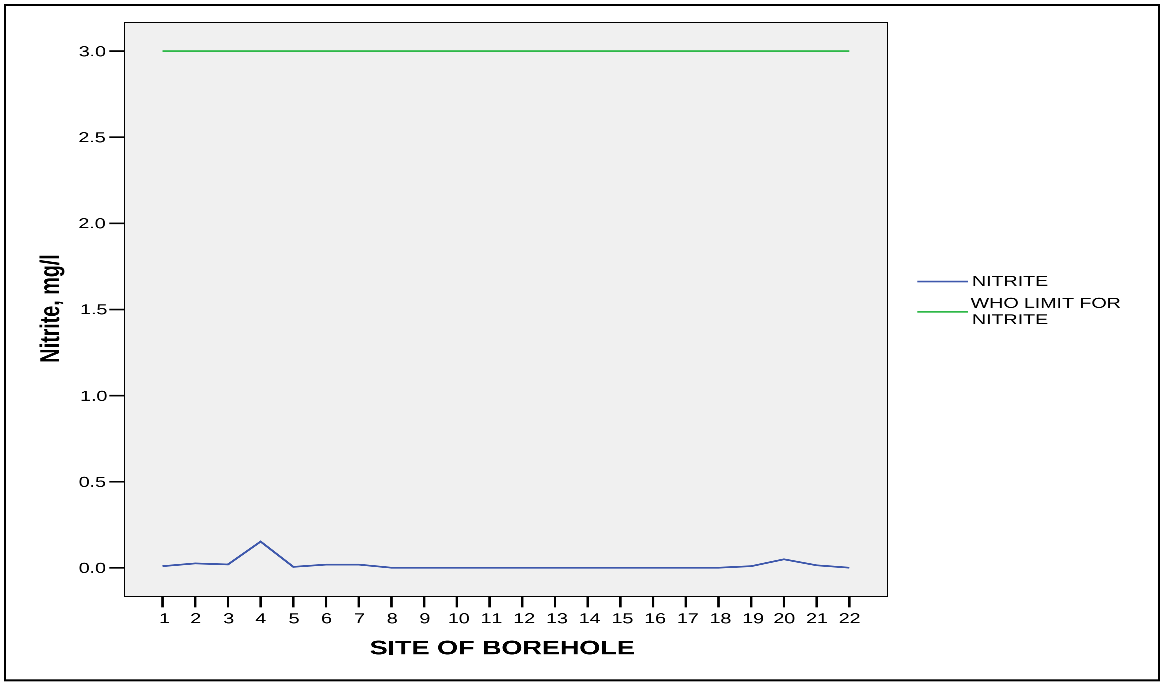


Figure 13: Nitrite concentrations of water samples from the indicated borehole sites as compared to the WHO acceptable limit value

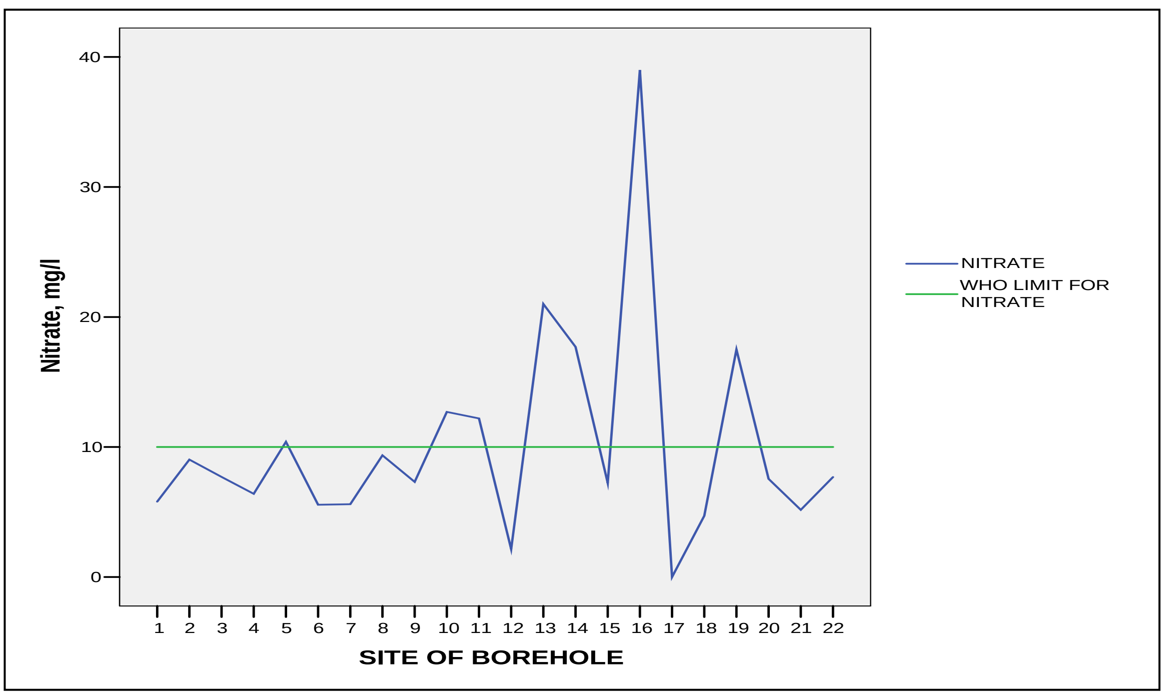


Figure 14: Nitrate concentrations of water samples from the indicated borehole sites: (The green line indicates the WHO acceptable limit)

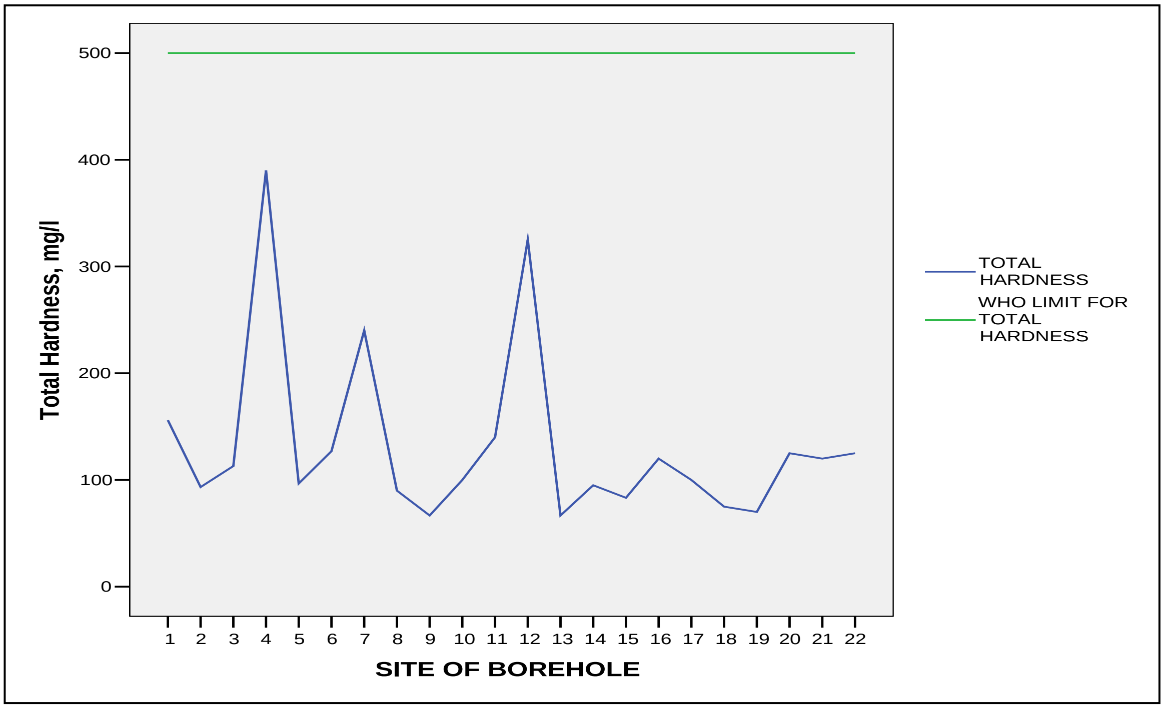


Figure 15: Total hardness of water samples from the indicated borehole sites: (The green line indicates the WHO acceptable limit level)

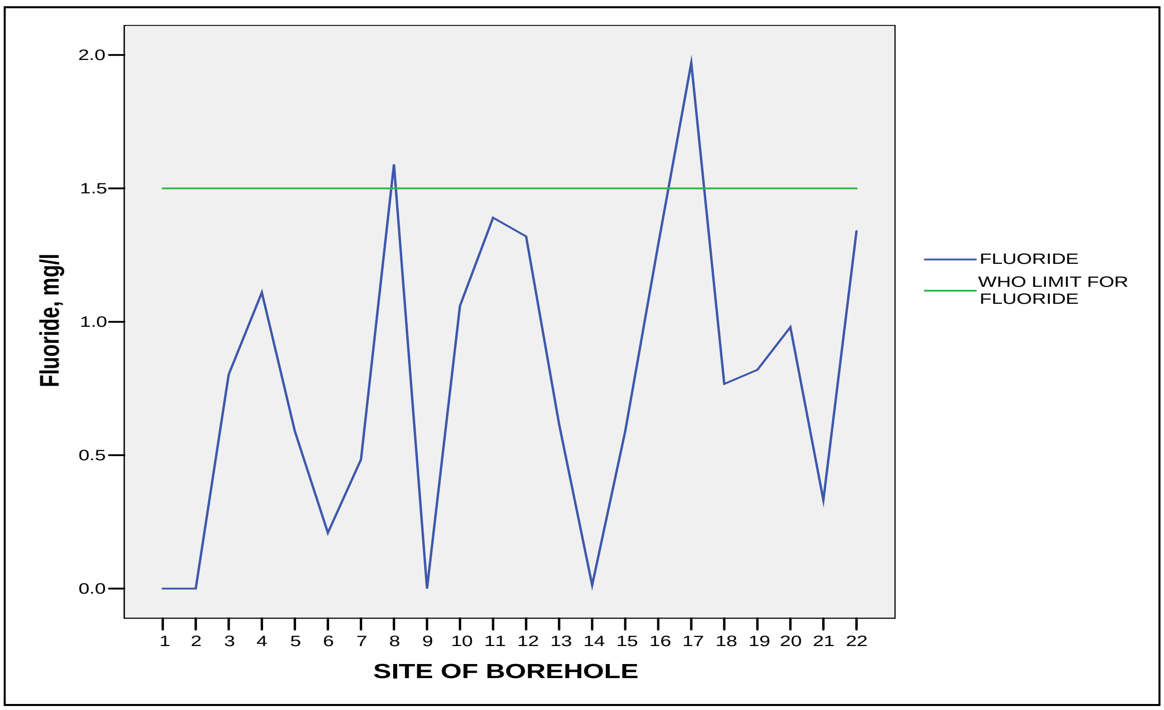


Figure 16: Fluoride concentrations of water samples collected from the indicated borehole sites: (The green line indicates the WHO acceptable limit level)

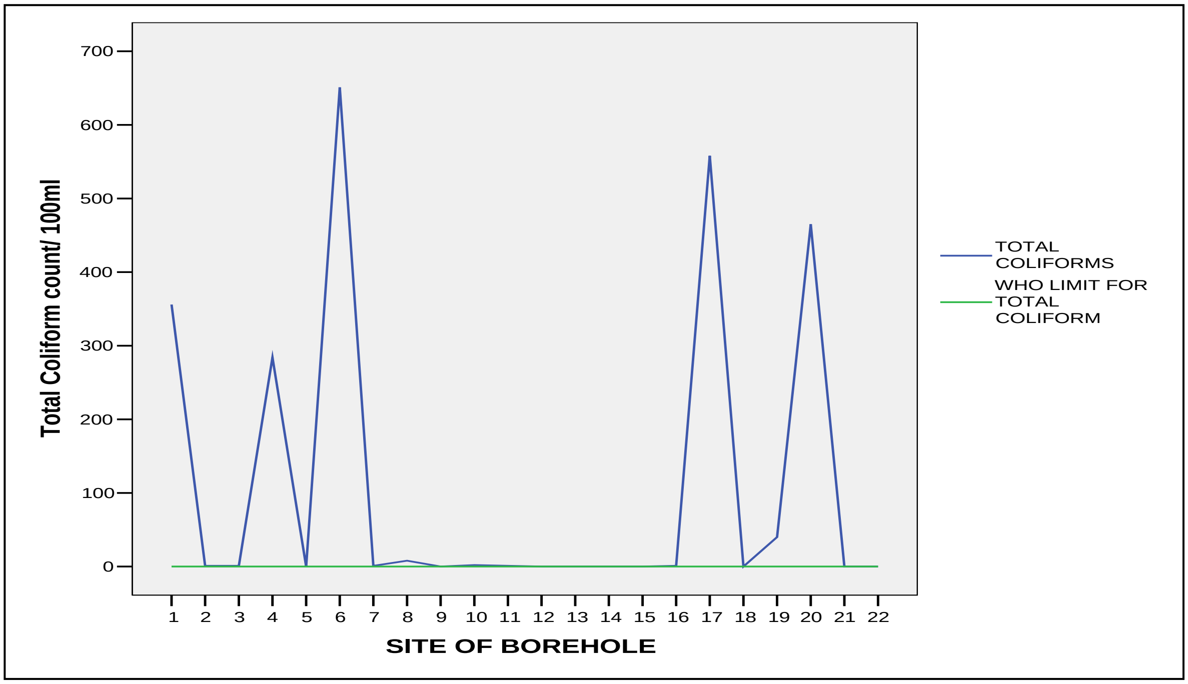


Figure 17: Total coliform counts of water samples collected from borehole sites at the indicated sites: (The green line indicates the WHO acceptable limit level. Note the preponderance of Total coliforms at some Boreholes).

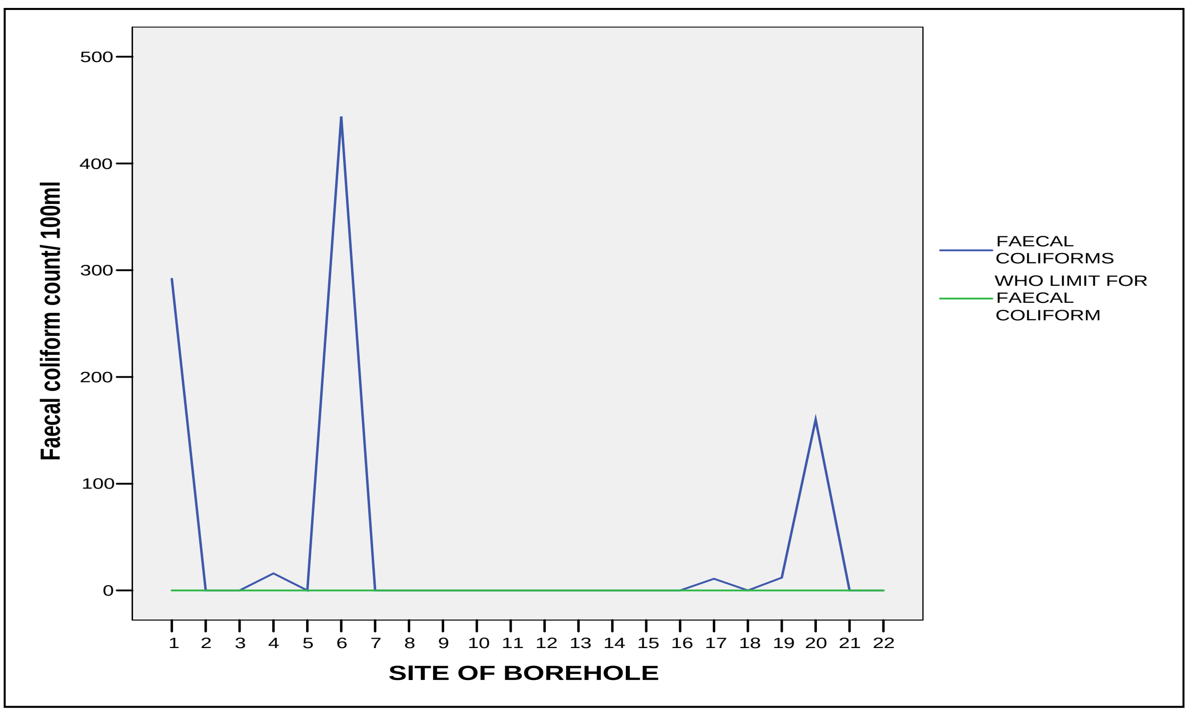


Figure 18: Faecal coliform counts of water samples collected from borehole sites at the indicated sites: (The green line indicates the WHO acceptable limit level). Note the preponderance of Faecal coliforms at six sites).

4.2 Hydro-geology and water quality

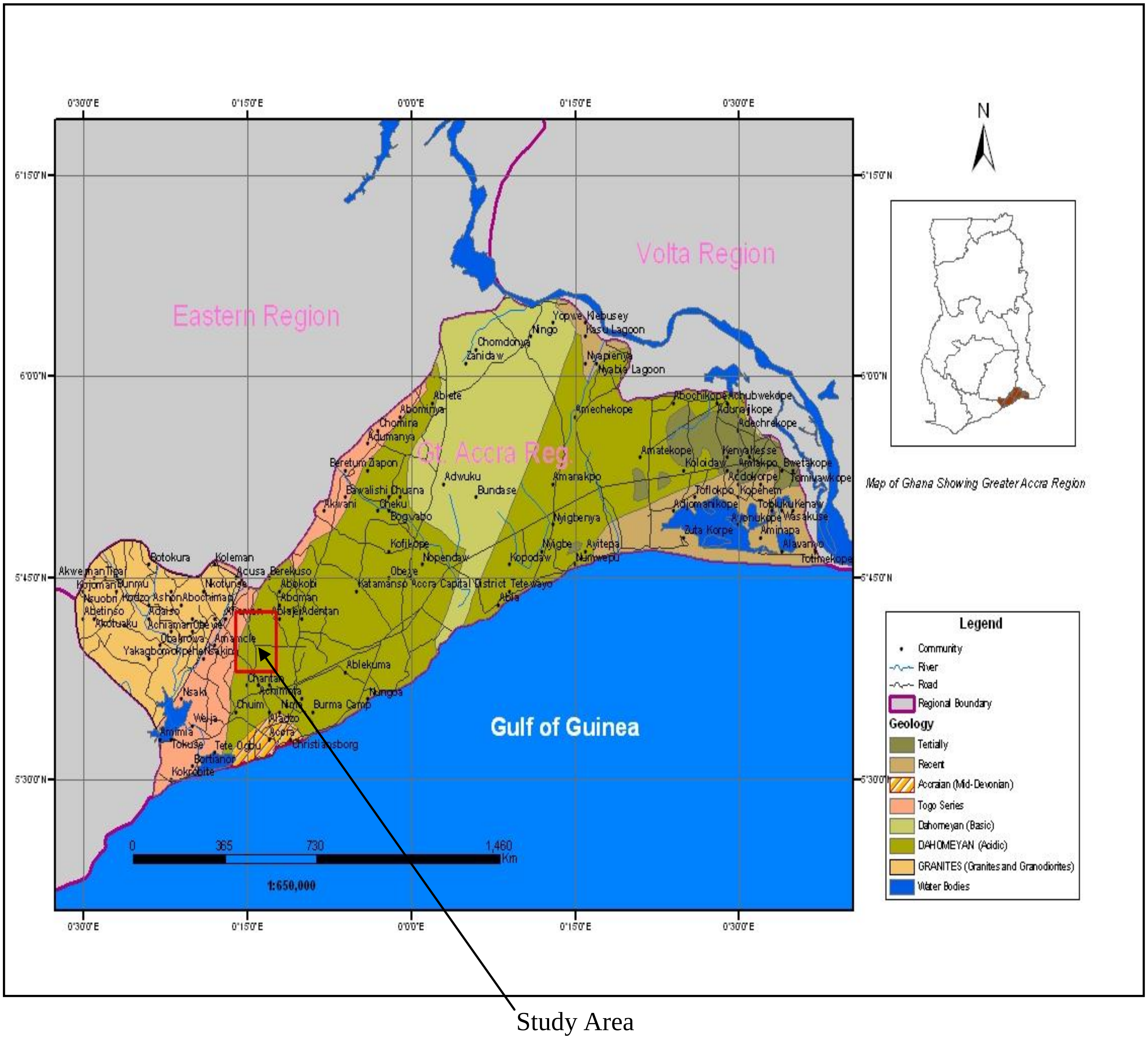


Figure 19: Geological Map of Greater Accra Region Showing the Study Area

Figure 19 illustrates the geological map of Greater Accra Region, Ghana, showing the study area. The geology of Taifa is called Dahomeyan (Acidic).

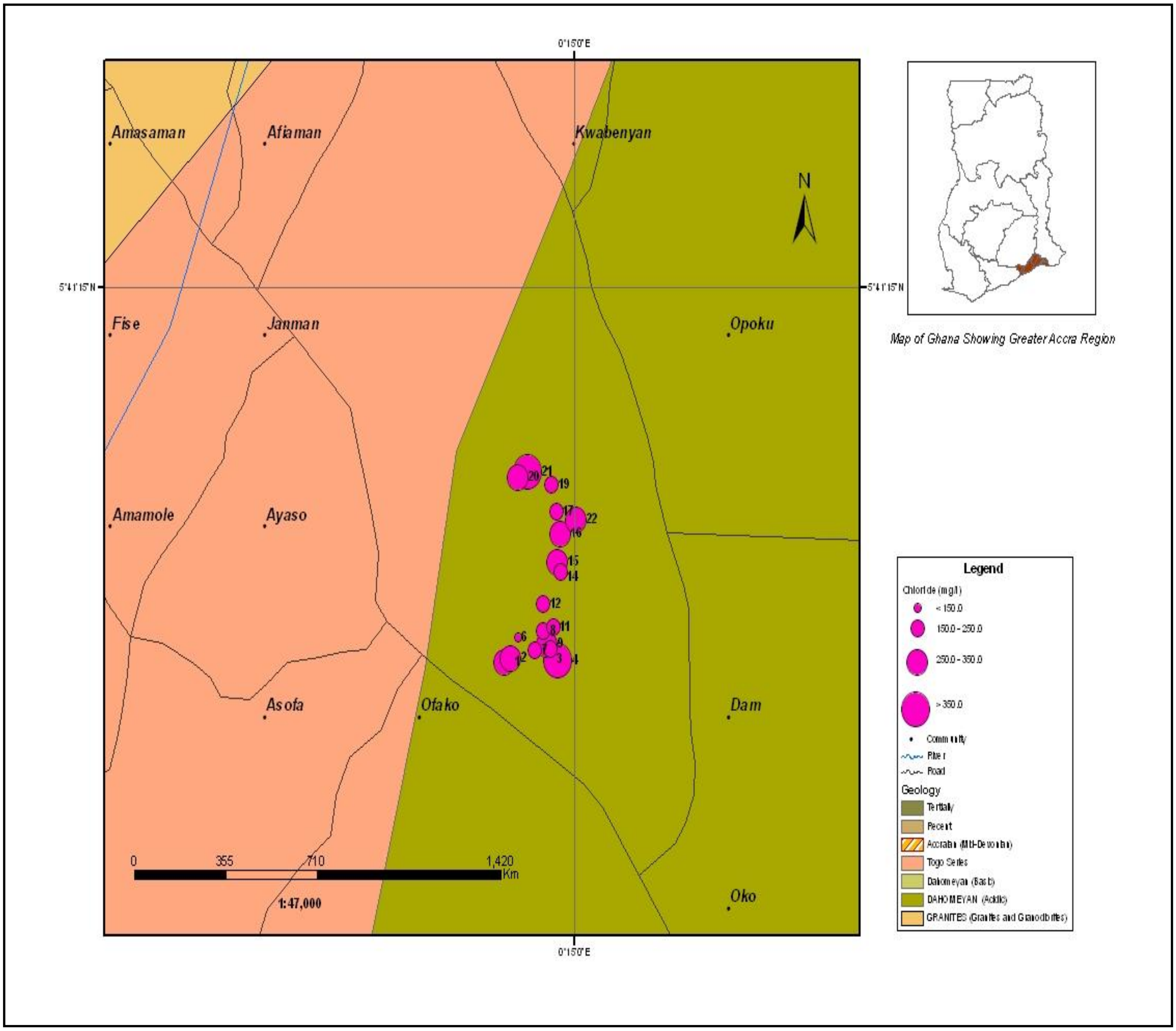


Figure 20: Map Showing Chloride concentrations in ground water at Taifa

The variations in the chloride concentrations at the sites is shown in figure 20. This shows a high concentration of Chloride at the northern and southern parts of Taifa while the central portion shows levels within the normal WHO limit of 250 mg/l.

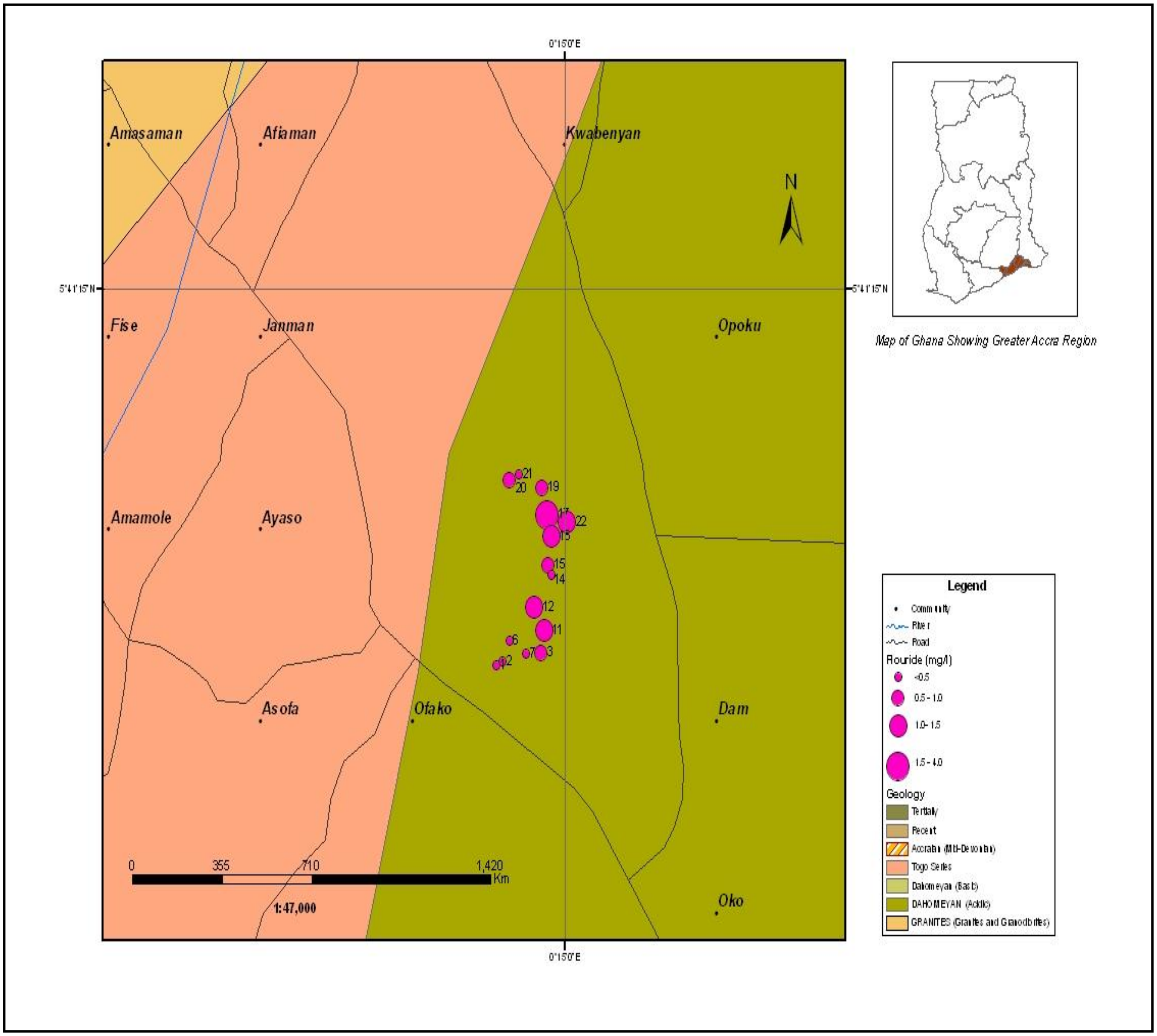


Figure 21: Map showing Fluoride concentrations of ground water at Taifa

The variations in the fluoride concentrations at the various sites is shown in figure 21. The map shows that with the exception of few areas as sites 8 and 17, the fluoride level throughout Taifa is within the optimal level of 1.5 mg/l (WHO guideline). The exceptional areas are sites 8 and 17 in the northern part of Taifa, which were slightly high with values of 1.6mg/l and 1.97mg/l respectively.

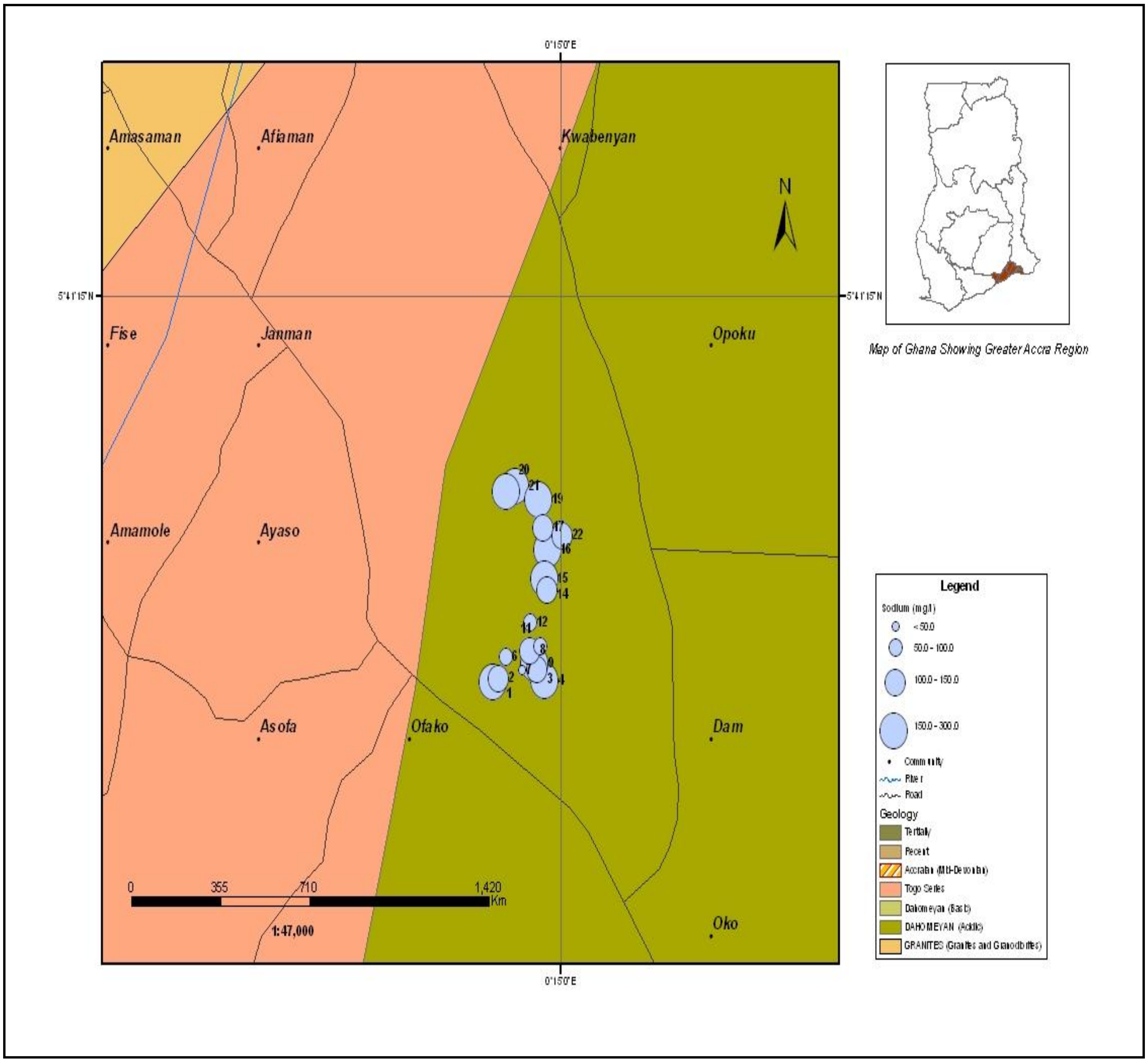


Figure 22: Map showing Sodium concentrations in groundwater at Taifa

The variation in the sodium concentrations at the various sites is shown in Figure 22. All but one value fell below the WHO limit of 200mg/l. (Except site 4 which contained 270mg/l of sodium.

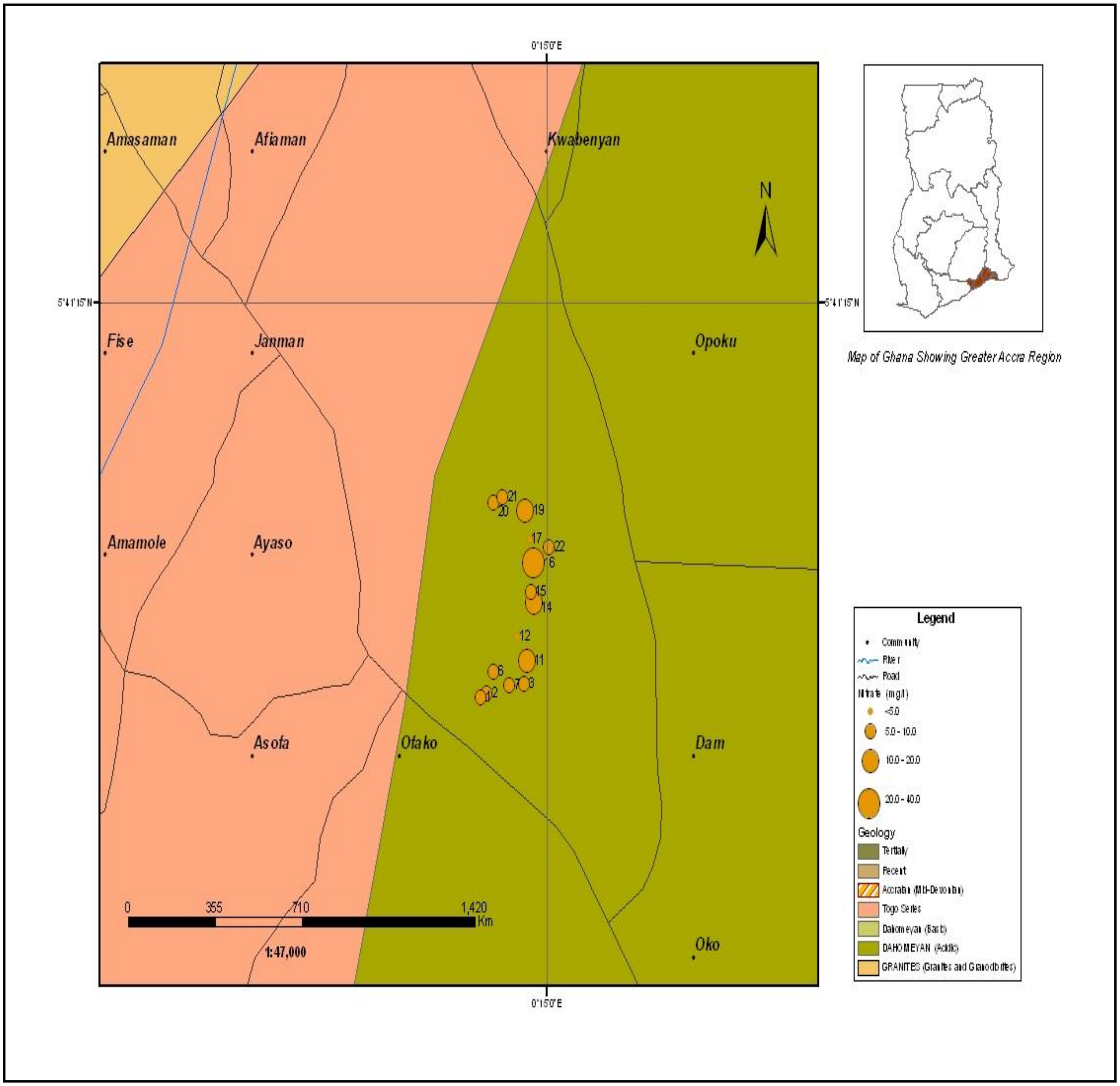


Figure 23: Map showing Nitrate concentrations in groundwater at Taifa

The variation in the nitrate concentrations at the various sites is shown in Figure 23. Generally, the nitrate concentration of the groundwater was within normal WHO limits with the exception of sites 11, 14, 16 and 19 which are located in the central part of the study area.

4.3 Groundwater use and policy

All 22 sites had boreholes that are supposed to supply water for domestic use. The boreholes had been in existence for 2 to 9 years with mean duration of 5.2 years. Fifteen (68%) out of the 22 boreholes were selling the water to the public within the neighbourhood. Eighteen (82%) out of the 22 respondents said they had checked the water quality before but only 6 out of the 18 (33.3%) said they check it yearly, while the rest said they had checked once, when the borehole was first drilled.

Table 3 below shows the uses of the water by the inhabitants.; (Sixty-five people out of 120 (22 borehole owners and 98 inhabitants) that is), 54%, use it for drinking purposes while all of them use it for cooking, bathing and washing of clothes.

Table 3: Groundwater uses in Taifa

Groundwater use	Sample size	Frequency	Percentage (%)
Drinking	120	65	54.0
Cooking	120	120	100.0
Bathing	120	120	100.0
Washing	120	120	100.0
Other	120	45	37.5

Ninety-two percent of the respondents stated that government should be responsible for the provision of potable water to the community; the rest were of the opinion that individuals have to support government efforts.

Analysis of the response to the questionnaire showed that 42% of the respondents could not assign any reasons for why government had not met the pipe-borne water needs of the community. About 21% attributed their plight to government neglect while 14% believed that the community was not exerting enough pressure on the agency responsible for potable water supply to the community. Interestingly, minority (9%) of the populace attributed the lack of government and assemblyman action on their water needs to the owners of boreholes in the Taifa area. They conjectured that the owners were exploiting the water shortage to their commercial advantage because of the revenue they accrue from selling the borehole water to the public at Taifa.

CHAPTER FIVE – DISCUSSION

5.1 Physico-chemical parameters and the water quality

The pH of the ground water samples taken from the area were all within acidic range with the exception of only three sites (3, 12 and 17) which were within the normal WHO range (6.5 – 8.5), even though, they were even on the borderline of the acidic. This finding could be attributed to the fact that the rock/soil type in the area is the Dahomeyan, hence affecting the pH of the groundwater.

The level of total dissolved solids in the borehole water were within normal acceptable WHO limit of 1000mg/l limits, for one site, (site 4), which had a value in excess of 1200. Consumers of this borehole could have gastrointestinal irritation. Site 4 also had very high sodium and chloride concentrations well above the WHO limit of 200 and 250 mg/l respectively. Water from borehole 4 could probably be unsuitable for people who have heart and kidney-related problems, congenital heart disease and kidney problems. When high levels of salt are consumed, it could lead to salt and water retentions in the body. This in turn may result in increased blood pressure of individuals after prolonged period of use and thus leads to hypertension and other cardiovascular- related diseases.

Cardiovascular diseases are risk factors for the development of renal problems and diabetes (Thomas *et al*., 2008). This implies that, continuous use of water which has high levels of salt exposes the population to the risk of developing heart and kidney-related diseases.

The high level of sodium and chloride in the groundwater at Site 4 (Figs. 5,10) partly could explain why the conductivity and total dissolved solids were also high at Site 4(Fig 4) since the state of mineralization of rock constituents in water affects conductivity.

Total iron concentrations were generally within the WHO guideline of 0.3 mg/l, with the exception of Site 12 which recorded iron content of 0.328mg/l. But this is not surprising because of the generally high levels of iron in Ghanaian waters (Pelig-Ba *et al*., 1991). High concentrations of iron in groundwater occur in many places in Ghana and can be as high as 21.50 mg/l (Adzaku, 1989).

Nitrate concentrations from borehole sites 10, 11, 13, 14, 16 and 19 exceeded the WHO guideline value of 10 mg/l. However, the nitrite concentrations were all within normal WHO limits. Sources of nitrogen and nitrate may include runoff or seepage from fertilized agricultural lands, municipal and industrial waste water, refuse dumps, animal feedstuffs, septic tanks, private sewage disposal systems and urban drainage (WHO, 2006). Previously, the lands at Taifa were agricultural lands and people still cultivate lands in the vicinity and the high level of nitrate could be as a result of use of fertilizer or sewage disposal systems. Many nitrogenous fertilizers are converted into mobile nitrates by natural processes which contaminate the nearby water bodies more profusely (Freeze and Cherry 1979, Walter *et al*., 1975). However, the real cause cannot be be properly ascertained. Exposure to high levels of nitrates for a long time could lead to methaemoglobinaemia (WHO, 2006). Methaemoglobinaemia, is called ‘blue-baby syndrome’. Nitrate is reduced to nitrite in the stomach of infants, and nitrite is able to oxidize haemoglobin (Hb) to methaemoglobin (metHb), which is unable to transport oxygen around the body. This reduced oxygen-transport becomes clinically manifest when metHb concentrations reach 10% or more of normal Hb concentrations; the condition, called methaemo-globinaemia, causes cyanosis and, at higher concentrations, asphyxia.

Potassium, calcium and magnesium concentrations as well as total hardness were within normal WHO limits while total iron was also within normal limits with the exception of one site.

The fluoride concentrations were within normal limits except two sites which had slightly high levels above the WHO lint of 1.5 mg/l. The use of this water for a long time could cause mottling of the teeth called fluorosis. It could also lead to brittle teeth (WHO, 2006).

5.2 Microbiology and the water quality

Pollution indicator bacteria, (faecal coliforms and total coliforms) were present in the ground water at 6/22 (27.3%) of the sampling sites. This could be due to both human and animal waste in the vicinity. Clapham (1993) reported that the risk of contracting diseases from Private Water Supplies was 22 times more probable than from a mains supply. Galbraith *et al*., (1987), however, suggested that the figure was more likely to be 50 times. According to van Derslice and Briscoe (1995), in areas with poor environmental sanitation, improved drinking water would have little or no effect. However, in areas with good community sanitation, reducing faecal coliform counts by two orders of magnitude would reduce the incidence of diarrhoea by 40%.

In the study area, about 30% of the population were presumably exposed to faecally contaminated water and therefore at risk of developing diarrhoea and other gastrointestinal diseases. Incidentally, diarrhea is among the top five diseases prevalent in the district.

5.4 Groundwater and water policy

Majority of the groundwater sources in Taifa are boreholes and have been in existence for about five years. About 70% of the borehole owners sell the water to others and so if the water is not of good quality, it will have a negative effect on the health of the population. Even though most of them use it for commercial purposes, only 27 % said they regularly checked the water quality, that is, yearly. This can therefore lead to the consumption of contaminated water as there is no regular monitoring of the quality.

Although about 50% of the inhabitants use the water for drinking, almost all of them use it for cooking, bathing and washing. There is no quality policy for monitoring private water supplies. Most of the inhabitants are buying water from these private suppliers and are therefore putting the health of the population at risk. This situation may lead to a possible outbreak of a water-borne disease and can also increase the risk of certain non-communicable diseases such as heart and kidney diseases from the intake of high-salt content-water from the boreholes over a prolonged period.

It is suggested that the appropriate state agency should be involved in the monitoring of quality from these private water supplies so as to safeguard the health of the population.

The GNWP 2007, launched in February 2008, projects that Ghana's consumptive water demand for 2020 would be 5 billion m^3, representing just 12% of the total surface water resources. If the remaining 88% is indeed accessible and potable or cost of making it ensures sustainable development, then Aqua Vitens Rand Company Limited must be encouraged to manage urban water supply. The water policy highlights that, sustainable development depends on potable water provision and this is the springboard driving NEPAD, the MDGs and GPRSII.

The Government of Ghana has adopted some principles of the MDGs' poverty reduction, such as "Improving access to safe water supply and sanitation to reduce the proportion of population without access to basic water supply and sanitation by 50% by 2015 and 75% by 2025". NEPAD's "African Water Vision 2025" and "Increasing access to potable water is key to achieving health outcomes and sustained poverty reduction" of the GPRS to which the GPRS II is a sequel.

Therefore, to ensure that there is continuity, consistency and complimentarity in the implementation (and not just in the policy formulation), concerted effort must be made to ensure that potable water is provided in acceptable quantities and quality to urban areas in Ghana.

CHAPTER SIX – CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The groundwater in Taifa would generally be classified as acidic and few sites, such as 4 and 21, had high levels of sodium and sites 4, 9,16,18,20 and 21 had high chloride levels which resulted in those sites having high concentrations of total dissolved solids and high conductivity.

Sites 8 and 17 also had high levels of fluoride and could lead to fluorosis if steps are not taken to create awareness on the associated hazard of using water of elevated fluoride concentration. Nitrate levels in some sites such as 10, 11,13,14,16 and 19 were also above the WHO limit and prolonged use of this water could lead to methaemoglobinaemia.

Microbiological indicator bacteria, namely, total coliforms and faecal coliforms were present in about 30% of samples, which suggest contamination of the water by human and animal waste.

The G.I.S.as a tool has aided in obtaining the spatial distribution of fluoride, chloride, sodium and nitrate at Taifa.

The groundwater of Taifa can be generally considered as not good for drinking purposes, with reference to the WHO Guidelines of some parameters.

6.2 Recommendations

In view of the findings of the study, it is recommended that the stakeholders mentioned below should do the following:

The Ministry of Water Resources, Works and Housing

- The Ministry should review its policy on private water provision especially with respect to borehole drilling. The Ministry should provide community-based water supply system for each community whereby one or more high yield boreholes are drilled and pumped up into a tank and distributed via pipe lines to the whole community so that different boreholes are not drilled, thereby reducing the possibility of contaminating the groundwater at various sources.
- The Ministry should also demand that Real Estate Developers, in consultation with the Water Resources Commission, use the Global Positioning and Geographical Information Systems to forecast good groundwater sources by testing for the quality and spatially locating the position of the ground water source, with the view to drill a high-yield borehole of good water quality for their estates, as the estate developers develop the estates far ahead of social amenities, potable water inclusive.

The Ministry of Health

- The Ministry of Health should embark on a screening programme in the area where the fluoride level was high to find out if there is fluorosis in the area and introduce the appropriate interventions.

The District Assembly

- The District Assembly should demand potable water quality test results conducted at accredited agencies from borehole owners every six months and defaulting owners should have their boreholes put out of operation till they comply with the regulation.
- To set up a task force to ensure that all borehole owners comply with the regulation to ensure that their water will be potable.
- The assembly should allocate funds for remuneration of task force members to ensure sustainability of task force.

The Opinion leaders

- Opinion leaders such as assemblymen should educate the community on the effect of using water which is not of good quality.

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APPENDIX

I. Questionnaire

Questionnaire Number. ……………………

1. House number………………………
2. Source of water supply…………………
3. Human waste disposal system in place……………………………………………..

Ground water

4. Type of ground water in the house [ ] borehole [ ] well
5. How long has it been in existence ………………………. years
6. What do you use the water for? (Tick all that apply)
7. [ ] drinking [ ] cooking [ ] bathing [ ] washing
8. [ ] other Specify …………………….
9. Do you sell the water to others? [ ] Yes [ ] No
10. Have you checked the water quality before [ ] Yes [ ] No
11. If yes, how often? (Tick what applies)
12. [ ] yearly [ ] every five years [ ] other (please specify)

13. If yes, when, and where was it last checked? ………………………………..years

…………..months……………………………… (respectively)

Policy

14. Who is responsible for providing water for you?

………………………………………………………………………………………………..

15. Why is it that there is no pipe-borne water in this area?

………………………………………………………………………………………………..

II. Pictures

UNICAM 969 AA Spectrometer

Using the AAS

Reading results from the AAS

A hand-held GPS device