ASSESSMENT OF POTENTIALLY TOXIC ELEMENTS IN HAND DUG WELLS AND BOREHOLE WATER IN IKOLE-EKITI AND ITS ENVIRONS, EKITI STATE, NIGERIA.

BY

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A RESEARCH PROJECT SUMMITTED TO
THE DEPARTMENT OF WATER RESOURCES AND AGROMETEOROLOGY, FACULTY OF AGRICULTURE, FEDERAL UNIVERSITY OYE EKITI,
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DEPARTMENT OF WATER RESOURCES AND AGROMETEOROLOGY, FACULTY OF AGRICULTURE
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DECLARATION

I hereby declare that this project titled "ASSESSMENT OF POTENTIALLY TOXIC ELEMENTS IN HAND DUG WELLS AND BOREHOLE WATER IN IKOLE-EKITI AND ITS ENVIRONS, EKITI STATE, NIGERIA" was written by me and that it is the record of my research work.

The information derived from literature has been duly acknowledged in the text and a list of references provided. It has never been presented in any previous application for a higher degree.

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CERTIFICATION

This project entitled: "ASSESSMENT OF POTENTIALLY TOXIC ELEMENTS IN HAND DUG WELLS AND BOREHOLE WATER IN IKOLE-EKITI AND ITS ENVIRONS, EKITI STATE, NIGERIA" meets the requirement of a final year project and regulation governing the award of a Bachelor degree of Agriculture of Federal University Oye Ekiti, and is approved for its contribution to knowledge and literacy presentation.

Makanjuola, Oluwasola E. **(Student)**	17-10-2016 **Date**
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Prof. J. O. Agbenin **(H.O.D WMA)**	21-10-2016 **Date**

DEDICATION

This project work is dedicated to the Almighty God the owner and lover of my soul and my loving parents, Mr. And Mrs Makanjuola Bamisile for the love they have lavished on me beyond measure.

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I remain eternally grateful to God almighty for His love, mercies and grace bestowed upon me during the course of this work, and filling the vacuum human beings could not occupy.

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ABSTRACT

Water is an important resource for almost all human activities like agriculture, industry, transportation, domestic uses and the proper functioning of the human body.

The study examined the physio-chemical properties and potentially toxic metals in hand-dug wells and boreholes in Ikole Ekiti and its Environs. Six functional hand-dug wells and six boreholes in the area were sampled and analyzed using standard procedures. Potential toxic metals were determined using Atomic Absorption Spectrometer. From the result, it was deduced that the odour, colour and turbidity of the samples were all within the WHO (2008) acceptable permissible limit.

All the other chemical parameters were within the WHO permissible limit in most of the locations except for Total hardness (TDS) that ranged from 530-680 mg/L in three hand-dug wells and borehole which exceeded WHO limits. Similarly, Total Hardness in three of the hand-dug and borehole wells exceeded WHO limits including Calcium concentration in the water.

Some of the potentially heavy metals analysed (Cr, Mn, Cd and Fe) in well and borehole water were below the WHO standard limits in some locations and but Manganese concentrations in two borehole samples and three hand-dug well samples exceeded the WHO limit. Chromium in Odo-Oro borehole at 0.24 mg/L Usin hand-dug well at 0.462 mg/L greatly exceeded WHO limit of 0.05 mg/L.

The generally low levels of heavy metal content in the water samples in both hand-dug wells/ boreholes showed they are less polluted and as such suitable for human consumption. In order to maintain the present quality status of wells and boreholes in the area, routine monitoring and assessment of boreholes by well owner or authorized agencies is recommended. Also, proper education on environmental requirement of citing well is essential for private well diggers for the purpose of preventing contamination from dung hill, underground tanks etc.

CHAPTER ONE

1.0 INTRODUCTION

Water is required by all living things for cell metabolism. Continuous existence of man on this planet will definitely depend on the availability of good quality water. It is a vital resource for almost all human activities like agriculture, industry, transportation, domestic uses and recreation (Awomeso *et al*. 2010).

Water is classified under two main categories based on its location and these are surface and ground water (Appelo et al., 2005).A well is an excavation or structure created in the ground aquifers. The well water is drawn by a pump or containers such as rubber or iron bucket that are raised by hand. Well can vary greatly in depth, water volume and may require treatment to soften it.

Borehole is a hydraulic structure which when properly designed and constructed permits the economic withdrawal of water from an aquifer. It is a narrow well drilled with machine. More costly to build than dug wells, but they are deeper and more reliable. Water from boreholes is also safer, since every borehole is covered and needs a pump. There is no direct user contact with the water.

Potentially toxic element is any chemical which through its chemical processes can cause death, temporary incapacitation, or permanent harm to humans, animals and plants. The major sources of pollution in streams, rivers and underground water arise from anthropogenic activities largely caused by the poor and uncultured living habit of people as well as the unhealthy practices of factories, industries and corporate bodies resulting in the discharge of effluents and untreated wastes. Pollution in water affects not only water quality but could also be dangerous to aquatic life (Sunnudo-Wilhelmy *et al*, 1999).

Municipal sources of groundwater contamination include open dumpsites, poorly constructed or unmaintained landfills, latrines and other waste sites. Each of these can contain a range of pathogens and toxins, including heavy metals that can migrate downward and contaminate aquifers. Industrial pollution of groundwater can come from dumping of wastewater or waste, from mining activities and from leakage or spillage from other industrial processes. Mining primarily affects groundwater through leaching of mine tailing piles. Chemical manufacture and storage similarly present a threat through leakage. Agricultural contamination comes primarily from overuse of pesticides and fertilizers that can later seep into groundwater sources.

Individuals can also cause groundwater contamination by improperly disposing of waste. Motor oil, detergents and cleaners can leak into water sources. Importantly, groundwater can also be contaminated by naturally occurring sources. Soil and geologic formations containing high levels of heavy metals can leach those metals into groundwater. This can be aggravated by over-pumping wells, particularly for agriculture (Fergusson, 2009).

Most of the water requirement for Ekiti people is met from surface and ground water supplies. Toxic elements that can be found in water include

i. Metals such as: cadmium, lead, mercury, nickel, silver, thallium, chromium, cobalt, copper, iron, manganese and zinc.
ii. Metalloids: arsenic.

The presence of trace metals in drinking water above the permissible limits could be deleterious to health. Rapid population growth in Ekiti State increases the demand for potable water for human. However, because of widespread shortage of public supply, the residents depend almost exclusively on hand-dug wells and boreholes for daily water supply. Consequently, analysis of potentially metals in hand-dug wells and boreholes is essential for the establishment of baseline data for groundwater quality in the study area.

Once these toxic elements are in the body they damage the cellular function by releasing dangerous free radicals. The damage that they cause on the cellular level can result into cancer and many other diseases. Heavy metal toxicity can also result in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs. Heavy metals such as lead, cobalt, chromium, zinc and copper cause damage to the intestinal tract. Repeated long-term contact with some metals or their compounds may even cause cancer (International Occupational Safety and Health Information Centre 1999). If unrecognized or inappropriately treated, toxicity can result in significant illness and reduced quality of life (Ferner, 2001).

Health effects from groundwater pollution depend on the specific pollutants in the water. Pollution from groundwater often causes diarrhoea and stomach irritation, which can lead to more severe health effects. Accumulation of heavy metals and some organic pollutants can lead to cancer, reproductive abnormalities and other more severe health effects. The need to assess the quality of water has become imperative because of the effect on the health of individuals. Therefore the objectives of this study to determine:

i. The physical and chemical characteristics of borehole and hand-dug well water in IkoleEkiti and its environs.

ii. The concentration of potentially toxic meta (Pb, Cu, Cd, Cu, Ar and Zn) with special reference to WHO permissible limits.

CHAPTER TWO

LITERATURE REVIEW

2.1 Toxic Heavy Metals

A toxic heavy metal is any relatively dense metal or metalloid that is noted for its potential toxicity, especially in environmental contexts. Heavy metals are naturally occurring elements that have a high atomic weight and a density at least 5 times greater than that of water (Fergusson. 1990). The term has particular application to cadmium, mercury, lead and arsenic, all of which appear in the World Health Organisation's list of 10 chemicals of major public concern (World Health Organisation 2015).

Toxic heavy metals occur naturally in the earth. They become concentrated as a result of human activities and can enter plant, animal, and human tissues via inhalation, diet, and manual handling. Then, they can bind to and interfere with the functioning of vital cellular components. Their multiple industrial, domestic, agricultural, medical and technological applications have led to their wide distribution in the environment: raising concerns over their potential effects on human health and the environment. Their toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individual some elements regarded as heavy metals are essential, in small quantities, for human health (Srivastava et al.,2010).

2.2 Sources of Heavy Metal

Although heavy metals occur naturally throughout the earth's crust, most environmental contamination and human exposure result from anthropogenic activities such as mining and smelting operations, industrial production and use, and domestic and agricultural use of metals and metal-containing compounds. Environmental contamination can also occur through metal corrosion, atmospheric deposition, soil erosion of metal ions and leaching of heavy metals, sediment re-suspension and metal evaporation from water resources to soil and ground water. Natural phenomena such as weathering and volcanic eruptions have also contributed significantly to heavy metal pollution. Industrial sources include metal processing in refineries, coal burning in power plants, petroleum combustion, nuclear power stations and high tension lines, plastics, textiles, microelectronics, wood preservation and paper processing plants (He et al., 2005).

2.3 Mode of Entry into Plant, Animal and Human

Heavy metals enter plant, animal and human tissues via air inhalation, diet and manual handling. Motor vehicle emissions are a major source of airborne contaminants including arsenic, cadmium, cobalt, nickel, lead, antimony, vanadium, zinc, platinum, palladium and rhodium (Balasubramanian *et al.*, 2009). Water sources (groundwater, lakes, streams and rivers) can be polluted by heavy metals leaching from industrial and consumer waste; acid rain can exacerbate this process by releasing heavy metals trapped in soils (Worsztynowicz *et al*, 1995). Plants are exposed to heavy metals through the uptake of water; animals eat these plants; ingestion of plant- and animal-based foods is the largest sources of heavy metals in humans. Absorption through skin contact, for example from contact with soil, is another potential source of heavy metal contamination. Toxic heavy metals can bio-accumulate in organisms as they are hard to metabolize (Pezzarossa *et al.*, 2011).

2.4 Groundwater Resources of Ekiti

Ekiti State has no coastal boundary; hence it has no coastal relief. Indeed, the term, Ekiti, denotes an interior or hinterland area as opposed to a maritime area (Oguntuyi, 1979). It also means mound. This name invariably implies that Ekiti State is mainly an upland area.

The relief is rugged with undulating areas and granitic outcrops in several Palaces. The notable ones among the hills are Ikere Ekiti Hills in the southern part of the state; Efon Alaaye Hills to the western boundary of the state and the Ado Ekiti Hills in the central part of the state. Most of these hills are over 250m above sea level. The drainage system over the areas of basement complex rocks is usually marked with the proliferation of many small river channels. The channels of these smaller streams are dry from November to May (The Official Website of the Government of Ekiti State, Nigeria; 2016).

In Ekiti State, there is no major river. However, the state serves as the watershed and source region for three major rivers that flow into the Atlantic Ocean. These are the Rivers Osun, Owena and Ogbese. Other rivers are Ero, Ose and Oni. Another important aspect of the relief of Ekiti state is the prevalence of erosion gullies along hill slopes and valleys. The gullies are very common in EfonAlaaye and in the northern part of the state. Indeed, in EfonAlaaye, the gullies could be devastating. (The Official Website of the Government of Ekiti State, Nigeria 2016).

2.5 Groundwater Quality Assessment of Ekiti State

Surface water is an important water resource for drinking and irrigation purposes in the central part of Ekiti-State. The water bodies are used with little attention to their quality status in addition to increased threat of anthropogenic contamination due to demographic pressure.

The central part of Ekiti-State which is predominantly basement terrain is characterized with occurrence of numerous surface water bodies. Groundwater occurrence in the area is erratic with incessant wells failures. These factors prompt the inhabitants to harness the surface water for drinking and domestic uses including agricultural activities. These surface water bodies are prone to pollution from anthropogenic activities apart from geogenic solute inputs from dissolved minerals. Major ion composition of surface water bodies is controlled by the interaction of precipitation with surficial geological and biological materials (Raymond et al. 1994). Therefore, knowledge of dissolved salts in such water bodies is required to make a decision on their proposed or potential use for any either industrial. irrigational or domestic purposes.

Olusiji (2015) in a study to groundwater quality appraisal of hand dug wells and borehole in two localities in Ekiti state showed that the water chemistry was strongly dependent on the chemistry of the basement rock, leaching during infiltration, exchange of ion with the reservoir rock, human activities and effluent, discharge from rivers. The study concluded that that the entire water sample analyzed met the requirements for good water supply with minimum scientific treatment.

Adefemi (2012) reported in a study titled "Physio-chemical and microbial Assessment of groundwater from Ijan-Ekiti south western, Nigeria". The study revealed that the physiochemical and metal analysis of the water samples are comparable to results of other studies conducted in other parts of Nigeria. The result also revealed that the values obtained were lower than the permissible limit recommended by WHO for drinking water.

2.6.0 Potentially Toxic Elements in Water

The permissible limits to potentially toxic metals in potable water by World Health Organization (WHO), Standard Organization of Nigeria (SON) and National Agency for Food and Drug Administration and Control (NAFDAC) are given in Table 2.1 below.

Table 2.1.Permissible Limits of physico-chemical parameters and potentially metals according to WHO, SON and NAFDAC Standards.

S/NO	Parameters	NAFDAC maximum allowed limits	SON Standard	WHO Standards Highest desirable	WHO Standards Maximum permissible
1	Colour	3.0 TCU	3.0 TCU	3.0 TCU	15.0 TCU
2	Taste	Unobjectionable	unobjectionable	unobjectionable	Unobjectionable
3	pH	6.50- 8.5	6.50- 8.5	7.0-8.9	6.50- 9.5
4	Turbidity	5.0 NTU	5.0 NTU	5.0 NTU	5.0 NTU
5	Conductivity	1000(us cm^{-1})	1000(us cm^{-1})	900(us/cm^{-1})	1200(us cm^{-1})
6	Total Alkalinity	100mg/L	100mg/L	100mg/L	100mg/L
7	Chloride	100mg/L	100mg/L	200mg/L	250mg/L
8	Copper	1.0mg/L	1.0mg/L	0.5mg/L	2.0mg/L
9	Nitrate	10 mg/L	10 mg/l	10 mg/L	50 mg/L
10	Zinc	5.0 mg/L	5.0 mg/L	0.01 mg/L	3.0 mg/L
11	Calcium	75 mg/L	75 mg/l	NS	NS
12	Lead	0.01 mg/L	0.01 mg/L	0.01 mg/L	0.01 mg/L
13	Cadmium	0.003mg/l	0.003mg/L	0.003mg/L	0.003mg/L
14	Arsenic	0.01 mg/L	0.01 mg/L	0.01 mg/L	0.01 mg/L
15	Total Hardness ($CaCO_3$)	100mg/L	100mg/l	100mg/L	500mg/L
16	Chromium				0.05mg/L
17	Manganese				0.05mg/L

2.6.1 Cadmium

Cadmium (Cd) is a naturally occurring metal with chemical actions similar to Zn. It may be present in water as the hydrated ion, as inorganic complexes such as carbonates, hydroxides, chlorides or sulphates, or as organic complexes with humic acids (OECD 1994). Cd exists in the earth's crust at about 0.1 part per million [Wedepohl 1995], usually being found as an impurity in Zn or lead (Pb) deposits, and as a result being produced primarily as a bye product of Zn or Pb smelting. Cadmium may penetrate aquatic systems through weathering and erosion of soils and bedrock, atmospheric deposition, direct discharge from industrial operations, leakage from landfills and contaminated sites, and the dispersive use of sludge and fertilizers in agriculture. Much of the cadmium entering fresh waters from industrial sources may be rapidly adsorbed by particulate matter, and thus sediment may be a significant sink for cadmium emitted to the aquatic environment (WHO; 1992).

Long-term exposure to lower levels leads to a build up in the kidneys and possible kidney disease, lung damage, and fragile bones. Hypertension, arthritis, diabetes, anaemia, cancer, cardiovascular disease, cirrhosis, reduced fertility, hypoglycemia, headaches, osteoporosis, kidney disease, and strokes are some of the long term effects (WHO: 1992).The World Health Organization-recommended maximum allowable concentration in drinking water for cadmium is 0.003 milligrams per litre.

2.6.2 Lead

Lead is an extremely poisonous metal distressing almost all organ and system in the body. The component limit of lead (1.0 μg/g) is a test benchmark for pharmaceuticals, representing the maximum daily intake an individual should have. Even at this level, a prolonged intake can be hazardous to human beings. The World Health Organization (WHO) recommended a legal limit of 50 ppb for lead in 1995, which is decrease to 10 ppb in 2010.

The main target for lead toxicity is the nervous system, both in adults and children. Long-term exposure of adults can result in decreased performance in some tests that measure functions of the nervous system. Long-term exposure to lead or its salts (especially soluble salts or the strong oxidant PbO_2) can cause nephropathy, and colic-like abdominal pains. It may also cause weakness in fingers, wrists, or ankles. Lead exposure also causes small increases in blood pressure, particularly in middle-aged and older people and can cause anaemia. Exposure to high lead levels can cause harsh damage to the brain and kidneys in adults or children and ultimately cause death. In pregnant women, high levels of exposure to lead may cause miscarriage. Chronic, high-level exposure has been shown to reduce fertility in males (*Golub et al., 2005*). Lead also damages nervous connections (especially in young children) and causes blood and brain disorders. Lead poisoning typically results from ingestion of food or water contaminated with lead, but may also occur after accidental ingestion of contaminated soil, dust, or lead-based paint. It is rapidly absorbed into the bloodstream and is assumed to have adverse effects on the central nervous system, the cardiovascular system, kidneys, and the immune system (Bergeson *et al., 2008).*

2.6.3 Copper

Copper is an indispensable substance to human life, but its significant doses can cause anaemia, acne, adrenal hyperactivity and deficiency, allergies, hair loss, arthritis, autism, cancer, depression, elevated cholesterol, diabetes, dyslexia, failure to thrive, fatigue, fears, fractures of the bones, headaches, heart attacks, hyperactivity, hypertension, infections, inflammation, kidney and liver dysfunction, panic attacks, strokes, tooth decay and vitamin C and other vitamin deficiencies (Kabata*et al.*, 1993). The maximum permissible limit according to WHO is 2.0mg/L

2.6.4 Iron

Iron is one of the mainly abundant metals in the Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/litre. Iron is present in drinking-water because of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability and range from about 10 to 50mg/day (WHO, 2011). The World Health Organization-recommended maximum acceptable concentration in drinking water for iron is milligrams per litre.

2.6.5 Manganese

Manganese is a mineral that occurs in rocks and soil and is a normal component of the human diet. It exists in well water as a naturally occurring groundwater mineral, but may also be present due to underground pollution sources. Manganese may become noticeable in tap water at concentrations greater than 0.05 milligrams per litre of water (mg/L) by imparting a color, odour, or taste to the water. However, toxic effects to health from manganese are not a major problem until concentrations are approximately 10 times greater than 0.05mg/L. The intensity of manganese in groundwater from natural leaching processes can vary extensively depending upon the types of rock and minerals present at the water table. Typically, manganese concentrations from natural processes are low but can range up to 1.5 mg/L or higher. Sources of pollution rich in organic matter can increase the background level by release from soil or bedrock into groundwater (CT- Manganese in drinking water).

Waterborne manganese has a greater bioavailability than dietary manganese (*Bouchard et al., 2010*). Exposure to high manganese concentration in drinking water increases intellectual impairment and reduced intelligence quotients in school-age children. However, data indicates that the human body can recover from certain adverse effects of overexposure to manganese if the exposure is stopped and the body can clear the excess (Devenyi *et al.*, 1994).

2.6.6 Zinc

Zinc is naturally present in water. The World Health Organization stated a legal limit of 5 mg Zn^{2+}/L. In natural surface waters, the concentration of zinc is usually below 10μg/litre, and in groundwater, 10–40 μg/litre (Elinder *et al*, 1986).Most rocks and countless minerals contain zinc in varying amounts and it enters the air, water, and soil as a consequence of both natural processes and human activities (Zinc: Human Health Fact Sheet 2005).

Zinc toxicity is a medical condition involving an overdose on, or toxic overexposure to, zinc. Such toxicity levels have been seen to occur at ingestion of greater than 225 mg of zinc (Fosmire, 1990). Excessive absorption of zinc can suppress copper and iron absorption. The free zinc ion in solution is highly toxic to bacteria, plants, invertebrates, and even vertebrate fish (Brita et al., 2006). Zinc is an essential trace metal with very low toxicity in humans (Ciubotariu *et al.*, 2015).

Excess zinc promotes obesity and related diseases in adolescents and makes diabetic patients more susceptible, as measured by an increase in glycosylated hemoglobin level in the blood (Singh and Taneja, 2009) and is also related to occurrence of severe anemia (Fiske and others 1994. When the intake of zinc is high, enzymatic activity of pancreas increases and so does mucin production in the intestine. Excess Zinc is not only linked to copper deficiency but also to cytopenias that typically resolve with the elimination of surplus zinc sources. Symptoms of zinc poisoning are quite serious and include convulsions and seizures, fever, aches and pains.

shock, fainting, a persistent taste of metal, inability to urinate, rash, low blood pressure, and vomiting (Fong, 2007).

2.6.7 Arsenic

Arsenic is found in the natural environment in some abundance in the Earth's crust and in small quantities in rock, soil, water and air. It is present in many different minerals. About one third of the arsenic in the atmosphere comes from natural sources, such as volcanoes, and the rest comes from man-made sources. Due to natural geological contamination, high levels of arsenic can be found in drinking water that has come from deep drilled wells. Inorganic arsenic is found throughout the environment; it is released into the water by volcanoes, the weathering of arsenic-containing minerals and ores, and by commercial or industrial processes (ATSDR 2007).

The dominant basis of arsenic poisoning is from groundwater that naturally contains high concentrations of arsenic. A 2007 study found that over 137 million people in more than 70 countries are probably affected by arsenic poisoning from drinking water (USA Today.com, 2007).

Chronic arsenic poisoning results from drinking contaminated well water over a long period of time. Many aquifers contain high concentration of arsenic salts (WHO Water-related diseases). The World Health Organization (WHO) recommends a limit of 0.01 mg/L of arsenic in drinking water. This recommendation was established based on the limit of detection for most laboratories' testing equipment at the time of publication of the WHO water quality guidelines. More recent findings show that consumption of water with levels as low as 0.00017 mg/L over long periods of time can lead to arsenicosis (WHO, 2011).

Symptoms of arsenic poisoning begin with headaches, confusion, severe diarrhoea, and drowsiness. As the poisoning develops, convulsions and changes in fingernail pigmentation called leukonychiastriata (Mees's lines, or Aldrich-Mees's lines) may occur (Yalçın, 2009).When the poisoning becomes acute, symptoms may include diarrhoea, vomiting, blood in the urine, cramping muscles, hair loss, stomach pain, and more convulsions. The organs of the body that are usually affected by arsenic poisoning are the lungs, skin, kidneys, and liver ("Test ID: ASU", 2012) .The final result of arsenic poisoning is coma and death (IHC World 2014).Arsenic is related to heart disease (hypertension-related cardiovascular disease), cancer (Tseng *et al.* 2003), stroke (Smith *et al.* July 1992) (cerebrovascular diseases), chronic lower respiratory diseases, and diabetes (Hendryx, 2009). Chronic exposure to arsenic is related to vitamin A deficiency, which is related to heart disease and night blindness (Hsuen *et al.* December 1998).

2.6.8 Chromium

Chromium is a naturally occurring element found in animals, plants, rocks, and soil and in volcanic dust and gases. Chromium has oxidation states (or "valence states") ranging from chromium (-II) to chromium (VI). However, the natural occurrence of chromium (VI) is rare but is usually produced from anthropogenic sources (EPA 1984a).

The World Health Organization-recommended maximum allowable concentration in drinking water for **chromium (VI)** is 0.05 milligrams per litre("WHO Guidelines on Drinking-Water Quality -- Chromium"). Oral intake of Cr (VI) compound may cause intense gastrointestinal irritation or ulceration and corrosion, epigastric pain, nausea, vomiting, diarrhoea, vertigo, fever, muscle cramps, hemorrhagic diathesis, toxic nephritis, renal failure, intravascular hemolysis, circulatory collapse, liver damage, acute multisystem organ failure, and coma, and even death, depending on the dose (Hay et al., 2000; Lewis 2004; Meditext 2005).

Lung cancer is the most serious long-term effect (Cohen et al., 1998; Lewis 2004; Meditext 2005). Apart from the carcinogenic potential, prolonged exposure can result in bronchitis, rhinitis, or sinusitis or the formation of nasal mucosal polyps. Besides the lungs and intestinal tract, the liver and kidney are often target organs for chromate toxicity (Rom, 2007).

CHAPTER THREE

MATERIALS AND METHOD

3.1 Geology of the study area

In general, Ekiti State is underlain by metamorphic rocks of the Pre Cambrian basement complex, the great majority of which are very ancient in age. These basement complex rocks show great variations in grain size and in mineral composition. The rocks are quartz gneisses and schist's consisting essentially of quartz with small amounts of white micaceous minerals. The rocks vary from very coarse grained pegmatite to medium grained gneisses with strong foliation. They occur as outcrops especially in Efon Alaaye and Ikere Ekiti areas (Smyth and Montgomery, 1962).

Geographically, Ikole Local Government is located between longitude 5° 30' 31.1" (5.5087°) East of Greenwich and latitude 7° 47' 29.3" (7.7915°) North of the Equator in Ekiti state Nigeria bordered by Kwara State to the North, Kogi State to the North east as shown in (Fig.1).The headquarters of the local government, Ikole Ekiti is about 22.5 kilometres from Ado – Ekiti, the Ekiti State capital as indicated in Figure 2.The local government is mainly on the upland zone heel rising to about 250 metres above the sea level. The Local Government occupies an area of about 374.940kms of land and according to the 2006 National Population Census figure, the total population of the local government was 168,436; Male:87,976; Female: 80,460.

Ikole is situated in the deciduous forest area of the State. The rainy season spans from April to October and the dry season from November to March. Temperatures range from 21°C to28°C with high humidity.

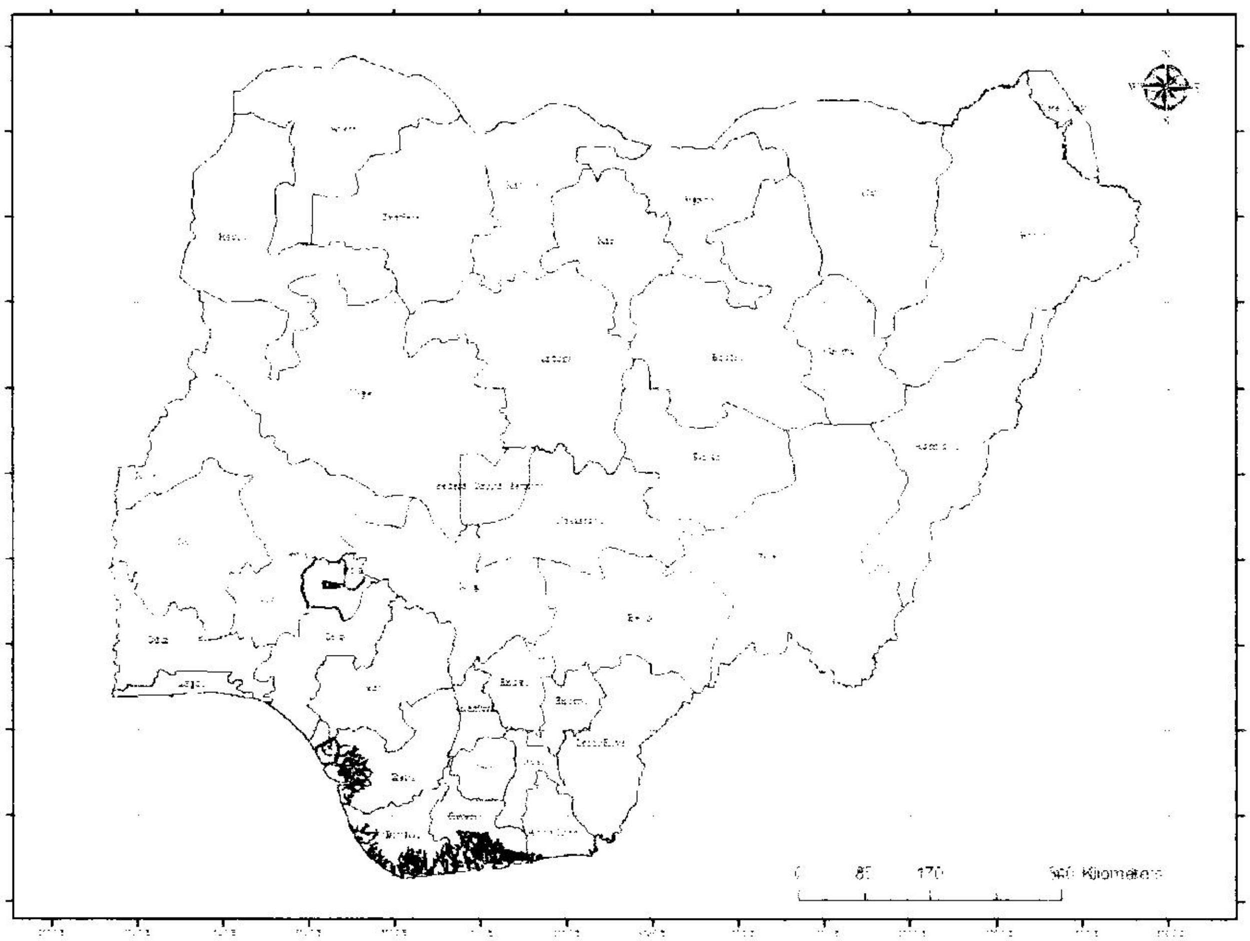

Figure 1. Map of Nigeria showing Ekiti State

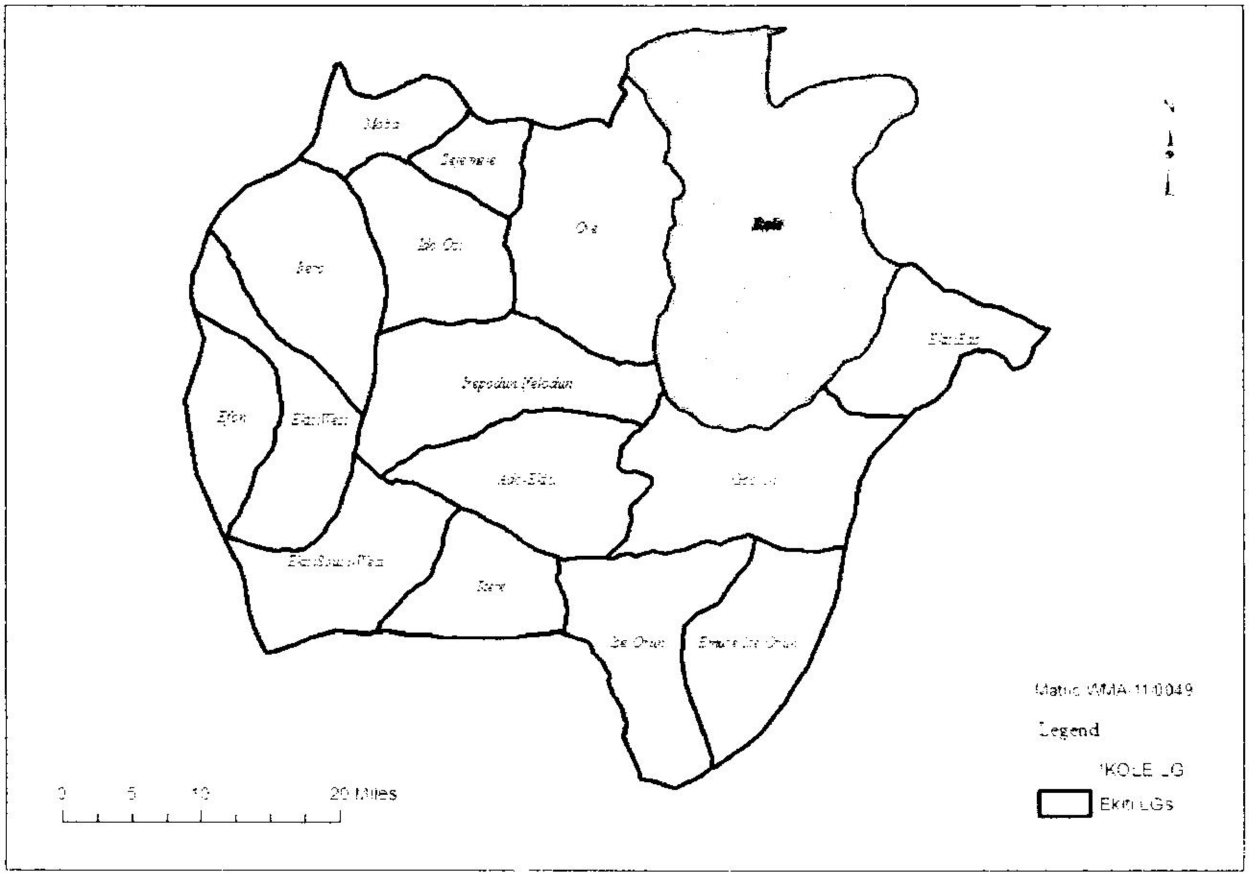

Figure 2. Map of Ekiti state showing the study area at Ikole Local Government Area.

Rainfall is about 70 inches per annum. Rain starts in March and peters out in November. The good drainage of the land makes it very suitable for agricultural pursuits. It is a common feature that trees shed their leaves every year during the dry season which begins in November and ends in February. The two seasons dry Season and rainy Season are quite distinct and are important to the agricultural pursuits of the people (The Official Website of the Government of Ekiti State, Nigeria » Ikole LGA.2016)

3.2 Sampling and sampling technique

The hand-dug well/borehole water samples were the main experimental materials. Six (6) wells and six (6) boreholes were randomly selected to represent the study area. Figure 3 shows the sampling points in Ikole-Ekiti while Figure 4 shows the road map of the sampling points.

3.3 Sampling procedure

Groundwater samples were collected from 6 boreholes and 6 hand-dug wells of the area from April 11th to13th 2016 into cleaned plastic polyethylene bottles. Global Positioning System (GPS) was used to determine the geographic positions of these wells. The sample bottles were thoroughly rinsed with the water collected and then corked. Water samples were collected from open wells by means of a bucket lowered into the well with a rope string. The bucket was allowed to sink some distance without disturbance so as to get a clear representative of the water in question. Water from the bucket was transferred into the bottle and acidified by adding two to three drops of HNO_3 and immediately transferred to a cooler containing ice block with a view to minimizing solute precipitation, microbial activities and loss of dissolved gases.

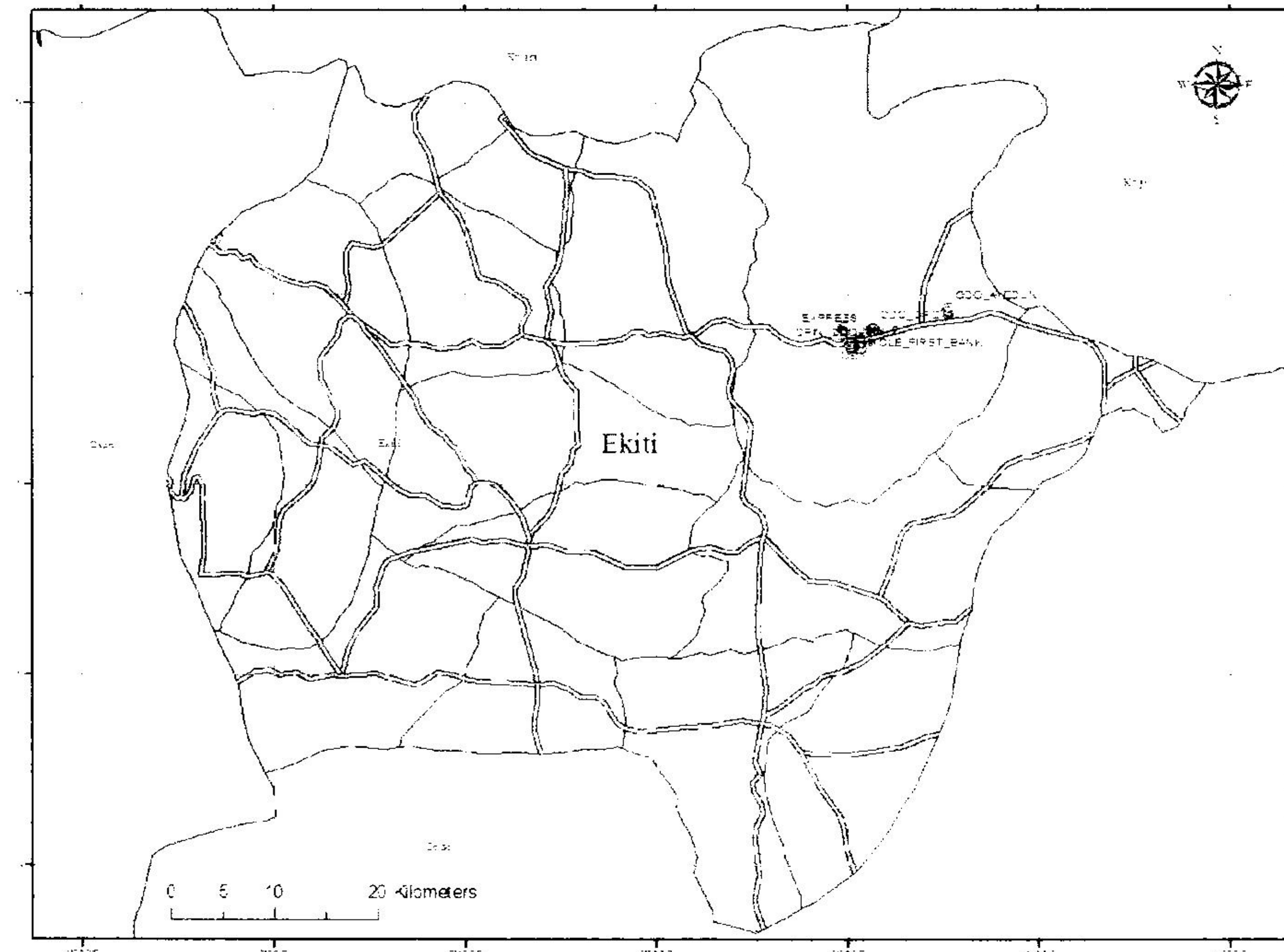

Figure 3. Map of Ekiti showing the sampling points

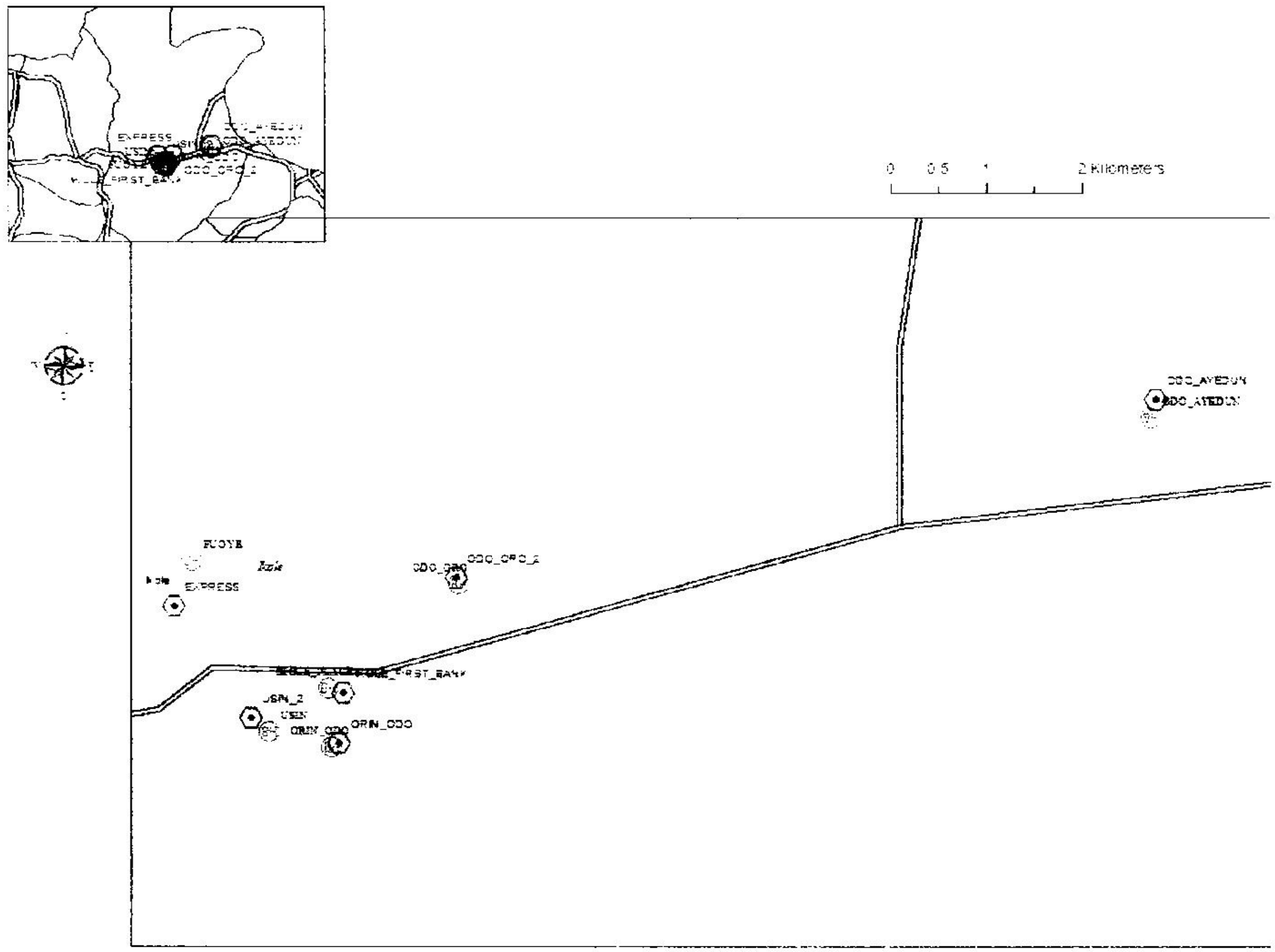

Figure 4. Road map of Ikole showing the sampling points

Table 3.1: The location and the geographical coordinates of the wells and boreholes sampled.

Location	**Geographical location**	**Water sample**
Usin	N 07°47.263′	Borehole 1 (B1)
	E005°30.290′	
	N 07°47.336	Hand-dug well 1 (W1)
	E005°30.186′	
Orin Odo	N 07°47°.179′	Borehole 2 (B2)
	E005°30.644′	
	N 07°47.196′	Hand-dug well 2 (W2)
	E 005°30.683	
IkolePalace	N 07°47.510′	Borehole 3 (B3)
	E 005°30.627′	
	N 07°47.478′	Hand-dug well 3 (W3)
	E 005°30.708′	
Odo Oro	N 07°48.104′	Borehole 4 (B4)
	E 005°31.367′	
	N 07°48.131′	Hand-dug well 4 (W4)
	E 005°31.347′	
Fuoye	N 07°48.236′	Borehole 5 (B5)
	E 005°29.856′	Hand-dug well 5 (W5)
	N 07°47.972′	
	E 005°29.741′	
Odoayedun	N 07°49.045′	Borehole 6 (B6)
	E 005°35.282′	
	N 07°49.148′	Hand-dug well 6 (W6)
	E 005°35.305	

Samples for analysis of potentially toxic metals were stored in a refrigerator at $4^{o}C$ to avoid precipitation of the metals. These samples collected were subjected to physico-chemical and heavy metal analysis at Ondo state water corporation (quality control) laboratory.

3.4.0 Physico-chemical analysis of the water samples

Standard methods as recommended by relevant authorities such as World Health Organization (WHO), United State Environmental Protection Agency (US- EPA) was employed for the preparation of reagents and determination of all water quality parameters.

The temperature and electrical conductivity (EC) was measured using mercury thermometer and conductivity meters immediately after sampling. Water sample collected in the field were analyzed in the laboratory for the major ions (Ca, Mg, Na, Cl), nitrate, and iron using the standard methods. Total hardness (TH) as CaCO3, Calcium (Ca2+), and chloride (Cl) were analyzed by volumetric methods.

Magnesium (Mg) was calculated from Total Hardness and Calcium hardness contents. Nitrate (NO_3), and iron (Fe) were determined by volumetric methods. Atomic absorption spectrophotometer (Phoenix-986 (AAS)) was employed for the determination of heavy metals in water.

3.4.1 Determination of total hardness by titration

Reagents: buffer solution, EDTA (ethylene-diamine-tetra-acetic acid) and Erichrome Black T indicator. Fifty millilitres of water sample was measured into the conical flask using measuring cylinder and 2 ml of buffer solution was added to the sample. Erichrome Black T (0.2g) indicator was added and then mixed together. The colour turned pink which indicated the end point. The burette was filled with 0.01M EDTA and the solution were titrated with EDTA until the colour changed from pink to blue. Then the reading along the burette was then taken. This procedure was repeated for other water samples.

Calculation: Total hardness = (millilitre of Titrant X 20) Mg/L $CaCO_3$

3.4.2 Determination of calcium hardness by titration

Reagent: standard 0.01M EDTA titrant, murexide indicator and 1N sodium hydroxide.

The burette was filled with 0.01M EDTA and 50ml of water sample was measured into a conical flask and 2ml of NaOH was added and shaken. Murexide indicator was added using the spatula.The solution was swirled until the colour turned to pink. The solution was then titrated with EDTA until the colour changed from pink to purple. The readings were observed and recorded and this procedure was repeated for other water samples.

Calculation: Calcium hardness = (Millilitre of Titrant X 20) Mg/L $CaCO_3$

3.4.3 Determination of Chloride in Water by Argentometric Titration

Reagents: potassium chromate (indicator), standard silver nitrate ($AgNO_3$) solution

Fifty millilitres of the water sample were measured in a conical flask and 1ml of potassium chromate was added and shaken vigorously to give a lemon greenish solution. The solution was titrated against silver nitrate ($AgNO_3$) until the colour turned from lemon green to ox blood. The reading along the burette was recorded and this analysis

Calculation: Chloride (Cl) = (Millilitres of Titrant X 10) Mg/LCl

3.4.4 Determination of Alkalinity by titration

REAGENT: Mixed indicator and 0.02N HCl

Fifty millilitres of water sample was measured into a conical flask.Mixed indicator was added to give a greenish solution. The burette was filled with 0.02N HCl. The solution was titrated against 0.02N HCl until the colour turned from green to pink.

Calculation: Alkalinity = (millilitre of Titrant X 20) Mg L

3.4.5 Determination of turbidity

Turbidity test was carried out using turbidity meter.

Micro processer turbidity meter that uses rays was used.

The curvette was filled with water sample to the marked point. The lower meniscus was watched out for. The curvette was wiped thoroughly with a lint free tissue. Cuvette was inserted into the chamber. It was covered and ensured that the cap points toward the LCD.

The read key was pressed and after 25 seconds the reading was taken.

3.4.6 Determination of iron

Reagent: conc. HCl NH_2OHCl solution (hydroxylamine hydro chloride. antibump granules. Ammonium acetate buffer solution and phenanthroline

50ml of the water sample was measured into a beaker. 2ml of conc. HCl was added. 2ml of NH_2OHCl solution (hydroxylamine hydro chloride) was added to the solution.

2 stones of antibump granules were added. The solution was boiled until the volume was reduced to 25ml. It was then allowed to cool. It was transferred into a 100ml conical flask. 10ml of Ammonium acetate buffer solution was added. 4ml of phenanthrolineindicatorwas also added.

The volume in the conical flask was made up to 100ml with distilled water. The colour of the solution was compared with a standard that ranges from 0.002 to 2.0 mg l^{-1}.

3.4.7 Nitrate test

Nitrate test was done used cadmium reduction column.

Reagent used: Colour developer, washing stock solution

The sample is passed through the cadmium reduction column to reduce the nitrate present to nitrite. 25ml of the sample was measured and 75ml of washing solution is added and passed through the column then collect at the rate of 7 to 10ml per minute. The first 25ml was discarded and the remainder was collected in the sample flask. 2ml of colour developer was added to the reduced sample and mixed. Between 10mins to 2 hours the absorbance was measured at 543nm against a distilled water reagent blank. The nitrate concentration was determined by comparing the absorbance with a standard nitrate graph.

3.4.8 Determination of Heavy Metals

Trace and heavy metals in the well/borehole water samples were determined by Atomic Absorption spectro-photometer. Phoenix-986 (AAS) using appropriate wave length for each metal. The atomic absorption spectrophotometer was operated in the air-acetylene flame mode and lamps operated at the following wavelengths according to the manufacturer's instruction (Cd, 518nm; Pb, 510; Cr, 540nm; Mn, 525nm).

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 Physical Parameters of the hand-dug and borehole water

The physico-chemical parameters and heavy metal analysis of the borehole and well water samples from Ikole and its environs are presented in Tables 4.1 and 4.2. Generally, all the borehole water and hand-dug well water samples showed unobjectionable odour (Table 4.1). Since odour is strictly of chemical and microbial origin (Schneider, 1975), its absence in water samples suggests that levels of materials causing odour are minimal in the water samples. According to WHO, odour should totally be absent or very faint for water to be acceptable for drinking. Therefore, on the basis odour the hand-dug well and borehole water can be suitable for drinking.

Colour was only detected in Odo Ayedun with a value of 0.35 which is below the WHO recommended limit of 15.0 (TCU) and (Ayodele et al., 2015)reported in the Water quality assessment of Otun and Ayetoro Area, Ekiti State, Southwestern Nigeria to be 5 TCU which still fell below the limit. Generally, the presence of colour in water is usually due to colouring matter (organic and inorganic) and also the underlying soil characteristics. Biotic activities and biodegradation of organic substances usually impact colour to water (Miller, 1988; Willis, 1989). The primary importance of colour in drinking water is aesthetic, but the sensory effects may be regarded as a health effect. Colour in domestic water may stain fixtures and clothes.

Temperature is basically important for its effects on other properties e.g. speeding up of chemical reactions, reduction in solubility of gases, amplification of taste and odour. The measured temperature values of the borehole water samples were between 25°C and 33°C and hand-dug wells water sample are also between 24.9°C-32°C. The temperature of the water

Table 4.1: Selected physico-chemical properties of borehole and hand-dug well water samples in Ikole-Ekiti.

Location	Colour	Odour	Turbidity	pH	EC	TDS (mg/l)	Total alkalinity (mg/l)	Total hardness (mg/l)	Mg (mg/l)	Ca (mg/l)	NO_3^- (mg/l)	Cl (mg/l)
Usin												
B	ND	Unobj	ND	6.0	71.6	320	ND	170	34	126	0.5	27
H	ND	Unobj	ND	5.8	76.2	510	ND	52	18	34	0.1	34
Orin odo												
B	ND	Unobj	ND	5.8	93.1	580	ND	150	26	124	0.15	32
H	ND	Unobj	ND	6.0	104.7	680	180	90	90	0.1	0.1	36
Ikole palace												
B	ND	Unobj	ND	6.2	147.8	610	ND	488	72	316	0.15	38
H	ND	Unobj	ND	6.2	121.1	660	82	480	50	430	0.16	37
Fuoye												
B	ND	Unobj	ND	6.0	84	490	ND	82	4	78	0.15	48
H	ND	Unobj	1.05	6.0	71	530	ND	78	12	66	0.15	43
Odo Oro												
B	ND	Unobj	ND	6.0	80.8	560	ND	74	3	71	0.1	42
H	ND	Unobj	ND	5.8	90.3	540	ND	90	26	64	0.1	29
OdoAyedun												
B	ND	Unobj	ND	5.6	97.5	530	ND	60	12	48	0.15	60
H	0.35	Unobj	ND	5.9	112.7	470	ND	186	48	138	0.12	32
Mean+SE								171±66.	25.2±11	127±	0.2±0	41±5
Borehole				5.9	95.8±11	515±43		178±65	41±12	40	.06	35±2
Well				6.0	96±8.2	565±35	13.7±			137±	0.12±	

										60	0.11	
WHO permissible limit	15.0	Unobjectionable	5.0	6.5-8.5	$1.0x10^3$	500	100	100	30	75	10	100

Table 4.2. Selected heavy metal composition of borehole and hand-dug well water in Ikole

Location	Mn	Fe	Cr	Zn	Cu	Pb	Ar	Cd
Usin								
B	0.052	0.60	ND	ND	ND	ND	ND	ND
H	0.020	0.22	0.462	ND	ND	ND	ND	0.027
Orin Odo								
B	0.040	0.30	0.004	ND	ND	ND	ND	ND
H	0.015	0.25	ND	ND	ND	ND	ND	0.400
Ikole Palace								
B	0.025	0.28	ND	ND	ND	ND	ND	ND
H	0.200	0.28	ND	ND	ND	ND	ND	0.002
Odo Oro								
B	0.042	0.22	0.240	ND	ND	ND	ND	ND
H	0.450	0.32	ND	ND	ND	ND	ND	ND
Fuoye								
B	0.055	0.35	ND	ND	ND	ND	ND	ND
H	0.400	0.33	ND	ND	ND	ND	ND	ND
Odo Ayedun								
B	0.045	0.20	ND	ND	ND	ND	ND	0.019
H	0.280	0.30	ND	ND	ND	ND	ND	ND
Mean± SE								
Borehole	0.040±0.004	0.15±0.06	0.122±0.068	±	±	±	±	±
Well	0.230±0.080	0.28±0.02	0.462±					0.28±0.11
WHO permissible limit(mg/L)	0.05	0.3	0.05	5	1	0.01	0.01	0.003

source does not have a direct health implication (Willis, 1989). However, the World Health Organization has no guideline for temperature.

Turbidity values for the study area are given in Table 4.1. The borehole water sample has no turbidity values. Only the hand-dug well water sample from Odo-oro has turbidity value of 1.05 F.T.U which is below the WHO standard range of 5 F.T.U. The clarity of water, which is measured in terms of turbidity, is an expression of its optical property that causes light to be scattered and absorbed rather than transmitted in straight lines (Willis, 1989).Turbidity may be caused when light is blocked by large amounts of silt, microorganisms, plant fibres, sawdust, wood ashes, and certain chemicals (Duncan, 1996). High turbidity is often associated with high levels of disease - causing microorganisms such as viruses, parasites and some bacteria. These organisms cause symptoms such as nausea, cramps, diarrhea and headaches. It would therefore be from hand-dug well water (Odo-oro), all other hand-dug well as borehole samples turbidity values acceptable for portable.

The lowest electrical conductivity (EC) value measured for the borehole sampling sites was 71.6μS /cm and for hand-dug well water was 71.0μS /cm and the highest value was 147.8μS /cm and for hand-dug well water was 121.1μS /cm as shown in Tables 3.The highest EC value was recorded in Ikole Palace borehole and hand-dug well water and Usin borehole water and Odo-oro hand-dug well water registering the lowest. The conductivity measured in all the location was low to the one reported in Groundwater Quality Appraisal of Some Hand- Dug Wells and (2012).Conductivity is the numerical expression of the ability of water to carry an electric current at 25^0C and a measure of free ion (charged particles) content in the water. These ions can come from natural sources such as bedrock, or human sources such as storm water runoff. The values indicate the extent to which chlorides, nitrates, sulphates, phosphates, sodium, magnesium, calcium, iron and aluminum ions are present in the water samples (Thriodore, 2004). The measured EC values indicate that the entire borehole and hand-dug well examined had values which were below the WHO maximum permissible EC level of between 500-1500µs/cm for drinking water. This also shows that contaminations due to dissolved ions are relatively low. Conductivity of a body of water has no health implications, but it is an important criterion in determining the suitability of water and waste water for irrigation and other uses (WHO, 1992; Thriodore, 2004).

The pH content of the water samples in the area ranges from 5.6 to 6.2 in the borehole with (Average = 5.9) and from 5.8 to 6.2 in well water with average value of 6.0. The water samples from the study area were slightly acidic in nature, suggesting that the activity of the hydrogen ions in water samples of the area were more than that of the hydroxyl ions. This low pH may be due to the release of chemical gasses, e.g. sulphur-dioxide, nitrogen dioxide, carbon monoxide and carbon dioxide from bush burning, combustion (organic and inorganic), and vehicular emission that generates acidic rains and water, which infiltrate into the ground and lowers the pH of the water. Besides, decaying vegetation could also produce some amount of tannic (weak) acids (Ayoade et al., 2012).Typically, the obtained pH values in this study fall below the World Health Organization standard of 6.5 to 8.5. When pH values is less than 6.5, it causes corrosion and the subsequent release of metals such as lead, zinc, and copper from pipes and plumbing fixtures into water, these substances can be toxic to humans (Ibitoye et al., 2012).Ayodele et al.,2015) also reported that Otun and AyetoroEkiti water was slightly acidic.

Table 4.1 gives TDS values for the water samples of the boreholes and hand-dug wells. TDS relates with electrical conductivity (EC) in dilute solutions.TDS value of borehole ranges from 320-610 mg/L with an average value of 515mg/L and is between 470-680 mg/L with an average value of 565 mg/L in hand-dug well water. Borehole water samples the values of TDS obtained in the borehole exceed the maximum contaminant levels as recommended by WHO except for Usin (320 mg/L) and Fuoye (490mg/L) borehole. According. to WHO (2004), the palatability of water with a TDS level 500mg/L is generally considered to be good and becomes significantly and increasingly unpalatable at TDS level greater than 1000 mg/L. High TDS was recorded by Olumide Benedict et al (2015) in a research carried in Akungba Akoko, Ondo State. The amount of TDS in a given source of water depends on the nature of the geological materials found in the area where the source is located. It also depends on the quantum of foreign materials that find their way into the source, as hand-dug well as the chemistry of the source. The chemistry of a water source to a large extent determines the degree to which such materials or substances dissolve in it (Lindorff, 1979).

Alkalinity values for the boreholes and hand-dug well are shown in Tables 4.1. Alkalinity is not a pollutant but is a total measure of the substances in water that have acid-neutralizing ability or quantitative capacity to react with hydrogen ions. Alkalinity of natural or treated waters is usually due to the presence of bicarbonates, carbonates and hydroxyl ions that may have been leached into ground water sources (Thriodore, 2004). Borates, silicates, and phosphates may also contribute to alkalinity. The measured alkalinity values for the water samples show that they are below WHO stipulated range of 100mg/L. Although there is currently no health implication for poor alkalinity in water, moderate alkalinity encourages the growth of aquatic life (Afuye *et al*. 2015).

Hardness is mostly due to the presence of carbonates and bicarbonates, chlorides, nitrates and sulphates of Ca and Mg. Table 4.1 gives total hardness values for the borehole and hand-dug well water samples from the study area. Total hardness of borehole water sample ranges from 60 mg/L (Odo-Ayedun) to 488mg/L (Ikole Palace) with an average value of 171mg/L and ranges from 52 mg/L (Usin) to 48mg/L (Ikole Palace) with an average value of 177mg/L in hand-dug well water. According to WHO (2004) water hardness classification, water can be classified as: soft (0 – 50 mg/L CaCO3), moderately soft (50 – 100 mg/L CaCO3), slightly hard (100 – 150 mg/L CaCO3), moderately hard (150 – 200mg/L CaCO3), hard (200 – 300mg/L CaCO3) and very hard (over 300mg/L CaCO3). Using the above water hardness classification by WHO, the borehole water and hand-dug well water samples studied in the report fall into the category of moderately soft to very hard as it can be seen in Ikole Palace borehole and hand-dug well water samples.

Hard water has a number of advantages: it tastes better than soft water because of the dissolved mineral salts in it, helps animals to build strong teeth and bones and can be supplied in pipes made of Pb as it does not dissolve Pb, which is the case with soft water (Thriodore, 2004). Hard water, if not in excess of 500mg/L does not constitute a health problem. It only leads to chronic diseases, especially cardiovascular diseases at levels higher than WHO maximum permissible limit of 500mg/L. From the measured values for the study area with respect to total hardness, two boreholes water and three hand-dug well in Table 4.1-4.2 are moderately soft, the rest are considered to be moderately hard.

Water hardness is usually as a result of dissolution of minerals containing multivalent metal ions in water. Studies have shown that regular consumption of hard water can have a lowering effect on the rate of cardiovascular disease (Sengupta, 2013). Nevertheless, the major negative effects of the use of hard water include wastage of soap, gray staining of washed clothes and scaling of pipes.

The concentration of Mg^{2+} ranges from 3 mg/L to 72mg/L with an average value of 25.16 mg/L in borehole water and ranges from 12 to 90 mg/L with an average value of 40.7 mg/L in hand-dug well water samples (Table 4.1). Only four borehole water which are Orin-Odo(26 mg/L), Odo-Oro (4 mg/L), Fuoye (32 mg/L), Odo-ayedun (12 mg/L), and three hand-dug wells: Usin (18mg/L), Odo-Oro (12 mg/L) and Fuoye (26 mg/L) water samples fell within the acceptable WHO limit of 30mg/L while others were above the limit. The possible source of the Mg^{2+} in the water could be from the chemical weathering of mafic and other related minerals constituting the basement complex rocks common in the area.

The result shows that the concentration of Ca ranges from 48 mg/L to 316 mg/L with an average value of 127.6 mg/L in borehole water and ranges from 34 mg/L to 430 mg/L with an average value of 137 mg/L in hand-dug well water. The concentration of Ca in borehole from Usin, Orin-Odo, Ikole Palace including the hand-dug well water from did not conform to the WHO acceptable limit of 75mg/L. They were all above the limit whereas Odo-Oro, Fuoye, Odo-Ayedun borehole water including the hand-dug well water samples from Orin-Odo and Odo-oro were all below the WHO limit.

The concentration of chloride ranges from 27mg/l to 60mg/L with an average value of 41.66mg/L in borehole water and 29mg/l to 43 mg/L with an average value of 35.2mg/L in hand-dug well water. All the samples showed relatively low chloride ions residual. High chloride in surface and groundwater may arise from both natural and anthropogenic sources such as run-off containing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds (WHO, 1993). Although chloride seems not to pose any health hazard, however, given that chloride ions are non-cumulative toxins (Ugboaja, 2004), continuous consumption of an excessive amount of the ion can lead to some health hazard (WHO; 1993). Excess chloride in water impacts bad tastes and may indicate contamination from urine and sewage. The WHO permissible limit is 100mg/L and all the borehole and hand-dug well water samples conform to the standard that is they are below the permissible level.

The results of nitrate are shown in Table 4.1.All samples analyzed met the WHO acceptable limits of 10mg/L. The nitrate ranges from 0.1mg/l (Usin) to 0.5mg/l (Fuoye) with an average value of 0.2mg/l in borehole water and 0.1mg/l -0.16mg/l with an average value of 0.12mg/l. Elevated nitrate concentrations are often caused by run-off from manure, excessive use of fertilizers, or septic systems. Consumption of water polluted with nitrates ion can lead to such health problems as methemoglobinemia in infants less than six months, diarrhoea and respiratory diseases (Ward *et al.* 2005).

4.2. Potentially Toxic Metals

Manganese ranges from 0.025 mg/l (Ikole Palace) to 0.055 mg/L (Fuoye) with an average value of 0.04mg/l in borehole water sample and from 0.015 mg/l (Orin-Odo)-0.45 mg/L (Odo-Oro) with an average value of 0.23 mg/l as shown in Table 4.2.The concentrations of Mn in the samples were less than the WHO permissible limit of 0.05 mg/L except for Usin borehole and Fuoye borehole as shown in Table 4.2 which had Mn value of 0.052 and 0.055mg/L respectively. The elevated concentration of Mn in Usin and Fuoye borehole might originate from the surrounding soil as reported by Alloway (1992) that soil around the hand-dug well constitute sources of Mn pollution. Manganese sources are widespread, and its distribution over long distances is favored because it is predominantly associated with dust particles (Udo, 1990). When Mn is present in potable water, it can cause neurological disorders. It imparts an undesirable taste to beverages and stain plumbing fixtures. The value of manganese (Mn) ranged from 0.02 to 0.06mgl^{-1} with a mean value of 0.03mgl^{-1} in Ife North in Osun state. The mean value of Mn (0.03mgl^{-1}) falls within the maximum permissible limit of 0.05mgl^{-1} set by WHO. The low concentration of Mn implies that water from the sampled wells and boreholes has good taste and would not promote the growth of algae in reservoirs or collection tanks (Nwankwoala*et al.*, 2011).

Table 4.2 shows the concentrations of cadmium in the water sample in Ikole Palace hand-dug well (0.002 mg/L) were below the WHO permissible limit of 0.003 mg/L while others Usin hand-dug well water (0.027 mg/L). Orin-Odo hand-dug well water (0.4mg/L). Odo-Ayedun borehole water (0.019 mg/L) were above the WHO permissible limit. The source of cadmium might have been from erosion of natural deposits. run off from economic activities involving disposal of waste batteries. The presence of high amount of Cadmium can cause damage to the kidney.

The concentration of iron in borehole water ranges from 0.20 mg/L in Odo-Ayedun borehole to 0.60 mg/l in Usin hand-dug well with an average value of 0.04 mg/L and 0.22 mg/l in Usin hand-dug well water) to 0.33 mg/L in Fuoye with an average value of 0.28 mg/L in hand-dug well water sample as shown in Table 4. Only two borehole water samples from Usin and Fuoye boreholes, and two hand-dug well water samples from Odo-Oro and Fuoye that did not conform to the WHO permissible limit of 0.3 mg/L but had Fe concentrations that were above the required standard while others were below the standard. Adefemi (2012) reported that Fe was high in his study carried in Ijan Ekiti with a mean value of 1.46 mg/L which contradicted the one in this project which had a mean value of 0.15 mg / L. Iron is naturally found widely in soils and is a constituent of many ground waters: however, excess residual Fe in water may cause taste, odour problem and reddish colouration of water thereby leading to staining of pipes, toilet and kitchen facilities and clothes.

Chromium was found in two borehole water samples Orin-Odo (0.004 mg/L) and Odo-Oro (0.240 mg/L) with an average value of 0.122 mg / L and a hand-dug well water sample from Usin (0.462 mg/L). The WHO limit of chromium is 0.05 mg/L. Odo-Oro borehole and Usin hand-dug well were above the limit. Zinc, Copper, Arsenic and Lead were not detectable in all the water samples.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

This study analyzed pH, turbidity, colour, odour, temperature, electrical conductivity, chloride, nitrate, magnesium, calcium, total alkalinity, total dissolved solid, total hardness, conductivity, manganese, total iron, chromium, zinc, cadmium, copper, lead and arsenic of underground water samples. The study has provided information about the groundwater quality status in Ikole Ekiti and its environs which are generally good for domestic uses, however, with minimum treatment. As at present, the results of physico-chemical parameters showed that the underground water in Ikole Ekiti falls within the highest desirable as well as maximum permissible limit of the WHO (2008) standards. Some of the metals analyzed (Cr, Mn, Cd and Fe) in well and borehole water were below the WHO standard limits in some location and was a little higher at other locations studied. This can pose harm to the rural dwellers that use these water sources for drinking and other uses.

The generally low levels of heavy metal content in the water across the sampled hand-dug wells/ boreholes showed they are less polluted and as such suitable for human consumption. The low content also suggests that boreholes in the area are located far away from dumpsites, automobile shops and other sources forms of heavy metal contamination.

Assessments of the controls of the water chemistry indicate a possible influence from the underlying geology of the area (basement bedrock and weathered products), the infiltrated precipitated water and anthropogenic factors. Very limited control can be exercised on the geology and groundwater recharge system in the area. Therefore, in order to keep the groundwater in Ikole Ekiti within safe limits for consumption, adequate measures must be taken to significantly reduce anthropogenic inputs into the groundwater contamination. because the population growth in Ikole-Ekiti is increasing at a geometric rate due to influx of students and staff to the newly established Campus of the Federal University Oye-Ekiti in Ikole-Ekiti.

The following are hereby recommended as possible solutions to the groundwater quality problems in the study area:

i. That water in such areas where the physic-chemical constituents are higher than the acceptable standards of the WHO should be treated to reduce the problems.

ii. Dwellers should be well educated on water hygiene and simple methods of keeping their water safe for drinking.

iii. That in areas where the cationic and anionic concentrations are far below the WHO acceptable levels. supplements should be advised to the residents of such areas or such be distributed so as to make up for the minimal intake recommended for domestic use by the World Health Organization:

iv. For the research approach, a larger number of samples should be taken to allow the optimization of a more routine study in the area.

v. In order to maintain the present quality status of wells and boreholes in the area. routine monitoring and assessment of boreholes mostly to prevent the indiscriminate sinking of these facilities to meet the ever increasing demands of people in the area by sanitary inspection officers is recommended.

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