

**CHEMICAL COMPOSITION OF BOREHOLE WATER IN TWO LOCAL
GOVERNMENT AREAS OF ONDO STATE WITH SPECIAL REFERENCE TO
POTENTIAL TOXIC METALS**

BY

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(WMA/11/0048)

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AND AGROMETEOROLOGY
FEDERAL UNIVERSITY OYE EKITI**
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SEPTEMBER, 2016

DECLARATION

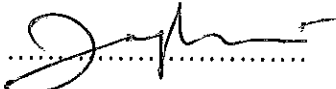
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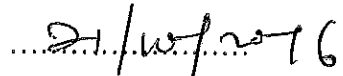
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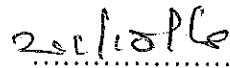
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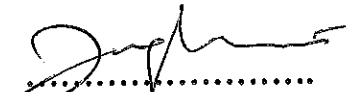
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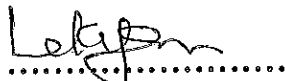
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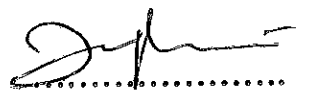
This project report entitled “chemical composition of borehole water in two Local Government Areas of Ondo state with special reference to potential toxic metals” meets the regulation governing the award of degree of Bachelor of Water Resources Management and Agro meteorology of Faculty of Agriculture, Federal University Oye-Ekiti, and is approved for its contribution to knowledge and literary presentation.


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DEDICATION

This project work is dedicated to God Almighty for his mercy upon my life, his grace for the accomplishment of the work. I also dedicate this work to my parents whose ceaseless effort in care and attention enabled me to carry out this work, also to my siblings, relatives and friends for their support.

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I am grateful to God Almighty, for the sustenance of life and provision, the one who has kept and guided me safe and healthy throughout the course of this research. He has never failed and He will never fail; may His holy name be glorified forever.

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ABSTRACT

Many households are used to the construction of shallow wells, but the wells hardly provide adequate water supply in term of volume and quality throughout the year. As a result, government adopted the construction of boreholes as an alternative to pipe-borne water supply and as an immediate solution to water supply and quality problem. Groundwater (borehole water) samples were collected randomly from two (2) Local Government Areas: Akure south (Oda, Ijoka, Sebi, Kajola, Ijapo housing, Alagbaka area and Akure metropolis) and Akure north (Oba-ile, Ugele, Odudu, Itaogbolu, and Iju) of Ondo-state. The water samples were subjected to physicochemical analysis with special reference to toxic metals that included Cd, Zn, As and others. The result shows that colour, odour, turbidity, pH, chloride, nitrate, total dissolved solids, total hardness, electrical conductivity and trace element like manganese were within WHO permissible limit in the two Local Government Areas, while calcium, magnesium, total alkalinity and some potentially toxic metals, particularly zinc, iron and cadmium, were above WHO permissible limit in six samples from Akure South Local Government Area and three samples from in Akure North Local Government Areas. This study, thus, concluded that since the concentration of total alkalinity, calcium, magnesium, iron, zinc, and cadmium were above WHO limits in some of the water samples, they are considered unfit for human consumption.

Table of Contents

DECLARATION	i
CERTIFICATION	ii
DEDICATION	iii
ACKNOWLEDGEMENT	iv
List of Figures	ix
List of Tables	ix
CHAPTER ONE	1
1.0. INTRODUCTION	1
1.1. Background	1
1.2. MAIN OBJECTIVES	3
CHAPTER TWO	4
2.0. LITERATURE REVIEW	4
2.1. HEAVY METALS.....	4
2.1.1. DISTRIBUTION OF HEAVY METALS.....	5
2.1.2. SOURCES OF HEAVY METAL.....	5
2.1.3. EFFECT OF HEAVY METALS ON HUMANS AND ANIMALS	7
2.2. CADMIUM.....	8
2.3. ARSENIC	9
2.3.1. MAJOR SOURCE OF ARSENIC	11
2.4. IRON.....	11
2.4.1. HEALTH CONCERNS OF IRON.....	12
2.4.2. MANGANESE.....	12
2.4.3. HEALTH EFFECT CAUSED BY MANGANESE.....	12
2.5 ZINC.....	13
2.5.1. OCCURENCE OF ZINC IN THE ENVIRONMENT.....	13
2.5.2. BENEFITS FROM ZINC.....	14
2.6. CHROMIUM	14
2.6.1. ENVIRONMENTAL OCCURENCE.....	14
2.6.2. TOXICOLOGY	16
CHAPTER THREE.....	17

3.0. MATERIALS AND METHODS.....	17
3.1. Site Description.....	17
3.2. SAMPLE SITES	20
3.3. METHODOLOGY.....	21
3.4. WATER SAMPLE ANALYSIS	21
3.4.1. Determination of pH	22
3.4.2. Determination of turbidity.....	22
3.4.3. Determination of conductivity.....	22
3.4.4. Test for Odour.....	23
3.4.5. Determination of Chloride in Water by Argentometric Titration	23
3.4.6. Determination of calcium hardness by titration.....	23
3.4.8. Determination of Magnesium	24
3.4.9. Determination of Alkalinity by titration.....	24
3.4.10. Determination of total hardness by titration.....	25
3.4.11. Determination of Heavy Metals	25
RESULT AND DISCUSSION	26
4.1. Physical properties of the water samples	26
4.2. Chemical properties of the water sample	28
4.3. Potentially Toxic metals in the water samples.....	33
CHAPTER FIVE.....	37
CONCLUSION AND RECOMMENDATION	37
REFERENCES	38

List of Figures

Figure 3.1 Map of Ondo state showing Akure South and North LGA in coloured.....	18
Figure 3.2 Map showing borehole (sample) point in Akure South and North LGA	19

List of Tables

Table 1 : Akure South Local Government Area borehole location	20
Table 2: Akure North Local Government Area borehole location	20
Table 3: The result of physical parameters measured at Akure South LGA borehole water sample.....	26
Table 4: NAFDAC, SON and WHO drinking water standards.....	27
Table 5: The result of physical parameters measured at Akure north LGA borehole water sample with WHO standard values	28
Table 6: The result of chemical parameter measured at Akure South LGA borehole water sample with WHO standard values	31
Table 7: The result of chemical parameter measured at Akure North LGA borehole water sample with WHO standard values	32
Table 8: The result of chemical parameter (heavy metals) measured at Akure south LGA borehole water sample with WHO standard	35
Table 9: The comparison of result of chemical parameter (heavy metals) measured at Akure north LGA borehole water sample with WHO standard values	36

CHAPTER ONE

1.0. INTRODUCTION

1.1. Background

Many households are used to the construction of shallow wells, but the wells hardly provide adequate water supply in term of volume and quality throughout the year. As a result, government adopted the construction of boreholes as an alternative to pipe-borne water supply and as an immediate solution to water supply and quality problem in the remote areas. (Oloruntade et al, 2014).

In term of borehole water (groundwater) composition with toxic metals, this is one of the most important environmental issues as they are toxic even at low concentrations. Human activities have increased the concentrations of heavy metals in the environment, (Mutaz et al, 2013).

Groundwater is water located beneath the ground surface in soil pores, in the fracture zone of rock and is pumped out using a submersible pump. A unit of rock or an unconsolidated deposit is known as an aquifer when it can yield a usable amount of water. Groundwater can be a long term reservoir of natural water cycle as opposed to short term reservoirs. The availability of borehole water has major public health benefits, since it typically reduces the risks of the public contracting water-borne diseases. However problems have beset the use of groundwater in the environment. Just as river waters have been over used and polluted in many parts of the universe, also are the aquifers. The quality of these ground water sources is affected by the characteristics of the media through which the water passes on its way to the groundwater zone of saturation. (Ihesinachi et al.2013).

The provision of good quality water is needed as an urgent step that will ensure groundwater quality, protection and conservation. Groundwater is an important means of drinking water for humans, which contains over 90% of the fresh water resources and it is an important reserve of high quality water (Gimba et al., 2015).

The quality of borehole water depends upon several factors including local geology, hydrology and geochemical characteristics of the aquifer, as well as the activities of microorganism; temperature and pressure are also responsible for the chemical characteristics of groundwater. Therefore borehole water often contains dissolve mineral ions whose type and concentration can affect their quality (Olalekan et al., 2015).

Physical, chemical and bacteriological contaminant should be found in water, but it is difficult to find such water. This lead to the reason why drinking water quality standard is setup to ensure the safety of drinking water supplies and the protection of human health. It is the knowledge of the properties and composition of water that seems to be more relevant for the evaluation of the potential use and managements of the water, knowing the water's physical, chemical, and biological characteristics allows expert to determine if it is suitable for drinking and other domestic use (Olalekan et al., 2015).

Heavy metals receive particular concern considering their strong toxicity even at low concentrations. They exist in water in colloidal, particulate and dissolved phases with their occurrence in water bodies being either of natural origin or of anthropogenic origin (Gimba et al., 2015).

Groundwater assessment and chemical analysis for heavy metals is very necessary as they are very much toxic and harmful pollutants because of their non-biodegradable nature and their potential to cause adverse effects in humans (Ihesinachi et al., 2013).

OBJECTIVES

1.2. MAIN OBJECTIVES

To determine the concentration of potentially toxic metals in borehole water at two local government areas in ondo state.

1.3. SPECIFIC OBJECTIVES:

The main objective is to be achieved through:

- i. To assess the physicochemical characteristics of the borehole water
- ii. To determine the concentration of potential toxic metal concentration in the samples
- iii. To ascertain the borehole portability in view of World Health Organization Standard Permissible Limit.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. HEAVY METALS

Metals exist naturally in the earth's crust, and their composition in the environment can vary between different regions resulting in spatial variations of background concentrations. The distribution of metals in the environment is governed by the properties of the metal and some environmental factors (Khlifi & Hamza-Chaffai, 2010).

Among the 92 naturally occurring elements, approximately 30 metals and metalloids are potentially toxic to humans, Be, B, Li, Al, Ti, V, Cr, Mn, Co, Ni, Cu, As, Se, Sr, Mo, Pd, Ag, Cd, Sn, Sb, Zn, Cs, Ba, W, Pt, Au, Hg, Pb, and Bi. Heavy metal is the generic term for metallic elements having an atomic weight higher than 40 the atomic mass of Ca (Ming-Ho, 2005). In other words heavy metals are chemical elements that are metallic in nature with relatively high density and toxic at low concentrations. Heavy metal includes Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr) and Lead (Pb), Copper (Cu) etc, (Lenntech, 2011).

Heavy metals are natural elements found within the earth's crust, which cannot be reduced or destroyed. Heavy metals by one way or the other enter our body via food and drinking water. These heavy metals are dangerous, because they tend to bioaccumulate (i.e. increase in the concentration of a chemical in a biological organism over a period of time, compared to the chemical's concentration in the environment). Heavy metals may enter a water supply by industrial and household wastes, or from acidic rain resulting in the disintegration of soils and releasing heavy metals into the ground water (Lenntech, 2011).

Some of the metals are needed to sustain life, such as calcium, magnesium, potassium and sodium. Others such as cobalt, copper, iron, manganese, molybdenum and zinc are needed at low levels as catalyst for enzyme activities (Bello et al., 2009).

The toxic metals may also replace other substances in other tissue structures. These tissues such as the arteries, joints, bones and muscles are weakened by replacement processes. Toxic metals can alter biochemical functions such as inhibition of enzymes, genetic damage, cardiovascular problems and hypertension. There is increase in epidemiological evidence indicating an association between water quality and mortality from cardiovascular and other chronic diseases (Ihesinachi et al., 2013).

2.1.1. DISTRIBUTION OF HEAVY METALS

Heavy metals cause damages to human health because they are persistent in nature and have accumulation capacity in biological systems. Heavy metals can be divided into four major groups based on their health importance

- i. Essential metals such as Cu, Zn, Co, Cr, Mn and Fe,
- ii. Non-essential metals such as Ba, Al, Li and Zr,
- iii. Less toxic metals such as Sn and As and
- iv. Highly toxic metals such as Hg, Cd and Pb (Mathew et al., 2015).

2.1.2. SOURCES OF HEAVY METAL

Nonpoint sources:

- Natural: Chemical and physical weathering of igneous and metamorphic rocks and soils often release heavy metals into the sediment and aquifer. Other contributions include the decomposition of plant and animal detritus, precipitation or atmospheric deposition of airborne particles from volcanic activity, wind erosion, forest fire smoke, plant exudates, and oceanic spray (Kennish, 1992).

- Anthropogenic: Surface runoff generated from mining operations usually has a low pH which contains high levels of metals such as iron, manganese, zinc, copper, nickel and cobalt. The combustion of fossil fuels pollutes the atmosphere with metal particulates that eventually settle to the land surface and later percolate into the groundwater. Urban stormwater runoff often contains metals from roadways and atmospheric fallout (Connell et al., 1984). Currently, anthropogenic inputs of metals exceed natural inputs.

Point sources:

Domestic wastewater effluent contains metals from metabolic wastes, corrosion of water pipes, and consumer products. Industrial effluents and waste sludges may substantially add to metal concentration (Connell et al., 1984).

High amounts of fertilizer are usually used on soil for the purpose of providing suitable levels of N, P and K for plant growth. These fertilizers contain heavy metals such as cadmium and lead as impurities. Long-term fertilizer application leads to the rapid increase of these heavy metals in the soil (Jone and Jarvis, 1981). Metals like Cd and Pb have no noticeable physiological actions. So also phosphorus fertilizer applications unintentionally add Cd and other possibly dangerous element for the soil, including Pb and Hg which may percolate to the groundwater aquifer (Raven et al., 1998).

Also in solids and manures: The addition of various bio-solids for example, composts, cattle's manure and municipal sewage sludge (MSS) to land gradually leads to the build-up of heavy metals like As, Cd, Cr, Cu, Pb, Hg etc, in the soil and to the groundwater (Basta et al., 2005).

In other word, heavy-metal cation can also be introduced into borehole ground water through agricultural processes such as application of fertilizer liming material sewage sludge, compost and other industrial and urban waste materials (Wikipedia, 2011) which infiltrate and then percolate to the aquifer.

Heavy metals such as Cu, Pb, Hg and Se infiltrate into water through other sources such as automobile discharges, mines, and also natural soil (Hart, 2003). The commonest toxic heavy metals encountered in ground water includes Pb, Cd, Hg, and As (Simone et al., 2012).

2.1.3. EFFECT OF HEAVY METALS ON HUMANS AND ANIMALS

Heavy metals have the ability of producing genetic harm to human and animal cells of both genders. They are also very poisonous at comparatively smaller amount. Food and drinking water containing high amount of heavy metals disturb the stomach causing diarrhea and vomiting. Correspondingly greater degree of Lead (Pb) results in anemia, a disease of blood in humans (Kamran et al., 2013).

Metals are non-degradable and are noted as main environmental contaminant causing cytotoxic, mutagenic and cancerous (carcinogenic) effect in human (More et al., 2003 and AL-Othman et al., 2011).

Heavy metal polluted food removes some major nutrient in human body, thus facilitating decline in immunological defences, growth delay, and psychosocial abilities (Kamran et al., 2013).

2.2. CADMIUM

Cadmium derive its toxicological property from its chemical similarity to Zn an essential micronutrient to human and animal. Cadmium is biopersistent and, once absorbed by an organism, remains resident for many years (over decades for humans) although it is eventually excreted (Lenntech, 2011).

High exposure causes obstructive lung disease linked to lung cancer, Cadmium may also cause bone defects (osteomalacia, osteoporosis) in humans and animals. In addition, the metal can be linked to increased blood pressure and have effect on the myocardium in animals, although most human data do not support these findings. The average daily intake for humans is estimated as 0.15µg from air and 1µg from water, but levels may vary widely (Lenntech, 2011).

Cadmium accumulates in the human body causing several negative impacts to the organs, like liver, kidney, lung, bones, placenta, brain and the central nervous system (Castro-Gonzalez & Méndez-Armenta, 2008). Cadmium can affect calcium, phosphorus and bone metabolisms in both industrial workers and people exposed to Cd in public environment (Mathew et al., 2015)

The kidney is the main critical organ that is affected after a long-term exposure to cadmium. The major sign of renal dysfunction is an increase urinary excretion of proteins; other damages that have been observed include reproductive, and development toxicity, hepatic, haematological and immunological effects (Apostoli & Catalani, 2011; ATSDR, 2008).

2.2.1. SOURCES OF CADMIUM

Cadmium is generated as an inevitable by-product of Zn and Pb refining, since these metals exist naturally within the raw ore (Lenntech, 2011).

The most obvious use of cadmium is in nickel/cadmium batteries, as rechargeable or secondary power sources possessing high output, long life, low maintenance and high tolerance to physical and electrical stress (Govind et al., 2014).

Cadmium coatings provide good corrosion resistance, particularly in high stress environments such as marine and aerospace applications where high safety or reliability is required; the coating is preferentially corroded if damaged. Other uses of cadmium are as pigments, stabilisers for PVC, in alloys and electronic compounds. Cadmium is also present as an impurity in several products, including phosphate fertilisers, detergents and refined petroleum products (Govind et al., 2014).

In general, for non-smokers the major exposure pathway is through food, via the addition of cadmium to agricultural soil from various sources (atmospheric deposition and fertiliser application) and through ambient air and drinking water (Lenntech., 2011).

2.3. ARSENIC

Arsenic is a naturally occurring element, present everywhere with a metalloid property. Highly mobilized element and mainly cycled by water in the environment and widely available in sediments, soil, rock and metals ores in the form of oxyhydroxide or sulfide or compounds of different metals (singh et al., 2006).

It exists in organic compounds (in combination with hydrogen and carbon), and within inorganic compound (in combination with sulphur, chlorine or oxygen). In water, arsenic is tasteless, odourless which can only be detected by chemical test. The As consumption in food and beverages by the general population typically lies between 20 and 300 ug/day, food is the major contributor to the daily intake of arsenic for much of the non-occupationally exposed population. In places where drinking water contains elevated levels

of arsenic, drinking water is a significant source of both total and inorganic arsenic. Especially where As exceeds 50Kg/L (Charles et al., 2001).

Humans are exposed to various forms of organic and inorganic arsenic species (arsenicals) in water, food and other environmental media, in which each of the forms possesses different bioavailability and physicochemical properties (Charles et al., 2001).

The end product of ingested or inhaled inorganic arsenic in the human body is largely dependent on its valence state. The two most common valence states to which humans might be environmentally exposed are the trivalent and pentavalent forms, arsenite (AsIII) and arsenate (AsV) (Charles et al., 2001).

The toxicity of an arsenic-containing compound depends on its valence state (zero-valent, trivalent, or pentavalent), its form (inorganic or organic), and factors that modify its absorption and elimination. After absorption into the body system, arsenic undergoes some accumulation in soft tissue organs such as the liver, spleen, kidneys, and lungs, but the major over term storage for arsenic is keratin-rich tissues, such as skin, hair, and nails, making the measurement of arsenic in these biological specimens useful for estimating total arsenic burden and long-term exposure under certain condition (Howard, 2002).

Chronic exposure to lower levels of arsenic leads to an abnormal (different from initial) pattern of skin hyper pigmentation, peripheral nerve damage manifesting as numbness, tingling, and weakness in the hands and feet, diabetes, and blood vessel damage resulting in a gangrenous condition affecting the extremities. Chronic arsenic exposure also causes a noticeable elevated risk for developing a number of cancers, most notably skin cancer, cancers of the liver (angiosarcoma), lung, bladder, and possibly the kidney and colon (Howard, 2002).

2.3.1. MAJOR SOURCE OF ARSENIC

Weathering of arsenic-containing rocks is observed to be the main natural source of arsenic in the environment same also as the volcanic activity and forest fires which emit arsenic into the atmosphere, from which the arsenic later settles on the earth surface. Naturally occurring arsenic can be mobilized chemically and subsequently can be infiltrated/percolated into the groundwater at landfills and other site, where contaminants such as volatile organic and petroleum are present (Anthony et al.,2002).

2.4. IRON

Iron is one of the abundant resources found on earth's crust, made up of at least five percent of the earth's crust, which infiltrates (seeps) through the soil. The iron in the earth's surface dissolves, making it to flow into almost every natural water sources and supply, including well water and percolated into the aquifer. Although iron is present in our water, is moderately found at concentrations greater than 10 milligrams per litre (mg/l) or parts per million (ppm) (WDNR, 2001).

Iron is generally divided into two main categories: soluble and the insoluble iron. Soluble iron, or "clear water" iron, is the most common form of iron is identified by users to be clear water in a glass container. If allowed to stand for a few minutes, reddish brown particles will appear in the glass and eventually settle to the bottom. While insoluble iron, or "red water"iron, if poured into a glass container, appears rusty or has a red or yellow colour, insoluble iron can create serious taste and appearance problems for the water user (WDNR, 2001).

2.4.1. HEALTH CONCERNS OF IRON

Iron is considered non-toxic to health, and regarded necessary for good health because it transports oxygen in your blood. The water may also have a metallic taste and an offensive odour (WDNR, 2001). The human system needs averagely 1-3 additional milligrams of iron per day (mg/day), and average intake of iron is approximately 16 mg/day, mostly consumed from food such as green leafy vegetables, red meat, and iron-fortified cereals. The amount of iron in water is usually low, and the chemical form of the iron found in water is not readily absorbed by the body and the Iron bacteria that may be associated with iron in water, are not a health problem (MDH, 2014).

2.4.2. MANGANESE

Manganese is an important nutrient whose daily requirement is noted to range between 2.5 to 5.0 mg for adults. It is a metal having relatively low toxicity to human being, leading to acute poisoning effect at higher concentrations intake. Effects of Manganese are decrease in systolic blood pressure, disturbed excretion of 17-ketosteroids, and change in erythropoiesis and granulocyte formation (Mathew et al., 2015).

2.4.3. HEALTH EFFECT CAUSED BY MANGANESE

The human body is approximately made up of about ten milligrams of manganese, majorly located in the liver, bones, and kidneys. This trace element is a cofactor for a number of important enzymes, including arginase, cholinesterase, phosphoglucomutase, pyruvate carboxylase, mitochondrial superoxide dismutase and several phosphotases, peptidases and glycosyltransferases. In certain instances, Mn^{2+} may be replaced by Co^{2+} or Mg^{2+} . Manganese functions with vitamin K in the formation of prothrombin (Blaurock-Busch., 2002).

Insufficient manganese consumption has been associated with parenteral nutrition, resulting in dermatitis, changes in hair pigmentation and slowed hair growth. Low cholesterol, triglyceride and phospholipid levels were low. Significant deficiencies have been found in epileptics (Blaurock-Busch., 2002).

Manganese can be consumed from our diet and in our drinking water. Domestic usage in manganese containing water does not increase your exposure since manganese does not penetrate the skin and does not get into the air. High exposure to manganese has been associated with toxicity to the nervous system, producing a syndrome that resembles Parkinsonism (APEC Water, 2016).

2.5 ZINC

2.5.1. OCCURENCE OF ZINC IN THE ENVIRONMENT

Zinc is found in the air, water, and soil as a result of both human activities and natural occurrence. Most zinc enters the environment as the result of mining, burning of waste, purifying of zinc, lead, and cadmium ores, steel production and coal burning. These activities can increase zinc levels in the atmosphere. Waste streams from zinc and other metal manufacturing and zinc chemical industries, domestic waste water, and run-off from soil containing zinc can discharge zinc into waterways. Zinc level in the soil (to the ground water) increases mainly from disposal of zinc wastes from metal manufacturing industries and coal ash from electric utilities. Sludge and fertilizer also contribute to increased levels of zinc in the groundwater. In air, zinc is present mostly as fine dust particles. This dust eventually settles over land and water. Rain and snow aid in removing zinc from air which is then percolated into the aquifer (ATSDR 2005).

In humans, overtime excessive dietary intake of zinc can cause deficiencies in iron and copper, leading to nausea, vomiting, fever, headache, tiredness and abdominal pain. Zinc intake in humans is good for immune and other beneficial functions but that too much is harmful. Like selenium, the demarcation between too much and too little is not precisely known and may vary between individuals (Irwin, 1997). Zinc consumed through mouth is relatively non-toxic, though the soluble salts in large doses may leads to vomiting & diarrhea. Symptoms of zinc toxicity are lassitude, slower tendon reflexes, bloody enteritis, diarrhea, lowered leukocyte count and depression of CNS, and paralysis of extremities (Irwin, 1997).

2.5.2. BENEFITS FROM ZINC

In humans system, consumption and digestion of zinc is essential for normal growth and maturation, cell metabolism, development of reproductive organs, prevention of anaemia, effective functioning of the prostate gland, healing of wounds, enzyme activity, regulating zinc dependent enzymes, manufacturing of proteins and nucleic acids, and component of DNA and RNA polymerases and a number of metalloenzymes (Irwin, 1997).

Zinc deficiency alters the production of DNA and RNA, which leads to declining of protein synthesis. Typical signs of severe deficiency including dermatitis, emaciation, testicular atrophy, retarded growth & anorexia and endemic zinc deficiency syndrome among young men and women (Irwin, 1997).

2.6. CHROMIUM

2.6.1. ENVIRONMENTAL OCCURENCE

Chromium (Cr) is a naturally occurring element found in the earth's crust, valence states ranging from chromium (II) to chromium (VI) whose compound are stable in the trivalent [Cr(III)] (Paul et al., 2014).

Chromium enters into air, water, and soil from a wide variety of natural and anthropogenic sources with the largest source coming from industrial establishment such as tannery facilities, chromate production, metal processing, stainless steel welding, and ferrochrome and chrome pigment production (Paul et al., 2014).

Chromium (VI) is the dominant form of Cr in shallow aquifers where aerobic conditions exist. Chromium (VI) can be reduced to Cr (III) by soil organic matter, S^{2-} and Fe^{2+} ions under anaerobic conditions often encountered in deeper groundwater. Major Cr (VI) species include chromate (CrO_4^{2-}) and dichromate ($Cr_2O_7^{2-}$) which precipitate readily in the presence of metal cations (especially Ba^{2+} , Pb^{2+} , and Ag^+). Chromate and di-chromate also adsorb on soil surfaces, especially iron and aluminium oxides. Chromium (III) is the dominant form of Cr at low pH (<4). Cr^{3+} forms solution complexes with NH_3 , OH^- , Cl^- , F^- , CN^- , SO_4^{2-} , and soluble organic ligands (Raymond et al., 2011).

Chromium (VI) is the most toxic form of chromium and is also the most mobile while the Chromium(III) mobility is decreased by adsorption to clays and oxide minerals below pH 5 and low solubility above pH 5 due to the formation of $Cr(OH)_3(s)$. Chromium mobility depends on sorption characteristics of the soil, including clay content, iron oxide content, and the amount of organic matter present (Raymond et al., 2011).

Chromium can be transported by surface runoff to surface waters in its soluble or precipitated form. Soluble and un-adsorbed chromium complexes can leach from soil into groundwater and leachability of Cr(VI) increases as soil pH increases (Raymond et al., 2011).

Recent rapid increase in the environmental concentrations of chromium has been linked to air and wastewater release of chromium, mainly from metallurgical, refractory, and chemical industries. Chromium released into the environment from anthropogenic activity occurs mainly in the hexavalent form [Cr (VI)] (Paul et al., 2014).

2.6.2. TOXICOLOGY

The most obvious exposure routes or intake modes are:

- Ingestion (eating and drinking)
- Dermal contact (Skin penetration)
- Inhalation (breathing)

Health effects of chromium are classified into two namely as carcinogenic (causing cancer) and non-carcinogenic.

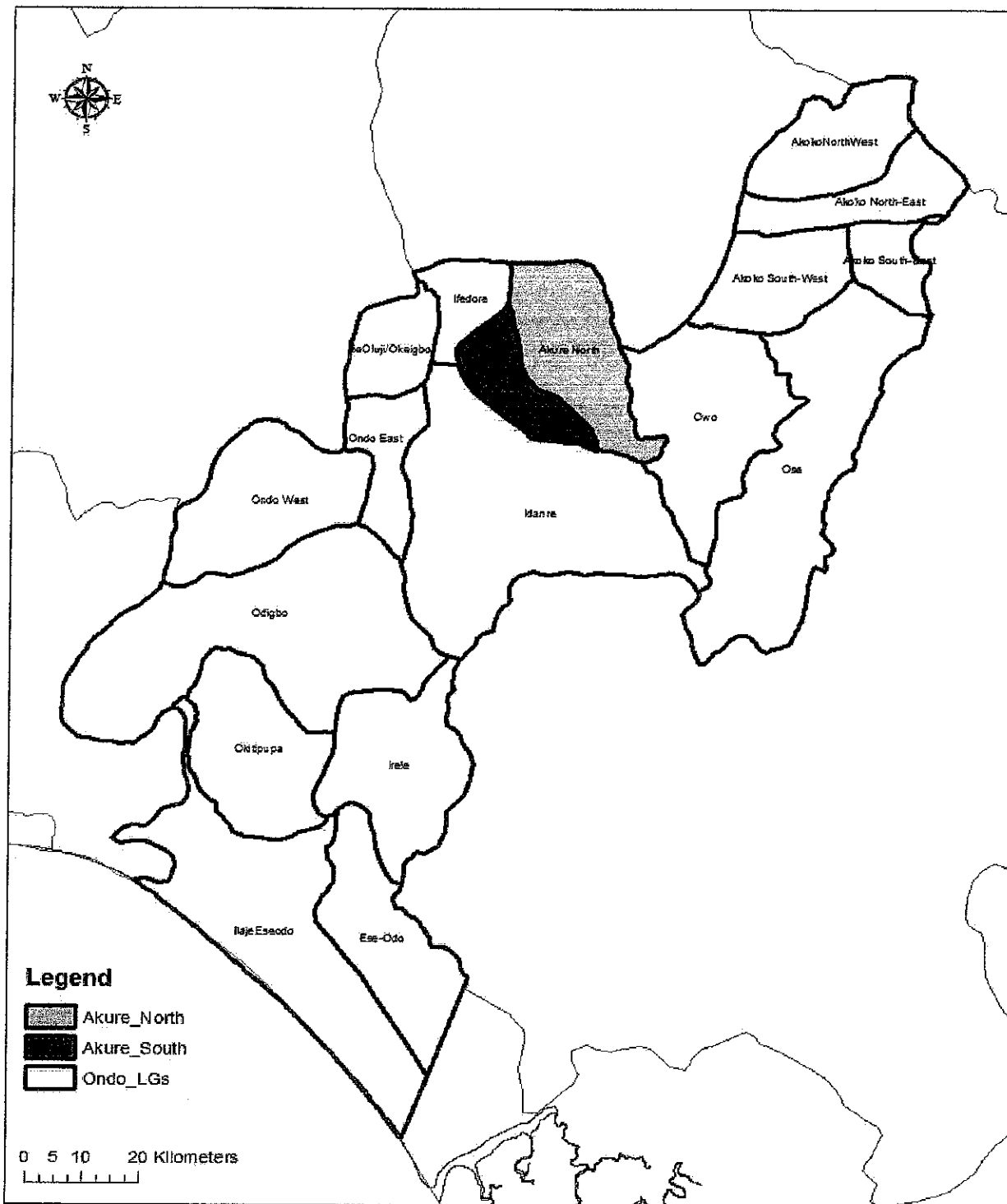


Figure 3.0.1 Map of Ondo state showing Akure South and North LGA in coloured.

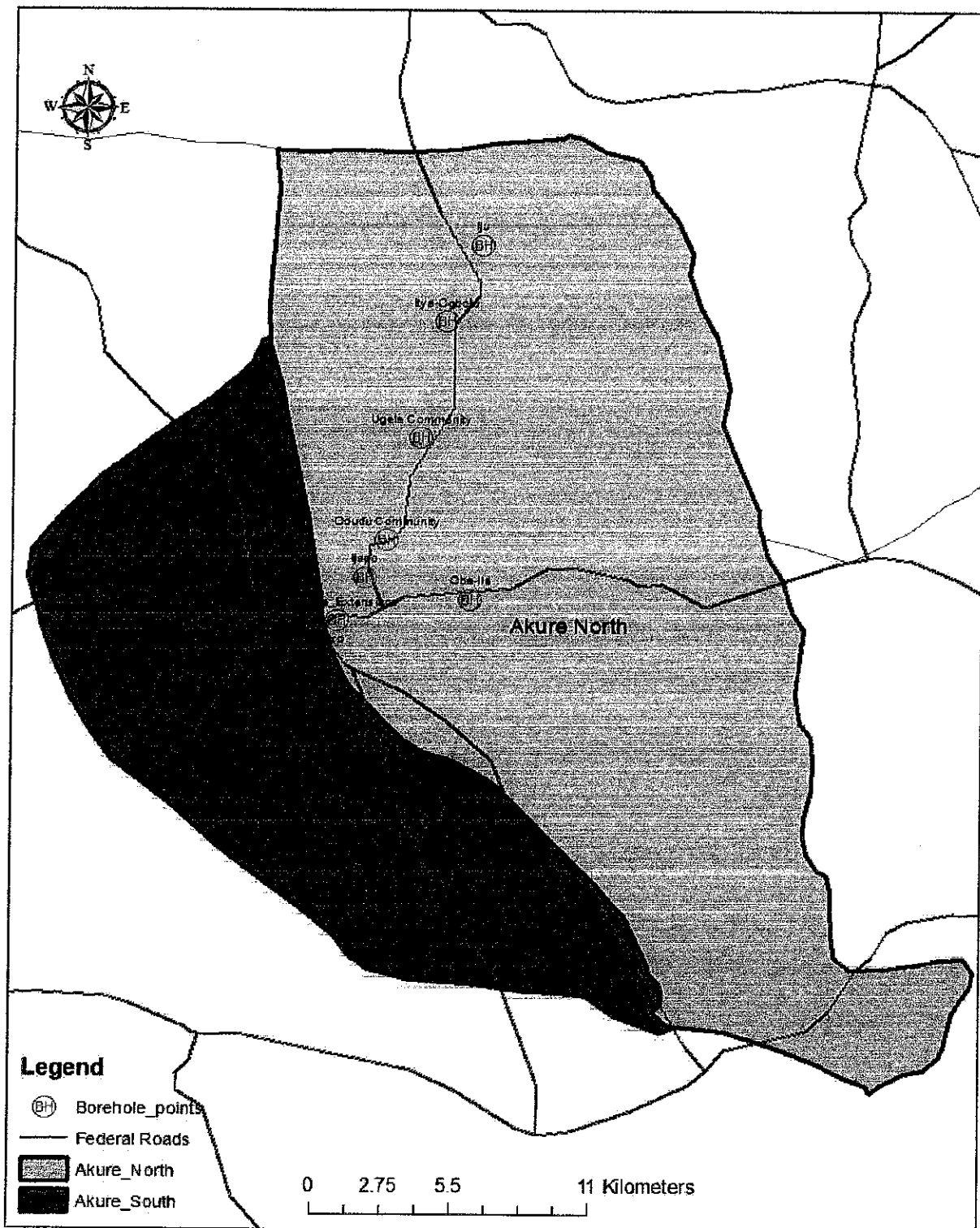


Figure 3.2 Map showing borehole (sample) point in Akure South and North LGA

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Site Description

Water samples were collected from the major towns in Akure North and South Local Government Area of Ondo state, South Western part of Nigeria.

Akure South is a Local Government Area in Ondo State, Nigeria. Its headquarters is in the town of Akure, located between longitude 5.2 and latitude 7.3, the Local Government Area occupies a geographical area of 1,591 square kilometres, with the population of about 420, 594 inhabitants (Wikipedia 2011). The study area comprises of towns and communities like Oda, Ijoka, Sebi, Kajola, Ijapo housing, Alagbaka area and Akure metropolis.

Akure North Local Government Area is located between longitude 5.3 and latitude 7.3, with an area of 660 km² and population of 131,587 at the 2006 census, and its headquarters in the town of Iju/itaogbolu (Wikipedia 2011). The study area comprises of villages and towns like Oba-ile, Ugele, Odudu, Itaogbolu, and Iju.

The climatic condition of the two Local Government Areas follows the pattern of south-western Nigeria, where the climate is by the rain-bearing southwest monsoon winds from the ocean and the dry northwest winds from the Sahara Desert. High temperatures and high humidity also characterize the climate. There are two seasons, the wet and dry seasons. The wet season occurs for about seven months from April to October and the dry season occurs from November to March. The major occupation of the people in these local government areas are farming and trading (folayan, 2013).

3.2. SAMPLE SITES

Table 1 : Akure South Local Government Area borehole location

Samples	Location	Geographical Coordinates
Sample A	Alagbaka	N 07 ⁰ 15.068' E 005 ⁰ 12.310'
Sample B	Ijapo	N 07 ⁰ 16.058' E 005 ⁰ 12.958'
Sample C	Akure Metropolis	N 07 ⁰ 14.215' E 005 ⁰ 11.087'
Sample D	Ijoka	N 07 ⁰ 10.00' E 005 ⁰ 12.041'
Sample E	Kajola	N 07 ⁰ 12.453' E005 ⁰ 12.898'
Sample F	Sebi	N 07 ⁰ 17.161' E 005 ⁰ 10.431'
Sample G	Oda	N 07 ⁰ 10.294' E005 ⁰ 14.021'

Table 2: Akure North Local Government Area borehole location

Sample	Location	Geographical Coordinates
Sample A	Oba-Ile	N 07 ⁰ 15.560' E005 ⁰ 15.640'
Sample B	Ugele	N 07 ⁰ 19.285' E005 ⁰ 14.316'
Sample C	Odudu	N 07 ⁰ 16.923' E005 ⁰ 13.516'
Sample D	Ita-Ogbolu	N 07 ⁰ 21.961' E005 ⁰ 14.905'
Sample E	Iju	N 07 ⁰ 23.721' E005 ⁰ 15.769'

The groundwater (borehole water) sample were collected randomly from the two (2) Local Government Areas, Akure South (Oda, Ijoka, Sebi, Kajola, Ijapo housing, Alagbaka area and Akure metropolis) and Akure North (Oba-ile, Ugele, Odudu, Itaogbolu, and Iju) of Ondo-state respectively.

3.3. METHODOLOGY

The plastic containers used were pre-treated by initially washing with detergent and rinsed, followed by washing with HCl (of 0.05M) and rinsed with distilled water and finally rinsed with the sample water before the collection of the sample. After the collection of each sample were preserved with HNO₃ (about 3 drops), and ensured the bottles were tightly covered and firmly arranged the sample storage container (cooler) of iced packed, and were then transported to the laboratory for chemical analysis at (Ondo state water corporation, central laboratory). Non preservative parameters such as P^H, temperature, turbidity and electric conductivity were determined.

3.4. WATER SAMPLE ANALYSIS

The P^H was measured using a calibrated P^H meter, the temperature was measured using mercury thermometer ranging from 0^oc to 100^oc, while the turbidity was tested using a calibrated colorimeter and the electrical conductivity also known as specific conductance was measured with a conductivity meter of accuracy 1000μS/cm. Other parameters such as total dissolved solid, total hardness (as CaCO₃), alkalinity and chloride were analysed by volumetric methods. The heavy metals such as Cd, Zn, As, and others, were determined using atomic absorption spectrophotometer (AAS).

All these were subjected to the standards both in preparation of reagents, determination of the parameters and compared with World Health Organization (WHO), Standard Organization of Nigeria (SON).

3.4.1. Determination of pH

Apparatus: Test Tubes, Lovibond Comparator, Cuvette

Reagent: Standard distilled water bromothymol blue

The standard was poured and the sample into another test-tube, 2 drops of bromothymol blue was added to the sample, the mixture was shaken vigorously for adequate mixture and the test-tube were placed into the lovibond apparatus to find the matching colour with the standard by rotating the cuvette.

3.4.2. Determination of turbidity

Turbidity test was carried out using turbidity meter.

Micro processor turbidity meter that uses rays was used.

The cuvette was filled with water sample to the marked point. The lower meniscus was watched out for. The cuvette 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.

3.4.3. Determination of conductivity

Apparatus: Conductivity meter with electrode/ATC probe, Magnetic stirrer with stirring, bead, Standard flask, Measuring jar, Beaker 250ml, Funnel, Tissue paper

Reagent: Potassium Chloride, Distilled water

The electrode was rinsed thoroughly with deionised water and gently wiped with a tissue paper. 200ml of the water sample was measured and transferred to the beaker and then placed on the magnetic stirrer and electrode was then dipped into the sample solution, and waited for steady reading.

3.4.4. Test for Odour

Equipment: free glass bottle

The free glass bottles was first washed with detergent and rinsed with distilled water to remove odour. The pre-cleaned bottle was filled half way with the water sample, it was then covered and shaken vigorously for about 2-3 secs and the stopper was then removed quickly removed and odour was observed by placing it near the nostrils.

3.4.5. Determination of Chloride in Water by Argentometric Titration

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

50ml of the water sample was measured in a conical flask. 1ml of potassium chromate was added and was 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: Formular= $(\text{Ml Titant} \times 10) \text{ Mg/L Caco}_3$

3.4.6. 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: Formulae= $(\text{Ml Titrant} \times 20) \text{ Mg/L Caco}_3$

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 Magnesium

Principle: Magnesium hardness was calculated from the determined total hardness and calcium hardness

Calculation

$$\text{Magnesium} = (t - c) \times 0.243 \text{ mg/l}$$

Where t= total hardness mg/l (as CaCO_3), c= calcium hardness mg/l (as CaCO_3)

3.4.9. Determination of Alkalinity by titration

REAGENT: Mixed indicator and 0.02N HCL

50ml 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: Formula= (Ml Titrant X 20) Mg/L CaCO_3

3.4.10. Determination of total hardness by titration

Reagents: buffer solution, EDTA (ethylene-diamine-tetra-acetic acid) and Erichrome Black T indicator.

50ml 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 indicate the end point. The burette was filled with 0.01M EDTA and the solution were titrated with EDTA until the colour changes from pink to blue. Then the reading along the burette was then taken. This procedure was repeated for other water samples.

Calculation: formula= (MI Titrant X 20) Mg/L CaCO_3

3.4.11. Determination of Heavy Metals

Heavy metals in the borehole water samples were determined by Atomic Absorption spectrophotometer, 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; Cr, 540nm; Mn, 525nm; Zn, 213.9nm).

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. Physical properties of the water samples

The physical parameters such as colour, odour and turbidity for water samples from Akure South and Akure North LGA are given in Table 3 and 5, the water samples were colourless and odourless. Turbidity ranged from 0.08-0.10 nephelometric (NTU) with the mean value of 0.09 NTU in Akure South Local Government Area and the range is within the WHO permissible limit, while in Akure North Local Government Area where turbidity was only detected, gave an outrageous value of 50 NTU which exceed WHO limit of 5 NTU, this result is in agreement with Abubakar et al. (2012), who reported that turbidity value of borehole water sample in Taraba state was above WHO limit. High turbidity is majorly related with higher levels of disease causing microorganism such as bacteria and other parasites; at no time should turbidity be allowed to rise above 5 NTU.

Table 3: Showing the result of physical parameters measured at Akure South LGA borehole water sample

Location	Colour(TCU)	Odour	Turbidity(NTU)
Alagbaka	ND	Unobjectionable	ND
Ijapo	ND	Unobjectionable	0.1
Akure metropolis	ND	Unobjectionable	ND
Ijoka	ND	Unobjectionable	ND
Kajola	ND	Unobjectionable	ND
Sebi	ND	Unobjectionable	0.08
Oda	ND	Unobjectionable	ND
WHO permissible limit	15	0	5

ND: Not Detected.

Table 4: showing NAFDAC, SON and WHO drinking water standards

S/NO	PARAMETER	NAFDAC MAXIMUM ALLOWED LIMITS		WHO STANDARDS		
		SON STANDARD	Highest desirable	Maximum permissible		
1	Colour(TCU)	3.0	3	15		
2	Odour	Unobjectionable	unobjectionable	unobjectionable		
3	Turbidity(NTU)	5.0	5.0	5.0		
4	pH	6.5-8.5	7.0-8.9	6.5-9.5		
5	Chloride(mg/l)	100.0	200	250		
6	Calcium(mg/l)	75.0	75	75		
7	Nitrate(mg/l)	10.0	10	50		
8	Magnesium(mg/l)	30.0	30.0			
9	Total alkalinity(mg/l)	100.0	100.0	100.0		
10	Total dissolved solid(mg/l)					
11	Total hardness(mg/l)	100.0	100	500		
12	Electrical conductivity (µs/cm)	1000.0	900.0	250		
13	Manganese(mg/l)	0.005	0.005	1200.0		
14	Total iron(mg/l)	0.3	0.3	0.5		
15	Chromium(mg/l)			0.3		
16	Zinc(mg/l)	5.0	5.0	0.05		
17	Cadmium(mg/l)	0.003	0.003	3		
18	Arsenic(mg/l)	0.01	0.01	0.003		
			0.01	0.01		

Source: NIS 2007 and African journal of environmental science and technology 2015

Table 5: Showing the result of physical parameters measured at Akure North LGA borehole water sample with WHO standard values

Location	Colour(TCU)	Odour	Turbidity(NTU)
Oba-Ile	ND	Unobjectionable	ND
Ugele	0.8	Unobjectionable	5
Odudu	ND	Unobjectionable	ND
Ita-Ogbolu	ND	Unobjectionable	ND
Iju	ND	Unobjectionable	ND
WHO permissible limit	15	Unobjectionable	5

ND: Not Detected

4.2. Chemical properties of the water sample

The pH of the water samples ranged from 6.0-7.6 with the mean value of 6.4 in Akure South Local Government Area (Table 6) and 6.0-6.8 with the mean value of 6.2 in Akure North Local Government Area (Table 7). These pH values are within the permissible limit by WHO of 6.5-8.5 and compared favourably with the pH of borehole water in Owo, Ondo state that ranged from 6.5-7.2 (Ibrahim et al., 2013). On the basis of pH, the water samples are suitable for human consumption.

The electrical conductivity Akure South Local Government ranged from $7\mu\text{s}/\text{cm}$ (0.07×10^2) to $690\mu\text{s}/\text{cm}$ (0.69×10^3) with the mean value of 0.16×10^3 (Table 6) and from $7\mu\text{s}/\text{cm}$ (0.07×10^2) to $570\mu\text{s}/\text{cm}$ (0.57×10^3) with the mean value of $242\mu\text{s}/\text{cm}$ (0.24×10^3) in Akure North Local Government Area (Table 7). The ranges are within the WHO permissible limit $1.0\times 10^3\mu\text{s}/\text{cm}$. This result is in agreement with Adogo et al. (2015) who reported that the electrical conductivity of borehole water in Auta Balefi, Nasarawa state ranged from 0.74 to $0.79\times 10^3\mu\text{s}/\text{cm}$.

The chloride (Cl^-) in the entire borehole water samples of Akure South Local Government Area collected ranged from 18 to 177mg/l with the mean value of 62mg/l (Table 6) and that of Akure North Local Government ranged from 17 to 92mg/l with the mean value

of 47.6mg/l, (Table 7). These concentrations are within the WHO standard limit of 250mg/l, in agreement with Abubakar et al. (2012) who reported that the borehole water from Yola-Jimeta metropolis Taraba, have low level of chloride. All the samples were low in Cl⁻ compared to the standard limit considered safe for consumption.

In Akure South Local Government Area, Calcium (Ca²⁺) concentration ranged from 04 to 158mg/l, with a mean value of 55mg/l (Table 6) and Akure North Local Government area water sample ranged from 46 to 360mg/l with mean value of 139.6mg/l (Table 7), all samples value were within WHO permissible limit of 150mg/l except for sample C (158mg/l) and sample E (139.6mg/l) in Akure south and Akure North Local Government Area respectively. My results are not in agreement with Afuye et al. (2015), who reported that the concentration of calcium in borehole water of Akoko South East area of Ondo state ranged from 25.4 to 120.2mg/l. It is possible that industrial activities involving soap and cement factories located in these areas probably caused the observed Ca²⁺ concentration in the samples C and E.

In Akure South Local Government Area nitrate concentration ranged from 0.1 to 07mg/l with the mean value of 0.185mg/l (Table 6), while that of Akure North Local Government Area ranged from 0.1-0.15mg/l with the mean value of 0.125mg/l (Table 7), The nitrate concentration of the water samples is within the WHO permissible limit of 10mg/l, this report is in agreement with Adogo et al. (2015) who reported safe nitrate level of borehole water in Auta Balefi in Nasarawa state.

Magnesium concentration ranged from 0.8 to 100mg/l in all water samples with the mean value of 25.25mg/l (Table 6), in Akure South Local Government Area and varied from 22-136mg/l with the mean value of 58.4mg/l (Table 7) in Akure North Local Government Area, All sample were below WHO permissible limit 30mg/l with exception to sample D in

Akure South and sample C and E in Akure North Local Government Area with high concentration of Mg^{2+} . The results contradict Adogo et al., (2015) who reported low magnesium concentration of borehole water in Auta-Balefi community.

The total alkalinity concentration of all samples ranged from 26 to 286mg/l with the mean value of 90.286mg/l in Akure South LGA (Table 6) and also ranged from 20 to 164mg/l with the mean value of 70.8mg/l (Table 7), in Akure North local government Area, All the samples were within the WHO permissible limit of 100mg/l except for sample C (Akure metropolis) in Akure South LGA and sample E (164mg/l) in Akure North LGA which are above the limit set by WHO. This report is not in agreement with David et al. (2015), who reported that the alkalinity of the borehole in Lagos ranged from 5.92 to 87.06mg/l. An increase in alkalinity leads to loss of colour, and is usually close to hardness of water (Olumuyiwa et al., 2012).

Total dissolved solid concentrations ranged from 50 to 480mg/l with the mean value of 144mg/l (Table 6) in Akure South Local Government Area and ranged from 50 to 390mg/l with the mean value of 170mg/l (Table 7) in Akure North Local Government Area. All the samples were within WHO permissible limit of 1000mg/l. This report agrees with Oluyemi et al. (2010) who reported similar value for total dissolved solid in borehole water in Ife North Local Government Area, Osun state. Total dissolved solid in drinking water has been linked with natural sources, sewage urban runoff, industrial waste water and chemical used in the water treatment process (Shittu et al., 2008).

Total hardness concentration ranged from 12 to 170mg/l with the mean value of 81.71mg/l (Table 6) in Akure South LGA and ranged from 74 to 496mg/l with the mean value of 198mg/l (Table 7) in Akure North LGA. All the water samples analysed were below the WHO permissible limit of 500mg/l, rendering the water for human consumption.

Table 6: showing the result of chemical parameter measured at Akure South LGA borehole water sample with WHO standard values

Sample	Location	pH	Cl ⁻ (mg/l)	Ca ²⁺ (mg/l)	NO ₃ (mg/l)	Mg ²⁺ (mg/l)	T.Alk(mg/l)	TDS(mg/l)	T.HDS(mg/l)	EC(μs/cm)
Sample A	Alagbaka	7.6	18	56	ND	24	90	60	80	0.09×10 ³
Sample B	Ijapo	6.0	58	46	ND	16	26	50	62	0.07×10 ²
Sample C	Akure metropolis	6.0	177	158	0.7	12	286	480	170	0.69×10 ³
Sample D	Ijoka	6.4	110	32	0.15	100	40	180	132	0.13×10 ²
Sample E	Kajola	6.4	21	4	ND	0.8	80	110	12	0.16×10 ³
Sample F	Sebi	6.4	19	54	0.35	ND	94	60	54	0.09×10 ³
Sample G	Oda	6.0	32	38	0.1	24	16	70	62	0.10×10 ³
Mean		6.4	62	55	0.185	25.25	90.286	144.286	81.7143	0.16×10 ³
WHO permissible										
limit		6.5-8.5	250	150	10	30	100	1000	500	1.0×10 ³

ND: Not Detected Cl⁻: Chloride, Ca²⁺: Calcium, NO₃: Nitrate, Mg²⁺: Magnesium, T.Alk: Total Alkalinity, TDS: Total Dissolve solid, T.HDS:

Total hardness, EC: Electrical conductivity

Table 7: showing the result of chemical parameter measured at Akure North LGA borehole water sample with WHO standard values

Sample	Location	pH	Cl ⁻ (mg/l)	Ca ²⁺ (mg/l)	NO ₃ ⁻ (mg/l)	Mg ²⁺ (mg/l)	T.Alk(mg/l)	TDS(mg/l)	T.HDS(mg/l)	EC(μs/cm)
Sample A	Oba-Ile	6.0	50	128	ND	22	36	160	150	0.23×10 ³
Sample B	Ugele	6.0	17	46	0.15	28	42	50	74	0.07×10 ³
Sample C	Odudu	6.2	19	72	ND	78	92	90	150	0.13×10 ³
Sample D	Ita-Ogbolu	6.0	55	92	ND	28	20	160	120	0.22×10 ³
Sample E	Iju	6.8	97	360	0.1	136	164	390	496	0.56×10 ³
Mean		6.2	47.6	139.6	0.05	58.4	70.8	170	198	0.24×10 ³
WHO permissible limit		6.5-8.5	250	150	10	30	100	1000	500	1.0×10 ³

ND: Not Detected, Cl⁻: Chloride, Ca²⁺: Calcium, NO₃⁻: Nitrate, Mg²⁺: Magnesium, T.Alk: Total Alkalinity, TDS: Total Dissolve solid, T.HDS:

Total hardness, EC: Electrical conductivity

4.3. Potentially Toxic metals in the water samples

Manganese concentration in the water sample analysed ranged from 0.025 to 0.05mg/l with the mean value of 0.036mg/l (Table 8) in Akure South Local Government Area while it ranged from 0.3 to 0.04mg/l with the mean value of 0.034mg/l (Table 9) in Akure North LGA, All water samples in both Local Government Areas were within WHO permissible limit of 0.10mg/l (Table 4). Musa et al., (2013) do reported that Mn concentration of between 0.001-0.010 in borehole water from Obajana and its environs in Kogi state.

The concentration of iron in Akure South Local Government Area ranged from 0.10 to 0.35mg/l with a mean value of 0.30mg/l (Table 8) and ranged from 0.25 to 0.35mg/l with a mean value of 0.31mg/l (Table 9) in Akure North Local Government Area. However water sample B, D, G in Akure South LGA and water sample A, B, D from Akure North Local Government Area had Fe concentration greater than WHO permissible limit of 0.3mg/l, (Table 4). The high concentration of Fe in some of the water sample from both Local Government Areas are in agreement with Christopher et al., (2011) who reported that the iron concentration of water samples from Akure Ondo state, far above WHO permissible limit. Olumuyiwa et al. (2012) stated that rock and mineral dissolution of acid mine drainage, lands fill leachates, sewage and iron related industries are causes of high iron levels in groundwater.

The concentration of zinc ranged from 0.367 to 4.90mg/l with a mean value 0.313mg/l (Table 8) in Akure South Local Government Area, while in Akure North Local Government Area, it ranged from 0.084 to 0.175mg/l with mean value of 0.1295mg/l (Table 9). All the samples from the study area were within the WHO permissible limit of 3.0mg/l.

Cadmium concentration ranged from 0.008 to 0.499mg/l with the mean value of 0.111mg/l (Table 8) in Akure South Local Government Area. The water samples in Akure South LGA exceeded the 0.003mg/l WHO permissible limit except for sample D, where Cd was beyond detection, In Akure North Local Government Area, the Cd concentration ranged from 0.018 to 0.067mg/l with mean 0.0385mg/l (Table 9) which exceeded the WHO permissible limit of 0.003mg/l with the exception of sample C, the water in the two LGA in Akure is not suitable for human consumption because of the high Cd concentration.

Cadmium is generated as a by-product of Zn and Pb refining (Lenntech 2011), and kidney is the main critical organ that is affected after a long-term exposure to cadmium. Chromium and arsenic were not detected in all the location of the study area.

Table 8: showing the result of chemical parameter (heavy metals) measured at Akure South LGA borehole water sample with WHO standard

Sample	Location	Mn(mg/l)	Fe(mg/l)	Cr(mg/l)	Zn(mg/l)	Cd(mg/l)	As(mg/l)
Sample A	Alagbaka	0.025	0.3	ND	ND	0.008	ND
Sample B	Ijapo	0.03	0.35	ND	0.490	0.499	ND
Sample C	Akure metropolis	ND	0.1	ND	ND	0.075	ND
Sample D	Ijoka	0.04	0.32	ND	0.367	ND	ND
Sample E	Kajola	0.04	0.3	ND	ND	0.043	ND
Sample F	Sebi	0.03	0.3	ND	ND	0.035	ND
Sample G	Oda	0.05	0.35	ND	ND	0.008	ND
Mean		0.036	0.289	0	0.313	0.111	0
WHO permissible limit		0.1	0.3	0.05	3.0	0.003	0.05

ND: Not Detected, Mn: Manganese, Fe: Iron, Cr: Chromium, Zn: Zinc, Cd: Cadmium, Ar: Arsenic

Table 9: showing the comparison of result of chemical parameter (heavy metals) measured at Akure north LGA borehole water sample with

WHO standard values

Sample	Location	Mn (mg/l)	Fe (mg/l)	Cr (mg/l)	Zn (mg/l)	Cd (mg/l)	As (mg/l)
Sample A	Oba-Ile	0.04	0.35	ND	ND	0.067	ND
Sample B	Ugele	0.04	0.35	ND	ND	0.067	ND
Sample C	Odudu	0.03	0.30	ND	0.084	ND	ND
Sample D	Ita-Ogbolu	0.03	0.32	ND	0.175	0.032	ND
Sample E	Iju	0.03	0.25	ND	ND	0.018	ND
Mean		0.034	0.314	0	0.129	0.038	0
WHO permissible limit		0.1	0.3	0.05	3.0	0.003	0.05

ND: Not detected, Mn: Manganese, Fe: Iron, Cr: Chromium, Zn: Zinc, Cd: Cadmium, Ar: Arsenic

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

Chemical composition analysis of borehole samples with special reference to potentially toxic metal in both Akure south and north local government area in Ondo-state, Nigeria indicated that the physical parameters; colour, odour and turbidity, and some chemical parameters like pH, chloride, nitrate, total dissolve solid, total hardness, conductivity, and trace metal; manganese were within WHO permissible limit in the two Local Government Areas, while chemical parameters such as calcium, magnesium, total alkalinity and trace metals like iron, zinc, and majorly cadmium are detected in six and three samples in Akure South and North Local Government Areas respectively. But Cr and As were not detected in the study area.

This study thereby concluded that the concentration of total alkalinity, calcium, magnesium, iron, zinc, and cadmium are of high concentration in the water and thus considered unfit for human consumption in the two Local Government Areas.

RECOMMENDATION

Public awareness on the dangers associated with the consumption of contaminated water should be increased especially in areas with outrageous concentration of toxic and harmful metals.

Further research should be conducted in other towns and communities in both Akure South and North Local Government Areas to determine the water suitability for human consumption.

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