ASSESMENT OF GROUNDWATER QUALITY FROM BOREHOLES AND HAND-DUG WELLS AROUND OBAJANA CEMENT FACTORY AND ITS ENVIRONS IN LOKOJA, KOGI STATE, NIGERIA.

By

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(MSc/SCIE/8227/2011-2012)

DEPARTMENT OF CHEMISTRY
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

JANUARY, 2015

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A THESIS WRITTEN IN THE DEPARTMENT OF CHEMISTRY AND SUBMITTED TO THE POSTGRADUATE SCHOOL AHMADU BELLO UNIVERSITY ZARIA, IN PARTIAL FULFILLMENT FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN ANALYTICAL CHEMISTRY

DEPARTMENT OF CHEMISTRY
AHMADU BELLO UNIVERSITY,
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Declaration

I declare that the work in this thesis entitled "**Assessment of groundwater quality from boreholes and hand-dug wells around Obajana cement factory and its environs in Lokoja, Kogi State, Nigeria.**" has been carried out by me in the Department of Chemistry. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma in any other Institution

Ahvo Akande JACOB		
Name of Student	Signature	Date

Certification

This project thesis entitled "ASSESSMENT OF GROUNDWATER QUALITY FROM BOREHOLES AND HANDDUG WELLS AROUND OBAJANA CEMENT FACTORY AND ITS ENVIRONS IN LOKOJA, KOGI STATE, NIGERIA" by Ahvo Akande JACOB meets the regulations governing the award of the degree of Master of Science in Analytical Chemistry of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Prof. C. E. Gimba Chairman, Supervisory Committee	______________________ Signature	______________ Date
Prof. G. I. Ndukwe Member, Supervisory Committee	______________________ Signature	______________ Date
Prof. V. O. Ajibola Head of Department	______________________ Signature	______________ Date
Prof. A. Z. Hassan Dean, School of Postgraduate Studies	______________________ Signature	______________ Date

Dedication

This work is dedicated first to GOD Almighty and in loving memory of my great parents Mr. & Mrs. U. Jacob, also my wonderful siblings Oremeyi, Onyami, Ozovehe, and Adeiza for their prayers, support and encouragement.

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Abstract

The groundwater (hand dug wells and boreholes) qualities of Obajana in Kogi State were determined. The study consisted of the determination of some heavy metals and physicochemical properties in drinking water samples. Ten (10) samples each of groundwater were collected from the four sampling sites The samples were analysed for the following parameters iron, copper, manganese, zinc, lead, nitrates, sulphate, phosphate, colour, dissolved solids, electrical conductivity, pH, dissolved oxygen(DO), biological oxygen demand (BOD), chemical oxygen demand (COD), temperature, turbidity, total hardness and total alkalinity using standard method. The data showed the variation of the investigated parameters in samples as follows: temperature 26-30^oC, pH 5.53-7.89, electrical conductivity (EC) 6.210-339.670 µS/cm, total hardness 50.00- 424.20 mg/l, alkalinity 1.10-145.67mg/l, turbidity 0.00-34 FTU, colour 5-15TCU, phosphate 0.02-0.760 mg/l, nitrate 10.24-48.20mg/l, sulphate 24.70-222.13mg/l, dissolved oxygen 0.2-1.8 mg/l, BOD 0.2-1.0mg/l, COD 1.1-3.2mg/l, Cu 0.00.1-0.10mg/l , Fe 0.01-0.060mg/l, Zn 0.029-5.046mg/l, Mn 0.0-0.44mg/l and Pb 0.0348-1.046mg/l. The concentrations of some of the investigated parameters in the drinking water samples from the research region were above the permissible limits of the World Health Organization standard for drinking water quality guidelines. lead was found to exceed 0.01mg/l which is the WHO maximum limit, also zinc and manganese were found to exceed the WHO maximum limit of 4.0mg/l and 0.1mg/l.

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Abbreviations

AAS	-	Atomic Absorption Spectrophotometer
ANOVA	-	Analysis of Variance
BOD	-	Biological Oxygen Demand
COD	-	Chemical Oxygen Demand
DO	-	Dissolved Oxygen
EC	-	Electrical Conductivity
EDTA	-	Ethylenediamine tetraacetic acid
EPA	-	Environmental Protection Agency
FTU	-	Formazin Turbidity Unit
SON	-	Standard Organization of Nigeria
SPSS	-	Statistical Package for Social Science
US-EPA	-	United States Environmental Protection Agency
WHO	-	World Health Organization
FAO	-	Food and Agricultural Organization
DS	-	Dissolved solids

Chapter One

Introduction

1.1 Water

Water is essential to maintain and sustain human life, animals and plants (Patil and Patil, 2010), this is because it constitutes to a large extent, the major solvent in which many of the body's proteins and other substances are dissolved. It enables many metabolic activities of the body to take place (Davis, 2005).Water is essential for growing food, for domestic uses and as a critical factor in industries, tourism and cultural purpose as it helps in sustaining the earth's ecosystem (Mark *et al.* 2002).

Water covers 70.9% of the earth's surface, and is vital for all known forms of life. On earth, it is found mostly in oceans and other large water bodies, with 1.6% of water below ground in aquifers and 0.001% in the air as vapor and precipitation. Oceans hold 97% of surface water, 2.4% for glaciers and polar ice caps, and 0.6% for other land surface water such as rivers, lakes and ponds. A very small amount of the earth's water is contained within biological bodies and manufactured products (Wikipedia, 2010). Water is precious and necessary for a sustainable economic development of an area as it is the next major support to life after air. In the urban areas where pipe-borne water, bore-hole water and hand-dug wells are available is an indication that water is a vital component of human existence. Groundwater is of major importance and is intensively exploited for private, domestic and industrial uses. According to Ajibade *et al.* (2011) 90% of the population in Nigeria depends largely on handdug wells and boreholes. Rapid growth in urban populations, industrial activities, commercial and agricultural developments result in increase in the search of potable water. The preference of groundwater as a source of drinking water in rural areas is because of its relatively better quality than river water

(Obiri- Danso *et al*., 2009). Historically, point of rural settlement was being determined by water source such as stream, river and spring (Okeola *et al*., 2010). The inhabitants of rural settlements relied on groundwater often within a few meters of the surface which they exploited by digging wells. Access to safe drinking water is a basic human need and a fundamental human right that is crucial for poverty reduction. According to a report (United Nation, 2003) this situation forces people to consume untreated water from rivers and ponds and represents a high risk to their health. About 1.1 billion people in the world lack access to good quality drinking water. Globally, 4 billion cases of diarrhoea are reported every year causing 1.8 million deaths, out of which about 90% are children under five years of age (UNESCO, 2007).

Pollution of groundwater is an impairment of water quality by chemicals, heat or bacteria to a degree that does not necessarily create public health hazards but does adversely affect such water for domestic, farm, municipal or industrial use (Akhilesh *et al.,* 2009; Weiss, 1974 and Ogbonna *et al.,* 2006). Water related diseases are responsible for 80% of all illness or death in the developing countries and kill more than 5 million people every year (UNESCO, 2007). The use of groundwater as a source of potable water supply is increasing worldwide. Although it can be contaminated due to pollution (Obiri- Danso *et al*., 2009). In the United States, 90-95% of rural and sub-urban water come from these sources.

Irrespective of the form in which water occurs, it can still be contaminated with impurities. Hence, water quality analysis is a very important issue which should be taken seriously. The presence of these wastes (pollutants) tampers with the natural quality of the environmental media (air, water, and land) thus, affecting plant, animal and human lives. The water pollution by heavy metals has become a question of considerable public and scientific concern in the light of the evidence of their toxicity to human health and biological systems (Anazawa *et al.,* 2004).

Dust emissions from the factory have not only affected the environment, but the water from open-wells has visibly suffered surface contaminations from cement dust deposition. These wells are the main source of drinking water and other domestic chores for inhabitants of the area surrounding the cement factory. This should elicit a concern since the water quality may experience undesirable changes as the result of cement dust intrusion. The quality of water influences the health status of any populace, hence, analysis of water for physical, biological and chemical properties including trace element contents are very important for public health studies (Chinedu *et al.*, 2011). Furthermore, Amira (2002) had indicated that cement dust is capable of changing salt content of water leading to serious disruption of aquatic communities and also decrease quality of water used for drinking. Thus, the current situation of the wells within the vicinity of the cement factory necessitate a study aimed at evaluating the health risk of the people who depends on water from hand-dug wells for drinking and other domestic useage.

Each pollutant has its own health risk profile, summarizing all relevant information into a short chapter will be difficult as it will focus on the problems caused by air and water pollution at the community, country, and global levels. Estimates indicate that the proportion of the global burden of disease associated with environmental pollution hazards range from 23 - 30% (Smith *et al.,* 1999) and (WHO, 1997). As the World Health Organization points out, outdoor air pollution contributes as much as 0.6 - 1.4 % of the burden of disease in developing regions especially Nigeria, and other pollution, such as lead in water, air and soil, may contribute 0.9 %. These percentages may appear small, but the contribution from most risk factors other than the "top 10" is within the 0.5 to 1.0% range (WHO 2002). Pollution of surface water can create health risks, because such waterways are often used directly as drinking water sources or flow into shallow wells used for drinking water. In addition, waterways have important roles for washing and cleaning, for fishing and fish farming and for recreation. . The purpose of this study is to ascertain the quality of water from these sources and to verify if there is adverse effect of the cement factory on the surrounding communities.

1.2 Portland Cement

Cements used in construction can be either being hydraulic or non-hydraulic. Portland cement which is produced in Obajana cement factory consists of limestone ($CaCO_3$), Clay ($2SiO_2.Al_2O_3$), Iron oxide (Fe_2O_3)and Silica sand (SiO_2). If all of these are put in a rotary klin and heated at 1450°c, cement is formed ($CaO.SO_3.2H_2O$).

Since the primary constituents of Portland cement are calcium silicate, Portland cement can be defined as a material which combines CaO and SiO_2 in a proportion that the resulting calcium silicate will react with water at room temperature and under normal pressure. Cement is a binder, a substance that sets and hardens independently and can bind other materials together. Hydraulic cement (e.g. Portland cement) hardens because of hydration, a chemical reaction between the anhydrous cement powder and water.

$$2C_3S + 7H = C_3S_2H_4 + 3CH \qquad \Delta H = -500j/g \text{ .... } 1.1$$

The chemical reaction results in hydrates that are not very water soluble and so are quite durable in water. This product is not a well defined compound as the formular $C_3S_2H_4$ is only an approximate description. It has an amorphous structure making up of poorly organized layers and its called glue gel binder.

1.3 Justification

The quality of drinking water in the Obajana town has become a major concern to the community. In addition, inhabitants are becoming increasingly dependent on wells, which have doubtful water quality, especially during the dry season. The town has no standard treated pipe borne water supply system causing most people to depend on other alternative sources of water such as rainwater and hand-dug wells and boreholes constructed in many households with doubtful water quality in the area. These alternative sources, are to a large extent exposed to contaminants such as metals, nitrates and other salts which have resulted in polluting the water.

The relationship between pollution levels from the cement factory will be established and mapped which will help pollution monitoring and remedial efforts. The study will determine if true there is pollution of water resources in the area.

1.4 Aim of Study

The assessment of groundwater in Obajana and its environs will be done to verify if there are adverse effects on the groundwater around the area as a result of the activities.

1.5 Objectives

The above aim will be achieved through the following objectives:

i. Determination of heavy metals (Fe, Zn, Cu, Pb, and Mn) concentrations in the groundwater from hand-dug wells and boreholes.
ii. Determination of physicochemical properties of groundwater such as (electrical conductivity, alkalinity, turbidity, pH, phosphate, sulphate, colour, dissolved oxygen, hardness, nitrate, temperature, biological oxygen demand and chemical oxygen demand);

iii. Statistically correlating the data in the water samples; and comparing pollution level in the groundwater with that of WHO standards for water quality.

1.6 Scope of the work

i. Collection of groundwater samples from Obajana community and its environs from hand-dug wells and boreholes.

ii Determination of the physicochemical properties of groundwater.

iii Determination of heavy metals (Fe, Zn, Cu, Pb, and Mn) concentration in the sampled groundwater using atomic absorption spectrophotometer.

Chapter Two

Literature Review

2.1 Water

Water is a liquid at ambient conditions, but it often co-exists on earth with its solid state being ice, and gaseous state being water vapor or steam (Ameyibor and Wiredu, 1991). Human bodies are approximately 60% water, blood is at least 50% water and the human brain made of 77% water (Stanistski *et al*., 2000).

2.2 Cement

The production of cement is increasing by about 3% annually (McCaffrey, 2002) and contribution of Portland cement production worldwide to the greenhouse gas emission is estimated to be about 7% of the total greenhouse gas emissions to the earth's atmosphere (Malhotra, 2002). Calcinations process of cement is heat dependent and contributes to rising global temperature (Metz *et al*, 2005). The production of one tonne of cement liberates about one tonne of CO_2 to the atmosphere, as a result of de-carbonation of limestone in the kiln during manufacturing of cement and the combustion of fossil fuels (Roy, 1999). The catastrophic effects of global warming are self evident in melting of the polar ice, flooding, drought and changing flora and fauna of natural habitat for both plants and animals. In slightly over a century, both marine air temperatures and sea surface air temperatures have increased between 0.4°C and 0.8°C (Sheppard and Soochow, 2007). Cement is also among the most energy-intensive construction materials, after aluminium and steel (Mehta and Burrows, 2001), thermal consumption of the order of 3.3tonne of clinker produced. Electrical energy consumption is about 90-120 kwh/tonne of cement (Giddings *et al, 2013;* EC, 2001). Materials are rarely found in the size range required. It is often necessary either to decrease or increase the particle size (Morrel, 2006). When, for example, the starting material is too coarse, and possibly in the form of large rocks, and the final product needs to be a fine powder, the particle size will have to be progressively reduced in stages (Pasikatan *et al*, 2001). The most appropriate type of machine at each stage of the process depends, not only on the size of the feed and of the product, but also on such properties as compressive strength, brittleness and stickiness (Jankovic and Mehta, 2010; Kano *et al*, 2000).

2.3 Sources of Water

Water can be grouped into surface water comprising of oceans, rivers, lakes, reservoirs, lagoons, streams and many others, Ground water which is considered mostly as more pure than the surface water and lastly the rain water which falls as a result of condensation and precipitation of the clouds (Stanistski *et al*., 2000). Surface water frequently contains substances that must be removed before it can be used as drinking water while groundwater is pumped from wells and boreholes that have been drilled from aquifers at subsurface and is usually free from harmful contaminants.

2.4 Wells

A Well is an excavation or a structure created in the ground by digging, driving, boring or drilling to access groundwater in aquifers (Roger,1982).The well water may be drawn by an electric submersible pump, a vertical turbine pump, a hand pump or a mechanical pump (e.g. from a water-pumping windmill). It can also be drawn up using containers, such as buckets that are raised mechanically or by hand (Obiri - Danso *et al.,* 2009).Wells can vary greatly in depth, water volume and water quality. Well water typically contains more minerals in solution than surface water and may require treatment to soften the water. There are basically three types of wells. They include hand-dug wells, driven wells and drilled wells. Hand-dug wells are constructed by hacking at the ground with pick and shovel to dig until the water table is reached. If the ground is soft and the water table is shallow, then water can be obtained from the dug wells. The well is lined with stones, brick, tile, or other material to prevent collapse, and is either covered with a cap of wood, stone, metal or concrete (Roger, 1982). In Nigeria, many of the wells we find in our homes are excavated until reaching the water table and are described as shallow (Obiri - Danso *et al*., 2009) . The depth of the wells depends on how far the water table could be reached. Driven wells are built by driving a small-diameter pipe into soft earth, such as sand or gravel (Roger, 1982). A screen is usually attached to the bottom of the pipe to filter out sand and other particles. They can only tap shallow water, and because the source of the water is so close to the surface, contamination from surface pollutants can occur. Drilled wells require a fairly complicated and expensive drill rig. They use rotary drill bits that chew away at the rock, percussion bits that smash the rock. Drilled wells can be drilled more than 30.48meters. Often a pump is placed at the bottom to push water up to the surface (Roger, 1982).

2.5 Well Contamination

Shallow pumping wells can often supply drinking water at a very low cost, but because impurities from the surface easily reach shallow sources, a greater risk of contamination occurs for these wells when they are compared to deeper wells. Contamination of the wells increases during the rainy seasons where the aquifer is "topped up" more rapidly and both vertical and horizontal migrations of water are accelerated (Morgan, 1990). Dug and driven wells are easy to contaminate because they are relatively shallow. The quality of the well water can be significantly increased by lining the well, sealing the well head, fitting a self-priming hand pump, constructing an apron, ensuring the area is kept clean and free from stagnant water and animals. Most of the bacteria, viruses, parasites, and fungi that contaminate well water come from faecal material from humans and other animals.

Groundwater is considered the healthiest source of drinking water, but domestic, agricultural and industrial activities have led to the degradation of groundwater quality in different parts of the world. Groundwater is a resource found under the earth's surface as most groundwater comes from rain and melting snow soaking into the ground. Groundwater - its depth from the surface, quality for drinking water, and chance of being polluted - varies from place to place. Generally the deeper the well, the better the groundwater, the amount of new water flowing into the area also affects groundwater quality.

Even if no sources of anthropogenic contamination exists there is potential for natural levels of metals and other chemicals to be harmful to human health. This was highlighted in Bangladesh where natural levels of Arsenic in groundwater were found to be causing harmful effects on the population (Anawara *et al*., 2007).

Groundwater contamination is responsible for water related and water borne diseases in developing countries like Nigeria. The source of groundwater contamination could be natural through groundwater-rock interaction or through anthropogenic contaminants which involve human activities that can affect ground water quality. Groundwater pollution which is man-made is worse than natural pollution as it eventually renders water unsuitable for use (Abimbola *et al*., 2005). Obajana Cement Factory is the largest in sub-Saharan Africa, sited in Obajana village, on 44,000m^2 of land allocated to Obajana Cement Plc by the government of Kogi State, Nigeria. The site is a relatively flat terrain, originally bearing a Guinea Savannah Vegetation type. The housing colony is sited about a kilometer away from the cement factory site on a land originally belonging to Oyoo-Iwaa community. At this factory the major air pollutant is dust which results from the activities involved in the processing of the cement. These activities include the burning of the raw material such as (marble, gypsum, red alluvium) in the rotary kiln and the burning of coal in the factory area which is also responsible for the phenomenon known as acid rain which causes the rainfall on the water surface to become highly acidic. Moreover, the major products that the factory produces are cement and paint and the raw materials used are marble, gypsum, clay and water.

However, toxic chemicals such as arsenic and fluoride can be dissolved from the soil or rock layers into groundwater. Chemicals can enter waterways from a point source or a non point source. Point- source pollution is due to discharges from a single source, such as an industrial site. Non point-source pollution involves many small sources that combine to cause significant pollution. For instance, the movement of rain or irrigation water over land picks up pollutants such as fertilizers, herbicides, and insecticides and carries them into rivers, lakes, reservoirs, coastal waters, or groundwater. Another non point source is storm-water that collects on roads and eventually reaches rivers or lakes.

At Obajana cement factory there are two major sources of water pollution which are the disposal of chemical waste from the factory on the surface and the constant settling of dust on the surface from the factory. Drinking contaminated water is the most direct route of exposure to pollutants in water. The actual exposure via drinking water depends on the amount of water consumed, usually 2 to 3 liters per day for an adult, with higher amounts for people living in hot areas or people engaged in heavy physical work. Use of contaminated water in food preparation can result in contaminated food, because high cooking temperatures do not affect the toxicity of most chemical contaminants. The toxic substances discharged into water bodies are not only accumulated through the food chain (Odiete, 1999).

Exposures to inhaling volatile compounds during hot showers and skin exposure while bathing or using water for recreation are also potential routes of exposure to water pollutants. Toxic chemicals in water can affect unborn or young children by crossing the placenta or being ingested through breast milk. Estimating actual exposure via water involves analyzing the level of the contaminant in the water consumed and assessing daily water intake (WHO, 2003). Biological monitoring using blood or urine samples can be a precise tool for measuring total exposure from water, food, and air.

2.6 Groundwater Pollution

Groundwater contamination is generally irreversible i.e. it is difficult to restore the original water quality of the water of the aquifer once contaminated. Excessive mineralization of groundwater degrades water quality producing an objectionable taste, odour and excessive hardness. Although the soil mantle through which water passes acts as an adsorbent retaining a large part of colloidal and soluble ions with its cation exchange capacity, but groundwater is not completely free from the menace of chronic pollution (Bhatia, 2009). The extent of groundwater pollution depends on the following factors: (a) Depth of water table; (b) Rainfall pattern; (c) Soil properties; (d) Distance from the sources of contamination. Radioactive water pollutants may originate from the following anthropogenic activities:

i. Mining and processing of ores, e.g. uranium tailings.

ii. Increasing use of radioactive isotopes in research, agricultural, industrial and medical/diagnostic as well as therapeutic applications e.g. I^{131}, P^{22}, Co^{60}, Ca^{45}, S^{35}, C^{14}, Rb^{86}, Ir^{132} and Cs^{137}.

iii. Radioactive materials from nuclear power plants and nuclear reactors, e.g. Sr^{90}, Cs^{127} Pu^{248}, Am^{241}.

iv. Radioactive materials from testing and use of nuclear weaponry, e.g. Sr^{90}, Cs^{137}. The radioactive isotopes found in water include Sr^{90}, I^{131}, Cs^{37}, Co^{60}, Mn^{54}, Fe^{55}, Pu^{239}, Ba^{140}, K^{40}, and Ra226. These radioactive isotopes are toxic to life form

2.7 Physicochemical Properties of Water

2.7.1 pH of water

The pH is a measure of the activity of the hydrogen ion [H^{+}]; also, it is the reciprocal of the logarithm of the hydrogen ion concentration (Silberberg, 2000). The pH scale range from 0 to 14 (Ameyibor and Wiredu, 1991). In general, water with a pH less than 7 is considered acidic, soft and corrosive. pH more than 7 is considered basic (Ameyibor and Wiredu, 1991).

2.7.2 Standards of pH

The pH of pure water is 7 at 25ºC (Silberberg, 2000) but when exposed to the carbon dioxide in the atmosphere, equilibrium results in the pH of approximately 5.2. The WHO optimum limit of pH values is between 6.5 and 9.5. Because of the association of pH with atmospheric gases and temperature, it is strongly recommended that the water be tested as soon as possible.

2.7.3 Potential health effect of pH

Water with a low pH could contain elevated levels of toxic metals, cause premature damage to metal piping, and have associated aesthetic problems such as a metallic or sour taste, staining of laundry and the characteristic "blue-green" staining of sinks and drains. Water with a pH more than 8.5 could indicate that the water is hard (Ameyibor and Wiredu, 1991). Hard water does not pose a health risk, but can cause aesthetic problems. These problems include formation of a "scale" or precipitate on piping and fixtures causing water pressures and interior diameter of piping to decrease, causes an alkali taste to the water and can make coffee taste bitter, formation of a scale or deposit on dishes, utensils, and laundry basins, difficulty in getting soaps and detergents to foam and formation of insoluble precipitates on clothing.

2.7.4 Treatment

The primary method to treat the problem of low pH water is with the use of a neutralizer (Staniski *et al*., 2000). The neutralizer feeds a solution into the water to prevent the water from reacting with the house plumbing or contributing to electrolytic corrosion; a typical neutralizing chemical is soda ash. Neutralizing with soda ash increases the sodium content of the water.

2.7.5 Dissolved solids

Solids refer to any minerals, salts, metals, cations or anions dissolved in water. Dissolved solids(DS) comprises of inorganic salts (principally, calcium, magnesium, potassium, sodium, bicarbonate, chlorides and sulphates) and some small amount of organic matter that are dissolved in water (Wikipedia, 2010).

2.7.6 Sources of dissolved solids

DS originate from natural sources such as, sewages, urban run-offs industrial waste water and chemicals used in the water treatment process. Dissolved solids concentration is the sum of the cations and the anions in the water**.**

2.7.7 Potential health effect of DS

i. An elevated DS concentration is not a health hazard. The DS concentration is a secondary drinking standard and therefore is regulated because it is more of an aesthetic rather than health hazard (Nkansah *et al.,* 2010). An elevated TDS also indicate the following; a) the concentration of the dissolved ions may cause the water to be corrosive, salty or brackish taste, result in scale formation and interfere and decrease efficiency of hot water heaters and b) Many contain elevated levels of ions that are above the primary or secondary drinking water standard such as an elevated level of nitrate, arsenic, aluminum copper, lead etc.

2.7.8 Standard of DS

The EPA establishes standards for drinking water in two categories; that is primary standards and secondary standards. The primary standard is based on health consideration and the secondary is based on taste, odour, and colour, corrosivity, foaming and staining properties of water. There is no primary drinking water standard for DS but secondary standard for DS is 500mg/l (EPA, 2006**).**

2.7.9 Turbidity

Turbidity is an optical property where suspended and dissolved materials such as silt, clay, finely divided organic and inorganic materials cause light to be scattered rather than penetrate in a straight lines (Wikipedia, 2010). It is a measure the amount of light scattered by suspended particles and can be considered as the "cloudiness" of a water sample (Stanistski *et al.*, 2000). Turbidity is contributed mainly by suspended sediment or plankton, which are solid particles of inorganic or biological origin.

2.7.10 Sources of turbidity

Human activities, including logging, grazing, agriculture, mining, road building, urbanization and commercial construction contribute to periodic pulse or chronic levels of suspended sediment in streams and other water bodies (Zoeteman, 1980).

2.7.11 Potential health effect of turbidity

In drinking water the higher the turbidity level, the higher the risk that people may develop gastrointestinal diseases. This is especially problematic for immune- compromised people, because contaminant like viruses or bacteria can become attached to the suspended solids (Stanistski *et al.*, 2000).

2.7.12 Standard of turbidity

The Environmental Protection Agency (EPA) establishes standards for drinking water which fall into two categories; primary standards and secondary standards. Primary standards are based on health considerations and secondary standards are based on taste, odour, colour, corrosivity, foaming, and staining properties of water. There is no primary drinking water standard for dissolved solids, but the secondary standard for DS is 500 mg/l. (EPA, 2006)

2.7.13 Electrical conductivity

Electrical conductivity or simply conductivity is a measure of water's ability to conduct an electric current. The measurement is important because it indicates the concentration of dissolved ions in the water (Pritchard, *et al*., 2007) which in turn reflects groundwater input, catchment geology of the area or diverse human impact. As the number of charged ions in the water increases, so does the electrical conductivity. Conductivity varies with temperature. High and low humidity result in evaporation of the water but leaves the ions behind giving the water a higher concentration of the salt and other compounds. Groundwater has higher electrical conductivity than surface water because the ground water is able to react with mineral in the soil and rocks in the ground. (Stanistski *et al.,* 2000).The WHO permissible limit for electrical conductivity of water is 8 – 10,000µS/cm (WHO, 2008).

2.7.14 Hardness of water

Hard water is water that has high mineral content. Hard water has high concentration of Ca^{2+} and Mg^{2+} ions (Ameyibor and Wiredu, 1991). Hard water is generally not harmful to one's health but can pose serious problems in the industrial setting. It is the measure of quantity of divalent ions (salts with 2 positive charges) such as calcium, magnesium or iron in water. The presence of iron confers a brownish (rust-like) colour calcification, instead of white which is the colour of most of the other compounds. These ions enter water supply or groundwater by leaching (Nkansah *et al*., 2010) from minerals within an aquifer. Water hardness is measured by adding up the concentration of calcium, magnesium and converting the value to an equivalent concentration of calcium carbonate ($CaCO_3$) in milligram per liter (mg/l) (APHA, 1998).

2.7.15 Potential health effect of hard water

Hardness does not pose a health risk and is not regulated by state agencies. In fact, calcium and magnesium in drinking water can help ensure average daily requirement for these minerals in a diet (Salami and Okafor, 2003). With hard water, soap solution forms a white precipitate instead of producing lather. The effect arises because the dications destroy the surfactant properties of the soap by forming a solid precipitate (Ameyibor and Wiredu, 1991). It also forms deposit also called scale that cause clog plumbing. This scale mainly caused by $CaCO_3$, $Mg(OH)_2$ and $CaSO_4$ (Silberberg, 2000). It often causes aesthetic problems, such as an alkali taste to the water that makes coffees taste bitter**.**

2.7.16 Nitrate in water

Nitrate is a colourless, odourless, and tasteless compound (Ameyibor and Wiredu, 1991) that is present in some groundwater. Nitrate can be expressed as either NO_3^- (nitrate) or NO^-_3 - N (nitrate-nitrogen) [Silberberg, 2000]. Nitrate (NO_3^-) is a naturally occurring form of nitrogen found in soil. Nitrogen is essential to all life. Most plants require large quantities to sustain high yields. The formation of nitrates is an integral part of the nitrogen cycle in our environment. In moderate amounts, nitrate is a harmless constituent of food and water. Plants use nitrates from the soil to satisfy nutrient requirements and may accumulate nitrate in their leaves and stems. Due to its high mobility, nitrate can leach into groundwater (Self and Waskom, 2008). Nitrates form when microorganisms break down fertilizers, decaying plants, manures or other organic residues. Usually plants take up these nitrates, but sometimes rain or irrigation water can leach them into groundwater.

2.7.17 Sources of nitrate

Although nitrate occurs naturally in some groundwater, in most cases higher levels are thought to have come from human activities. Common sources of nitrate include fertilizers and manure, animal feedlots, municipal wastewater and sludge, septic systems, and N-fixation from atmosphere by legumes, bacteria and lightning.

2.7.18 Potential health effect of nitrate

High nitrate levels in water can cause methemoglobinemia or blue baby syndrome, a condition found especially in infants less than six months. This causes an increase in bacteria that can readily convert nitrate to nitrite (NO^{2-}). Nitrite is absorbed in the blood, and heamoglobin (the oxygen-carrying component of blood) is converted to methemoglobin. Methemoglobin does not carry oxygen efficiently. This results in a reduced oxygen supply to vital tissues such as the brain. Methemoglobin in infant blood cannot change back to heamoglobin (Hole, 1999), which normally occurs in adults. Severe methemoglobinemia can result in brain damage and death (Self and Waskom, 2008). Infants should not be allowed to drink water that exceeds 10 mg/l NO_3^- - N. This includes formula preparation. The most obvious symptom of methemoglobinemia is a bluish colour of the skin, particularly around the eyes and mouth. Other symptoms include headache, dizziness, weakness or difficulty in breathing. If recognized in time, methemoglobinemia is treated easily with an injection of methylene blue (Self and Waskom, 2008). Nitrate in water is undetectable without testing because it is colourless, odourless, and tasteless (Silberberg, 2000). A water test for nitrate is highly recommended for households with infants, pregnant women, nursing mothers, or elderly people. These groups are the most susceptible to nitrate or nitrite contamination. Nitrate-nitrogen occurs naturally in groundwater, usually at concentrations far below the level of concern for drinking water safety.

2.7.19 Standard of nitrate

Nitrate values are commonly reported as either nitrate (NO_3^-) or as nitrate-nitrogen (NO_3^- - N). The maximum contaminant level (MCL) in drinking water as nitrate (NO_3^-) is 45mg/l (EPA, 2006). Protecting your drinking water supply from contamination is important for health and to protect property values and minimize potential liability. High nitrate levels often are associated with poorly constructed or improperly located wells (Zoeteman, 1980). Although there is no enforceable drinking water standard for livestock, it is not advisable to allow animals to drink water with more than 100 mg/l NO_3^- - N. This is especially true of young animals. They are affected by nitrates the same way as human babies. Older animals may tolerate higher levels.

2.7.20 Sulphate in water

Sulphate (SO_4^{2-}) is a combination of sulphur and oxygen. It occurs naturally in many soil and rock formation (Silberberg, 2000). Sulphate also occurs naturally in most groundwater. At high levels, sulphate can give water a bitter or astringent taste and can have laxative effects.

2.7.21 Sources of sulphate

As water moves through soil and rock formations that contain sulphate minerals, some of the sulphate dissolves into the groundwater. Minerals that contain sulphate include magnesium sulphate (Epsom salt), sodium sulphate (Glauber's salt), and calcium sulphate (gypsum). Salt water intrusion and acid rock drainage are also sources of sulphate in drinking water. In addition, manmade sources include industrial discharge and deposition from burning of fossil fuel (Okeola *et al*., 2010).

2.7.22 Potential health effect of sulphate

People unaccustomed to drinking water with elevated levels of sulphate can experience diarrhoea and dehydration. Infants are often more sensitive to sulphate than adults. As a precaution, water with a sulphate level exceeding 400 mg/l should not be used in the preparation of infant formula. Older children and adults become accustomed to high sulphate levels after a few days. High sulphate levels may also corrode plumbing, particularly copper piping.

2.7.23 Standard of sulphate

According to Minnesota Health Department, if sulphate in water exceeds 250 mg/l, a bitter of medicinal taste may render the water unpleasant to drink. Sulphate above 500mg/l in water may affect the taste of the water (EPA, 2006). At levels above 1000mg/l, sulphate in drinking water can have a laxative effect, although, these levels are not normally found in drinking water.

2.7.24 Colour

Colour is the sensation produced in the eyes by the rays of a decomposed light. Even pure water is not colourless: it has a pale green-blue tint in large volumes. It is necessary to differentiate between true colour due to material in solution and apparent colour due to suspended matter. Natural yellow colour in water from upland catchments is due to organic acids which are not in any way harmful, being similar to tannic acid from tea (Tebbutt, 1983). Colour in water may be due to the presence of colouring matter such as humic and tanning substances leached into water and suspended in it. Colour of water aesthetically affects its portability and may not be necessarily harmful (Nikoladze and Mints, 1989; Nsi, 2007)

2.7.25 Alkalinity

The capacity of water to accept H^+ ions (protons) is called alkalinity. Alkalinity is important in water treatment and in the chemistry and biology of natural water. Frequently, the alkalinity of water must be known to calculate the quantities of the chemicals added in treating water. Highly alkaline water often has a high pH and generally contains elevated levels of dissolved solids. These characteristics may be detrimental for water to be used in boilers, food processing and municipal water systems. Alkalinity serves as a pH buffer and reservoir for inorganic carbon, thus helping to determine the ability of water to support algae growth and other aquatic life, so it can be used as a measure of water fertility. Generally, the basic species responsible for alkalinity in water are bicarbonate ion, carbonation, and hydroxide ion.

$$HCO_3^- + H^+ \rightarrow CO_2 + H_2O \quad \ldots\ldots 2.1$$

$$CO_3^{2-} + H^+ \rightarrow HCO_3^- \quad \ldots\ldots 2.2$$

$$OH^- + H^+ \rightarrow H_2O \quad \ldots\ldots 2.3$$

2.7.26 Chemical oxygen demand

When chemical substances which are oxygen demanding are discharge into water body; they consumed the oxygen demand in water and lead to low oxygen concentration .This has adverse effects on the organism that require oxygen for the survival in the environment (Hammer,1996).

2.7.27 Biological oxygen demand

The biodegradable material found in water usually the microbes and other organic matters which require oxygen for their system tend to compete with aquatic animals in the consumption of the Oxygen dissolved in water. The amount of these microbes and materials present in water are very important because it affects the available dissolved oxygen in water (Sada, 1988).

2.7.28 Dissolved oxygen

The amount of oxygen dissolved in water is very essential, since its supports aquatic life is an important parameter which need to be monitored in water (Hammer, 1996)

2.8 Metallic Pollutants

Some metallic elements present in natural waters act as pollutants. Typical chemical form or oxidation state for each element is also present. In any particular situation the element might be present in some other form, depending on the source. It should be noted that many of the metals that can act as a pollutant are actually essential in human nutrition.

2.8.1 Effects of heavy metals

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals that are harmful to humans include mercury, lead, and arsenic. Chronic exposure to these metals can have serious health consequences. Humans are exposed to heavy metals through inhalation of air pollutants, consumption of contaminated drinking water, exposure to contaminated soils or industrial waste, or consumption of contaminated food. Food sources such as vegetables, grains, fruits, fish and shellfish can become contaminated by accumulating metals from surrounding soil and water. Heavy metal exposure causes serious health effects, including reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death. Exposure to some metals, such as mercury and lead, may also cause development of autoimmunity, in which a person's immune system attacks its own cells. This can lead to joint diseases such as rheumatoid arthritis, and diseases of the kidneys, circulatory system, and nervous system.

Metals are particularly toxic to the sensitive, rapidly developing systems of fetuses, infants, and young children. Some metals, such as lead and mercury, easily cross the placenta and damage the fetal brain. Childhood exposure to some metals can result in learning difficulties, memory impairment, damage to the nervous system, and behavioural problems such as aggressiveness and hyperactivity. At higher doses, heavy metals can cause irreversible brain damage. Children may receive higher doses of metals from food than adults, since they consume more food for their body weight than adults(IARC, 1990).

2.8.2 Lead

Lead and its compounds are toxic and are retained by the body, accumulating over a long period of time, a phenomenon known as cumulative poisoning until a lethal quantity is reached. The toxicity of lead compounds increases as their solubility increases. In children and adults the accumulation of lead may result in progressive renal disease. Symptoms of lead poisoning include abdominal pain and diarrhoea followed by constipation, nausea, vomiting, dizziness, headache and general weakness.

Elimination of contact with a lead source is normally sufficient to effect a cure (Leonard *et al*.,1998).

In humans the main sources of lead are usually lead - based paint and drinking water carried through lead pipes; lead-based paints are especially harmful to children who chew on painted toys and furnishings and eat paint peelings from walls. Industries in which workers encounter lead-containing solids, dusts, or fumes include the petroleum industry, mining, smelting, printing, cutlery, storage-battery manufacture, plumbing, gas fitting, paint, pigments manufacture, manufacture of ceramics, glass and ammunition. Other possible sources of lead poisoning include the agricultural use of insecticide containing lead compounds; the spraying of fruits and vegetables may affect the workers and eventually, the consumers. In the mid-20th century, constant exposure to the exhaust fumes of motor vehicles would bed by fuel containing tetraethyl lead became a significant cause of lead poisoning, especially in children (Kersten *et al.*, 2003).

Symptoms of lead poisoning vary; they may develop gradually or appear suddenly after chronic exposure. The poison affects the entire body especially the nervous system, the gastrointestinal track and the blood forming tissues when taken above WHO maximum tolerable level of 0.04mg/l.

2.8.3 Manganese

Manganese is essential in nutrition and low level of toxicity. Its toxicity effect is not well characterized. Maximum tolerable limit is 0.05mg/l. However, this limit is not determined by its toxicity, but because they stain clothing and ceramic plumbing fixtures (Nsi, 2007).

2.8.4 Copper

The major portion of copper produced in the world is used by the electrical industries; most of the remainder is combined with other metals to form alloys (Prusty, 1983).

Important series of alloys in which copper is the chief constituent are brasses (copper and zinc) and bronzes (copper and tin) (Morse*,* 1994). Copper resists the action of the atmosphere and seawater; exposure for long periods to air, however, results in the formation of a thin green protective coating (patina) that is a mixture of hydroxocarbonate, hydroxosulphate and small amounts of other compounds. Copper is a moderately noble metal, being unaffected by non-oxidizing or non-complexing dilute acids in the absence of air; it will however, dissolve readily in nitric acid and in sulphuric acid in the presence of oxygen (Frits *et al*., 2000).

Copper is among heavy metals that are essential to life but could be toxic at elevated levels (Rogers *et al*., 2009). It is toxic at low concentration in water and is known to cause brain damage in mammals. Elevated levels of this metal has however, been found to be toxic (Hukabee *et al*., 2011). Toxicity of Copper in plants as a result of high level in sewage treated agricultural soil has been reported. Contribution of copper to environmental burden could be by atmospheric deposition from metal industries, dumpsites and power plants that burn fuels (Baryla *et al*., 2011).

2.8.5 Zinc

The major uses of zinc metal are in galvanizing iron and steel against corrosion and in making brasses and alloys for die-casting. Zinc itself forms an impervious coating of its oxide on exposure to the atmosphere and hence the metal is more resistant to ordinary atmospheres than iron and corrodes at a much lower rate. Zinc is an essential trace element in the human body, where it is found in high concentration in the red blood cells as an essential part of the enzyme carbonic anhydrate, which promotes many reactions relating to carbon dioxide metabolism. The toxicity of zinc is low, in drinking water zinc can be detected by taste only when it reaches a concentration of 15 mg/L; water containing 40 mg/l, zinc has a definite metallic taste. Vomiting is induced when the zinc content exceeds 800 mg/l. Cases of fatal poisoning have resulted through the ingestion of zinc chloride or sulphide, but these are rare. Both zinc and zinc salts are well tolerated by the human skin. Excessive inhalation of zinc compounds can cause such toxic manifestations as fever, excessive salivation and a cough that may cause vomiting; but the effects are not permanent (Kline *et al*., 2010).

2.8.6 Iron

Iron is one of the most abundant metals in the earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/L. Iron may also be present in drinking water as a result 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/L per day (WHO, 2008)

2.9 Atomic Absorption Spectrophotometric Analysis

Digested samples in this study were analysed for heavy metals using Atomic absorption spectrometry, where the elements of interest (Pb, Cu, Fe, Zn and Mn) were assayed using a Varian AA240FS Atomic absorption spectrophotometer.

2.9.1 Theory of atomic absorption spectrophotometer

The atomic absorption spectrophotometer (AAS) is a form of optical analysis that is used primarily for detecting the presence of trace elements. AAS relies on the absorption, emission or transmittance of light by atoms in an excited state to allow the determination of the concentration of atoms in the sample. The liquid samples are neb-ulized and the resulting aerosol passes through a very hot flame which vaporizes the solvent, leaving a cloud of atoms. The light is beamed at a particular wavelength by a hollowed cathode lamp specific for the element of interest. The light beam passes through the hotter part of the flame and the amount of light absorbed/emitted /transmitted by the excited atom cloud is detected by the instrument and the concentration of atoms present can be measured. AAS gives accurate measurement of very small amounts of elements (typically 1mg/l detection limit for flame mode), but it can only measure the atoms specific to the cathode lamp used.

Chapter Three

Methodology

3.1 Study Area

The cement factory which was founded in 1992, is located on latitude 7°55'0" N and longitude 6°26'0"E has a community located next to the site of the cement plant and truck park and three communities surrounding the place. The original inhabitants of obajana are oworos, who claim to originate from the yoruba land. Occupations of the people include cattle rearing, rain-fed farming, hunting and petty trading. The agricultural system in the study area can be categorized into an intensive smallholder rain-fed agriculture. Since the only source of water – the Onyi River - dries up during the dry season, there is generally no irrigation farming being practiced in the area. As there is no recognized health institution in Obajana and environs, there are no detailed records on mortality and morbidity. However, records of clinical diagnosis for the oworo people at the general hospital in lokoja shows that majority (80%) of the ailments affecting the people are communicable diseases. Amongst the communicable diseases, malaria was the most prevalent followed by gastroenteritis as the study area is devoid of portable water, thus the high rate of gastroenteritis. The inhabitants in the area and surroundings source their water from hand-dug wells, very few boreholes and the semi-perennial Onyi River system. Obajana lies within the sub-humid tropical zone, and has a mean annual rainfall that range from 1100 to 1320mm. It experiences two main alternating seasons: dry and wet seasons. Rainfall lasts from April/May to September/October, characterized by moisture laden southwesterly winds blowing from the atlantic ocean, while the dry season lasts between November/March with predominantly northeast trade winds (EIA 2004).

3.2 Sampling Sites

The town was categorized into three suburbs based on the main road network in the town, Obajana community, Oyoo community, and Iwaa/amogbe respectively. Hand-dug wells that were open for communal use were considered in this study. 12 wells,8 boreholes were selected from Obajana community, and 6 wells,4 boreholes from the each of the suburbs for sampling, which gave a total of forty sample sites as listed in Tables 3.1 - 3.5 with tables showing the sampling sites / location, designated codes groundwater type and coordinates for sampling sites. Figures 3.1 – 3.4 shows pictures of hand-dug wells and boreholes from some of the sites, while Figure 3.5 shows map of Lokoja indicating Obajana and surrounding communities and Figure 3.6 shows map of Obajana and environs with the location of the cement factory.

3.3 Sample Collection

Samples were consistently taken in August 2013. Groundwater samples were collected according to standard procedures by (APHA, 2000) from different hand-dug wells in houses around the cement factory in obajana , kogi state in duplicate by lowering a clean plastic container tied to a synthetic rope down the well. Two litres of samples collected were transferred into washed containers and labeled appropriately. Groundwater samples were obtained directly from the water pump after allowing the water to run for at least five minutes and each sample bottle and its cap rinsed three times with the water sample. These samples were subsequently stored at 4°C for as short a time as possible before analysis to minimize physicochemical changes.Samples for heavy metals determination was preserved by treating to a pH of 2 with analytical grade concentrated nitric acid (Anonymous, 1996).Parameters with extremely low stability such as pH, electrical conductivity, turbidity and temperature, were measured

Table 3.1 Sampling sites and their designated codes

Site 1	Location	Site 2	location
Obj 1	Obajana	Obj 11	Obajana
Obj 2	Obajana	Obj 12	Obajana
Obj 3	Obajana	Obj 13	Obajana
Obj 4	Obajana	Obj 14	Obajana
Obj 5	Obajana	Obj 15	Obajana
Obj 6	Obajana	Obj 16	Obajana
Obj 7	Obajana	Obj 17	Obajana
Obj 8	Obajana	Obj 18	Obajana
Obj 9	Obajana	Obj 19	Obajana
Obj 10	Obajana	Obj 20	Obajana

Table 3.2 Sampling locations and the codes used

SITE 3	LOCATION/CODES	SITE 4	LOCATION/CODES
Iwaa 1	Amogbe/iwaa	Ooyo 1	Ooyo
Iwaa 2	Amogbe/Iwaa	Ooyo 2	Ooyo
Iwaa 3	Amogbe/Iwaa	Ooyo 3	Ooyo
Iwaa 4	Amogbe/Iwaa	Ooyo 4	Ooyo
Iwaa 5	Amogbe/Iwaa	Ooyo 5	Ooyo
Iwaa 6	Amogbe/Iwaa	Ooyo 6	Ooyo
Iwaa 7	Amogbe/Iwaa	Ooyo 7	Ooyo
Iwaa 8	Amogbe/Iwaa	Ooyo8	Ooyo
Iwaa 9	Amogbe/Iwaa	Ooyo 9	Ooyo
Iwaa 10	Amogbe/Iwaa	Ooyo 10	Ooyo

Table 3.3 Four sites, their water type and codes

S/N	SITE 1	WATER TYPE	SITE 2	WATER TYPE	SITE 3	WATER TYPE	SITE 4	WATER TYPE
1	Obajana	Hand-dug well(HW)	Obj	Well(HW)	Iwaa	Well(HW)	Ooyo	Well(HW)
2	Obajana	Well(HW)	Obj	Well(HW)	Iwaa	Well(HW)	Ooyo	Well(HW)
3	Obajana	Well(HW)	Obj	Well(HW)	Iwaa	Well(HW)	Ooyo	Well(HW)
4	Obajana	Well(HW)	Obj	Well(HW)	Iwaa	Well(HW)	Ooyo	Well(HW)
5	Obajana	Well(HW)	Obj	Well(HW)	Iwaa	Well(HW)	Ooyo	Well(HW)
6	Obajana	Well(HW)	Obj	Well(HW)	Iwaa	Well(HW)	Ooyo	Well(HW)
7	Obajana	BoreHole(BH)	Obj	BoreHole(BH)	Iwaa	BoreHole(BH)	Ooyo	BoreHole(BH)
8	Obajana	BoreHole(BH)	Obj	BoreHole(BH)	Iwaa	BoreHole(BH)	Ooyo	BoreHole(BH)
9	Obajana	BoreHole(BH)	Obj	BoreHole(BH)	Iwaa	BoreHole(BH)	Ooyo	BoreHole(BH)
10	Obajana	BoreHole(BH)	Obj	BoreHole(BH)	Iwaa	BoreHole(BH)	Ooyo	BoreHole(BH)

Table 3.4 Sampling locations and coordinates for sampling sites 1 and 2

S/NO	Groundwater type	Site 1	Coordinates	Groundwater type	Site 2	Coordinates
1	HW	Obj 1	6^{0}25’37.2”N 7^{0}55’19.2”E	HW	Obj 1	6^{0}26’06.0”N 7^{0}55’12.0”E
2	HW	Obj 2	6^{0}25’40.8”N 7^{0}55’36.6”E	HW	Obj 2	6^{0}25’48.0”N 7^{0}54’54.0”E
3	HW	Obj 3	6^{0}25’40.8”N 7^{0}55’26.4”E	HW	Obj 3	6^{0}25’55.2”N 7^{0}55’04.8”E
4	HW	Obj 4	6^{0}25’40.8”N 7^{0}55’19.2”E	HW	Obj 4	6^{0}26’06.0”N 7^{0}55’12.0”E
5	HW	Obj 5	6^{0}25’30.0”N 7^{0}55’19.2”E	HW	Obj 5	6^{0}26’16.8”N 7^{0}55’19.2”E
6	HW	Obj 6	6^{0}25’33.6”N 7^{0}55’15.6”E	HW	Obj 6	6^{0}26’09.6”N 7^{0}55’19.2”E
7	BH	Obj 7	6^{0}26’06.0”N 7^{0}55’12.0”E	BH	Obj 7	6^{0}26’06.0”N 7^{0}55’12.0”E
8	BH	Obj 8	6^{0}25’26.4”N 7^{0}55’22.8”E	BH	Obj 8	6^{0}26’13.2”N 7^{0}55’15.6”E
9	BH	Obj 9	6^{0}26’09.6”N 7^{0}55’19.2”E	BH	Obj 9	6^{0}26’02.4”N 7^{0}55’12.0”E
10	BH	Obj 10	6^{0}25’30.0”N 7^{0}55’12.0”E	BH	Obj 10	6^{0}25’48.0”N 7^{0}55’44.4”E

Table 3.5 Sampling locations and coordinates for sampling sites 3 and 4

S/NO	Groundwater type	Site 3	Coordinates	Groundwater type	Site 4	Coordinates
1	HW	Iwaa	$6^0$20’31.2”N $7^0$55’31.2”E	HW	Oyoo	$6^0$25’58.8”N $7^0$55’44.4”E
2	HW	Iwaa	$6^0$20’45.6”N $7^0$55’48.0”E	HW	Oyoo	$6^0$25’48.0”N $7^0$55’12.0”E
3	HW	Iwaa	$6^0$20’02.4”N $7^0$56’02.4”E	HW	Oyoo	$6^0$25’58.8”N $7^0$55’44.4”E
4	HW	Iwaa	$6^0$20’24.0”N $7^0$56’16.8”E	HW	Oyoo	$6^0$25’48.0”N $7^0$55’37.2”E
5	HW	Iwaa	$6^0$20’49.2”N $7^0$56’02.4”E	HW	Oyoo	$6^0$25’27.6”N $7^0$55’04.8”E
6	HW	Iwaa	$6^0$20’42.0”N $7^0$55’55.2”E	HW	Oyoo	$6^0$25’20.4”N $7^0$55’30.0”E
7	BH	Iwaa	$6^0$20’34.8”N $7^0$55’58.8”E	BH	Oyoo	$6^0$25’31.2”N $7^0$55’01.2”E
8	BH	Iwaa	$6^0$20’45.6”N $7^0$56’02.4”E	BH	Oyoo	$6^0$25’16.8”N $7^0$55’36.0”E
9	BH	Iwaa	$6^0$20’24.0”N $7^0$56’09.6”E	BH	Oyoo	$6^0$25’58.8”N $7^0$55’44.4”E
10	BH	Iwaa	$6^0$20’24.0”N $7^0$56’02.4”E	BH	Oyoo	$6^0$25’48.0”N $7^0$55’04.8”E

Figure 3.1 Picture of a well in site 1(Obajana 1)

Figure 3.2 Picture of a well in site 3 (Iwaa/amogbe 2)

Figure 3.3 Picture of a well in site 4 (Oyoo 4)

Figure 3.4 Picture of a borehole in site 2 (Obajana 8)

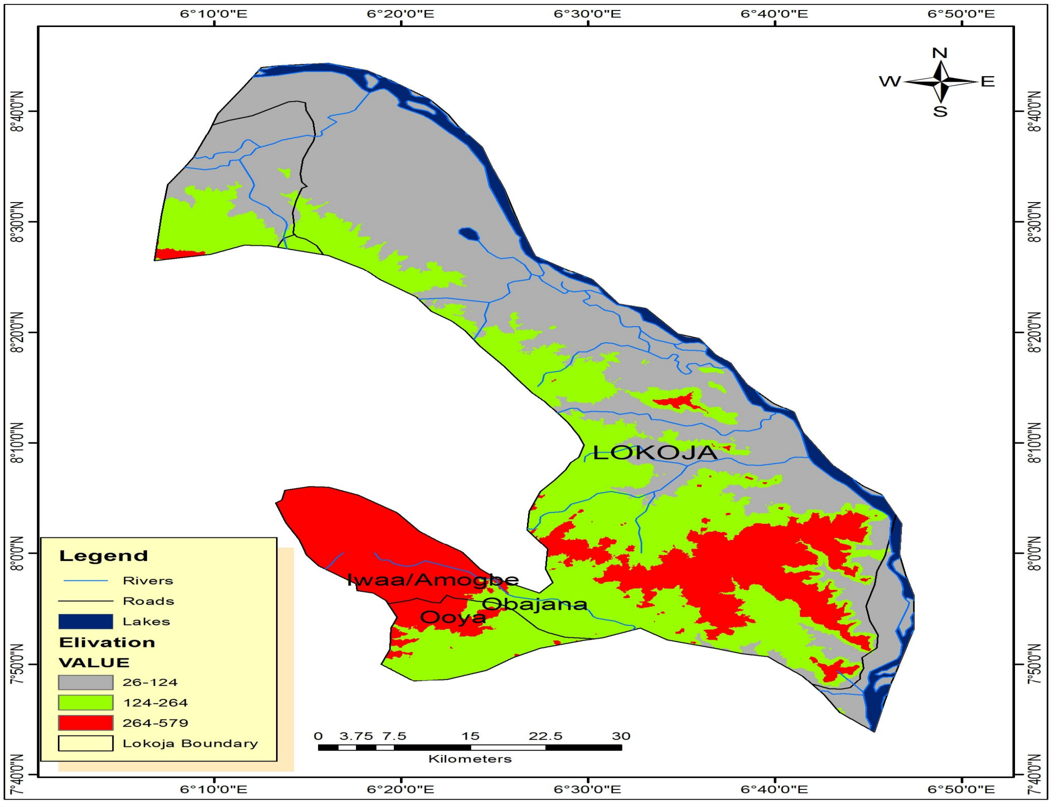

Figure 3.5 Map of Lokoja showing Obajana and surrounding communities
Source: Adapted and modified from the google map of Kogi State and SRTM image, 2013.

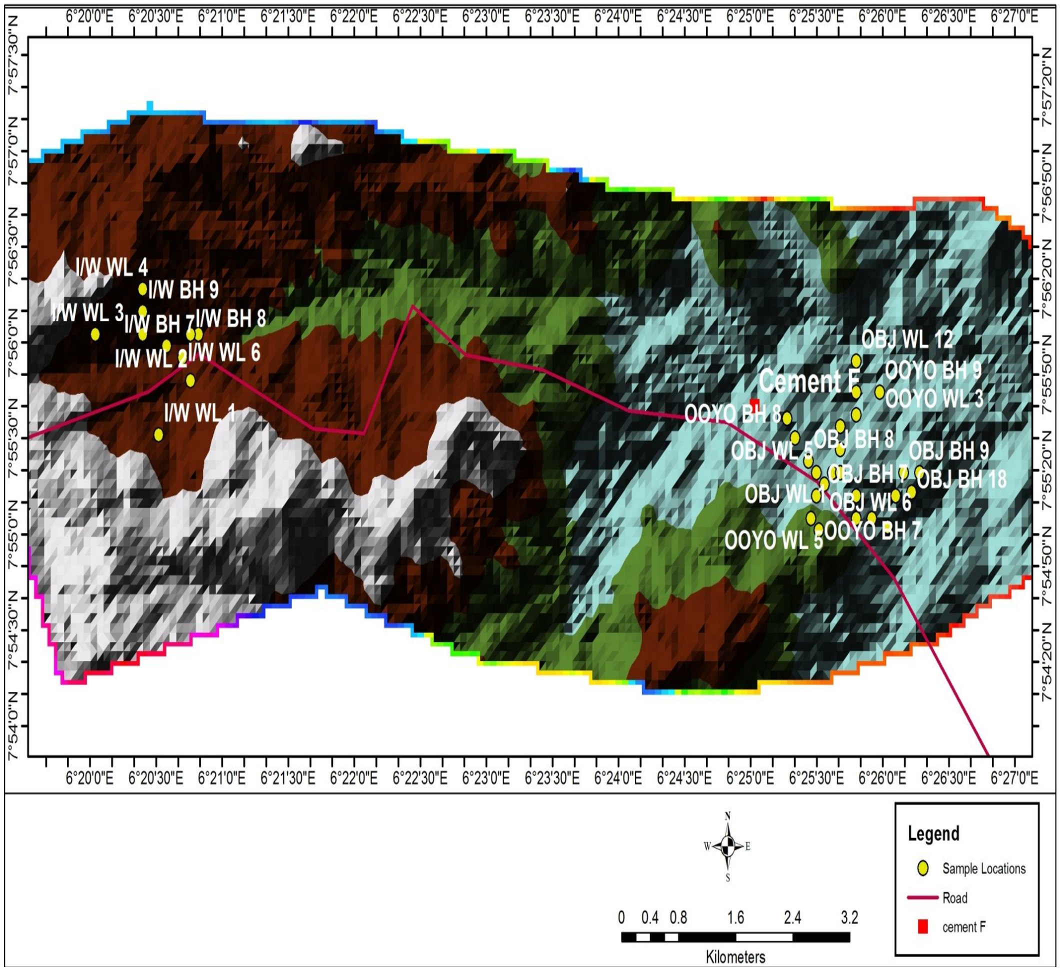

Figure 3.6 Map of Obajana and its environs showing cement factory and sample locations
Source: Adapted and modified from the google map of Kogi state and SRTM image, 2013

on the field using field kit. Thereafter, other parameters were measured in the laboratory using standard procedures American Public Health Association (APHA, 2000) and all the samples were measured in triplicate distilled water.

3.4 Preparation of Aqueous Stock Solutions

All chemicals used were of analytical grade. All solutions used for this analysis were prepared by dissolving appropriate amount in distilled water. Distilled and deionizer water was used for solution preparations.

3.4.1 Sodium nitrite solution (1%):

This was prepared by dissolving 1g of sodium nitrite in $100cm^3$ distilled water in a volumetric flask. This solution was kept in a brown bottle and is stable for at least one week.

3.4.2 Iron solution

Iron $FeCl_3.6H_20$ (0.483g) was weighed and dissolved in $100cm^3$ of distilled water in $1000cm^3$ volumetric flask. Thus gives a 1000ppm standard solution.

3.4.3 Copper solution

This was prepared by dissolving 3.803g of $Cu(NO_3)_2.3H_2O$ in $5.00cm^3$ concentrated HNO_3 and made up to 1000.00 cm^3 with distilled water giving 1000.00 mg/l copper solution.

3.4.4 Lead solution

This was prepared by dissolving 1.599 g $Pb(NO_3)_2$ in distilled water and made up to $1000cm^3$ giving 1000.00 mg/l lead solutions.

3.4.5 Zinc solution

This was prepared by dissolving 1.244 g of ZnO in 5.00 cm^3 of water then 25.00 cm^3 concentrated HNO_3 was added and made up to 1000.00 ml with distilled water giving 1000 mg/l zinc solution.

3.4.6 Manganese solution

This was prepared by dissolving 4.058 g $MnSO_4$. $4H_2O$ in 5.00 cm^3 of water, 1.00cm^3 concentrated H_2SO_4 was then added and the solution was made up to 1000.00cm^3 with distilled water giving 1000.00 mgl^{-1} manganese solution.

Five working standards were prepared in triplicates for each metal by serial dilution of stock solution. These standards and the blank solution were aspirated in a Varian AA240FS atomic absorption spectrophotometer.

3.5 Measurements of Physicochemical Parameters

The physicochemical properties of water, plays a vital role in determining the extent to which heavy metal pollution of water occurs. Standard methods as recommended by relevant authorities such as World Health Organization (WHO), United States Environmental Protection Agency (US- EPA), etc were employed for the preparation of reagents and determination of all water quality parameters.

3.5.1 Determination of temperature

This was determined *in-situ* using mercury in glass thermometer. (Maitera *et al*., 2011)

3.5.2 Determination of pH

The pH of the water samples was determined using a portable pH meter after being standardized with buffers of pH 4.0 and pH 9.2 (Ademoroti, 1996).

3.5.3 Determination of colour

Colour was determined by visual comparism using Lovibond colour disc (Pt-Co).The disc consists of different colours which is graduated. Sample was placed on disc and observed to see colour changes, and then the reading was taken for the colour which it corresponds with (US-EPA, 1983; ARHA-AWWA-WPCF, 1985; Trivedy and Goel, 1986).

3.5.4 Determination of conductivity

Conductivity of the surface water and the underground water samples was determined using the standard procedure approved by AOAC (1998). The conductivity meter (Hach model CO150) was used. The power key and the conductivity key of the conductivity meter was switched on, and the temperature of the meter adjusted; the instrument was calibrated with 0.001m KCl to give a value of 14.7ms/m at 25^0C. The probe was dipped below the surface of both samples. Time was allowed for the reading to be stabilized and the reading was recorded.

3.5.5 Determination of turbidity

A nephelometer was used in determining turbidity of the samples. The turbidimeter was first set to zero with distilled water. Sample was thoroughly shaken and a portion of it was poured into the sample tube, making sure that no air bubbles were trapped. The sample tube was shaken vigorously and then thoroughly wiped dry, inserted into the instrument and the reading was noted. Calibration curve was prepared from standard turbidity suspension (Formazin Polymer which is a product of hydrazine sulphate and Hexamethylenetetramine). Standard solutions of the suspension of concentrations of 5, 10, 15, 20, 25, and 30 were prepared and these were to determine the turbidities of the samples and to calibrate the instrument. The unit of measurements is called Formazin Turbidity Units (FTU)

3.5.6 Determination of total hardness

This was determine by EDTA titration using Eriochrome black T indicator as described by Hydrology Project, by Government of India and Netherland, 1999.

Procedure: The sample was shaken thoroughly; 75ml was taken and 2ml of buffer solution was added, 2 drops of Eriochrome black T indicator was added immediately and titrated with EDTA within 5 minutes intervals, blue coloration indicates the end point.

$$\text{Total hardness (mg } CaCO_3\text{/L)} = \frac{A \times B \times 1000}{\text{ml of sample}} \quad \ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

where A = ml EDTA titrated for sample and B = mg $CaCO_3$ equivalent to 1.00 ml EDTA titrant.

3.5.7 Determination of dissolved solids

Water sample ($100cm^3$) was quantitatively transferred into an evaporating dish that has been previously weighed and dried in an oven for one hour and cooled in desiccators. The content of the dish was evaporated to dryness on a water-bath to a constant weight. The residue was dried in an oven between 103-105^oC for two hours, cooled in a desiccators and the difference in weight calculated. (US-EPA, 1983; APHA-AWWA-WPCF, 1985; Trivedy and Goel, 1986; NWRI, 2001).

Calculation

$$\text{DS (mg/ l)} = = \frac{\text{difference in weight} \times 1000}{\text{ml of sample}} \quad \ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

3.5.8 Determination of chemical oxygen demand (COD)

The COD of the surface water and the underground water samples was determined using the standard method described by Ademoroti (1996).

$0.4cm^3$ of $H_2 SO_4$ was placed in a refluxing flask. About $20cm^3$ of the samples was diluted with 20ml of distilled water. 10ml standard solution of $K_2Cr_2O_7$ was then added to glass leads already heated to 600^oC for 1 hour. The flask was then attached to the reflux condenser and about $30cm^3$ of concentrated H_2SO_4 containing Ag_2SO_4 was added through the open end of the condenser. The resulting solution was thoroughly mixed by switching.

The mixture was refluxed for 1hour, cooled and the condenser was washed with about $25cm^3$ of distilled water. The mixture was diluted with $150cm^3$ of distilled water and cooled to room temperature. About 3 drops of ($0.10-0.15cm^3$) ferroin indicator was added. The mixture was the titrated with $Fe(NH_4)_2(SO_4)_2$ taking as the end point the sharp colour change from blue-green to reddish brown. In the same manner a blank containing 20ml distilled water was refluxed together with the reagent.

Calculation

$$\text{COD mg/l} = \frac{(a-b) \times M \times 8000}{\text{ml of sample}} \quad \ldots\ldots 3.3$$

where COD = Chemical Oxygen Demand, a = ml Fe $(NH_4)_2$ $(SO_4)_2$ used as blank, b = ml Fe $(NH_4)_2(SO_4)_2$ used for sample and M = Molarity of Fe $(NH_4)_2$ $(SO_4)_2$

3.5.9 Determination of dissolved oxygen

The azide modification of the Winkler's method was used to determine DO and BOD.

250 ml of the sample was introduced into a stopped dark bottle and 2 ml of manganese sulphate solution and 2 ml alkali-iodide-azide reagent was added well below the surface of the liquid and mixed by inverting the bottle several times. Then 5 ml of conc. H_2SO_4 was added immediately precipitate settled. The bottle was then shaken to ensure distribution of iodine, until titrant changed to pale-straw colour. 25 ml of the mixture with 5 ml of starch indicator was then titrated against 0.01M sodium thiosulphate. Titration continued until first disappearance of the blue colour. The titration was carried out three times and average titre value obtained was the equivalent value of dissolved oxygen (DO).

3.5.10 Determination of biological oxygen demand (BOD)

A fresh sample was incubated at 20^{o}C for five days and the above procedure for the determination of dissolved oxygen was then repeated. The difference between DO for incubated sample and DO not incubated was determined (US-EPA, 1983; APHA – AWWA – WPCF, 1985).

Calculation:

$$BOD_{5\ mg/L} = \frac{DO(0) - DO(5)}{\text{dilution factor}} \quad \ldots\ldots 3.4$$

$$\text{Dilution factor} = \frac{\text{no of days}}{\text{ml of sample}} \quad \ldots\ldots 3.5$$

where DO (5) = demand oxygen at day five and DO (0) = dissolved oxygen before incubation.

3.5.11 Determination of nitrate, phosphate and sulphate

The HANNA multi parameter logging spectrophotometer (HI83200) was used to digitally determine the nitrate, phosphate and sulphate in the surface water and ground water samples. The concentration of nitrate, sulphate and phosphate was determined using standard procedure. Sulphate was determined using Sulfa Ver methods 8051. Phosphate was determined using direct reading from HI 83200 HANNA multi parameter (Greenberg *et al.*, 1992).

3.5.12 Determination of total alkalinity

Water sample (100ml) was transferred into a conical flask, two drops of phenolphthalein indicator was added and the solution titrated with H_2SO_4 to the end point. Again, two drops of methyl orange was added to the titrated mixture and titration was continued to methyl orange end point (US-EPA, 1983;APHA-AWWA-WPCF, 1985; Trivedy and Goel, 1986; NWRT, 2001).

Calculation:

Total Alkalinity, mg $CaCO_3$

$$\frac{A \times B \times 1000}{\text{ml of sample}} \quad \ldots\ldots 3.6$$

where A=Vol. of standard H_2SO_4 and B=Titre of standard acid.

3.6 Digestion of Water Sample

The determination of heavy metals in water is often regarded as the movement of total suspended and dissolved metals (soluble metals). In such cases consistent and dependable digestion procedures must be used so that data derived for total metal content is reliable. The water was immediately digested after sampling to prevent changes in composition of water samples according to standard procedures of the American Public Health Association (APHA, 2000).

3.7 Procedure for Water Digestion

Water samples (100 ml) were transferred quantitatively into beakers, concentrated HNO_3 acid (10ml) and concentrated HCl (5 ml) in ratio (2:1) were added and heated on a hot plate making sure the sample did not boil, until the volume was reduced to about 15ml. The samples were then allowed to cool, filtered and quantitatively transferred into a 100ml standard volumetric flask and made up to mark with distilled water and further analysed using AAS.

3.8 Statistical Analysis

In this study, the experimental results obtained were statistically analyzed using Excel 2007, the values were expressed as means which were obtained from a set of observations and statistical analysis were carried out using SPSS to describe the pattern of distribution of the heavy metals in all the samples that were under study, while ANOVA and Pearson Correlation analyses were used to compare test parameters using the SPSS 20 software (Bryman and Crammer, 1997)

Chapter Four

Results

4.1 Physicochemical Parameters

The results of the physicochemical parameters analysed for the hand-dug wells and boreholes water samples from Obajana are presented in Tables 4.1 - 4.4, each table shows the comparison for the mean concentration of the physicochemical parameters to that of the WHO standard for drinking water. Table 4.5 shows the correlation matrix of physicochemical parameters.

4.2 Correlation Matrix of Heavy Metals

Table 4.6 shows the correlation matrix of heavy metals.

4.3 Heavy Metals Comparison in Water Samples

Figures 4.1 - 4.5 show respectively, the comparison of cadmium, copper, iron, zinc and manganese metals concentrations in the water samples to the maximum limit set by WHO/SON for the four different sites.

4.4 WHO Standard for Heavy Metals

Table 4.7 shows WHO standard for heavy metals

4.5 Mean values of Compounds and Heavy Metals in all Sites.

Table 4.8 shows the mean values of compounds and heavy metals in all sites

4.6 Cluster Analysis

Cluster analysis carried out on the sampling areas with Table 4.9 showing the descriptive analysis of cluster associated with different sites and heavy metals.

4.7 Analysis for Turbidity, Nitrates, Lead, Zinc, Manganese

Table 4.10 shows the analysis of turbidity, lead, zinc, manganese, nitrate from the four sites.

Table 4.1: Mean values of physicochemical parameters for wells and borehole water samples compared with WHO standard for site 1.

S/N	PARAMETER	WHO	OBJ 1	OBJ 2	OBJ 3	OBJ 4	OBJ 5	OBJ 6	OBJ 7	OBJ 8	OBJ 9	OBJ 10
1	Temp. ^{o}C	30.0	30.000	31.000*	30.000	28.000	27.000	26.000	29.000	29.000	30.000	29.000
2	pH	6.5-9.5	5.650	6.280	6.370	6.500	6.770	7.200	7.400	7.550	7.050	7.600
3	E.Cond µS/cm)	8-10,000	52.530	75.300	97.530	106.000	112.300	185.000	129.800	129.80	155.400	219.000
4	Turb (FTU)	5.0	34.000*	28.000*	0.000	2.000	5.000	3.000	5.000	4.000	1.00	3.000
5	Alkalinity(mg/l	150.0	34.000	26.000	14.000	44.000	68.000	83.000	35.000	29.000	24.000	145.670
6	T.Hard (mg/l)	500.0	50.000	80.500	202.000	206.000	212.000	260.000	212.000	181.800	242.400	333.300
7	D.O (mg/l)	5.0	1.200	1.400	1.500	1.500	1.500	1.400	0.900	0.200	0.500	0.300
8	C.O.D (mg/l)	10.0	2.200	1.600	1.800	1.850	1.900	1.500	2.100	1.500	2.300	3.100
9	B.O.D (mg/l)	3.0	0.700	0.800	0.900	0.600	0.200	0.400	0.900	0.200	0.500	0.300
10	Sulphate mg/l)	250.0	21.80	42.030	73.470	128.710	100.200	151.700	59.120	86.680	150.300	130.460
11	D.S (mg/l)	500.0	24.400	30.200	45.800	50.500	53.100	80.500	61.300	61.400	73.700	104.73
12	Nitrate(mg/l)	50.0	24.240	48.240	27.030	23.020	20.950	18.020	21.070	15.560	13.387	10.240
13	Colour (TCU)	3-15	5.000	5.000	5.000	5.000	5.000	10.000	5.000	10.000	5.000	5.000
14	phosphate (mg/l)	6.5	0.320	0.280	0.220	0.320	0.420	0.350	0.250	0.300	0.580	0.720

Key: * were observed to be more than the WHO maximum tolerance limit for drinking water

Table 4.2: Mean values of physicochemical parameters for wells and borehole water samples compared with WHO standard for site 2.

S/N	PARAMETER	WHO	OBJ 1	OBJ 2	OBJ 3	OBJ 4	OBJ 5	OBJ 6	OBJ 7	OBJ 8	OBJ 9	OBJ 10
1	Temp. ^oC	30.0	30.000	28.000	27.000	28.000	31.000*	28.000	27.000	26.000	30.000	30.000
2	pH	6.5-9.5	7.750	7.890	7.550	7.450	6.190	5.580	7.690	7.780	7.370	7.180
3	E. Cond(µS /cm)	8-10,000	230.000	286.000	250.000	193.000	100.400	90.200	219.000	339.000	339.670	338.000
4	Turb (FTU)	5.0	2.000	0.000	2.000	3.000	3.000	5.000	3.000	4.000	3.000	0.000
5	Alkalinity(mg/l	150.0	120.000	99.000	80.000	50.000	51.300	43.000	121.000	51.000	119.000	76.000
6	T.Hard (mg/l)	500.0	363.500	323.300	280.000	220.000	373.700	353.300	333.300	373.700	373.700	383.300
7	D.O (mg/l)	5.0	1.300	1.100	1.300	1.500	1.400	0.800	0.900	1.500	0.800	1.600
8	C.O.D (mg/l)	10.0	1.100	3.100	3.050	3.030	2.500	2.800	3.000	2.700	3.200	2.300
9	B.O.D (mg/l)	3.0	0.600	0.300	0.300	0.300	0.900	1.000	0.400	0.700	0.400	0.700
10	Sulphate mg/l)	250.0	80.180	87.650	110.700	200.140	200.500	222.130	110.310	126.840	150.550	180.350
11	Colour(T.C.U)	3-15	10.000	5.000	5.000	5.000	5.000	10.000	5.000	5.000	5.000	10.000
12	Nitrate(mg/l)	50	12.240	7.740	14.490	16.670	6.130	4.480	12.560	7.730	5.460	3.330
13	D.S(mg/l)	500	109.500	136.400	120.300	90.500	80.200	60.500	103.400	161.100	160.700	161.200
14	phosphate (mg/l)	6.5	0.310	0.190	0.210	0.230	0.250	0.300	0.760	0.400	0.400	0.260

Key: * were observed to be more than the WHO maximum tolerance limit for drinking water

Table 4.3: Mean values of physicochemical parameters for wells and boreholes water samples compared with WHO standard for site 3

S/N	PARAMETER	WHO	IWA 1	IWA 2	IWA 3	IWA 4	IWA 5	IWA 6	IWA 7	IWA 8	IWA 9	IWA 10
1	Temp. ^oC	30.0	32.000*	30.670	28.000	29.000	28.000	29.000	27.000	30.000	27.300	32.000
2	pH	6.5-9.5	7.540	7.290	6.570	6.810	7.000	7.020	7.740	7.740	7.550	7.690
3	E. Cond µS /cm)	8-10,000	53.000	136.800	64.700	362.000	360.000	362.000	100.400	98.200	95.300	92.300
4	Turb (FTU)	5.0	13.000*	5.000	22.000*	4.00	5.000	7.000*	3.000	5.000	7.000*	11.000*
5	Alkalinity(mg/l	150.0	34.000	43.000	45.000	47.000	52.000	57.000	58.000	57.000	56.000	56.000
6	T.Hard (mg/l)	500.0	171.700	212.000	90.900	353.500	363.700	373.700	151.500	161.300	181.500	191.900
7	D.O (mg/l)	5.0	1.100	1.400	1.500	1.800	1.700	1.600	1.700	1.600	1.500	1.300
8	C.O.D (mg/l)	10.0	2.400	3.000	2.600	3.000	3.100	3.200	2.200	2.000	1.500	1.600
9	B.O.D (mg/l)	3.0	0.600	0.800	0.500	1.000	0.900	0.800	0.100	0.300	0.500	0.300
10	Sulphate mg/l)	250.0	97.400	82.520	78.290	65.540	94.450	132.070	179.030	100.300	47.630	24.790
11	Colour(TDU)	3-15	10.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	10.000	5.000
12	Nitrate(mg/l)	50.0	14.430	18.270	21.08	25.770	28.230	20.540	14.580	10.330	8.680	6.420
13	D.S(mg/l)	500	24.500	64.700	30.130	173.200	173.100	173.100	47.200	46.500	45.200	43.200
14	phosphate (mg/l)	6.5	0.290	0.02	0.020	0.380	0.190	0.280	0.260	0.200	0.180	0.150

Key: * were observed to be more than the WHO maximum tolerance limit for drinking water

Table 4.4: Mean values of physicochemical parameters for wells and borehole water samples compared with WHO standard for site 4

S/N	PARAMETER	WHO	OYO 1	OYO 2	OYO 3	OYO 4	OYO 5	OYO 6	OYO 7	OYO 8	OYO 9	OYO 10
1	Temp. ^oC	30.0	32.000*	30.000	30.000	33.000*	27.000	29.000	28.000	29.000	32.000*	30.000
2	pH	6.5-9.5	7.450	7.040	7.020	6.100	5.85	7.320	7.490	7.890	7.860	7.490
3	E. Cond µS /cm)	8-10,000	87.100	74.300	74.500	6.240	6.210	198.200	194.500	224.000	226.000	224.000
4	Turb (FTU)	5.0	5.000	5.000	5.000	7.000*	6.000*	4.000	6.000*	3.000	3.000	5.000
5	Alkalinity(mg/l	150.0	54.500	5.000	30.000	11.000	9.000	63.000	64.000	106.000	125.000	120.000
6	T.Hard (mg/l)	500.0	200.000	171.700	212.000	20.200	50.000	373.700	303.000	383.800	424.200	402.000
7	D.O (mg/l)	5.0	1.600	0.800	0.900	1.500	1.500	1.300	1.400	0.600	0.700	0.500
8	C.O.D (mg/l)	10.0	1.400	2.500	2.900	1.100	2.800	2.100	2.300	3.100	2.000	2.100
9	B.O.D (mg/l)	3.0	0.900	0.400	0.400	0.900	0.700	0.300	0.600	0.300	0.300	0.500
10	Sulphate mg/l)	250.0	15.660	38.500	40.440	50.550	76.700	90.600	120.270	83.470	94.780	112.430
11	Colour(TDU)	3-15	5.000	5.000	5.000	5.000	5.000	5.000	10.000	15.000	10.000	10.000
12	Nitrate(mg/l)	50.0	27.490	39.980	30.230	24.770	21.460	18.460	14.470	12.290	10.020	9.650
13	D.S	500	40.800	34.600	34.600	2.400	2.400	93.800	92.100	106.900	107.400	103.400
14	phosphate (mg/l)	6.5	0.250	0.120	0.270	0.110	0.490	0.120	0.260	0.450	0.490	0.400

Key: * were observed to be more than the WHO maximum tolerance limit for drinking water

Table 4.5: Correlation matrix of the physicochemical variables (hand-dug wells and boreholes)

	COD	.BOD	T.D.S	D.O	E.C	TURB	pH	COL	ALK	PHOS	HARD	SUL	NIT	TEMP
C.O.D	1													
B.O.D	-.036	1												
T.D.S	.495**	.011	1											
D.O	-.216*	.339**	-.029	1										
E.C	.471**	-.025	.992**	-.026	1									
TURB	-.143	.164	-.411**	.062	-.392**	1								
pH	.094	-.514**	.398**	-.186*	.442**	-.433**	1							
COL	-.189*	-.132	.099	-.353**	.100	-.129	.272**	1						
ALK	.188*	-.388**	.541**	-.435**	.550**	-.292**	.555**	.332**	1					
PHOS	.184*	-.200*	.208*	-.344**	.215*	-.175	.113	.123	.436**	1				
HARD	.377**	-.047	.831**	-.310**	.795**	-.548**	.418**	.343**	.671**	.291**	1			
SULP	.333**	-.088	.380**	-.054	.324**	-.423**	.019	.145	.250**	.214*	.460**	1		
NIT	-.095	.207*	-.371**	.189*	-.336**	.470**	-.472**	-.370**	-.528**	-.196*	-.526**	-.572**	1	
TEMP	-.246**	.165	-.181*	-.167	-.183*	.199*	-.016	.118	-.013	-.109	-.060	-.263**	.065	1

*. Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table 4.6: Correlation matrix of the metal ions (hand-dug wells and boreholes)

	Lead	Zinc	Copper	Manganese	Iron
Lead	1				
Zinc	.229*	1			
Copper	.301**	-.129	1		
Mangnese	-.006	-.030	.058	1	
Iron	.156	-.061	.091	.289**	1

*. Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table 4.7: World Health Organisation(2008)

S/no	Metals	Highest desireable limit (mg/l)
1	Copper	2.000
2	Iron	0.300
3	Manganese	0.100
4	Lead	0.010
5	Zinc	4.000
6	Nickel	0.020
7	Chromium	0.050
8	Cadmium	0.030
9	Arsenic	0.050
10	Barium	0.050

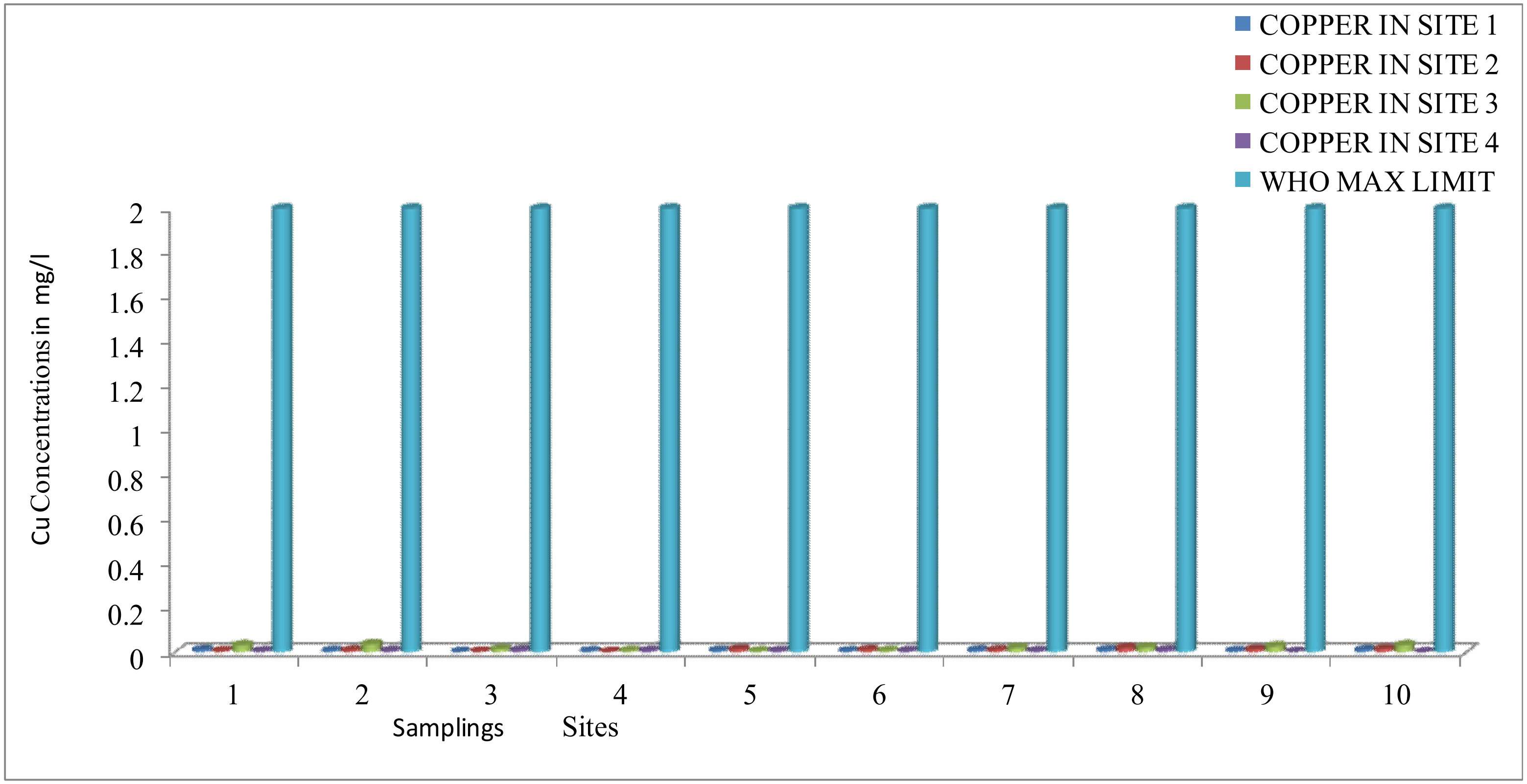

Figure 4.1: A comparison of the copper concentrations (mg/L) in water samples and the maximum limit set by WHO for site 1-4.

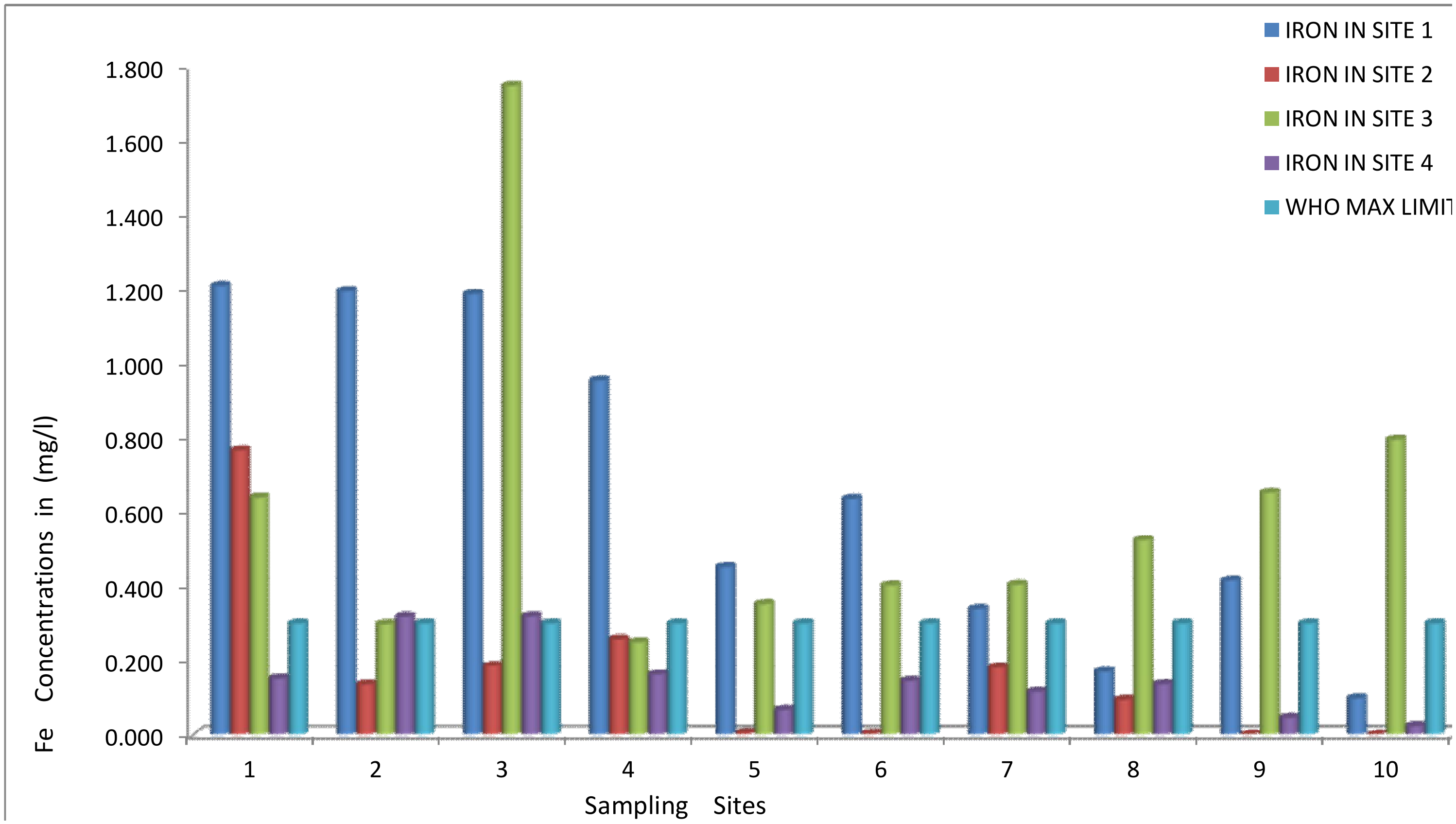

Figure 4.2: A comparison of the iron concentrations (mg/L) in water samples and the maximum limit set by WHO for site 1-4.

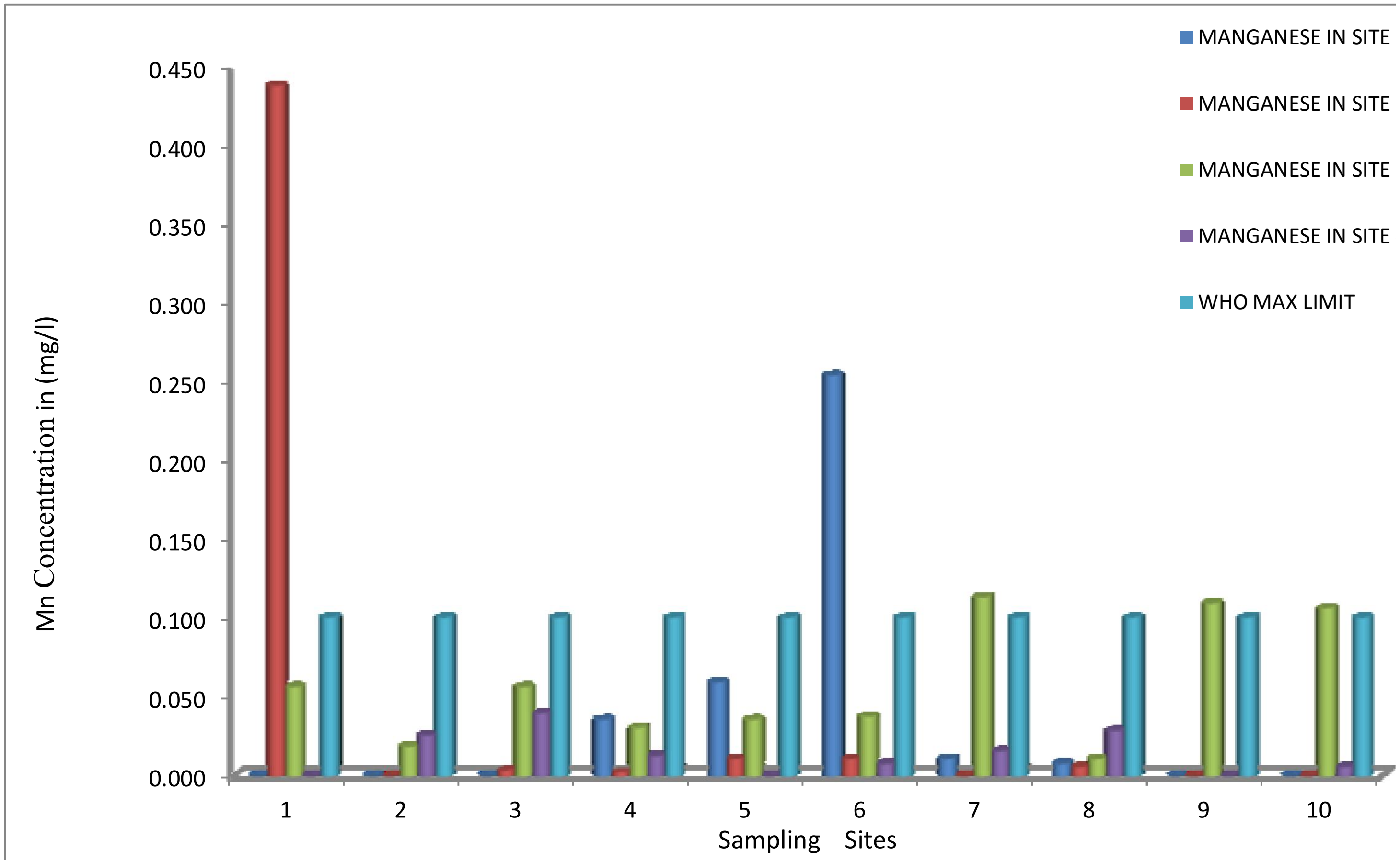

Figure 4.3: A comparison of the manganese concentrations (mg/L) in water samples and the maximum limit set by WHO for site 1-4.

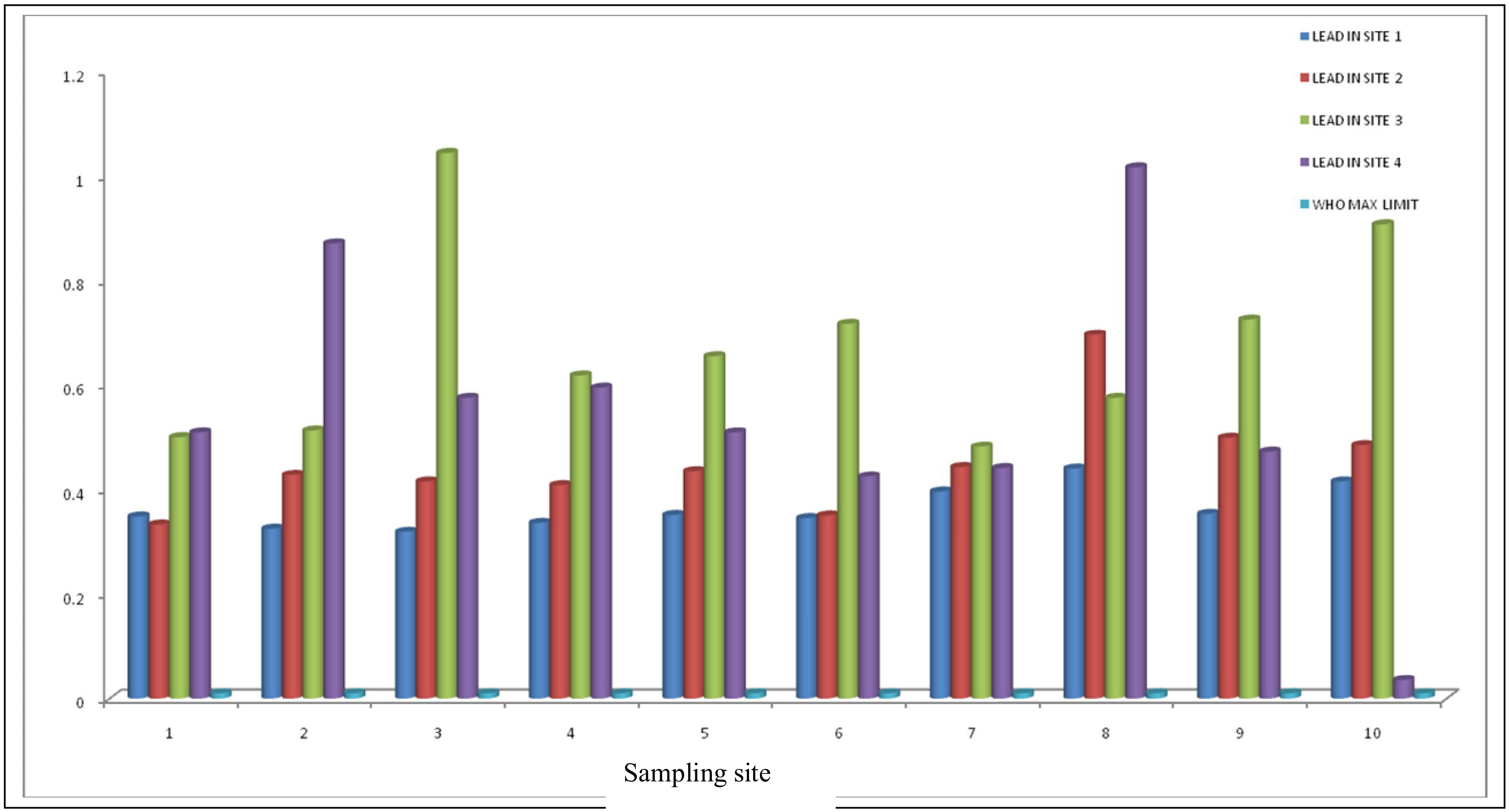

Figure 4.4: A comparison of the lead concentrations (mg/L) in water samples and the maximum limit set by WHO for site 1-4.

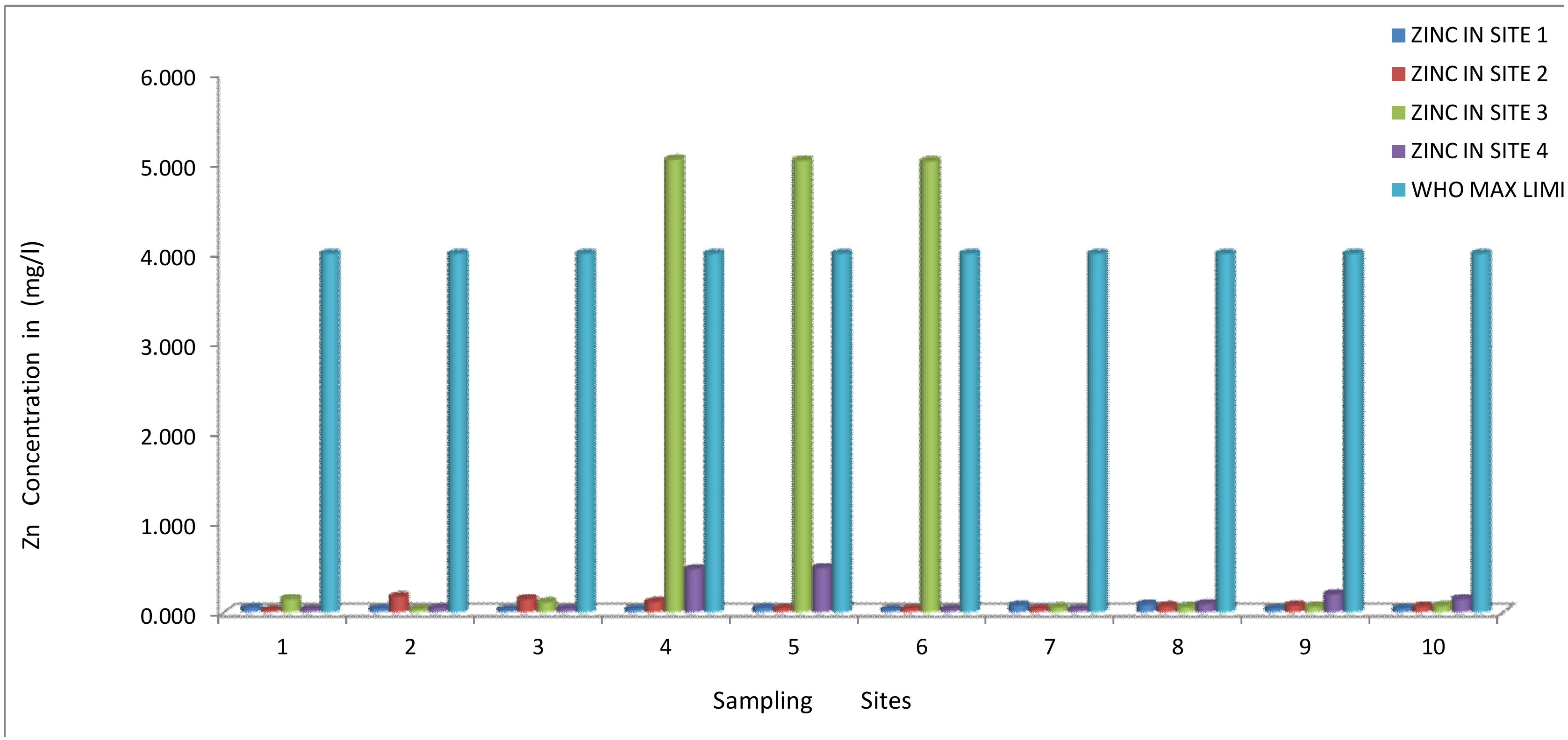

Figure 4.5: A comparison of the zinc concentrations (mg/l) in water samples and the maximum limit set by WHO for site 1-4.

Table 4.8: Mean value of all compounds and heavy metals in all the sites

	Comparing Sites			
	Obajana site1	Obajana site2	Iwaa site	Oyoo site
	Mean	Mean	Mean	Mean
COD	198.50	267.80	247.00	223.00
BOD	000.55	000.57	000.60	000.53
DO	001.29	001.22	001.52	001.08
TDS	058.43	118.38	82.11	61.84
Conductivity	126.30	238.46	172.47	131.49
Turbidity	008.50	002.50	008.20	004.90
pH	006.84	007.23	007.30	007.15
Colour	006.00	006.50	006.00	007.50
Alkalinity	050.27	080.90	050.50	058.70
Phosphate	000.38	000.33	000.20	000.30
Hardness	198.05	333.80	225.17	254.26
Sulphate	094.45	147.19	090.20	072.34
Nitrate	022.18	009.08	016.83	020.90
Temperature	028.73	028.50	029.30	029.93
Lead	000.36	000.45	000.67	000.55
Zinc	000.05	000.09	001.57	000.17
Manganese	000.04	000.05	000.06	000.01
Copper	000.01	000.01	000.02	000.01
Iron	000.67	000.16	000.61	000.15
Cobalt	000.02	000.04	000.04	000.05

Cluster Analysis

Clustering the six (6) variables (turbidity, nitrate, lead, zinc, manganese and iron) with respect to the various sites yielded four (4) clusters whose strength is fair enough from the figure. Hence, the cluster members in suitable for analysis.

Model Summary

Algorithm	TwoStep
Inputs	7
Clusters	4

Cluster Quality

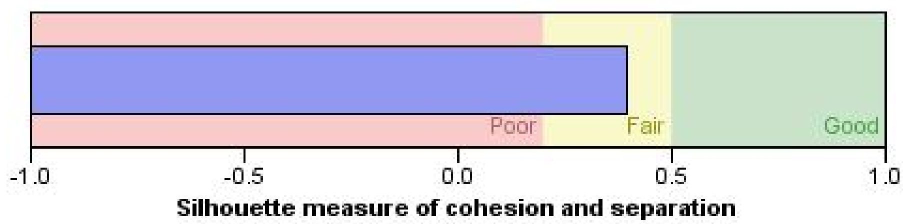

Table 4.9: Descriptive analysis of clusters associated with the different sites and heavy metals

		Two Step Cluster Number				
		Outlier Cluster	1	2	3	4
		frequency	frequency	frequency	frequency	frequency
Various Sites	Obajana Site1	0	30	0	0	0
	Obajana Site2	0	0	30	0	0
	iwaa site	0	0	0	30	0
	oyoo site	0	0	0	0	30

Cluster 1 comprises of Obajana site1

Cluster 2 comprises of Obajana site2

Cluster 3 comprises of Iwaa site.

Cluster4 comprises of Oyoo site

Table 4.10: Analysis of variance for turbidity, nitrate, lead, zinc, manganese, iron for all sites

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Turbidity of all site	Between Groups	736.425	3	245.475	5.654	0.001
Nitrate on all site	Between Groups	3136.517	3	1045.506	16.021	0.000
Lead in all site	Between Groups	01.599	3	00.533	19.822	0.000
Zinc in all site	Between Groups	48.655	3	16.218	12.088	0.000
Manganese in all site	Between Groups	0.032	3	0.011	1.697	0.171
Iron in all site	Between Groups	6.984	3	2.328	22.455	0.000

Table 4.11 Shows group statistics of wells and boreholes near the cement factory. Table 4.12 shows the independent sample t-test of wells and boreholes near the cement factory. Table 4.13 shows group statistics of wells and boreholes far away from the cement factory. Table 4.14 shows independent sample t-test of wells and boreholes far from the cement factory. Table 4.15 shows group statistics of wells and boreholes near and far away from the cement factory. Table 4.16 shows independent t-test of wells and boreholes near and far away from the cement factory

Table 4.11: Group statistics of wells and bore-holes near the cement factory

Group statistics					
	Comparing Sites	N	Mean	Std. Deviation	Std. Error Mean
Turbidity	Obajana site1	30	08.500	11.676	02.131
	Obajana site2	30	02.500	01.697	00.309
Nitrate	Obajana site1	30	22.183	10.116	01.847
	Obajana site2	30	09.083	04.418	00.807
Lead	Obajana site1	30	00.363	00.038	00.007
	Obajana site2	30	00.449	00.097	00.018
Zinc	Obajana site1	30	00.054	00.019	00.003
	Obajana site2	30	00.085	00.048	00.009
Manganese	Obajana site1	30	00.037	00.076	00.014
	Obajana site2	30	00.047	00.133	00.024
Iron	Obajana site1	30	00.666	00.421	00.077
	Obajana site2	30	00.162	00.223	00.041

Table 4.12: Independent sample t-test of wells and bore-holes near the cement factory

Independent samples test						
		t-test for Equality of Means				
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Turbidity of all site		2.785	30.224	0.009	6.000	2.154
Nitrate on all site		6.501	39.673	0.000	13.101	2.015
Lead in all site		-4.514	38.044	0.000	-.0864	0.019
Zinc in all site		-3.219	37.362	0.003	-0.030	0.009
Manganese in all site		-.369	46.235	0.714	-.0103	.0279
Iron in all site		5.780	44.118	0.000	0.503	.087

Table 4.13: Group statistics of wells and bore-holes far away from the cement factory

Group statistics					
	Comparing Sites	N	Mean	Std. Deviation	Std. Error Mean
Turbidity of all site	Iwaa site	30	8.200	5.640	1.029
	Oyoo site	30	4.900	1.626	0.296
Nitrate on all site	Iwaa site	30	16.834	6.985	1.275
	Oyoo site	30	20.901	9.507	1.735
Lead in all site	Iwaa site	30	0.674	0.178	0.033
	Oyoo site	30	0.545	0.254	0.046
Zinc in all site	Iwaa site	30	1.568	2.309	0.422
	Oyoo site	30	0.165	0.173	0.031
Manganese in all site	Iwaa site	30	0.057	0.038	0.007
	Oyoo site	30	0.013	0.013	0.002
Iron in all site	Iwaa site	30	0.606	0.422	0.076
	Oyoo site	30	0.148	0.097	0.018

Table 4.14: Independent sample t-test of wells and bore-holes far from the cement factory

Independent samples test							
		t-test for Equality of Means					
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Turbidity of all site		3.079	58	0.003	3.300	1.072
Nitrate on all site		-1.888	58	0.064	-4.067	2.154
Lead in all site		2.269	58	0.027	0.129	0.057
Zinc in all site		3.319	58	0.002	1.404	0.423
Manganese in all site		6.047	58	0.000	0.044	0.007
Iron in all site		5.795	58	0.000	0.458	0.079

Table 4.15: Group statistics of wells and bore-holes near and far away from the cement factory

Group statistics					
	Various Sites	N	Mean	Std. Deviation	Std. Error Mean
Turbidity	Obajana Site1 and 2	60	5.500	8.807	1.137
	Iwaa and Oyoo Sites	60	6.550	4.439	0.573
Nitrate	Obajana Site1 and 2	60	15.633	10.175	1.314
	Iwaa and Oyoo Sites	60	18.868	8.522	1.100
Lead	Obajana Site1 and 2	60	0.406	0.085	0.011
	Iwaa and Oyoo Sites	60	0.609	0.227	0.029
Zinc	Obajana Site1 and 2	60	0.069	0.039	0.005
	Iwaa and Oyoo Sites	60	0.867	1.771	0.228
Manganese	Obajana Site1 and 2	60	0.042	0.107	0.014
	Iwaa and Oyoo Sites	60	0.035	0.035	0.005
Iron	Obajana Site1 and 2	60	0.414	0.419	0.054
	Iwaa and Oyoo	60	0.377	.381	0.049

Table 4.16: Independent t-test of wells and bore-holes near and far away from the cement factory

Independent samples test						
		t-test for Equality of Means				
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Turbidity	Equal variances assumed	-0.825	118	0.411	-1.050	1.273
Nitrate	Equal variances assumed	-1.888	118	0.061	-3.235	1.713
Lead	Equal variances assumed	-6.480	118	0.000	-0.203	0.031
Zinc	Equal variances assumed	-3.488	118	0.001	-0.797	0.229
Manganese	Equal variances assumed	0.452	118	0.652	0.007	0.015
Iron	Equal variances assumed	0.503	118	0.616	0.037	0.073

Chapter Five

Discussion

The results obtained for various analyses carried out on the physicochemical properties of the groundwater samples and their comparison with the World Health Organization (WHO) standards specified for drinking water as shown in Tables 4.1, 4.2, 4.3 and 4.4. The Tables, shows the mean values of the parameters determined in this research along with the recommended standards.

5.1 pH and Temperature

The pH ranged from 5.53 to 7.89 pH units. With the exception of Obajana 1, 2, 3 from site 1, Obajana 5,6 from site 2, Oyoo 4,and 5 from site 4, all other samples fell within the WHO range for portable water. This pH result shows that the well waters of the exceptional areas is slightly acidic. pH values lower than 6.5 are considered too acidic for human consumption and can cause health problems such as acidosis which could have adverse effects on the digestive and lymphatic systems of human (Nkansah *et al,* 2010). Water temperature recorded during the sampling period for the various sites did not differ significantly. Temperature ranged from 26 to 33ºC .With the exception of Obajana 2 in site 1, Obajana 5 in site 2, Iwaa 1 and 10 in site 3, Oyoo1 and 9 in site 4 This may be due to sampling season as pollution of ground water might have occurred.

All others temperature values are within WHO (1998) limit for drinking water. Temperature is a factor of great importance for aquatic ecosystem, as it affects the water organisms, as well as the physical and chemical characteristics of water (Delince, 1992). The values obtained are within the permissible level of WHO drinking water standards.

5.2 Conductivity and Dissolved Solids

Conductivity of the water samples ranged from 6.210 – 339.670 μS/cm,with exception of and OYOO 4 and 5 in site 4.All other values are within the WHO regulatory limit of 8-10,000 μS/cm. Conductivity is related to the concentration of dissolved solids (DS). According to Chapman (1992), TDS may be obtained by multiplying the conductivity by a factor between the ranges of 0.55 to 0.75. Given these low conductivity values, it is not surprising that the DS, which is an index of the amount of dissolved solids in water is low. Thus, the DS which ranged between 2.400 to 161.200 mg/L was obtained for the study. According to the study statistics, the DS is directly an average multiplication factor of 0.5 of the conductivity values measured across all the sampling points investigated. A health-based value has not been proposed by the WHO, however, a DS above 1,000 mg/L may be objectionable to consumers (Amoako *et al,* 2011).

5.3 Turbidity

Turbidity values ranged from 0 to 34.0 FTU. One way ANOVA test showed that Turbidity level in the four sites significantly differs as its confident level is less than 0.005. Four borehole samples and six well samples showed turbidities between 6.0 and 34.0 FTU from sites 1, 3 and 4. All other samples had their turbidity values between 5.0 FTU. The WHO guideline for turbidity in drinking water is 5 FTU. The high turbidity may be attributed to larger particles such as organic matter and dissolved solids. The greater the turbidity, the higher the risk of gastro-intestinal diseases Eric and Catherine (1997).

5.4 Dissolved Oxygen, Chemical Oxygen Demand and Biological Oxygen Demand

Dissolved oxygen (DO) measured in milligram/litre ranged between 0.20 and 1.800. The WHO has set a provisional health-based guideline value of 5.0 mg/L for DO which should be adequate to protect public health (WHO, 1995). Dissolved oxygen (DO) is very crucial for survival of aquatic organisms and it is also used to evaluate the degree of freshness of a river. The measured value was; however, lower than the WHO's standard. Very low DO may result in anaerobic conditions that can cause bad odour in water. The low DO levels situation may result through the decomposing organic matter, dissolved gases, industrial waste, mineral waste and landfill leachate.

Chemical oxygen demand (COD) is one of water quality parameters in determining the oxygen consuming potential of a water resource. COD measured for the water samples ranged from 1.1 to 3.2mg/L All samples from the four sites were found below the maximum permissible limit by WHO (10 mg/L). The test is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water, making COD a useful measure of water quality (Clair, 2003)

Biological oxygen demand: The minimum and maximum values for biological oxygen demand obtained from the hand dug wells and boreholes water samples at the four different sampling sites in Obajana and its environs as shown in Tables 4.1, 4.2, 4.3 and 4.4) range from (0.2-1.0mg/L). Which were found to be below the maximum permissible limit by WHO (3 mg/L). The BOD represents the amount of oxygen needed by microbes to stabilize biologically oxidizable matter.

5.5 Total Hardness

The minimum and maximum values for total hardness obtained from the hand dug wells and boreholes water samples at the four different sampling sites in Obajana and its environs as shown in Tables 4.1- 4.4 were 50 – 424.20mg/Lwhich is below the WHO (500 mg/L) permissible limits for drinking water WHO (2005).

5.6 Colour

The minimum and maximum values for colour obtained from the hand dug wells and boreholes water samples at the four different sampling sites in Obajana and its environs as shown in Tables 4.1- 4.4 were 5 – 15 TCU which is below the WHO (3–15TCU) permissible limits for drinking.

5.7 Total alkalinity

This is a measure of the capacity of water to neutralize acids. The predominant chemicals present in natural waters are carbonates, bicarbonates and hydroxide compounds of calcium, sodium and potassium. The bicarbonate ion is usually prevalent, the minimum and maximum values for alkalinity obtained from the hand dug wells and boreholes water samples at the four different sampling sites as shown in Tables 4.1, 4.2, 4.3 and 4.4 range from (1.1 – 145.670mg/L). All samples from the four sites were found below the maximum permissible limit of WHO (150 mg/L). This is in agreement with the findings of Ezeribe *et.al,* 2012 and Abdulhakeem *et al*., 2011.

5.8 Ions and Nutrients

Sulphate may cause concern due to taste if found at higher concentration. Evidence relating to chronic human health effects to specific drinking water contamination is very limited. In the absence of exact scientific information, scientists predict the likely adverse effects of chemicals in drinking water using laboratory animal studies and, when available, humandata from clinical reports and epidemiological studies (Nkansah and Ephraim, 2009).

Sulphate does not have a health-based guideline value. However, the WHO recommends that values higher than 250mg/L should be reported to "the health authorities" due to problems to the gastro-intestinal track (WHO, 2003). Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals (Manivaskam, 2005). However, source to such levels could be traced to the natural or industrial. The concentration of sulphate in the subject samples ranged from 24.790 mg/L to a high of 222.130 mg/L which is within WHO limit.

Nitrate (NO_3^--N) is a contaminant that is regulated as it has significant health risks associated with excess nitrate consumption in the human diet. Nitrites are veritable indication of biological pollution in natural waters (Addo *et al,* 2011). The presence of nitrates and nitrites in elevated concentrations is an indication of organic pollution in the water body. Levels in excess of 50 mg/L indicate pollution (McCutcheon *et al*., 1989). The WHO has adopted the 10 mg/L standard as the maximum contaminant level (MCL) for nitrate–nitrogen.

One way ANOVA test showed that nitrates level in the four sites significantly differs as its confident level is less than 0.005.Nitrate levels varied between 10.24 to 48.24 mg/L. these concentration levels are not alarming and therefore the wells were free from organic pollution.

Phosphate

The minimum and maximum values for phosphate obtained from the hand dug wells and boreholes water samples at the four different sampling sites in Obajana and its Environ as shown in Tables 4.1, 4.2, 4.3 and 4.4 range from 0.02 to 0.760 mg/L. All samples from the four sites were found below the maximum permissible limit by WHO (6.5mg/L). The observation is also in agreement with the findings of other workers in similar studies (Abulhakeem *et al*., 2011 and Ezeribe *et al.,* 2012).

5.9 A Comparison of the Concentrations of Metal ions in Water and WHO Maximum Permissible Limit.

The results obtained for the concentrations of metals ions (Cu, Mn Fe, Pb and Zn) in the Water samples collected from different hand dug wells and boreholes, was compared with the WHO maximum permissible limit. The results are presented as a bar chart in chapter four.

5.9.1 Copper

The minimum and maximum concentrations of copper obtained from the hand dug wells and boreholes water samples at the four different sampling sites in Obajana and its environs as shown in (Fig 4.4), ranges from 0.001 mg/L to 0.10 mg/L. The maximum permissible limit by WHO is (2.0 mg/L). Copper is an essential nutrient, but at high doses it has been shown to cause stomach and intestinal distress, liver, kidney damage, and anaemia (US EPA, 2003).

5.9.2 Iron

Most groundwater contains some iron because it is common in many aquifers and it is found in trace amounts in practically all sediments and rock formations. One way ANOVA test showed that iron level in the four sites significantly differs as its confident level is less than 0.005. The minimum and maximum concentrations of iron obtained from the hand dug wells and boreholes waters at the four different sampling sites in Obajana and its environs as shown in Fig 4.5 ranges from 0.01 mg/L – 0.06 mg/L. The maximum permissible limit by WHO is 0.3mg/L for iron.

5.9.3 Manganese

One way Anova confirmed that manganese in the four sites do not differ significantly with its confident level being greater than 0.05, however, the minimum and maximum concentration of manganese metal ions obtained from the hand dug wells and borehole waters at the four different sampling sites in Obajana and environs as shown in Fig 4.6, ranges from 0.0 mg/L – 0.44 mg/L, which is higher than the maximum permissible limit by WHO (0.10mg/L), Manganese impacts a bitter taste to water, stains cloths and metal parts and precipitate in foods when used for cooking and it also promotes the growth of algae in reservoirs.

5.9.4 Zinc

Zinc impacts an undesirable astringent taste to water at a taste threshold concentration of about 4mg/litre (as zinc sulphate). One way ANOVA test showed that zinc level in the four sites significantly differs as its confident level is less than 0.005.The minimum and maximum level of zinc metal ion obtained from the hand dug wells and boreholes water samples at the four different sampling sites in Obajana and its environs as shown in

Fig. 4.7 range from 0.029 – 5.046mg/L. The maximum permissible limit by WHO is (4.0 mg/L).The level of dissolved zinc in water may increase as the acidity of water increases, ingesting high levels of zinc can lead to stomach cramps, nausea, vomiting, cause anemia, damage the pancreas and decrease levels of high density lipoprotein cholesterol.

5.9.5 Lead

One way ANOVA test showed that lead level in the four sites significantly differs as its confident level is less than 0.005 but lead concentration in the samples range from 0.0348 – 1.046 mg/L which is very high when compared to the 0.01mg/L WHO guideline limit,the values disagrees with Musa *et al* (2013) but agrees with Environmental Impact Assesment (2004) which states high level of lead of river sediments in Obajana. These results indicated that the well waters are not desirable for consumption, because Pb alone even at low concentration could be toxic to the human system. It is important to trace the contribution of this contaminants which is affecting the water quality. The source to indict is the types and amounts of minerals in the water, water acidity and temperature (WHO,1993). However, the contamination levels are so high enough not to limit the allegation to the dust alone and that other anthropogenic sources might be at play.

A one way ANOVA test reveals that turbidity, nitrate, lead, zinc and iron in all the four sites i.e. (obajana site1, obajana site2, iwaa and oyoo site) significantly differ from each other, $P<0.05$. only manganese that do not differ significantly in the four sites, $P>0.05$.

The independent sample T-test of obajana site1 and obajana site2 also revealed that turbidity, nitrate, lead, zinc and iron are statistically significantly different with $P<0.05$. only manganese do not significantly differ between the two sites, $P>0.05$.

Chapter Six

Summary, Conclusions and Recommendations

6.1 Summary

The groundwater (hand dug wells, boreholes) in Obajana and its environs of Kogi state were collected and analysed for various physicochemical parameters and some metal ions like lead, copper, iron, manganese and zinc.

Independent sample t-test of wells and boreholes close to the cement factory was carried out and it showed that 5 variables(turbidity, nitrate, lead, iron and zinc) significantly differ with its confident level being less than 0.05, manganese however do not differ in these sites, same independent sample t-test was carried out on sites far away from the cement factory and it showed that turbidity, lead, zinc, manganese and iron are statistically significantly different with its confidence level being less than 0.05, only nitrate do not differ between the two sites.

Further comparison (independent sample t-test) was done between the sites far away from the cement factory and sites close to the cement factory and it showed that Turbidity, Nitrate, Iron, and manganese do not differ significantly as confident level showed greater than 0.05, lead and zinc differ significantly in this comparison.

6.2 Conclusions

The results of the above work showed that most of the physicochemical parameters e.g.

total alkalinity, total hardness, turbidity, dissolved oxygen, biological oxygen demand, electrical conductivity, sulphate, phosphate, copper, and iron were respectively within the acceptable limits of WHO's recommended. However pH, lead, nitrate, manganese, zinc, were mostly found to exceed the maximum permissible limit as recommended by WHO at some study sites, further analysis showed that there is an equal amount of manganese in the four sites. Iwaa showed the highest case of heavy metals compared to the remaining sites .

Dissolution of rock minerals with the ground water is a possible reason for pollution. All the above results confirmed the high pollution of the ground water sources and hence, they are not suitable for consumption without any prior treatment.

6.3 Recommendations

a. Continuous water quality monitoring in the study area should be frequently carried out.
b. It is advised that underground waters from Obajana and its environs, should not be used as drinking water without prior treatment.
c. In addition to metal studies, frequent research on lead, zinc, manganese which are water contaminants of concern must be evaluated in the wells and boreholes. Heavy metals slowly accumulate in the kidney, liver, pancreas, bones, CNS where they degrade health without being noticed or diagnosed.

   Chelation is a primary method (by the use of a chelating agent which has the ability to hold the metal ion while being discharged by the liver or kidney into urine or feaces) used to remove heavy metals and can be done locally with the use of intravenous chelators or supplements. Many of the amino acids (which is known as the building block of life and healing) found in the protein of meat are good chelators. Red meat ,fish ,fowl and seafood are food that should be encouraged in this area as they provide natural chelators of toxic heavy metals (Kent, 2013).

A number of filtering devices which include carbon, ion exchange resins, activated alumina are also effective in the reduction of lead (EPA, 2013). Reverse-Osmosis can be carried out by government agencies as remedial measures. The overall implication of this observation calls for an urgent water resources management strategy (including treatment of the water) in the area in order to circumvent the fast deteriorating water resources quality, which may pose associated health risk and environmental hazards

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