

**PHYSICO-CHEMICAL AND STATISTICAL ASSESSMENT OF SOIL
AND WATER SAMPLES FROM OSUBI CENTRAL DUMPSITE,
WARRI, SOUTHERN NIGERIA.**

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(ENVIRONMENTAL GEOLOGY OPTION)

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**A THESIS WRITTEN IN THE DEPARTMENT OF GEOLOGY AND
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SEPTEMBER, 2019

CERTIFICATION

This is to certify that this project was carried out by Mr. Samuel Ebinum OSEJI of the department of Geology, University of Benin, Benin City, Edo State, Nigeria.

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Head of Department

(Date)

DEDICATION

I dedicate this work to God ALMIGHTY, and my parents Dr.and Mrs Fred OSEJI, whose sacrifice has brought me this far.

AKNOWLEDGEMENTS

I herein express my sincere appreciation to God Almighty for his love and protection which saw me through my post graduate years.

I specially thank my project supervisor in the person of Professor Isaac.O.Imasuen for his fatherly advice and encouragement at all stages of the project work. Special appreciation also goes out to the Head of Department, Professor.C.N.Akujieze, Post graduate seminar coordinator, Dr.Salami, Dr.Lucas, Dr.Odokuma Alonge , and other management staff too numerous to mention.

I remain eternally grateful to my immediate family for their care, support, understanding, and encouragement which contributed immensely to the success of this project work. A million thanks to my parents, Dr & Mrs. Fred Oseji, my siblings, Ifeoma Oseji, Associate Professor Fred Oseji, chioma Oseji.

Special thanks to the graduating MSc Geology class of 2016/2017, I say a big thank you to you all. To the likes of John, Daniel, Dudu, Joy, Wilson, Mr. sunny, Madam Patricia, Laura, Chinwike, Chief Osazuwa (Uwelu Mayor), Baba Sam the Yoruba man, Tope, May God bless you all.

To Fred. E. Chegwe, I say thank you for making the final lap of my post graduate days worth the while. Your contribution to the success of this work will forever be treasured.

.

ABSTRACT

The extent of groundwater and soil pollution arising from an open dumpsite was carried out to examine the physico-chemical and trace metals status in Osubi, Delta State. Twenty two (22) soil samples were collected randomly at depths of 0-15 cm, and 15-30 cm and one control (natural environment). While sixteen (16) groundwater samples were collected through random sampling technique for analysis. The soil samples were digested into solution using aqua regia and analyzed using the Atomic Absorption Spectrometer (AAS), [buck model 210 VGP]. The results of the analysis was then subjected to statistical treatment (One-way Analysis of Variance), Spearman's Correlation Coefficient and Pollution Load Index to ascertain significant difference among the trace metals, association and status of contamination/pollution respectively. Result from the analysis showed that both groundwater and soil samples in the study area is acidic with pH values ranging from 5.28-5.96, and 2.30-6.20 respectively. The level of average metal contents obtained from soil samples at the different depths is as follows: Arsenic; 10.58-20.4 mg/kg, Manganese; 1.42-3.58 mg/kg, cadmium; 1.05-3.46 mg/kg, Chromium; 1.61-4.55 mg/kg, Lead; 2.11-3.71 mg/kg, Zinc; 5.77-15.5 mg/kg, Copper; 1.69-3.23 mg/kg, Cyanide; 0-0.005 mg/kg, Nickel; 1.31-4.59 mg/kg and Vanadium; 1.24-0.3.95 mg/kg which were much higher than that of the control. The correlation result between the analyzed parameters in hand-dug wells and borehole samples, revealed positive and negative correlation coefficients at $r(0.01)$ and $r(0.05)$ indicating strong association between them, which probably reflects their related source of contamination. However, correlation was also not significant among some parameters in the groundwater samples indicating an uncommon source of contamination. Calculated pollution load index (PLI) indicated that location SS8 had maximum pollution load index of 2.15 and a minimum pollution load index value of 1.80 was obtained at location SS6. The order of pollution load index per location for the sediments is as follows: SS8 > SS5 > SS9 > (SS4=SS7=SS10) > SS2 > SS3 > SS6. While the order of contamination factor (CF) revealed among the heavy metals is as follows: Mn > V > Cr > Ni > Cd > Zn > As > Pb > Cu. The results revealed that both the groundwater and soil were slightly-moderately contaminated. It is hereby recommended that groundwater monitoring and proactive steps be taken to minimize gradual accumulation of these contaminants from the dumpsite.

Key words: Heavy Metals, Contamination, Physico-Chemical.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 INTRODUCTION TO BACKGROUND STUDY

Soil is one of the repositories for anthropogenic wastes. Biochemical processes can mobilize them to pollute sources of water and impact food chains (Ihenyen&Aghimien, 2002). Trace heavy metal contamination in sediments/soils is a major concern because of their toxicity and threat to human life and the environment. Heavy metals such as Cu, Cr, Cd, Ni, and Pb are potential soil and water pollutants.

Most Nigerian cities have inefficient and/or non-existent drainage system leading to contamination of immediate surroundings and the ground water with trace heavy metals (Ihenyen&Aghimien, 2002). Heavy metal studies are necessary to evaluate both soil/sediment and groundwater contamination. This becomes necessary because most of the municipal water supplies come from boreholes, most of which are shallow wells. Pollution of the natural environment by heavy metals is a universal problem because these metals are indestructible and most of them have toxic effects on living organisms, when permissible concentration levels are exceeded (Ihenyen&Aghimien, 2002). Heavy metals are elements of high molecular masses, most of which belong to the transition elements. Studies have shown that soils around refuse dumpsite contain different kinds and concentrations of heavy metals. In recent times, it has been reported that these elements accumulate and persist in soils at an environmentally hazardous levels (Alloway, 1996).

Waste materials which are generated from residential areas, markets, industries and hospitals are on the increase with increasing population and are disposed of in government approved and non-approved dumpsites in urban and rural areas across Nigeria. In dumpsites, heavy metals such Cadmium (Cd), Copper (Cu), Chromium (Cr), Lead (Pb), Zinc (Zn) and Nickel (Ni) are also usually found due to remains from metals and other products (Shayley *et al.*, 2009). These heavy metals are not only associated with pollution and toxicity but also include some elements which are essential for living organisms at low concentrations.

Study of heavy metals in ecosystems has shown that many areas near urban complexes where waste is dumped contain high concentration of these heavy metals (Adelekan and Abegunde, 2011). The accumulation of these heavy metals above the threshold value in the soil,

groundwater, or environment can lead to toxicity and this can be very dangerous to plants, animals including humans. The effects of these heavy metals include: destruction of ecosystem, destruction of marine biota, contamination of surface and underground water, disturbances of soil function, and reduction of plants productivity. Unlike organic contaminants, these heavy metals do not usually undergo microbial or chemical degradation through changes in their chemical forms. According to Anna and Piotr, (2014), soils are the major sink for heavy metals released in to the environment by dumping of refuse on land.

Heavy metals occur naturally in the soil environment due to pedogenic processes of weathering of parent rocks at levels that are regarded as trace ($< 1000\text{mg/kg}$) and rarely toxic. These heavy metals become contaminants in the soil environment because their rate of generation through man-made cycles are rapid and also, the concentrations of these metals in discarded products are relatively high compared to those in the receiving environment. Interest has most recently been stimulated in researches at evaluating the levels of heavy metals around refuse dumpsite due to the growing concerns expressed by the government, regulatory agencies and the public over the large acres of land covered by the dumpsites, (Imasuen and Omorogieva, 2013). Heavy metal is often generally referred to as a silent killer and was defined by Harmsen (1977) as those having density greater than 5g/cm^3 , but most often denote metals that are toxic such as lead (Pb), arsenal (As), mercury (Hg), nickel (Ni), and Selenium (Se). Therefore, heavy metal analysis form an important component tool needed to regulate environmental impact assessment in towns and cities (Asuen *et al.*, 2005).

Soil is very important in ecosystem research as it is where many types of interactions take place between minerals, air, water and biota. In the recent, the soil system has been subjected to physical stress by input of foreign substances such as heavy metals (Imasuen and Omorogieva, 2013). 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 hand-dug wells and boreholes. A visible form of environmental degradation is waste disposed through open surface landfills or open dumps. These can be cleared up, the land cleaned up but a most visible and potentially dangerous environment degradation includes soil erosion and gully sites used as waste dumping points.

Both soil and groundwater qualities can be costly and challenging to remediate or recover (Akujieze, 2006, Akujieze and Ezomo, 2010). Landfills, opens up the geology and renders the groundwater systems highly vulnerable to contamination and pollution (Akujieze, 2004),

especially when such open sites are used for waste disposal/dumpsites. 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 (Roger, 1982). Dug and driven wells are easy to contaminate because they are relatively shallow. Most of the bacteria, viruses, parasites, and fungi that contaminate well water come from faecal material from humans and other animals. Ground water is considered the healthiest source of drinking water, but domestic, agricultural and industrial activities have led to the degradation of ground water quality in different parts of the world. Akujieze and Oteze (2007) observed that some aquifer are shallow and subject to groundwater contamination especially in areas of high anthropogenic activities where there is no clay materials acting as seal to the infiltrating contaminants while, Onyeobi and Akujieze (2014) reported that soil and sediments have a role to play in groundwater contamination.

1.2 AIM AND OBJECTIVES

The aim of this research is to evaluate the level of heavy metals and their relationship in the soil and groundwater sampled locations within and around the vicinity of the dumpsites in Osubi town. This aim would be achieved through the following objectives:

- (i) To assess the degree of pollution in the sediments/soil in the study area using the pollution load index (PLI) and contamination factor (CF) of the metals.
- (ii) To assess the heavy metal concentration levels (Cd, Fe, Ni, Pb, Zn, Cr, Mn, Cu, As and V) in sediments within the dumpsite to background/control values in the study area.
- (iii) To ascertain if there is/are a significant difference between and within sediment sampled locations using one-way analysis of variance (ANOVA).
- (iv) To investigate the statistical relationship and dissimilarity between heavy metal concentration and other soil properties such as pH, EC and organic matter.
- (v) To determine the potability of groundwater in the study area by comparing it with WHO (2011) and NSDWQ (2007) drinking water standards.

1.3 STATEMENT OF PROBLEM

Like many cities in Nigeria, Osubi in southern Nigeria faces problems of environmental sanitation such as improper disposal of refuse near residential areas; poor refuse collection and handling, and it is common to find huge refuse dumpsite within residential areas. This however, leads to accumulation of heavy metals which are either dissolved by rain water and leached into the soil contaminating the underground water, or washed away by runoff into streams and rivers, thereby contaminating the environment. But like most towns in southern Nigeria, Osubi lacks drainage systems. It is based on these facts that this study is aimed at determining the total concentration of cadmium, copper, nickel, lead, manganese, arsenic, cyanide, zinc, vanadium and chromium in dumpsite soils and groundwater in Osubi town, southern Nigeria.

1.4 JUSTIFICATION OF THE RESEARCH

Osubi is a growing town which is in the southern part of Nigeria, which faces problems of environmental sanitation such as improper disposal of refuse, poor refuse collection in residential areas within the town, these wastes are found on large open dumpsites serving as breeding grounds for pathogens and as reservoir of heavy metals leaching into the surrounding soil and groundwater. These activities have necessitated the study of their effects on the surrounding because of the pollution associated with heavy metal at elevated concentration to human lives, surface water and underground water in the environment. There is need to ascertain the levels of the heavy metal in this environment. The work is intended to give a base line data for future investigation of activities leading to temporary changes, in concentrations of heavy metals in the vicinity of the dumpsites in the study area (Osubi). Since no known work of this nature has been reported in literature on the level of heavy metals in groundwater and soils in the study area, this study therefore aims to determine the levels of cadmium, chromium, lead, zinc, manganese, arsenic, and nickel in soils and groundwater within the vicinity of the dumpsite in Osubi, Delta State.

1.5 SCOPE AND LIMITATION OF THE STUDY

There are many heavy metals, but this study will consider ten metals which from literature are prevalent in soils and water. The study will cover about 1km² in Osubi town, with thirty eight (38) samples (8 borehole, 8 hand-dug well samples and 22 soil/sediment samples) to be analyzed. Some metals could be present in the underlying rocks and this could be reflected in the levels and assumed to be from anthropogenic sources.

1.6 HEAVY METALS IN DUMPSITES

Modern civilization is completely dependent on a large range of metals for all aspects of daily life. There is a long historic association between metals and human development. Heavy metal pollution not only affects the production and quality of crops, but is environmentally problematic due to their high persistence and toxic effects (Esakku *etal.*, 2003). Nigeria is becoming a dumping ground for technological waste, especially used electronics and automobiles from the developed countries. It is a known fact that some of these products contain hazardous metals such as lead, mercury, nickel, cadmium, copper, zinc, arsenic etc. The indiscriminate dumping of damaged parts of these imported and other similar locally produced materials in different forms can perturb the distribution and concentration of these metals in the environment. The Nigerian government at all levels through their agencies have invested much in waste management and enforcement of sanitation laws but little has been achieved so far (Ojeshiria, 1999).

1.7 HEALTH IMPLICATIONS OF DUMPSITES

Poor waste management poses a great challenge to the well-being of city residents, particularly those living around the vicinity of the dumpsites due to the potential of the waste to pollute water, food sources, land, air and vegetation. The poor disposal and handling of waste thus leads to environmental degradation, destruction of the ecosystem and may cause great risks to public health. The resultant accumulation of waste poses a health hazard to urban inhabitants, and also threatens the surrounding environment (UNEP, 2005). According to Marshal (1995), open dumpsites are a major problem to the environment, especially on the

air that the people inhale. Dumpsites emit obnoxious Odour and smoke that cause illness to people living in, around or closer to them. In a number of community health surveys, a wide range of health problems, including respiratory symptoms, irritation of the skin, nose and eyes, gastrointestinal problems, psychological disorders and allergies, have been discovered. A number of researches have been carried out in response to concerns of the public, often triggered by nuisances caused by emissions of volatile organic compounds.

According to Dolk (1997), dumpsites closer to residential areas are always feeding places for dogs and cats.

These pets, together with rodents, carry diseases with them to nearby homesteads. UNEP (2005) states that wastes that are not properly managed, especially excreta and other liquid and solid wastes from households and the community constitute a serious health hazard and could lead to the spreading of diseases. Normally, wet waste decomposes and releases bad odour. The bad odour affects the people that are settled next to the dumpsite, which clearly shows that the dumpsites have serious effects on people settled around them (Ekwumemgbo *et al.*, 2013). Wastes from agriculture and industries can also cause serious health risks. Other than this, co-disposal of industrial hazardous wastes with municipal wastes can expose people to chemical and radioactive hazards. Uncollected solid waste can also obstruct stream water runoff, resulting in the formation of stagnant water bodies that become breeding grounds for disease causing organisms. Wastes dumped near a water source also cause contamination of the water body or the ground water source. The direct dumping of untreated wastes in rivers, seas and lakes result in the accumulation of toxic metals and organic pollutants in man through the food chain (Medina, 2002). This clearly shows how waste disposal seriously affects the health of residents located closer to dumpsites. The smelly and unsightly conditions of dumpsites are worse in dry conditions, because of extreme temperatures, which speed up the rate of bacterial action on biodegradable organic material. Disposal of solid wastes on land without careful planning and management can present a danger to the environment and the human health (USEPA, 2006).

1.8 WATER POLLUTION

Pollution of water still remains one of the most significant environmental problems of recent times. Water can be regarded polluted when it gets changed in its quality or composition either naturally or as a result of human activities so as to become less suitable for drinking, domestic, agricultural, industrial, recreational, wildlife and other uses for which it would have been otherwise suitable in its natural or unmodified state. Gross pollution of water has its origin mainly in urbanization, industrialization, agriculture and increase in human population.

In addition to toxic chemicals, water pollutants occur in many other forms, including pathogenic microbes, excess fertilizers and trash floating on streams, lakes and beaches.

Water pollution can also take the form of sediment eroded from stream banks, large booms of algae, low levels of dissolved oxygen or abnormally high temperatures. Water pollution threatens our health and environment and therefore we need to implement an expanding array of techniques for its assessment, prevention and remediation.

1.9 SOIL POLLUTION

Soil is a very important natural resource to man as it is a source of his life on this planet. Without soil the earth would be as barren as the moon hence lifeless (Misra and Mani, 2009). Despite its importance, soil is often contaminated by human activities this is reflected in the high horizontal and vertical variability brought about by the anthropogenic influence on soil formation and development (Fong *et al.*, 2008). A variety like municipal waste disposal, industrial emissions, military testing and agricultural practices, have left their impacts on soils in the form of toxicants. Materials that find their entry into the soil system persist and accumulate in toxic concentrations becoming sources of pollution in the soil (Misra and Mani, 2009). Among the pollutants that persist and accumulate in the soils include; inorganic toxic compounds for example fertilizers, organic wastes, organic pesticides and radionuclides (Misra and Mani, 2009; Jia *et al.*, 2010). The soil is thus becoming increasingly polluted with chemicals and other pollutants which can reach the food chain, surface water or groundwater and ultimately be ingested by man (Misra and Mani, 2009).

1.10 LOCATION ACCESSIBILITY OF THE STUDY AREA

The Osubi dumpsite (Fig.1) which is the largest in Osubi is located along the Osubi road, beside a sand mining pit that was used in building the Osubi airport, which is now a massive stagnant water body (blue colour body in Fig.1).The dumpsite is surrounded by residential houses, churches, schools, and offices. The study area is located Osubi, southern Nigeria (Fig.1). It lies within latitudes $5^{\circ} 35' 00''\text{N}$ to $5^{\circ} 35' 30''\text{N}$ of the equator and longitude $5^{\circ} 48' 30''\text{E}$ to $5^{\circ} 49' 00''\text{E}$ of the Greenwich Mean Time, along the Osubi road. The area is easily accessible through a series of interconnecting minor roads, footpaths, with a distribution of flat topography. The land surface of the study area is characterized by low lying plains typical of the modern Niger Delta.

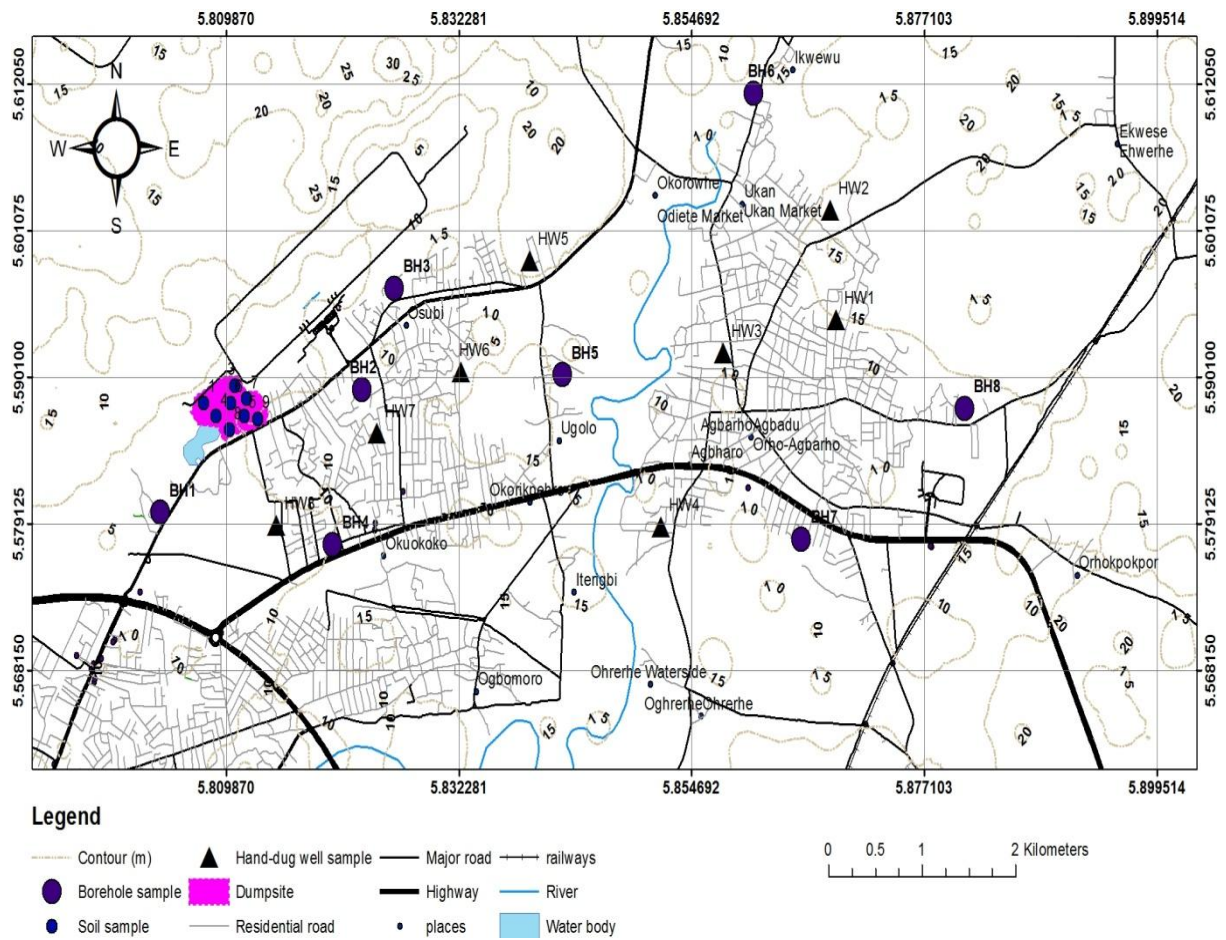


Figure 1.0 Location map of the study area.

1.11. LITERATURE REVIEW

Numerous scholars from various fields made a lot of contributions on the issues of environmental impact of waste on both soil and groundwater through sound programs or studies. In the quest for previous knowledge, the researcher attempted to review a number of these literatures from journals, books and electronic devices.

Jire and Imeokparia (2018), examined the statistical evaluation of the heavy metals in the sediments of Warri River and environs in order to assess and characterize the pollution/contamination status of the sediments in view of the increasing level of oil spillages induced by willful acts of vandalization, urbanization, industrial activities and indiscriminate dumping of wastes. The results of their findings showed that, majority of the heavy metals in the sediments exhibited moderate contamination range at several locations, while Cr has considerably contaminated locations B2, B3, B4 and B6 with high contamination level at location B1.

Egai and Imasuen, (2015) carried out an assessment of soil quality in a crude oil impacted site in Aguobiri, Bayelsa State. Their results indicated significant difference in the concentration of Pb^{2+} , Zn^{2+} , and Cu^{2+} in the impacted area compared to non-impacted site and established standard. The results also show that most of the parameters exceeded the background values and natural concentration in the soil at the impacted sites, which signifies pollution.

Akujieze and Idehai (2014), carried out the physiochemical assessment of landfill generated leachates in Lagos. The physiochemical analyses of the Lagos landfill leachates showed that most of the measured physiochemical parameters are within standards devised by FEPA, LASEPA, etc. But, the presence of arsenic above prescribed limits in the Epe leachate is a major concern, because of its porous sandy lithology, shallow unconfined aquifer and a reported depth of about 3m to the unconfined aquifer that adjoins the Epe Lagoon and recommended the closure of the Epe landfill.

Imasuen and Omorogieva (2013), also carried out a comparative study of heavy metals distribution in a mechanic workshop and a refuse dumpsite in Oluku and Otofure Benin City, Edo State. The results of their findings showed that the mechanic workshop contributes more of the heavy metals assessed in the environment except for Cadmium whose concentration was found to be slightly higher in the refuse dumpsite. The results further revealed that the

concentration of the heavy metals assessed decreased from top to subsoil in and around and at a distance away from the sample locations (mechanic workshop and dumpsite). The results also show that the sources of the heavy metals were anthropogenic which was further buttressed by the strong positive correlation between the soils.

Imasuen and Omorogieva (2013), examined the sources and environmental implication of heavy metals pollution in plants grown around contaminated site in Edo State. The results of their findings obtained when compared to standards revealed that the metals investigated were above threshold value; consequently exposing humans that consume such food crops grown in the area of study to health risk. The decrease in concentration from around and away from the sites as well as correlation range $r = (P < 0.01 - 0.001)$ shows anthropogenic source of contamination. The study also revealed that the acidic nature of the soil as a result of the leaching effect caused by heavy rainfall could be attributed to the high cadmium content in the food crops which were directly absorbed from the soil or by foliar absorption as a result of air pollution caused by burning of waste currency solid waste as well as vehicular emission.

Ihenyen (1992), conducted a comparative study of Pb, Cu, and Cr in roadside sediments in metropolitan Lagos and Benin City. The results of analyses of 85 sediment samples from roadside drains, 60 from metropolitan Lagos and 25 from Benin City, show clear differences in pollution levels between the two cities. There are proportionately high Pb, Cu, and Cr concentrations in sediments along high density motorways in both cities considered while lower trace metals are found along medium and light density motorways. However, there are higher levels of trace metal enrichment in Benin City than in Lagos. In particular, high levels of Pb (480-5112 btg/g, mean: 1207+35) are found in sediments along high density motorways in Benin City in comparison to 221-1252 lag/g (mean: 540+82) recorded for Lagos samples. The generally higher trace metal concentrations in Benin City are inferred to result from very poor municipal drainage systems.

CHAPTER TWO

REGIONAL GEOLOGICAL SETTING

2.0 TECTONIC SETTING

The Niger Delta Basin occupies the coastal and ocean-ward part of a much larger and older tectonic feature, the Benue Trough. The Benue Trough is a NE-SW folded rift basin (Fig.2.2) that runs diagonally across Nigeria. It formed simultaneously with the opening of the Gulf of Guinea and the Equatorial Atlantic in Aptian-Albian times, when the equatorial part of Africa and South America began to separate. Taphrogenic subsidence along fundamental transform faults which had cut through the lithosphere and are the landward continuations of the Chain and Charcot oceanic fracture zones, initiated the Benue Trough, and also later controlled the location of the main axis of subsidence of the Niger Delta. The Chain Fracture Zone coincides with the Benin Hinge Line of the western Niger Delta, whereas the eastern delta frame generally referred to as the Calabar Flank (Reyment, 1965), is more complicated, with NW-SE-trending structures such as the Ikang Trough, the Ituk High, and the Calabar Hinge Line. Sinistral transcurrent shearing along the fracture zones caused deformation in the Benue Trough and modified the Gulf of Guinea continental margin from the simple pull-apart basement structures with half-grabens that underlie the West African continental margins north and south of the Gulf of Guinea. In the Benue Trough, sedimentary infillings lie in Cretaceous subbasins such as the Gongola, the Yola, the Abakaliki, the Anambra, and the Afikpo subbasins. The Niger Delta can therefore be considered as the youngest sub-basin in the Benue Trough, a region whose stratigraphic and paleogeographic evolution have been controlled by southward shifting deltaic depocentres (Benkhelil, 1989; Petters 1985); westward post-deformational displacement of depocentres, and northward directed marine transgressions.

2.1 STRATIGRAPHY OF THE NIGER DELTA BASIN

The Atlantic Ocean where a triple junction developed during the separation of the continents of South America and Africa plates in the late Jurassic (Whiteman, 1982). Subsidence of the African continental margin and cooling of the newly created oceanic lithosphere followed this separation in early Cretaceous times. Marine sedimentation took place in the Benue Trough and the Anambra Basin from mid-Cretaceous onwards. The Niger Delta started to

evolve in early Tertiary times when clastic river input increased. Generally the delta prograded over the subsidizing continental-oceanic lithospheric transition zone, and during the Oligocene spread onto oceanic crust of the Gulf of Guinea (Adesida *et al.*, 1997). The weathering flanks of out-cropping continental basement sourced the sediments through the Benue-Niger drainage basin. The delta has since Paleocene times prograded a distance of more than 250 km from the Benin and Calabar flanks to the present delta front (Evamy *et al.*, 1978). Thickness of sediments in the Niger Delta averages 12 km covering a total area of about 140,000 km².

Whilst the early Niger Delta is interpreted as being a river-dominated delta, the post Oligocene delta is a typical wave-dominated delta with well-developed shore-face sands, beach ridges, tidal channels, mangrove and freshwater swamps. It is one of the world's largest deltas and shows an overall upward transition from marine shales (Akata Formation) through a sand-shale paralic interval (Agbada Formation) to continental sands of the Benin Formation. Depending on sea level changes, local subsidence and sediment supply, the delta experienced phases of regressions and transgressions. The stratigraphic framework and the detailed tertiary stratigraphy of the Niger Delta are based on correlation of palynomorphs and foraminifera zones. The stratigraphic sequence of the Niger Delta comprises three broad lithostratigraphic units namely, (1) a continental shallow massive sand sequence – the Benin Formation, (2) a coastal marine sequence of alternating sands and shales – the Agbada Formation and (3) a basal marine shale unit- the Akata Formation.

Table 2. 1: Stratigraphic Units of the Niger Delta Basin (after Short and Stauble 1967).

Outcropping Units	Subsurface Units	Present-day Equivalents
Benin Formation	Benin Formation	Continental (fluvial) deposits mainly sandstones
Ogwashi-Asaba Formation	Agbada Formation	Mixed continental brackish water and marine deposits, sandstones and clays
Ameki Formation Imo Shales	Akata Formation	Marine deposits, mainly clays

THE BENIN FORMATION

The Benin Formation is characterized by high sand percentage (70–100%) and forms the top layer of the Niger Delta depositional sequence. The massive sands were deposited in continental environment comprising the fluvial realms (braided and meandering systems) of the upper delta plain. It is a continental deposit, various structural unit are identifiable within the formation indicating the variability of the shallow water depositional medium. It ranges from Miocene to Recent; the thickness is about 2100m, it is made up of Delta Coastal Plain which is subdivided into upper coastal delta plain (fresh water) and lower coastal delta plain (brackish water).

THE AGBADA FORMATION

The Agbada Formation consists of alternating sand and shales representing sediments of the transitional environment comprising the lower delta plain (mangrove swamps, floodplain, and marsh) and the coastal barrier and fluvial marine realms. The sand percentage within the Agbada Formation varies from 30 to 70%, which results from the large number of depositional off lap cycles. A complete cycle generally consists of thin fossiliferous transgressive marine sand, followed by an offlap sequence which commences with marine shale and continues with laminated fluviomarine sediments followed by barriers and/or fluvial sediments terminated by another transgression (Weber, 1972; Ejedawe, 1989). It is about 300-4500m in thickness and ranges from Eocene in the north to Pliocene/Pleistocene in the south and recent in the delta surface. The presence of growth fault and rollover anticlines acts as a trapping mechanism for petroleum accumulation.

THE AKATA FORMATION

The Akata Formation consists of dark grey clays and shales with minor sand intercalations. The shale unit is thick and homogeneous. Lenses of sandstones occur near the top close to the base of the overlying Agbada Formation. The environment is anoxic with plankton foraminifera accounting for over 50% of the rich micro fauna and the benthonic assemblage indicating shallow marine shelf depositional environment. The sediments were deposited in prodelta environments. The sand percentage here is generally less than 30%. It is about 600-6000m thick with the shale unit exhibiting diapirism at the basin frontier.

Table 2.2: Geologic units of the Niger Delta Basin (after Etu-Efeotor and Akpokodge, 1990).

Geologic Unit	Lithology
Alluvium	Gravel, sand, clay and silt
Freshwater swamp	Sand, clay, silt and gravel
Mangrove/saltwater swamps	Fine-medium grained sand, clay and silt
Active/Abandoned beach ridges	Sand, clay and silt
Sombeiro-Warri Deltaic plain	Sand, clay and silt
Benin Formation (Coastal plain-sand)	Medium-coarse grained sand, clay lenses
Agbada Formation	Intercalation of sand, clay and silt
Akata Formation	Clay and Shale

2.2 GEOLOGY OF THE STUDY AREA

The study area (Fig. 2.1) is underlain by the deposits of the Quaternary Sombreiro-Warri Deltaic Plain Sands (Wigwe,1975).This Formation, The Sombreiro Warri formation, consists of fine to medium and coarse-grained unconsolidated sands that are often feldspathic, with 30 - 40 wt% feldspars and occasionally gravelly. This sequence is locally stratified with peat and lenses of soft and plastic clay that could be sandy. The Formation generally does not exceed 120 meters in thickness and it is predominantly unconfined. Lithologically, it consists of sands, clays and silt. This plain has swamps that are commonly flooded during the peak of the rainy season.

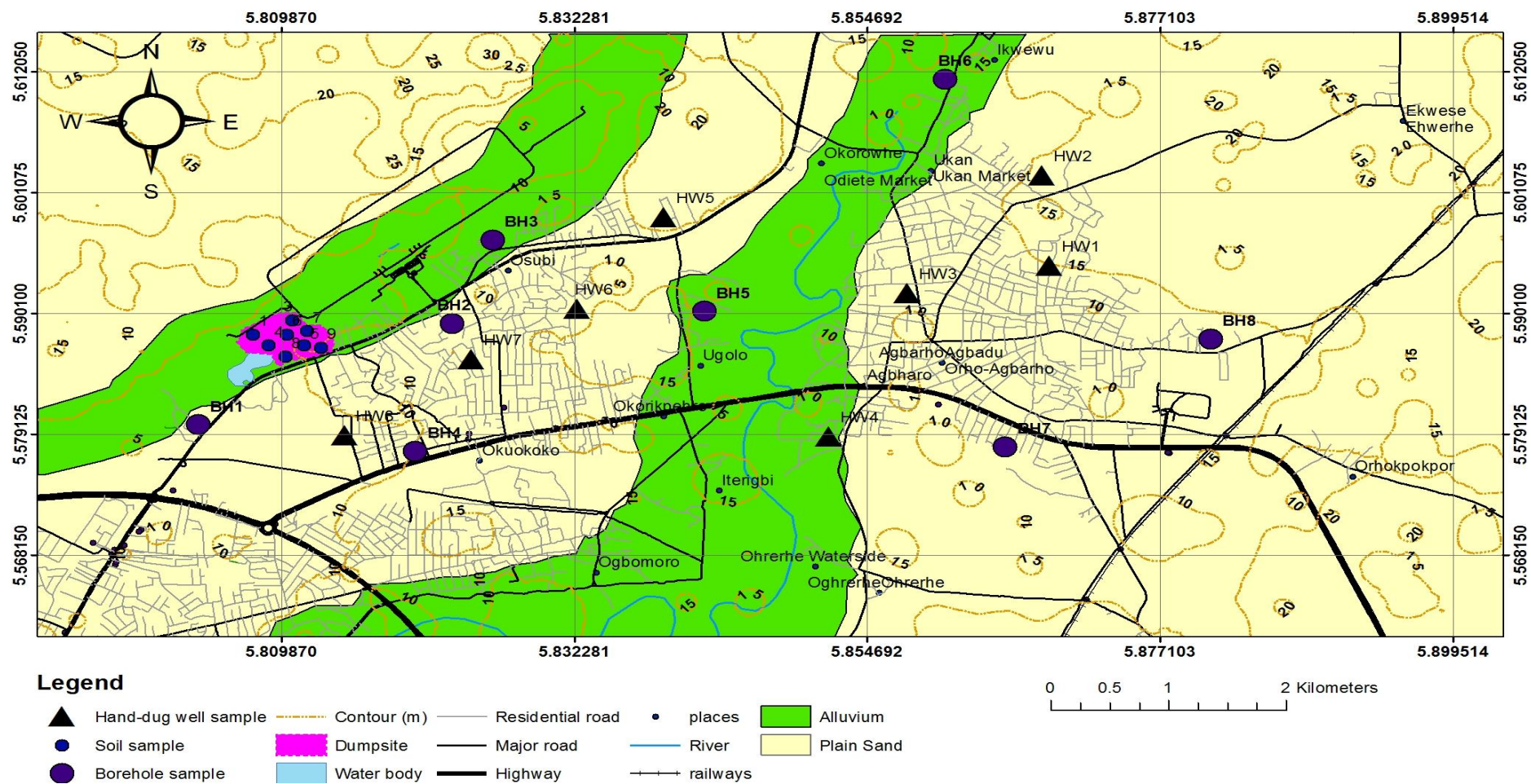


Figure 2.1: Geological Map of the Study Area.

CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS

The materials used for this study include:

1. Sample bottles (0.75L plastic bottles)
2. Sample bags
3. Field notebook and pen
4. Measuring and masking tapes
5. Nose masks
6. location map
7. GPS (Garmin 72-model)
8. Cooler (containing ice)
9. Shovel
10. Stainless steel spoon

3.2 METHODOLOGY

Thirty eight (38) samples were collected from field; sixteen water samples (8 borehole and 8 hand-dug well samples) were collected through the random sampling technique, and twenty two (22) soil/sediment samples were collected in and around the refuse dumpsite at depths of 0-15cm and 15-30cm through composite random sampling technique. Two (2) of the samples were collected at a distance of one (1) kilometer away from the dumpsite as control point (a pristine environment devoid of anthropogenic activities having the same lithology as the sampled locations) to show the degree of dispersion from the source. The samples were stored in polythene bags and taken to the laboratory to be air dried for three (3) days. They were then ground in an agate mortar and sieved through a 2mm nylon sieve. 0.5g of the processed sample was weighed in 250cm³ hard glass (conical flask) digestion tubes. About 10ml of concentrated Nitric acid (HNO₃) was added which produced effervescence. There after 5ml of perchloric acid (HClO₄) was added and heated for about one (1) hour in an electric heater. The colour was observed to change to white and the content was allowed to cool for thirty (30) minutes. Subsequently 20 percent (%) diluted Hydrochloric acid (HCl) was added and filtered into 120ml container and diluted to volume with distilled water.

The concentrations of the heavy metals were then determined using air acetylene flame atomic absorption spectrophotometer (AAS) (Perkin Elmer A3100).

3.2.1 DATA ANALYSIS

Two different multivariate statistical analyses were used to analyze the groundwater geochemical data. One-way analysis of variance (ANOVA) and Spearman's correlation matrix at $P < 0.05$ (95%) and $P < 0.01$ (99%) test of significance. Statistical analysis is very useful in providing knowledge, and assists in interpretation of data. It is widely applied in recent times to investigate the heavy metal concentration, accumulation and distribution in soils and groundwater (Imasuen and Omorogieva, 2013; Akujieze, 2006). Statistical analysis of physico-chemical results in the soil and groundwater samples in the study area was performed using one-way analysis of variance (ANOVA) and Spearman's correlation matrix. One-way analysis of variance (ANOVA) was used in determining if the heavy metal content in the sediments varies within the sampled locations. While Spearman's correlation matrix was used to establish if there was a relationship among the physico-chemical parameters in the water samples (groundwater and hand-dug well) in the dataset of the study area. Finally, descriptive statistics was performed to ascertain the measures of dispersion (mean, range, standard error, and standard deviation) of the physico-chemical content. All statistical treatment mentioned above were performed using IBM-SPSS 16.0 software and Microsoft Excel (2007 version).

3.2.2 QUANTIFICATION OF HEAVY METAL POLLUTION IN THE SOIL

In order to have an idea about the levels of contamination of the dumpsite soil, data obtained were compared with the background/control values. The background value of an element is the maximum level of the element in an environment beyond which the environment is said to be polluted with the element (Puyate *et al.*, 2007).

Pollution Load Index (PLI): PLI was used to quantify the enrichment of heavy metals in contaminated soils with respect to soil background, and was calculated as below (Hakanson, 1980):

$$PLI = (C_{F1} \times C_{F2} \times C_{F3} \dots C_{Fn}) \dots \dots \dots \text{eqn 3.1}$$

n = number of metals

C_F = contamination factor. Values of the PLI are interpreted as follows:

$PI < 1$, low contamination,

$1 \leq PI < 3$, moderate contamination,

$3 \leq PI < 6$, considerable contamination, and

$PI \geq 6$, very high contamination (Loska *et al.*, 1997).

For each sampling site, a pollution load index (PLI) was calculated to indicate the degree of integrated heavy metal pollution in affected soils (Wang *et al.*, 2010):

Contamination factor (CF)

Contamination factor is a quantification of the degree of contamination relative to either average crustal composition of respective metal or to the measured background values from geologically similar and uncontaminated area (Tijani *et al.*, 2004). The assessment of soil contamination is also carried out using the contamination factor. CF is defined according to four categories as follows:

$CF < 1$ - Low contamination factor,

$1 < CF < 3$ - Moderate contamination factor,

$3 < CF < 6$ - Considerable contamination factor,

$6 < CF$ - Very high contamination factor.

It is expressed as: $CF = C_m/B_m$ ----- Equ 3.2

Where C_m is the mean concentration, while B_m is the background concentration of metal directly determined from a geologically similar area (control sample), (Lar and Shehu, 2014).

3.2.3 QUALITY ASSURANCE/CONTROL

The quality assurance programme covers all aspects of the study, including sample collection, handling, laboratory analysis, data coding and manipulation, statistical analysis, presenting and communicating results. Soil samples were collected with plastic made implements to avoid contamination. Samples were kept in polythene bags that were free from heavy metals and organics and well covered while transporting from field to the laboratory to avoid contamination from the external environment.

Reagent blanks were used in all analyses to check reagent impurities and other environmental contaminations during analysis. BDH Analar grade reagents were used for all analyses. All the reagents were standardized against primary standards to determine their actual

concentrations. All the glassware used were soaked in appropriate dilute acids overnight and washed with Teepol and rinsed with deionized water before use. All the instruments used were calibrated before use. Tools and work surfaces were carefully cleaned for each sample during grinding to avoid cross contamination. Duplicate samples were analyzed to check precision of the analytical methods and instruments.

Field Procedures

All field procedures were in accordance with general QA/QC requirements.

- Contamination of samples was avoided using clean and sterile sampling containers.
- Separate samples were used in analyzing for parameters requiring different treatment or preservation before analysis.
- Composite and systematic random sampling techniques were adopted for soil and water respectively.
- Control samples were collected at appropriate points remote from focus areas.
- Samples were appropriately preserved and labelled.

Laboratory Procedures

- Analyses were carried out within the holding time of respective parameters
- Only functional and calibrated equipment were used for sample analysis.
- Only competent and experienced staff was involved in analytical work.

3.3 LABORATORY ANALYSES

Soil and surface water sample were analyzed for physical, chemical and bacteriological as well as heavy metals parameters.

The methods of analysis used were those specified in NSDWQ/FMEnv/DPR Guidelines and Standards and other International Analytical Standards such as WHO for water quality. Physicochemical parameters were determined using air acetylene flame atomic absorption spectrophotometer (AAS) (Perkin Elmer A3100). Two drops of Nitric Acid (HNO₃) was dropped in the Cation sampling bottle to prevent metallic ions from adhering to the walls of the container and homogenize the water sample. Cations and heavy metals analyses were carried using air acetylene flame atomic absorption spectrophotometer (AAS) (Perkin Elmer A3100), while anion analysis was done using ion chromatographic method while titrimetric method was used for SO₄ and PO₄.

3.3.1 PHYSICO-CHEMICAL LABORATORY PROCEDURE OF WATER SAMPLES

Hydrogen ion concentration (pH)

The pH value of the water samples were determined using the Hanna pH meter instrument Hi-1922 model after being standardized with buffers of pH 4.0 and pH 9.2 (Ademoroti, 1996), rinsed severally with distilled water and inserted into each of the samples.

Turbidity

Turbidity was determined using the cell riser which was installed in the cell holder of model 2100A Turbidimeter in one of the two highest ranges (100 or 1000 NTU). A clean sample cell of turbidimeter was filled with 25 ml of each sample and covered with light shield and turbidity read in nephelometric turbidity units (NTU).

Temperature

This was determined at the time of analysis. An aliquot of 50 ml of sample was measured into a 100ml beaker and a 0-60°C thermometer immersed in the solution. The reading on the thermometer was then recorded.

Total Dissolved solids

In determining total solids, four washed 100 ml beakers were dried and then put in an oven for a while, cooled and weight of each beaker was taken which became the initial weight. Fifty ml of each of the water sample was added into each of the beakers and weighed. These were then placed on a Bunsen burner to dry off the water sample completely. The weight of each beaker was taken again which becomes the final weight.

Calculation

Final weight – Initial weight = X mg/l

X mg x 1000/volume of water used mg/l

Amount of total dissolved solids is the difference in weight.

Total Suspended Solids

Suspended solids were determined by first taking the weight of a filter paper. One hundred ml of each water sample was filtered using the filter paper. The used filtered paper was put in an oven at 50°C for 10 minutes. It was taken out and weighed.

Calculation

Final weight – Initial weight = y mg

$y \times 1000 / \text{volume of water sample used mg/l.}$

Biological Oxygen Demand

Biological oxygen demand (BOD) measures the rate of consumption of oxygen by organisms in the water over a 5-day period. Increases in BOD can be due to animal and crop wastes and domestic sewage. One N acid/1 N alkali was added to each water sample to adjust the pH to 7. The sample was then transferred into BOD bottles gently so that bubbles did not come out. One ml of allylthiourea was added to each bottle to avoid nitrification. Dissolved oxygen was then measured using the steps described for dissolved oxygen. The other BOD bottle was incubated at 27°C for 5 days in a BOD incubator. The amount of oxygen was measured as done earlier.

Calculation

$\text{BOD (mg/l)} = D1 - D2$

Where D1 = initial dissolved oxygen (mg/l) in the first halved sample (mg/l)

D2 = dissolved oxygen (mg/l) in the second halved sample after 3 days of incubation.

Chemical Oxygen Demand

Pipette 50ml of water sample into a conical flask. Add 10ml of the 0.00833 K₂Cr₂O₇ solution. Add 1g of HgSO₄ and 80ml of Ag₂SO₄– H₂SO₄ solution and a few beads. Fit a reflux greaseless condenser and heat gently to boiling and then boil for exactly 10 minutes. Leave to cool. Rinse the condenser with 50ml of water and cool the flask under running tap. Add two drops of Ferroin indicator and titrate with 0.025M Fe(NH₄)₂ (SO₄)₂6H₂O until the colour changes from blue-green to red-brown. Do a blank determination as above on 50ml of water.

Calculation

The difference in value between the two titres gives the titre of the sample.

That is 1ml of difference = 0.2mg DO or 4 mg DO/L if a 50ml sample is taken.

Sulphate Determination

Five series of standard solution with concentration range of 1mg/l to 5mg/l were prepared and analyzed with the samples. To each 10ml of standard, 1ml of barium chloride gelatin was added. The mixtures were allowed to stand for 45 minutes. The respective absorbance of the solution at 420nm was determined. From this data a graph of absorbance against concentration was plotted. Barium chloride gelatin (1ml) was added to 10ml of sample and the mixture was diluted to 50ml with double distilled water. Prepared samples were allowed to stand for 45 minutes. The concentrations were determined using UV-Visible spectrophotometer at 420nm. A blank without sample was prepared and read at the same wavelength.

Phosphate Determination

Ascorbic acid Method (Orthophosphate-Phosphorus) was used. Five series of phosphate standard solution with concentration range of 0.2mg/l to 1mg/l orthophosphate (PO_4^{3-}) was used to standardize the UV-Visible spectrophotometer, 50ml of standard was measure into test tube and 2ml of ascorbic acid molybdenum was added.

The absorbance of the solutions after 10 minutes was taken at 655nm against a blank solution with UV-Visible spectrophotometer. A curve of absorbance verses concentration was plotted. To 50ml of the sample was added 2ml of ascorbic acid molybdenum. The mixture was allowed to stand for 10 minutes after which the absorbance of the samples was taken at 655nm with UV-Visible spectrophotometer. A blank analysis was performed with all the reagents without the samples for all the analysis.

Chloride Determination by Titration

An aliquot of 50ml of sample was measured into a conical flask. The pH was then adjusted to a range of 7-10 with tetraoxosulphate (vi) acid (H_2SO_4) for high pH samples and sodium hydroxide (NaOH) for low pH samples. Two drops of potassium heptaoxodichromate (vii) (K_2CrO_4) indicator was added. Standard silver nitrate (AgNO_3) solution of 0.01M was titrated

against the resulting mixture above to a pink yellow end point. Blank titration with only the reagents and no water sample was also performed.

Calculation

$$\text{Chloride (mg chloride per liter)} = \frac{T \times N \times 1000 \times 35.5}{1 \text{ ml of sample}}$$

T=end point volume.

N=Normality of AgNO₃.

Total, Dissolved and Suspended Solids (TDS/TSS)

Total solids (TS) are the solid matter in water, also referred to as residue. It has two components, suspended solids (SS) and dissolved solids (DS). The dissolved solid component was determined in situ in the field using the HACH dissolved solid meter. The field results were cross-checked gravimetrically in the laboratory. Total solids (TS) in water were determined gravimetrically by evaporating to dryness 100 ml of unfiltered water in a pre weighed and pre-dried evaporating basin.

Dissolved solids were determined as above using filtered water and the difference in weight between total and dissolved solids gave the suspended solids.

Alkalinity (mg/l)

Phenolphthalein and total alkalinity were determined using the Hach Digital Titration Method with phenolphthalein and Bromocresol Green Methyl-Red as indicators and titrating with 1.600N sulphuric acid. This is a modification of the titrimetric method of the Standard Methods for the Examination of Water and Waste water (APHA, 2005).

Dissolved Oxygen (DO)

Dissolved oxygen (DO) was determined by the Azide modification of Winkler Method adapted for the HACH equipment from Standard Methods. Clean 60 ml glass-stoppered BOD bottles were filled to overflowing with water samples directly from source. Fixation in the field was carried out by adding the contents of Dissolved Oxygen 1 and Dissolved Oxygen 2 powder pillows, and the bottle stopper and thoroughly mixed by rotation and inversion until a flocculent brownish precipitate was produced. The bottles were stored away in darkened containers under water until their contents were titrated in the laboratory. Before titration, the content of Dissolved Oxygen 3 powdered pillow (sulphamic acid) was added thoroughly mixed, and aliquots of 20 ml titrated with 0.200 N sodium thiosulphate using the HACH Digital Titrator, until the sample changed from yellow to colourless. Using starch indicator

towards the end of the titration remarkably improved the end point from deep blue to colourless. The number of digits from the digital counter window multiplied by 0.1 gave the concentration of dissolved oxygen in mg/l.

Electrical Conductivity ($\mu\text{S}/\text{cm}$)

This is the capacity of water for conveying electrical current and is directly related to the concentrations of ionized substances in the water. Conductivity was measured in situ using a HACH Portable Conductivity Meter.

Sulphate

The procedure employed to determine sulphate is a modification of the Barium Sulphate Turbidimetric Method using the HACH equipment.

Sodium and Potassium

Sodium and potassium were analyzed by flame photometry.

Calcium

Calcium was determined by the EDTA titration method using CalVer 2 Calcium Reagent in a HACH modification of the Standard Methods according to APHA (2005). A 100 ml water sample was taken in a clean titration flask and 2 ml of 9N KOH was added and swirled to mix. The content of one CalVer 2 Calcium Reagent indicator was added and the content of the flask titrated with 0.900N EDTA solution using the HACH digital titrator until the colour changed from pink to blue. The concentration of calcium hardness is read from the digital counter as mg/l CaCO_3 .

Magnesium

Magnesium hardness (as CaCO_3) was determined by subtracting the amount of calcium hardness from the results of the total hardness test. Total hardness of water was determined using the ManVer 2 total Hardness reagent (erichrome black T) as indicator after adding 2 ml of buffer solution. This was titrated with a standard EDTA titrant until the last reddish tinge disappeared. Magnesium hardness was converted to mg/L magnesium by multiplying with 0.243.

3.3.2 MICROBIAL LABORATORY PROCEDURE OF WATER SAMPLES

Total and Faecal coliforms

Total and Faecal coliforms were analyzed using the Most Probable Number (MPN) method. Serial dilutions of 10^{-1} to 10^{-8} were prepared by serially diluting 1 ml of the water sample. One-milliliter aliquots from each of the dilutions were inoculated into 5ml of MacConkey

Broth with inverted Durham tubes and incubated at 37°C for total coliforms and 44°C for faecal coliforms for 18-24 hrs. Tubes showing colour change from purple to yellow and gas collected in the Durham tubes after 24 hrs were identified as positive for both total and faecal coliforms. Counts per 100 ml were calculated from MPN Tables (Anon, 1992).

E.coli

From each of the positive tubes identified, a drop was transferred into 5ml test tube of Trypton water and incubated at 44°C for 24 hours Kovac's reagent was then added to the tube of trypton water. All tubes showing a red ring colour development after gentle agitation denoted the presence of indole and recorded as presumptive for thermo tolerant coliform (E.coli). Counts per 100ml were calculated using the MPN tables.

3.3.3 TRACE METAL LABORATORY PROCEDURE OF WATER SAMPLES

Arsenic, Manganese, Cadmium, Chromium, Lead, Zinc, Copper, Cyanide, Nickel and Vanadium Flame Atomic Absorption spectrophotometry was used. The water sample was sprayed through a nebulizer into an air-acetylene flame. Free atoms of the elements were generated in the flame resonance line of the element, generated in a hollow cathode lamp, was simultaneously passed through the flame. The absorbance of radiant energy by the element of interest was related to its concentration in the water sample by Beer-Lambert law.

3.3.4 PHYSICO-CHEMICAL LABORATORY PROCEDURE OF SEDIMENTS

Samples collected from the field were air dried, sieved through 2 mm sieve and analyzed for the following physico-chemical parameters:

Hydrogen ion concentration (pH)

This was determined in a 1:1 soil/water suspension with a glass electrode pH meter. The pH 20g of dried soil was weighed into a 50 cm³ beaker, 20 cm³ of distilled water was then added. The mixture was stirred with a glass rod and allowed to stand for 30 minutes. A pre calibrated HANNA pH meter was inserted into the slurry and the pH was recorded.

Electrical conductivity

The Electrical conductivity (EC) was determined using 25g of an air-dried soil sample placed in a 250cm³ beaker, distilled water was added slowly drop by drop over the entire soil surface in a uniform pattern, until the soil appeared wet. A stainless steel spatula was used to form a

homogeneous soil paste. The beaker was then covered with a Petri-dish; 50cm³ of distilled water was added and shaken for 1 hour. 40cm³ of the diluted extract was transferred into 100cm³ beaker and the electrode of the conductivity meter inserted to record the electrical conductivity of the soil recorded in $\mu\text{S}/\text{cm}$.

Organic matter

This was determined by the Chromic acid oxidation method of Walkley and Black (1937). The organic carbon determined was expressed as percentage of the sample taken.

Calculation

$$\frac{\text{Blank} - \text{Sample} \times \text{Normality of Ferrous Ammonium Sulphate} \times 0.03 \times 1.3 \times 100}{\text{Weight of Sample}} \dots \text{eqn 3.3}$$

Sulphate and Phosphate determination

Ten milliliter of digest was transfer into fifty milliliter flask, five milliliter of water, one milliliter of barium chloride gelatin reagent was added and the solution was allowed to stand for thirty minutes, and ten milliliters of concentrated sulphuric acid were added. The mixture was mixed and allows standing for ten minutes. Stock working standards 0,2,4,6,8 and 10 ppm were prepared and treated in similar way. The optical density (OD) of the samples and standard were taken spectro-photo-metrically at 420nm

Calculation

$$\text{SO}_4^{2-}\text{-S}(\text{mg}/\text{kg}) = \frac{\text{OD} \times \text{SR} \times \text{ColourVol} \times \text{Ext. vol}}{\text{Weight of sample} \times \text{Vol. taken}} \dots \text{eqn 3.4}$$

$$\text{PO}_4^{2-}\text{-P}(\text{mg}/\text{kg}) = \frac{\text{OD} \times \text{SR} \times \text{ColourVol} \times \text{Ext. vol}}{\text{Weight of sample} \times \text{Vol. taken}} \dots \text{eqn 3.5}$$

Determination of Sodium, Potassium, Magnesium and Calcium

Five (5) grams of air dried soil was weighed into a plastic bottle. One hundred (100) milliliters of neutral 1 M ammonium acetate was then added to the soil and the mixture was shaken with the aid of a mechanical shaker for 30 minutes. The mixture was filtered using a No 42 Whatman filter paper into a 100 ml volumetric flask. The filtrate was made up to mark with the acetate. Stock working standards 0,2,4,6,8 and 10 ppm were prepared for sodium, potassium, calcium and magnesium using 2.54g of oven dried sodium chloride, 100 ml of ammonium acetate, 1.9067 g oven dried potassium chloride, 0.5004g of calcium carbonate (at

105°C) in 5 ml of hydrochloric acid and 0.1216 g of magnesium turning in volume of 6 M hydrochloric acid. The concentration of the exchangeable cations (Na, Ca, K and Mg) in the filtrate was determined using a flame photometer (Model). The flame photometer was adjusted according to its instruction manual and the standards were aspirated to obtain reliable curves before aspirating the samples. The blank utilized was ammonium acetate (Onyeonwu, 2000).

Calculation

$$\text{Ca (Meq/100g)} = \frac{\text{Instrument reading} \times 100}{\text{Weight of sample} \times \text{Eq.wt.}} \dots\dots\dots \text{eqn 3.6}$$

$$\text{K (Meq/ 100g)} = \frac{\text{Instrument reading} \times 100}{\text{Weight of sample} \times \text{Eq.wt.}} \dots\dots\dots \text{eqn 3.7}$$

$$\text{Mg (Meq/ 100 g)} = \frac{\text{Instrument reading} \times 100}{\text{Weight of sample} \times \text{Eq.wt.}} \dots\dots\dots \text{eqn 3.8}$$

$$\text{Na (Meq/ 100 g)} = \frac{\text{Instrument reading} \times 100}{\text{Weight of sample} \times \text{Eq.wt.}} \dots\dots\dots \text{eqn 3.9}$$

3.3.5 TRACE METAL LABORATORY PROCEDURE OF SEDIMENTS

Sample digestion method

Conventional aqua regia (i.e. solution of HCl& HNO₃ with ratio of 3:1) digestion was employed. This was performed in 250 mL glass beaker covered with watch glasses. A well-mixed sample of 0.500g was digested in 12 mL of aqua regia on a hot plate for 3hrs at 110°C. After evaporation to near dryness, the sample was diluted with 20mL of 2% (v/v with H₂O) nitric acid and transferred into a 100mL volumetric flask after filtering through Whatman no. 42 paper and diluted to 100mL with distilled water. The extract where then taken for subsequent analysis of heavy metals.

Determination of trace/heavy metals

One gramme of the soil sample was digested with a mixture of hydrofluoric, nitric, perchloric and sulphuric (HF + HClO₄ + H₂SO₄) acids. The clear digest was diluted into 50ml mask with deionized water.

The sample solution was analyzed for Pb, Ni, Cr, As, Cd, Zn, Cu, Cn, Mn and V using air acetylene flame atomic absorption spectrophotometer (AAS) (Perkin Elmer A3100).

Principle of flame atomic absorption spectrophotometer (AAS)

Atomic absorption spectroscopy is based on the ability of an “excited” atom of an element to absorb energy from wavelength of light of the same frequency as the element. This creates a decrease in the initial signal energy and this difference is proportional to the concentration. Each element has its own series of specific characteristics for sensitivity; noise and linearity define the range in which calibration curve will be accurate. The optical system is set up with a hollow cathode lamp for element of interest (analyte). With the appropriate slit and wavelength selected for the element. A solution of a known concentration of the analyte (standard) is aspirated and the absorbance reading is rational to the standard and a sample concentration is interpolated from the intensity of the reading.

Atomic Absorption Spectrophotometer (AAS) has various models but for this analysis the buck model 210 VGP systems was used. This model has the advantages over other models because it operates in two (2) modes: direct measurement deuterium background correction (dz) and variable giant pulse correction (gp). The two correction modes allow the chemist to analyze samples that have complex or “dirty” matrices; which would normally give significant interference in the analytical determination.

CHAPTER FOUR

RESULTS AND DISCUSSION

Table 4.1: The table below summarily tabulates the physicochemical parameters of the soil samples and control in the study area.

Parameters	Depth (cm)	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	Control
pH	0-15	5.5	4.4	4.7	4.1	2.6	5.6	5.7	4.8	4.8	4.3	4.0
	15-30	5.4	3.6	6.2	4.8	2.3	5.1	5.2	5.3	3.8	3.7	3.0
EC	0-15	700	610	770	780	3010	270	370	2670	2030	1640	150
	15-30	500	600	730	610	2990	510	520	2630	1900	1750	140
O.M	0-15	1.53	3.74	0.93	3.74	5.83	1.46	1.51	1.56	3.13	3.37	1.3
	15-30	1.44	2.96	0.52	3.68	5.44	1.34	1.44	1.08	2.45	2.98	0.3
Na	0-15	12.8	11.8	9.4	13.2	10.2	11.7	11.9	15.6	10.7	12.5	9.1
	15-30	11.5	11.0	7.7	12	10.1	9.6	11.4	13.1	10.3	11.4	9.0
K	0-15	9.1	8.5	4.7	9.4	9.4	8.2	9.1	7.2	7.1	7.1	4.0
	15-30	8.2	8.4	3.9	8.5	7.4	3.9	8.3	9.3	5.9	6.6	3.4
Mg	0-15	13.1	9.4	8.1	12	9	8.7	8.3	14.9	11.4	10.6	10.8
	15-30	12.6	9	8.8	10.5	8.5	9.8	13.2	10.8	9.9	10.9	6.3
Ca	0-15	15.5	13.1	10.5	15.5	12.1	13	12.1	17.3	12.2	14.7	9.1
	15-30	14.1	12.5	9.1	14.4	11.2	10.3	15.2	15.1	11.7	12.2	8.6
Sand	0-15	76.9	80.0	76.2	78.6	88.4	84.2	76.8	70.8	83.6	79.7	87.3
	15-30	80.4	78.5	82.0	74.9	86.7	80.3	84.5	78.9	74.2	85.4	78.8
Silt	0-15	5.60	6.80	4.80	5.80	6.40	5.40	7.40	6.90	5.70	6.60	5.70
	15-30	6.20	5.85	6.50	4.75	6.20	6.70	4.50	6.20	4.90	6.40	6.30
Clay	0-15	15.5	12.2	18.5	14.5	4.6	8.2	14.8	18.9	10.0	13.5	5.6
	15-30	13.4	14.7	13.2	18.7	3.2	12.1	10.5	13.8	18.2	8.4	14.5
As	0-15	19.2	23.4	21.6	19.1	18.03	14.36	15.34	19.6	19.28	19.06	11.56
	15-30	16.4	21.2	19.16	17.6	16.8	12.63	13.32	17.28	18.06	16.47	10.58
Mn	0-15	3.58	3.42	3.49	3.58	3.26	3.37	3.48	3.54	3.4	3.44	1.46
	15-30	3.51	3.37	3.47	3.42	3.52	3.43	3.51	3.52	3.39	3.42	1.42
Cd	0-15	2.08	2.13	2.14	2.22	3.25	2.13	2.12	3.46	2.07	2.21	1.08
	15-30	2.07	2.11	2.11	2.18	3.19	2.09	2.12	3.43	2.05	2.24	1.06
Cr	0-15	3.51	3.51	3.52	3.57	4.49	3.48	3.54	4.52	3.53	3.54	1.64
	15-30	3.54	3.49	3.53	3.56	4.55	3.49	3.51	4.55	3.38	3.32	1.61
Pb	0-15	2.72	2.54	2.56	3.69	2.87	2.81	2.32	3.42	2.89	2.85	2.14
	15-30	2.71	2.51	2.55	3.71	2.87	2.83	2.3	3.40	2.92	2.83	2.11
Zn	0-15	8.54	10.21	10	10.2	9.97	10.8	11.5	14.21	8.18	10.46	5.79
	15-30	8.46	9.66	9.6	9.81	10.3	8.0	9.50	13.5	8.09	10.44	5.77
Cu	0-15	2.02	2.54	2.06	2.17	2.86	2.21	2.95	2.16	3.23	3.2	1.86
	15-30	1.98	2.34	1.76	2.04	1.99	2.06	2.51	2.08	3.17	2.57	1.69
Cn	0-15	0.004	0.005	0.001	0.004	0.003	0.002	0.001	0.002	0.005	0.003	BDL
	15-30	0.002	0.003	0.003	0.002	0.002	0.003	0.001	0.003	0.006	0.002	BDL
Ni	0-15	3.18	2.64	3.36	2.29	3.24	2.81	2.95	3.41	4.59	2.49	1.35
	15-30	3.21	2.54	3.21	2.03	3.13	2.02	2.26	3.32	4.51	2.38	1.31
V	0-15	2.83	2.54	2.87	2.87	2.79	3.71	3.81	2.34	3.18	2.76	1.24
	15-30	2.80	2.41	2.84	2.13	2.81	3.91	3.95	2.27	3.55	2.21	1.20

BDL= Below Detection Limit

Table 4.2: Physicochemical parameters of groundwater samples in the study area.

Parameters	OSBH ₁	OSBH ₂	OSBH ₃	OSBH ₄	OSBH ₅	OSBH ₆	OSBH ₇	OSBH ₈	OSHW ₁	OSHW ₂	OSHW ₃	OSHW ₄	OSHW ₅	OSHW ₆	OSHW ₇	OSHW ₈
pH	5.4	5.69	5.89	5.96	5.55	5.44	5.49	5.63	5.59	5.78	5.28	5.76	5.6	5.67	5.73	5.69
EC	400	250	350	250	260	210	610	100	550	220	850	460	370	350	410	480
Temperature	26	26.02	26.01	25.8	26.04	26.2	26.25	26.24	26.28	26.31	26.25	26.38	26.43	26.61	26.75	26.63
Turbidity	2.6	BDL	1.9	BDL	2.2	1.1	1.5	1.6	12.4	14.8	12.5	10.3	10.4	12.1	11.4	9.4
Alkalinity	6.5	9.7	7.4	5.1	7.8	7.4	6.3	6.4	5.6	6.6	13.8	5.3	8.2	5.1	6.2	6.5
BOD	0.56	0.43	0.52	0.73	0.49	1.36	0.41	0.26	23.13	17.56	26.03	20.06	26.03	14.32	16.49	12.26
COD	12.1	22.4	38.3	18.4	16.1	51.9	32.7	40.4	52.6	26.4	68.6	27.2	48.1	51.9	39.3	41.6
TDS	210	130	180	120	180	130	300	240	270	110	420	230	180	270	340	280
TSS	8.1	BDL	3.7	BDL	38.3	7.5	4.7	23	11.8	7.3	13.8	9.6	12.6	15.1	11.5	13.7
Sulphate	73.7	76.15	87.22	93.05	83.7	89.6	86.3	76.9	103.5	69.3	129.3	75.35	53.72	61.62	57.38	46.61
Phosphate	0.63	0.49	4.89	0.82	7.2	4.32	4.96	5.45	2.34	2.29	2.95	1.35	1.85	1.8	1.66	1.44
Chloride	18.7	18.2	11.4	11.6	12.1	10.9	12.6	11.8	49.6	52.2	55.3	55.5	56.1	53.4	51.6	55.1
Calcium	1.04	0.73	8.29	0.93	91.6	7.82	12.55	0.81	37.65	20.12	94.31	61.91	39.3	35.1	55.38	32.4
Magnesium	0.61	0.92	0.75	1.16	6.45	1.83	1.63	2.24	2.74	1.47	4.53	1.29	2.54	3.18	4.84	3.08
Sodium	4.04	4.54	1.89	8.66	13.17	11.6	15.63	13.03	6.38	3.64	8.54	14.67	6.51	9.68	5.76	4.26
Potassium	0.83	0.9	1.33	2.42	21.37	10.29	8.89	7.94	8.62	9.29	11.19	11.76	7.71	15.62	10.69	8.03
Arsenic	0.08	0.07	0.03	0.03	0.02	0.05	0.04	0.07	0.04	0.09	0.08	0.08	0.09	0.08	0.07	0.06
Manganese	0.1	BDL	0.2	0.1	0.3	0.1	0.3	0.1	0.3	0.2	0.2	0.4	0.3	0.23	0.3	0.30
Cadmium	0.02	BDL	0.02	0.02	0.03	0.02	0.02	0.01	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.03
Chromium	0.06	0.03	0.02	0.01	0.03	0.02	0.01	0.02	0.07	0.7	0.07	0.06	0.06	0.05	0.04	0.04
Lead	0.01	BDL	0.01	0.02	0.02	0.01	BDL	0.01	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.02
Zinc	0.19	0.16	0.17	0.14	0.13	0.17	0.15	0.13	0.36	0.23	0.17	0.24	0.19	0.19	0.16	0.15
Copper	0.11	0.04	0.12	0.06	0.07	0.23	0.09	0.04	0.11	0.10	0.06	0.09	0.07	0.08	0.06	0.06
Cyanide	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Nickel	0.05	0.03	0.03	0.04	0.05	0.04	0.03	0	0.05	0.09	0.08	0.08	0.07	0.1	0.11	0.13
Vanadium	0.03	0.03	0.02	0.01	0.03	0.01	0.01	0.00	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
E.Coli	2	1	1	2	6	2	1	BDL	5	6	5	4	3	3	2	2
Coliform	14	11	14	17	18	13	9	8	47	43	46	48	42	45	36	38

BDL = Below Detection Limit

Table 4.3: Physicochemical parameters of groundwater samples in the study area with comparism to standard.

Parameters	OSBH ₁	OSBH ₂	OSBH ₃	OSBH ₄	OSBH ₅	OSBH ₆	OSBH ₇	OSBH ₈	OSHW ₁	OSHW ₂	OSHW ₃	OSHW ₄	OSHW ₅	OSHW ₆	OSHW ₇	OSHW ₈	NSDWQ (2007)	WHO (2011)
pH	5.4	5.69	5.89	5.96	5.55	5.44	5.49	5.63	5.59	5.78	5.28	5.76	5.6	5.67	5.73	5.69	6.5	8.5
EC	400	250	350	250	260	210	610	100	550	220	850	460	370	350	410	480	1000	1000
Temperature	26	26.02	26.01	25.8	26.04	26.2	26.25	26.24	26.28	26.31	26..25	26.38	26.43	26.61	26.75	26.63	N/S	N/S
Turbidity	2.6	0	1.9	0	2.2	1.1	1.5	1.6	12.4	14.8	12.5	10.3	10.4	12.1	11.4	9.4	5	5
Alkalinity	6.5	9.7	7.4	5.1	7.8	7.4	6.3	6.4	5.6	6.6	13.8	5.3	8.2	5.1	6.2	6.5	150	N/S
BOD	0.56	0.43	0.52	0.73	0.49	1.36	0.41	0.26	23.13	17.56	26.03	20.06	26.03	14.32	16.49	12.26	N/S	N/S
COD	12.1	22.4	38.3	18.4	16.1	51.9	32.7	40.4	52.6	26.4	68.6	27.2	48.1	51.9	39.3	41.6	N/S	N/S
TDS	210	130	180	120	180	130	300	240	270	110	420	230	180	270	340	280	500	600
TSS	8.1	0	3.7	0	38.3	7.5	4.7	23	11.8	7.3	13.8	9.6	12.6	15.1	11.5	13.7	N/S	N/S
Sulphate	73.7	76.15	87.22	93.05	83.7	89.6	86.3	76.9	103.5	69.3	129.3	75.35	53.72	61.62	57.38	46.61	100	260
Phosphate	0.63	0.49	4.89	0.82	7.2	4.32	4.96	5.45	2.34	2.29	2.95	1.35	1.85	1.8	1.66	1.44	N/S	N/S
Chloride	18.7	18.2	11.4	11.6	12.1	10.9	12.6	11.8	49.6	52.2	55.3	55.5	56.1	53.4	51.6	55.1	250	250
Calcium	1.04	0.73	8.29	0.93	91.6	7.82	12.55	0.81	37.65	20.12	94.31	61.91	39.3	35.1	55.38	32.4	260	260
Magnesium	0.61	0.92	0.75	1.16	6.45	1.83	1.63	2.24	2.74	1.47	4.53	1.29	2.54	3.18	4.84	3.08	0.2	N/S
Sodium	4.04	4.54	1.89	8.66	13.17	11.6	15.63	13.03	6.38	3.64	8.54	14.67	6.51	9.68	5.76	4.26	200	200
Potassium	0.83	0.9	1.33	2.42	21.37	10.29	8.89	7.94	8.62	9.29	11.19	11.76	7.71	15.62	10.69	8.03	N/S	260
Arsenic	0.08	0.07	0.03	0.03	0.02	0.05	0.04	0.07	0.04	0.09	0.08	0.08	0.09	0.08	0.07	0.06	0.01	0.01
Manganese	0.1	0.0	0.2	0.1	0.3	0.1	0.3	0.1	0.3	0.2	0.2	0.4	0.3	0.23	0.3	0.30	0.2	0.4
Cadmium	0.02	0	0.02	0.02	0.03	0.02	0.02	0.01	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.03	0.003	0.003
Chromium	0.06	0.03	0.02	0.01	0.03	0.02	0.01	0.02	0.07	0.7	0.07	0.06	0.06	0.05	0.04	0.04	0.05	0.05
Lead	0.01	0	0.01	0.02	0.02	0.01	0	0.01	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.01
Zinc	0.19	0.16	0.17	0.14	0.13	0.17	0.15	0.13	0.36	0.23	0.17	0.24	0.19	0.19	0.16	0.15	3	4
Copper	0.11	0.04	0.12	0.06	0.07	0.23	0.09	0.04	0.11	0.10	0.06	0.09	0.07	0.08	0.06	0.06	1	2
Cyanide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.07
Nickel	0.05	0.03	0.03	0.04	0.05	0.04	0.03	0	0.05	0.09	0.08	0.08	0.07	0.1	0.11	0.13	0.02	0.07
Vanadium	0.03	0.03	0.02	0.01	0.03	0.01	0.01	0.00	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	N/S	N/S
E.Coli	2	1	1	2	6	2	1	0	5	6	5	4	3	3	2	2	0	N/S
Coliform	14	11	14	17	18	13	9	8	47	43	46	48	42	45	36	38	10	N/S
BH Depth	50	50	60	45	55	50	65	65										

BDL = Below Detection Limit

Table 4.4: Summary of physicochemical parameters of groundwater samples in the study area.

	BOREHOLES					HAND-DUG WELLS					NSDWQ (2007)	WHO (2011)
	Mean	Std.E	Std.Dev	Min	Max	Mean	Std.E	Std.D	Min	Max		
<i>pH</i>	5.63	0.07	0.21	5.4	5.96	5.64	0.06	0.16	5.28	5.78	6.5	8.5
<i>EC</i>	303.75	53.98	152.68	100	610	461.25	65.59	185.51	220	850	1000	1000
<i>Temp</i>	26.07	0.05	0.15	25.8	26.25	26.46	0.07	0.19	26.25	26.75	N/S	N/S
<i>Turb</i>	1.36	0.34	0.95	0	2.6	11.66	0.60	1.69	9.4	14.8	5	5
<i>Alkty</i>	7.08	0.48	1.36	5.1	9.7	7.16	1.01	2.85	5.1	13.8	150	N/S
<i>BOD</i>	0.60	0.12	0.34	0.26	1.36	19.49	1.85	5.22	12.26	26.03	N/S	N/S
<i>COD</i>	29.04	4.93	13.95	12.1	51.9	44.46	4.96	14.02	26.4	68.6	N/S	N/S
<i>TDS</i>	248.75	65.42	185.04	120	680	262.50	33.37	94.38	110	420	500	600
<i>TSS</i>	10.66	4.71	13.33	0	38.3	11.93	0.89	2.51	7.3	15.1	N/S	N/S
<i>SO4</i>	83.33	2.48	7.01	73.7	93.05	74.60	9.95	28.13	46.61	129.3	100	260
<i>PO4</i>	3.60	0.91	2.58	0.49	7.2	1.96	0.19	0.54	1.35	2.95	N/S	N/S
<i>Cl</i>	13.41	1.11	3.15	10.9	18.7	53.6	0.81	2.30	49.6	56.1	250	250
<i>Ca</i>	15.47	10.99	31.09	0.73	91.6	47.02	8.19	23.16	20.12	94.31	260	260
<i>Mg</i>	1.95	0.67	1.90	0.61	6.45	2.96	0.45	1.27	1.29	4.84	0.2	N/S
<i>Na</i>	9.07	1.79	5.06	1.89	15.63	7.43	1.25	3.54	3.64	14.67	200	200
<i>K</i>	6.75	2.50	7.07	0.83	21.37	10.36	0.92	2.59	7.71	15.62	N/S	260
<i>As</i>	0.67	0.04	0.12	0.51	0.83	0.77	0.05	0.15	0.41	0.9	0.01	0.01
<i>Mn</i>	0.24	0.09	0.27	0.03	0.76	0.23	0.05	0.15	0.03	0.43	0.2	0.4
<i>Cd</i>	0.02	0.00	0.01	0	0.03	0.04	0.00	0.00	0.03	0.04	0.003	0.003
<i>Cr</i>	0.02	0.01	0.01	0.013	0.06	0.14	0.08	0.23	0.04	0.71	0.05	0.05
<i>Pb</i>	0.01	0.00	0.01	0	0.02	0.02	0.00	0.00	0.02	0.03	0.01	0.01
<i>Zn</i>	0.16	0.01	0.02	0.13	0.19	0.21	0.02	0.07	0.15	0.36	3	4
<i>Cu</i>	0.09	0.02	0.06	0.04	0.23	0.08	0.01	0.02	0.06	0.11	1	2
<i>Cn</i>	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.07
<i>Ni</i>	0.039	0.006	0.018	0	0.059	0.08	0.01	0.02	0.06	0.10	0.02	0.07
<i>V</i>	0.017	0.004	0.011	0	0.029	0.047	0.002	0.005	0.038	0.052	N/S	N/S
<i>E.Coli</i>	1.88	0.64	1.81	0	6	3.75	0.53	1.49	2	6	0	N/S
<i>Coliform</i>	13	1.25	3.55	8	18	43.13	1.52	4.29	36	48	10	N/S

BDL = Below Detection Limit

N/S = No Specification

Table 4.5: Summary of physicochemical parameters of soil samples and control in the study area.

	Mean	Std.E	Std.D	Min	Max	Control mean
pH (0-15cm)	4.65	0.26	0.86	2.6	5.7	4.7
pH (15-30cm)	4.48	0.34	1.11	2.3	6.2	3.9
EC (0-15cm)	1354.55	290.65	963.97	270	3010	2050
EC (15-30cm)	1379.09	277.83	921.47	510	2990	2100
O.M (0-15cm)	2.75	0.45	1.48	0.93	5.83	3.5
O.M (15-30cm)	2.35	0.42	1.41	0.52	5.44	2.49
Na (0-15cm)	11.79	0.53	1.76	9.4	15.6	9.9
Na (15-30cm)	10.76	0.45	1.48	7.7	13.1	9.6
K (0-15cm)	8.05	0.43	1.42	4.7	9.4	8.7
K (15-30cm)	6.8	0.6	1.99	3.9	9.3	4.4
Mg (0-15cm)	10.57	0.65	2.16	8.1	14.9	10.8
Mg (30-15cm)	10.03	0.58	1.93	6.3	13.2	6.3
Ca (0-15cm)	13.57	0.59	1.97	10.5	17.3	13.3
Ca (15-30cm)	12.22	0.7	2.31	8.6	15.2	8.6
As (0-15cm)	18.23	1.01	3.34	11.56	23.4	11.56
As (15-30cm)	16.32	0.92	3.05	10.58	21.2	10.58
Mn (0-15cm)	3.27	0.18	0.61	1.46	3.58	1.46
Mn (15-30cm)	3.27	0.19	0.62	1.42	3.52	1.42
Cd (0-15cm)	2.26	0.19	0.63	1.08	3.46	1.08
Cd (15-30cm)	2.24	0.19	0.62	1.06	3.43	1.06
Cr (0-15cm)	3.53	0.22	0.74	1.64	4.52	1.64
Cr (15-30cm)	3.5	0.23	0.76	1.61	4.55	1.61
Pb (0-15cm)	2.8	0.13	0.45	2.14	3.69	2.14
Pb (15-30cm)	2.8	0.14	0.46	2.11	3.71	2.11
Zn (0-15cm)	9.99	0.63	2.1	5.79	14.21	5.79
Zn (15-30cm)	10.27	0.78	2.57	5.77	15.5	5.77
Cu (0-15cm)	2.48	0.15	0.5	1.86	3.23	1.86
Cu (15-30cm)	2.2	0.13	0.42	1.69	3.17	1.69
Cn (0-15cm)	0	0	0	0	0.005	0
Cn (15-30cm)	0	0	0	0	0.006	0
Ni (0-15cm)	2.94	0.24	0.81	1.35	4.59	1.35
Ni (15-30cm)	2.77	0.25	0.84	1.31	4.51	1.31
V (0-15cm)	2.81	0.21	0.69	1.24	3.81	1.24
V (15-30cm)	2.83	0.24	0.79	1.26	3.95	1.26

Table 4.6: Spearman's correlation coefficient matrix of groundwater quality parameters.

Parameters	pHBH	ECBH	TempBH	TurbBH	AlktyBH	BODBH	CODBH	TDSBH	TSSBH	SO4BH	PO4BH	ClBH	CaBH	MgBH	NaBH	KBH	AsBH	MnBH	CdBH	CrBH	PbBH	ZnBH	CuBH	NiBH	VBH	FeBH
pHHW	.333	-.323	.143	-.850**	-.180	-.262	.048	-.359	-.515	.071	-.310	.190	-.548	.167	.333	0.000	-.072	-.500	-.299	-.310	-.263	-.398	-.714*	-.132	-.429	-.001
ECHW	.119	.311	-.333	.575	-.455	0.000	-.095	.132	.120	-.024	.143	-.071	.095	-.429	-.429	-.405	.217	.190	-.144	-.167	.084	.205	.286	-.156	-.048	-.001
TempHW	-.286	-.228	.833*	-.228	-.371	-.405	.405	.395	.347	.167	.548	-.095	.167	.762*	.929**	.714*	.843**	.381	.180	-.571	-.180	-.566	-.143	0.000	-.690	-.001
TurbHW	-.095	.359	-.262	0.000	.623	.190	-.071	-.275	-.431	-.286	-.619	.238	-.071	-.690	-.643	-.548	.410	-.310	-.323	.571	-.383	.771*	.262	-.096	.595	-.001
AlktyHW	.381	.216	.048	.359	.515	-.548	-.095	.443	.096	-.310	.357	.143	.214	0.000	-.143	-.071	.024	.429	-.192	.143	-.335	-.229	-.238	-.216	.238	-.001
BODHW	.204	.554	-.623	.482	.307	.275	-.647	.120	-.024	-.024	-.012	.132	.455	-.359	-.431	-.204	.545	.216	.319	.359	.386	.182	.204	.482	.719*	-.001
CODHW	-.381	.252	-.119	.755*	.144	.357	.095	.228	.443	0.000	.214	-.286	.476	-.214	-.381	-.024	.036	.405	.275	.286	.240	.518	.810*	.036	.357	-.001
TDSHW	-.084	.301	.311	.325	-.440	-.168	.491	.247	.084	.216	.359	-.323	.323	-.156	-.036	0.000	-.455	.467	-.060	-.515	-.301	.224	.527	-.398	-.455	-.001
TSSHW	-.286	-.252	.286	.419	.132	.238	.595	.180	.515	.262	.476	-.667	.381	.286	-.024	.405	-.422	.476	.383	0.000	.216	.169	.690	-.275	-.095	-.001
SO4HW	.214	.395	-.786*	.036	.024	.571	-.262	-.563	-.587	.119	-.667	-.024	-.095	-.905**	.881**	.714*	.699	-.429	-.108	.262	.144	.759*	.381	.012	.452	-.001
PO4HW	-.190	.443	-.286	.515	.671	.119	-.214	.096	.012	-.429	-.262	.238	.190	-.571	-.643	-.452	.422	.048	-.180	.690	-.204	.663	.381	.024	.762*	-.001
ClHW	.619	-.359	-.190	-.048	.072	.119	.024	-.012	.096	.524	.500	-.571	.238	.500	.119	.476	-.060	.310	.575	-.238	.611	-.615	-.143	.012	-.095	-.001
CaHW	.333	.551	-.333	.192	-.419	.286	-.167	.024	-.216	.595	.238	-.333	.595	-.214	-.119	.071	.012	.405	.503	-.476	.371	.048	.429	.252	-.048	-.001
MgHW	-.381	.347	.619	.299	-.132	-.214	.571	.407	.204	.119	.405	-.238	.500	.024	.190	.238	-.675	.595	.036	-.357	-.455	.277	.619	-.275	-.333	-.001
NaHW	.167	-.036	-.452	-.060	-.275	.833*	.024	-.407	-.132	.810*	.024	-.690	.357	0.000	-.167	.262	.096	.048	.778*	-.214	.838**	.145	.571	.275	.024	-.001
KHW	.190	-.084	-.190	-.587	-.263	.643	.452	-.743*	-.659	.762*	-.405	-.619	-.048	-.286	-.262	-.024	-.060	-.333	.252	-.357	.180	.446	.476	-.216	-.286	-.001
AsHW	.347	-.343	.024	.090	.373	.192	.287	.072	.235	.491	.551	-.707	.419	.515	.072	.587	-.242	.467	.639	-.060	.482	-.345	.204	-.090	.024	-.001
MnHW	.071	.587	-.643	.180	-.335	.381	-.833*	-.036	-.156	.119	-.190	.310	.286	-.333	-.119	-.190	.530	-.048	.347	.024	.527	.060	.048	.778*	.405	-.001
CdHW	-.786*	.719*	.095	.455	.168	.143	-.476	.419	.287	-.357	-.095	.548	.524	-.190	.143	.024	.048	.238	.192	.405	-.060	.446	.429	.731*	.571	-.001
CrHW	.095	.311	-.667	.120	.611	.262	-.571	-.275	-.335	-.405	-.643	.429	-.167	-.667	-.714*	-.643	.819*	-.429	-.240	.762*	0.000	.518	-.048	.216	.857**	-.001
PbHW	.060	.267	-.843**	-.097	.085	.578	-.530	-.624	-.545	-.133	-.892**	.301	-.349	-.843**	-.771*	.771*	.890**	-.723*	-.212	.506	.194	.677	.084	.242	.602	-.001
ZnHW	-.072	.145	-.802*	-.060	.114	.647	-.695	-.500	-.289	-.132	-.743*	.335	-.252	-.527	-.503	-.491	.855**	-.647	.048	.587	.470	.436	0.000	.542	.683	-.001
CuHW	-.238	.156	-.595	-.156	.180	.524	-.619	-.455	-.299	-.262	-.810*	.476	-.310	-.500	-.381	-.476	.735*	-.690	-.084	.619	.240	.482	-.048	.515	.643	-.001
CnHW																										-.001
NiHW	.095	.299	-.857**	.036	.263	.452	-.690	-.455	-.419	-.286	-.786*	.429	-.286	-.762*	-.738*	.738*	.952**	-.619	-.204	.643	.204	.542	-.048	.335	.762*	-.001
VHW	.156	.259	-.838**	-.042	.313	.419	-.659	-.488	-.476	-.275	-.802*	.419	-.323	-.743*	-.731*	.731*	.939**	-.647	-.229	.635	.163	.509	-.108	.289	.743*	-.001
E.ColiHW	.267	.146	-.764*	-.073	.488	.364	-.400	-.543	-.537	-.242	-.776*	.242	-.364	-.764*	.861**	.752*	.859**	-.618	-.317	.643	.018	.577	-.048	-.006	.691	-.001
ColiformHW	.238	0.000	-.929**	-.048	-.108	.810*	-.333	-.707	-.407	.262	-.619	-.190	-.238	-.619	-.762*	-.524	.783*	-.571	.132	.286	.611	.506	.262	.156	.405	-.001

*. Correlation is significant at the 0.05 level (2-tailed). $r(0.05)(\infty 2) df(2)=0.811$

**. Correlation is significant at the 0.01 level (2-tailed). $r(0.01)(\infty 2) df(2)=0.917$

Bold values = Significant (P<0.05) , Bold values with underline = Highly Significant (P<0.01)

Table 4.7: Test of Difference between Control and Soil samples.

	Control Mean $\pm$ SE	Soil Mean $\pm$ SE	<i>F-value</i>	<i>P-value</i>
pH	4.5 $\pm$ 0.2	4.36 $\pm$ 0.2	0.00350	**P<0.01
EC	219 $\pm$ 4	1576.8 $\pm$ 749.1	2.03736	P>0.05
O.M	3.44 $\pm$ 0.31	3.31 $\pm$ 0.34	2.55403	P>0.05
Na	6.27 $\pm$ 0.25	4.1 $\pm$ 1.0.27	0.00168	**P>0.01
K	6.32 $\pm$ 0.08	2.77 $\pm$ 0.57	0.28793	P>0.05
Mg	7.3 $\pm$ 0.1	4.65 $\pm$ 0.18	0.27197	P>0.05
Ca	10.3 $\pm$ 0.4	8.46 $\pm$ 1.38	0.08797	*P>0.05
As	19.2 $\pm$ 0.6	17.89 $\pm$ 1.07	0.00004	**P<0.01
Mn	3.64 $\pm$ 0.03	3.45 $\pm$ 0.25	1.20917	P>0.05
Cd	2.37 $\pm$ 0.56	1.07 $\pm$ 0.56	7.36368	P>0.05
Cr	3.71 $\pm$ 0.37	1.60 $\pm$ 0.37	4.32242	P>0.05
Pb	2.9 $\pm$ 0.15	2.10 $\pm$ 0.38	2.08313	P>0.05
Zn	9.09 $\pm$ 0.08	5.21 $\pm$ 0.14	2.02502	P>0.05
Cu	5.39 $\pm$ 0.12	4.97 $\pm$ 0.31	0.00192	**P<0.01
Cn	2.63 $\pm$ 0.06	1.18 $\pm$ 0.65	0.00323	**P<0.01
Ni	3.64 $\pm$ 0.03	2.76 $\pm$ 0.33	3.76520	P>0.05
V	2.87 $\pm$ 0.15	1.50 $\pm$ 0.07	7.36368	P>0.05

*Bold values indicate significant difference and **Bold indicate highly significant difference

Table 4.8: Results of CF and PLI of heavy metals in sediments from the dumpsite.

Sample Code	Soil Assessment	Elements								
		As	Mn	Cd	Cr	Pb	Zn	Cu	Ni	V
SS1	CF	1.6	2.8	1.9	2.2	1.3	1.5	1.1	2.4	2.3
	PLI					2				
SS2	CF	2.01	2.72	1.98	2.15	1.19	1.72	1.37	2.02	2.06
	PLI					1.9				
SS3	CF	1.84	2.78	1.99	2.16	1.2	1.78	1.07	2.47	2.28
	PLI					1.9				
SS4	CF	1.66	2.8	2.06	2.19	1.74	1.73	1.18	1.77	2
	PLI					2				
SS5	CF	1.57	2.71	3.01	2.77	1.35	1.75	1.36	2.39	2.24
	PLI					2.04				
SS6	CF	1.22	2.72	1.97	2.14	1.32	1.89	1.2	1.82	3.05
	PLI					1.8				
SS7	CF	1.29	2.8	1.98	2.16	1.08	2.15	1.53	1.96	3.1
	PLI					2				
SS8	CF	1.67	2.82	3.22	2.78	1.61	2.57	1.19	2.53	1.84
	PLI					2.15				
SS9	CF	1.69	2.72	1.93	2.12	1.36	1.41	1.8	3.42	2.69
	PLI					2.03				
SS10	CF	1.6	2.74	2.08	2.1	1.33	1.81	1.62	1.83	2.27
	PLI					2				

Table 4.9: The Contamination and Pollution Levels based on CF and PLI Values (Hakanson 1980; Tomlinson *et al.*, 1980).

Sample Locations	CF.As	CF.Mn	CF.Cd	CF.Cr	CF.Pb	CF.Zn	CF.Cu	CF.Ni	CF.V	PLI	Remarks
1	1.6	2.8	1.9	2.2	1.3	1.5	1.1	2.4	2.3	2	Slightly Polluted/Moderately Contaminated
2	2.01	2.72	1.98	2.15	1.19	1.72	1.37	2.02	2.06	1.9	Slightly Polluted/Moderately Contaminated
3	1.84	2.78	1.99	2.16	1.2	1.78	1.07	2.47	2.28	1.9	Slightly Polluted/Moderately Contaminated
4	1.66	2.8	2.06	2.19	1.74	1.73	1.18	1.77	2	2	Slightly Polluted/Moderately Contaminated
5	1.57	2.71	3.01	2.77	1.35	1.75	1.36	2.39	2.24	2.04	Moderately-Highly Polluted/Moderately Contaminated
6	1.22	2.72	1.97	2.14	1.32	1.89	1.2	1.82	3.05	1.8	Slightly Polluted/Moderately Contaminated
7	1.29	2.8	1.98	2.16	1.08	2.15	1.53	1.96	3.1	2	Slightly Polluted/Moderately Contaminated
8	1.67	2.82	3.22	2.78	1.61	2.57	1.19	2.53	1.84	2.15	Moderately-Highly Polluted/ Moderately Contaminated
9	1.69	2.72	1.93	2.12	1.36	1.41	1.8	3.42	2.69	2.03	Moderately-Highly Polluted/ Moderately

											<i>Contaminated</i>
10	1.6	2.74	2.08	2.1	1.33	1.81	1.62	1.83	2.27	2	<i>Slightly Polluted/Moderately Contaminated</i>

4.2 DATA PRESENTATION

Physicochemical and bacteriological water quality parameters analyzed for groundwater samples were Hydrogen potential, Electrical conductivity, Temperature, Turbidity, Alkalinity, Total Suspended Solids, Total Dissolved Solids, Biological Oxygen Demand, Chemical Oxygen Demand, Sulphate, Phosphate, Chloride, Sodium, Potassium, Calcium, Magnesium, Arsenic, Manganese, Cadmium, Chromium, Copper, Zinc, Lead, Cyanide, Nickel, Vanadium, E.Coli, and Coliform. Physicochemical parameters analyzed for soil were Hydrogen Potential, Electrical Conductivity, Organic Matter, Sodium, Potassium, Magnesium, Calcium, Arsenic, Manganese, Cadmium, Chromium, Copper, Zinc, Lead, Cyanide, Nickel and Vanadium. The results are presented in Tables 4.1 and 4.2.

4.3 DESCRIPTIVE ANALYSIS

The summary of physicochemical analysis which includes mean, maximum values, minimum values, standard error and standard deviations for groundwater of control for soil samples and Nigerian Standard for Drinking Water Quality (NSDWQ, 2007), World Health Organization (WHO, 2011) limit for groundwater samples were indicated in Tables 4.3 and 4.4. The concentrations of the parameters in the study area for groundwater exceed both the NSDWQ (2007) and WHO (2011) permissible limit in some locations except for Hydrogen potential, Electrical conductivity, Alkalinity, Total Dissolved Solids, Sulphate, Chloride, Calcium, Sodium, Potassium, Zinc and Copper.

DISCUSSION OF RESULTS

4.3.1 GROUNDWATER

4.3.2. PHYSICO-CHEMICAL CHARACTERISTICS

4.3.3 HYDROGEN POTENTIAL

pH is the hydrogen-ion activity of water and also the negative base -10 log of the hydrogen ion activity in moles per liter. The pH recorded for groundwater in the study area ranged

from 5.40 to 5.96 (Table 4.3). Sample OSBH4 has the highest value of 5.96 while OSHW3 recorded the lowest value of 5.28. The pH recorded falls below the acceptable NSDWQ and WHO limit of 6.5 – 8.5. Hence, the groundwater is acidic. The distribution of pH concentration in groundwater across the study area is presented in figure 4.1.

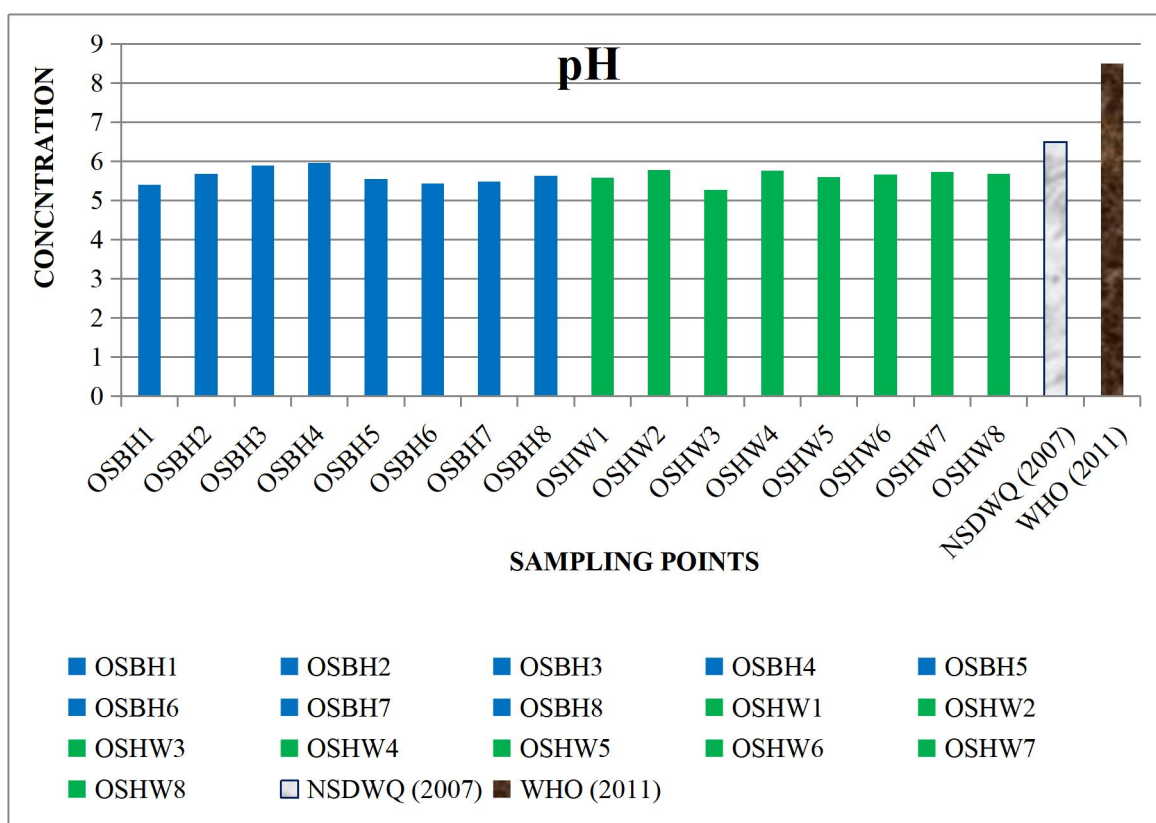


Figure 4.1: Comparative Hydrogen Potential values with NSDWQ and WHO limit of borehole hand-dug well locations within the study area.

4.3.4. ELECTRICAL CONDUCTIVITY

Electrical conductivity is a measure of how well a material accommodates the transport of electric charge. It helps to estimate the amount of total dissolved salts or the total amount of dissolved ions in water. Electrical conductivity recorded in borehole and hand-dug samples collected from the study area indicates mean value of 313.75 and 461.25 μ S/cm respectively and a minimum and maximum value of 100 and 850 μ S/cm respectively (Table 4.3). When compared to NSDWQ and WHO standards, all values recorded falls within the standards. The distribution of Electrical conductivity values in groundwater across the study area is presented in figure 4.2.

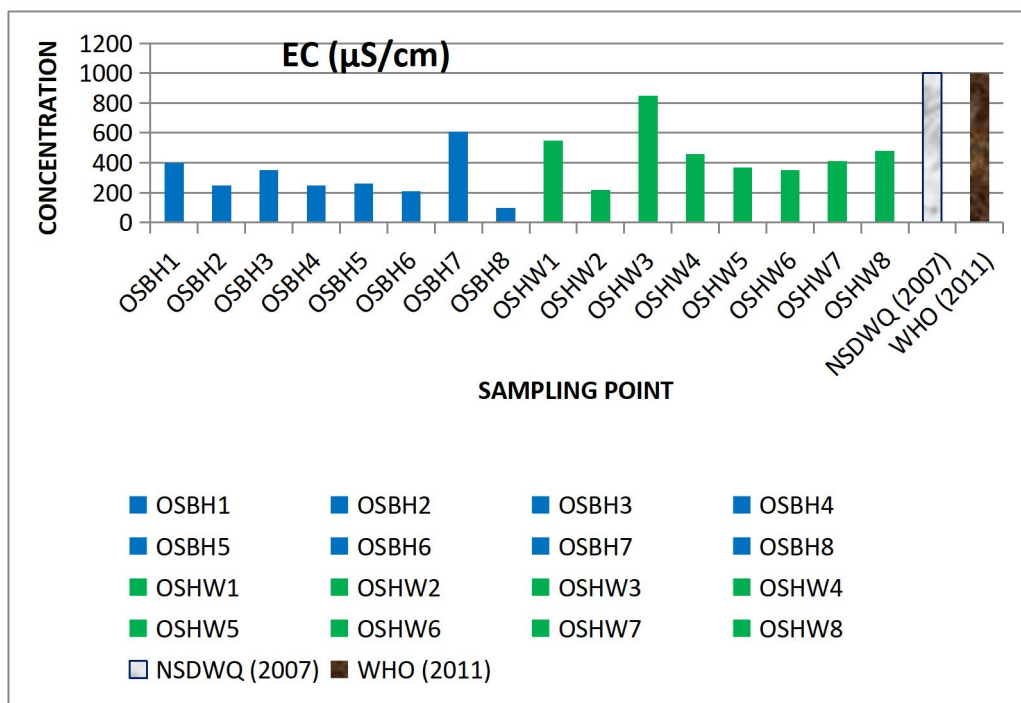


Figure 4.2: Comparative Electrical Conductivity values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.3.5 TURBIDITY

Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particles. The more total suspended solids in the water, the murkier it seems and the higher the turbidity. Turbidity values recorded in the study area ranged between 0 and 14.8NTU with a mean value of 1.36 and 11.66NTU for borehole and hand-dug wells respectively (Table 4.3). The turbidity values recorded borehole locations in the study area were below NSDWQ and WHO limit of 5 NTU, except those of hand-dug well locations in the study area.. The low/high turbidity values indicates a transparent/turbid water with very low/high total suspended solids. The distribution of turbidity value across the study area is presented in figure 4.3.

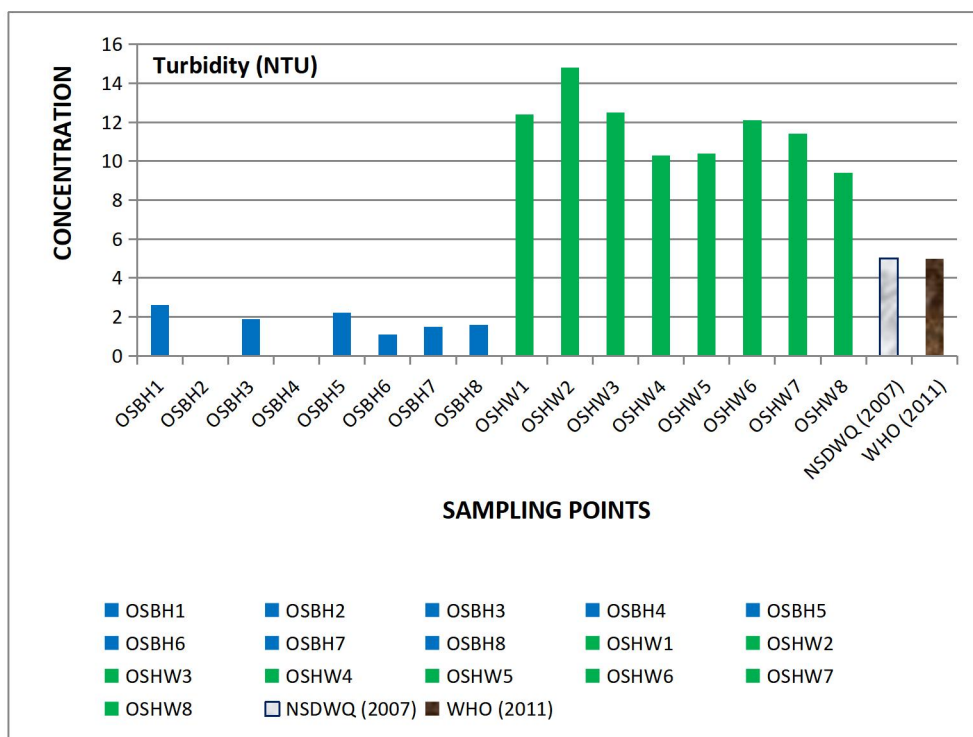


Figure 4.3: Comparative Turbidity values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.3.6 TOTAL DISSOLVED SOLIDS

Total dissolved solids (TDS) comprises inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and some amount of organic matter that are dissolved in water. Values recorded for Total Dissolved Solids in groundwater within the study area ranged from 110-680mg/l (Table 4.4). The highest value of 680 mg/l was recorded in OSBH5 (Table 4.3). The NSDWQ and WHO limit for Total Dissolved Solids is 500 mg/l and 600 mg/l respectively. The TDS values recorded in the study area were within the limit value. The distribution of turbidity value across the study area is presented in figure 4.4.

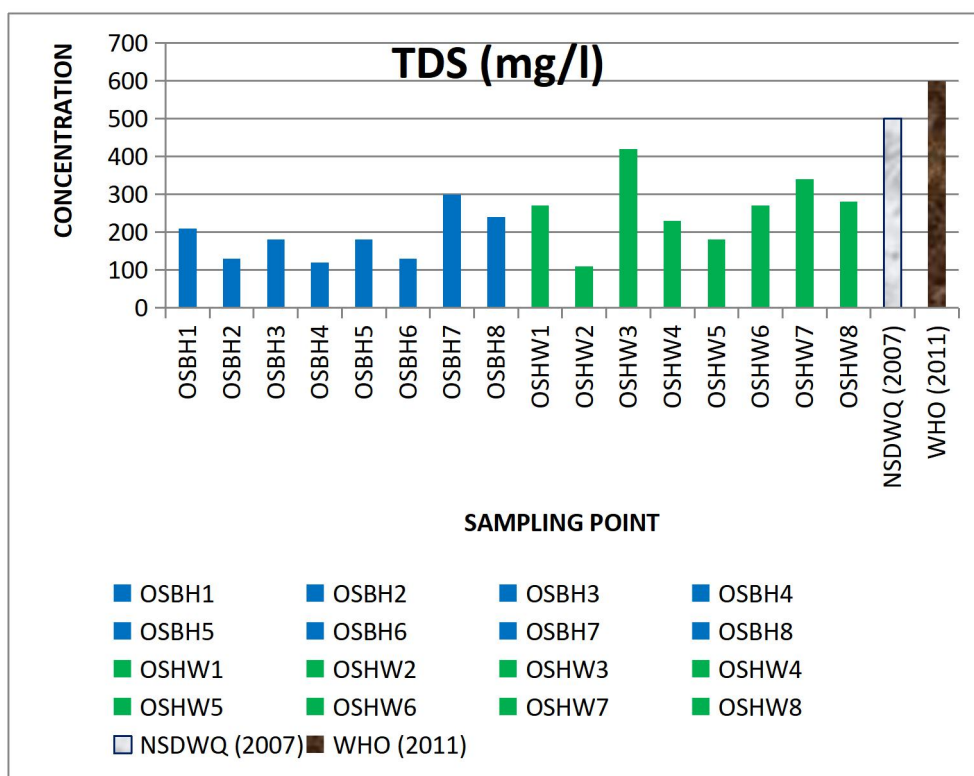


Figure 4.4: Comparative Total Dissolved Solids values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.4 ANIONS

4.4.1 SULPHATE

Sulphate ions are known to readily form complex species. They are also anthropogenic indicators. The Sulphate value for groundwater recorded in the study area ranged from 46.61 to 129.3mg/l. Samples OSHW3 and OSHW8 had the highest and lowest values (Table 4.3). A mean of 83.33 and 74.60mg/l was also recorded in borehole and hand-dug wells sample locations in the study area (Table 4.4). The entire sulphate concentration in groundwater samples fall within the NSDWQ and WHO limits. The distribution of Sulphate concentration in groundwater within the sample locations in the study area is presented in figure 4.5.

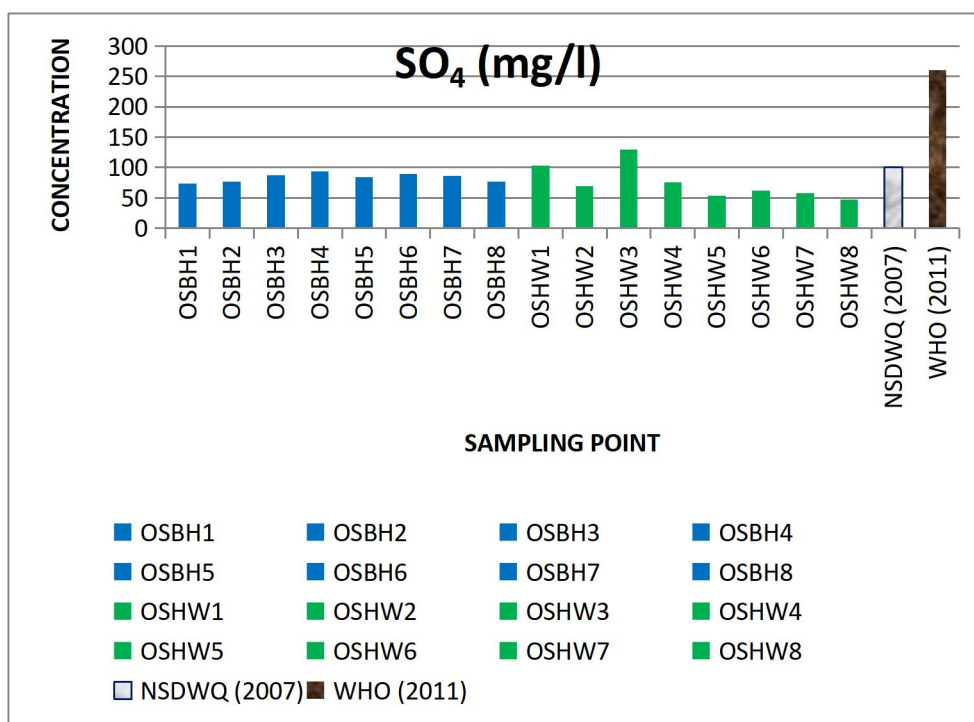


Figure 4.5: Comparative Sulphate values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.4.2 CHLORIDE (Cl⁻)

Chloride naturally occurs in water as a major dissolved constituent. Chloride concentrations recorded in groundwater from the study area ranged between 10.9 to 18.8mg/l in borehole samples and 49.6 to 56.1mg/l in hand-dug wells in sampled locations. The mean and standard deviation value recorded are 13.41/3.15mg/l and 53.6/2.30mg/l in borehole and hand-dug well locations (Table 4.4). The lowest value was recorded in sample OSBH8 while the highest was recorded in sample OSHW5 (Table 4.3). All the chloride concentrations recorded in the groundwater samples were within the NSDWQ and WHO limit of 200 mg/l considering the minimum value recorded as 10.9mg/l (Table 4.3). The distribution of Chloride concentration of surface water samples within the study area is presented in figure 4.6.

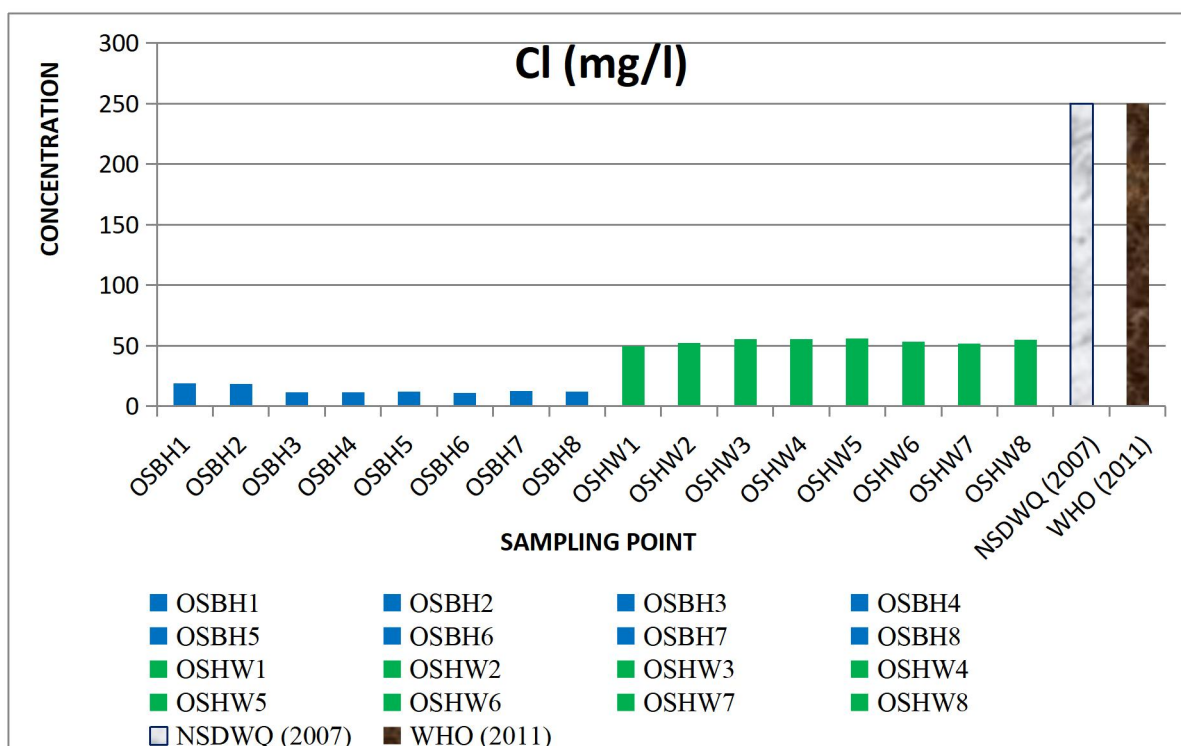


Figure 4.6: Comparative Chloride values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.4.3 CATIONS

4.4.4 CALCIUM

Calcium is the most abundant of the alkali earth metals hence a very common constituent of rock minerals. Due to its abundance it is the most common ion in groundwater. The values recorded for calcium in groundwater samples within the study area ranged from 0.73 to 91.6mg/l in borehole samples and 20.12 to 94.31mg/l in hand-dug wells. The mean and standard deviation recorded for Calcium is 15.47/31.09mg/l and 2.96/1.26mg/l in borehole and hand-dug well locations (Table 4.4). The highest value of Calcium concentration recorded was observed in sample OSHW3 while the lowest value of Calcium concentration recorded was observed in sample OSBH2 (Table 4.3). All the groundwater samples are within NSDWQ and WHO standard. The distribution of Calcium concentration in groundwater within the study area is presented in figure 4.7.

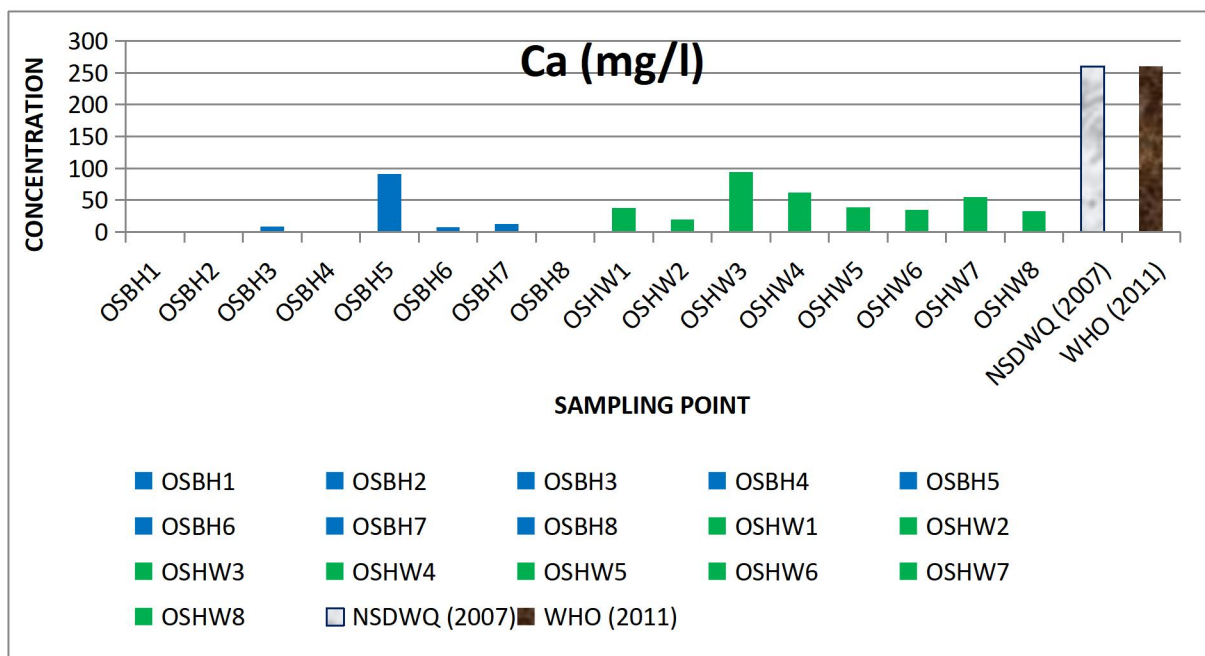


Figure 4.7: Comparative Calcium values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.4.5 MAGNESIUM

Magnesium is a major component of dark colored minerals in igneous rocks. Its chemistry is quite similar to calcium. The values recorded for magnesium in groundwater samples within the study area ranged from 0.61 to 6.45mg/l in borehole samples and 1.29 to 4.84mg/l in hand-dug wells. The mean and standard deviation recorded for magnesium is 1.95/1.90mg/l and 2.96/1.27mg/l in borehole and hand-dug well locations (Table 4.4). The highest value of magnesium concentration recorded was observed in sample OSBH5 while the lowest value of magnesium concentration recorded was observed in sample OSBH1 (Table 4.3). The entire groundwater samples exceed both the NSDWQ and WHO drinking water standard. The distribution of magnesium concentration in groundwater within the study area is presented in figure 4.8.

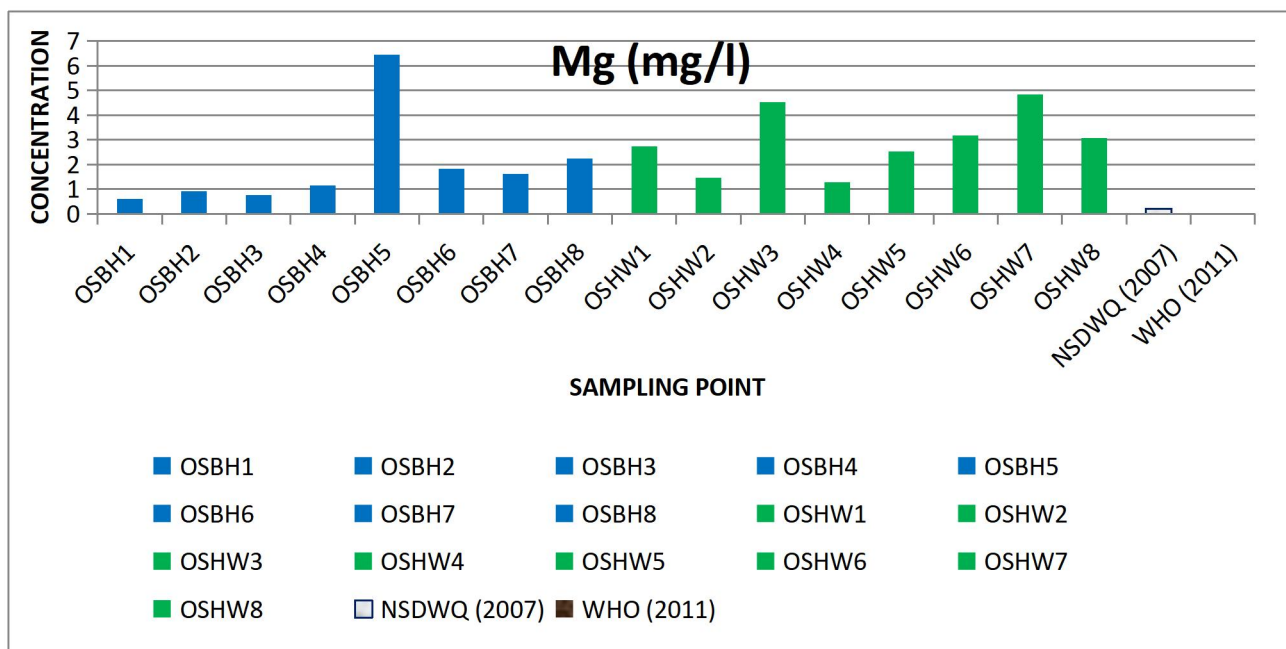


Figure 4.8: Comparative Magnesium values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.4.6 SODIUM

One of the most abundant alkali-earth metal members is Sodium. Rocks containing sodium weather easily to form clay. The values recorded for sodium in groundwater samples within the study area ranged from 1.89 to 15.63mg/l in borehole samples and 3.64 to 14.67mg/l in hand-dug wells. The mean and standard deviation recorded for sodium is 9.07/5.06mg/l and 7.43/3.54mg/l in borehole and hand-dug well locations (Table 4.4). The highest value of sodium concentration recorded was observed in sample OSBH7 while the lowest value of sodium concentration recorded was observed in sample OSBH3 (Table 4.3). The entire groundwater samples fall within the NSDWQ and WHO drinking water standard. The distribution of sodium concentration in groundwater within the study area is presented in figure 4.9.

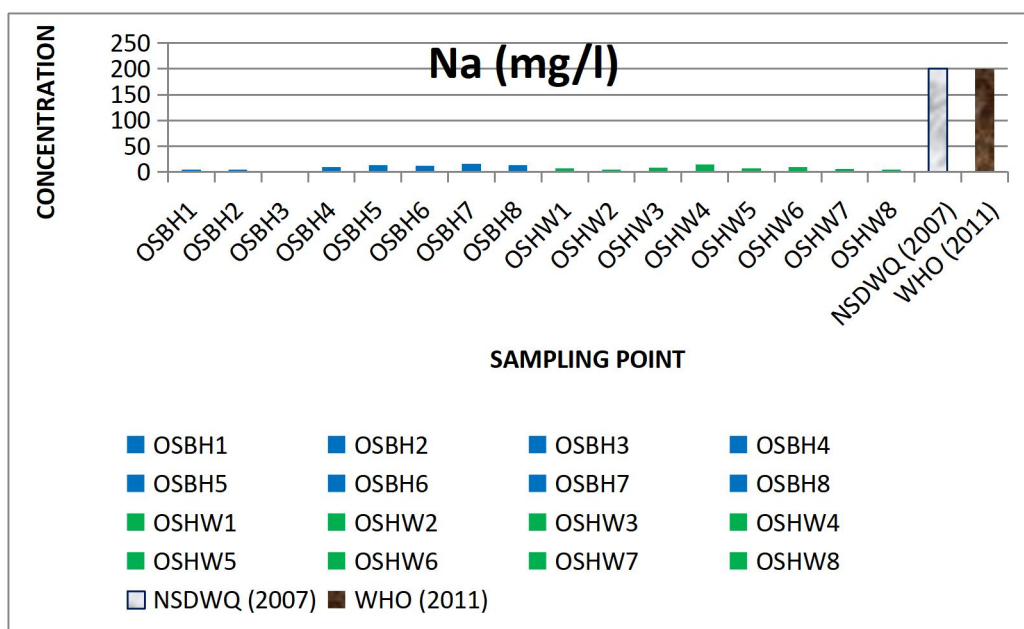


Figure 4.9: Comparative Sodium values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.4.7 POTASSIUM

Potassium is also a member of the alkali earth group and less abundant than sodium. In most cases, potassium concentrations are lower than sodium concentrations. The values recorded for potassium in groundwater samples within the study area ranged from 0.83 to 21.37mg/l in borehole samples and 7.71 to 15.62mg/l in hand-dug wells. The mean and standard deviation recorded for potassium is 6.75/7.07mg/l and 10.36/2.59mg/l in borehole and hand-dug well locations (Table 4.4). The highest value of potassium concentration recorded was observed in sample OSHW6 while the lowest value of potassium concentration recorded was observed in sample OSBH1 (Table 4.3). The entire groundwater samples fall within the NSDWQ and WHO drinking water standard. The distribution of potassium concentration in groundwater within the study area is presented in figure 4.10.

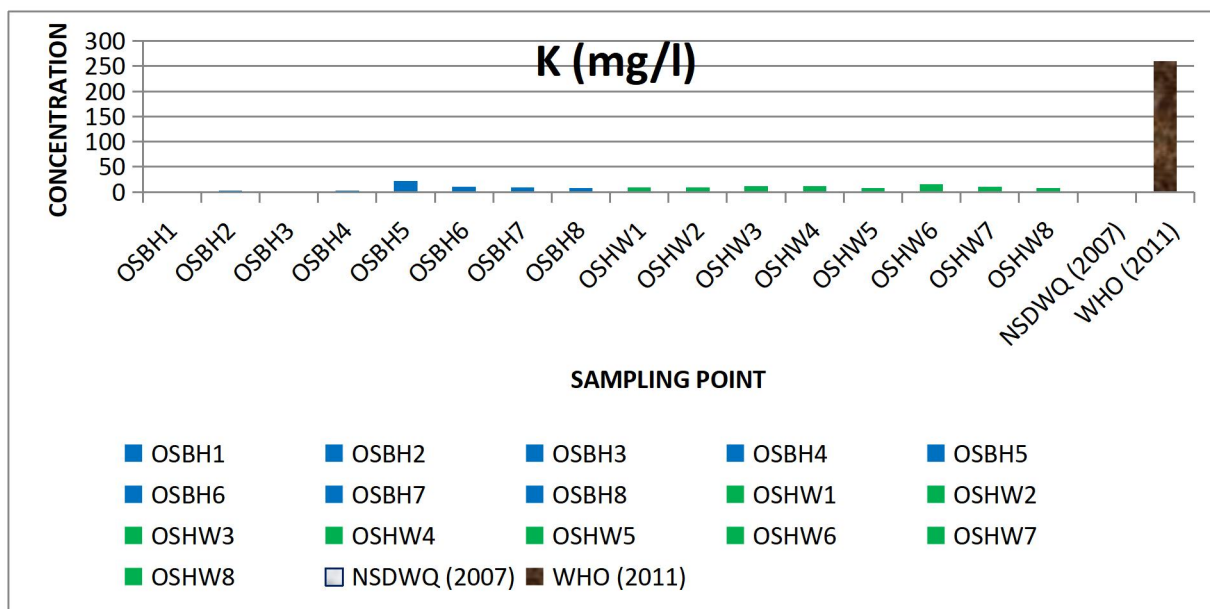


Figure 4.10: Comparative Potassium values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.5 TRACE METALS

4.5.1 ARSENIC

Arsenic occurs in many minerals, usually in combination with sulfur and metals, but also as pure elemental crystal. The values recorded for arsenic in groundwater samples within the study area ranged from 0.51 to 0.83mg/l in borehole samples and 0.41 to 0.9mg/l in hand-dug wells. The mean and standard deviation recorded for arsenic is 0.67/0.12mg/l and 0.77/0.15mg/l in borehole and hand-dug well locations (Table 4.4). The highest value of arsenic concentration recorded was observed in sample OSHW5 while the lowest value of arsenic concentration recorded was observed in sample OSHW1 (Table 4.3). The entire concentration of arsenic groundwater samples exceed the NSDWQ and WHO drinking water standard. The distribution of arsenic concentration in groundwater within the study area is presented in figure 4.11.

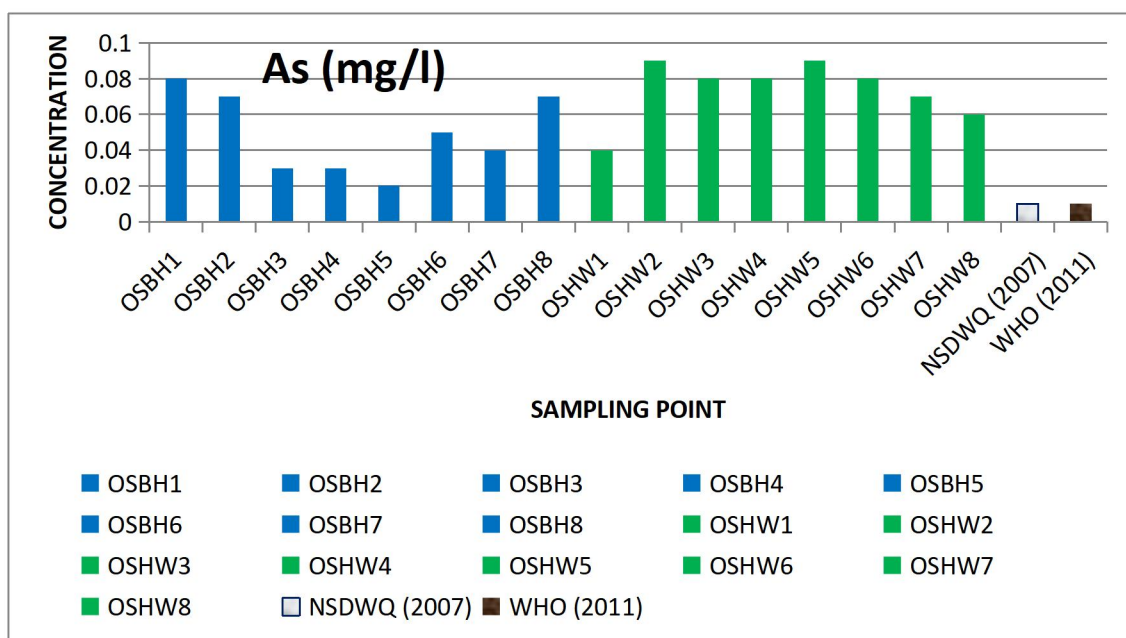


Figure 4.11: Comparative Arsenic values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.5.2 MANGANESE

Manganese is a micronutrient for plant and animal and mostly in association with iron compounds. The values recorded for manganese in groundwater samples within the study area ranged from 0.03 to 0.76mg/l in borehole samples and 0.03 to 0.43mg/l in hand-dug wells. The mean and standard deviation recorded for manganese is 0.24/0.27mg/l and 0.23/0.15mg/l in borehole and hand-dug well locations (Table 4.4). The highest value of manganese concentration recorded was observed in sample OSBH5 while the lowest value of manganese concentration recorded was observed in sample OSBH2 (Table 4.3). Most of the groundwater samples fall within the NSDWQ and WHO drinking water standard except OSBH1-4, OSBH6, OSBH8, and OSHW2. The distribution of manganese concentration in groundwater within the study area is presented in figure 4.12.

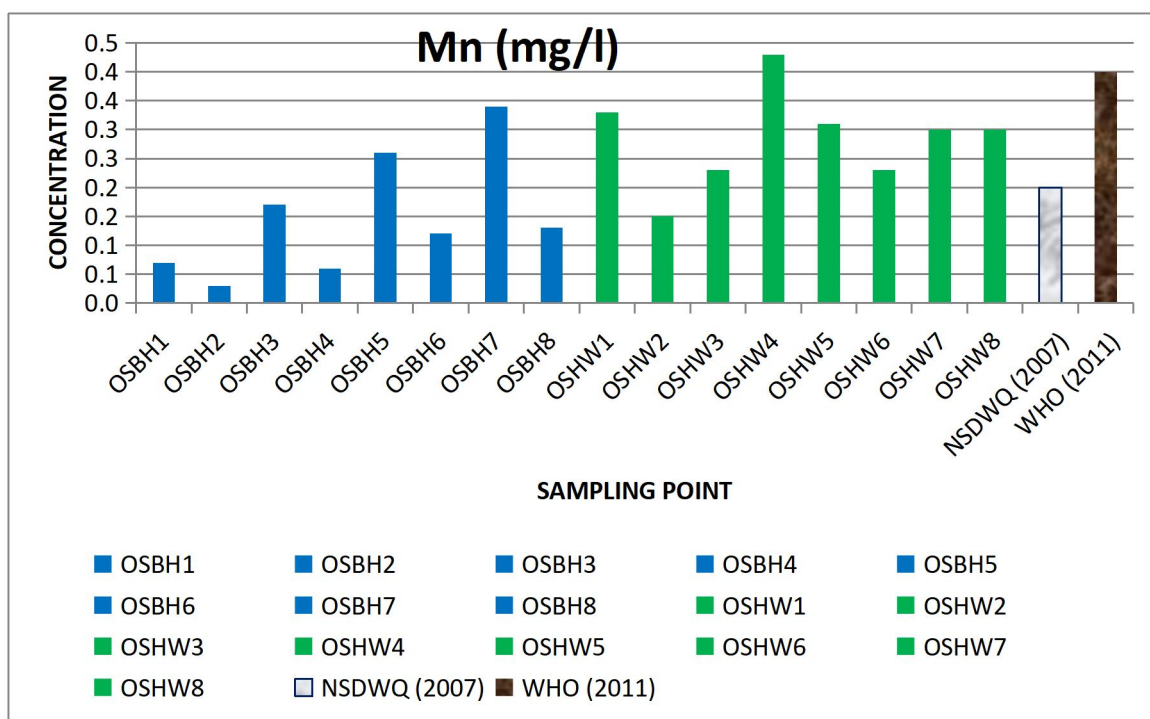


Figure 4.12: Comparative Manganese values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.5.3. CADMIUM

Cadmium is a metal with an oxidation of +2. It is chemically similar to zinc and occurs naturally with zinc and lead in sulfide ores. The values recorded for cadmium in groundwater samples within the study area ranged from 0.03 to 0.76mg/l in borehole samples and 0 to 0.03mg/l in hand-dug wells. The mean and standard deviation recorded for cadmium is 0.24/0.27mg/l and 0.03/0.04mg/l in borehole and hand-dug well locations (Table 4.4). The highest value of cadmium concentration recorded was observed in sample OSHW1 while the lowest value of cadmium concentration recorded was observed in sample OSBH2 (Table 4.3). The entire groundwater samples exceed the NSDWQ and WHO drinking water standard limit of zero. The distribution of cadmium concentration in groundwater within the study area is presented in figure 4.13.

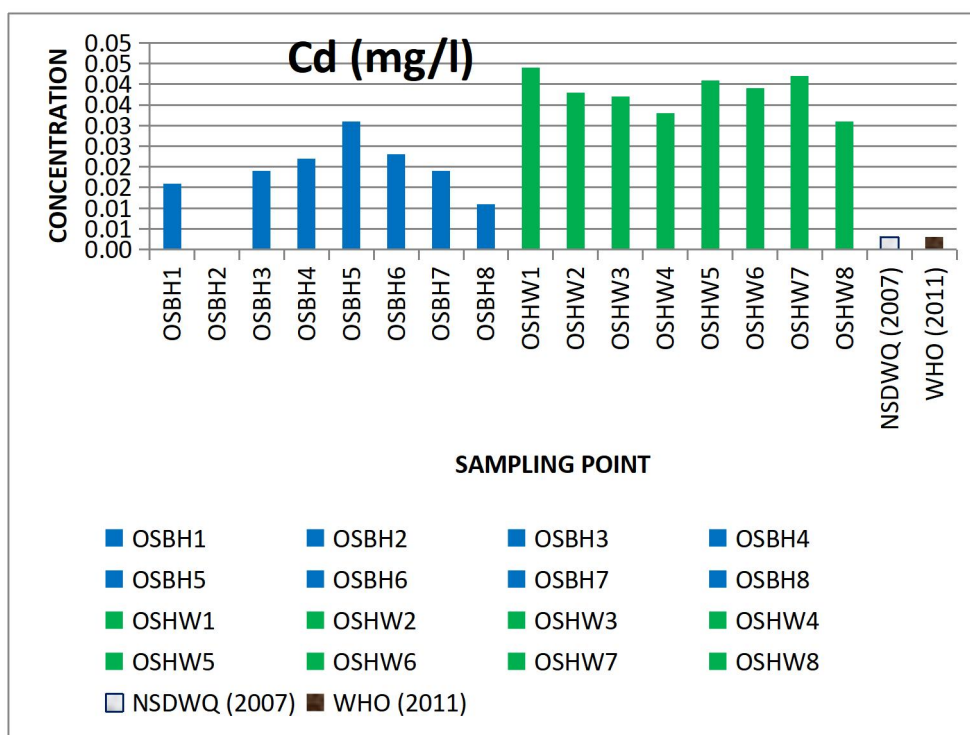


Figure 4.13: Comparative Cadmium values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.5.4 CHROMIUM

Chromium is widely distributed in the earth's crust and it's an odorless and tasteless metallic element. The values recorded for chromium in groundwater samples within the study area ranged from 0.013 to 0.06mg/l in borehole samples and 0.04 to 0.71mg/l in hand-dug wells. The mean and standard deviation recorded for chromium is 0.02/0.01mg/l and 0.14/0.23mg/l in borehole and hand-dug well locations (Table 4.4). The highest value of chromium concentration recorded was observed in sample OSBH7 while the lowest value of chromium concentration recorded was observed in sample OSHW2 (Table 4.3). Most of the groundwater samples exceed the NSDWQ and WHO drinking water standard limit of 0.05mg/l except OSBH2-8, OSHW7 and OSHW8. The distribution of chromium concentration in groundwater within the study area is presented in figure 4.14.

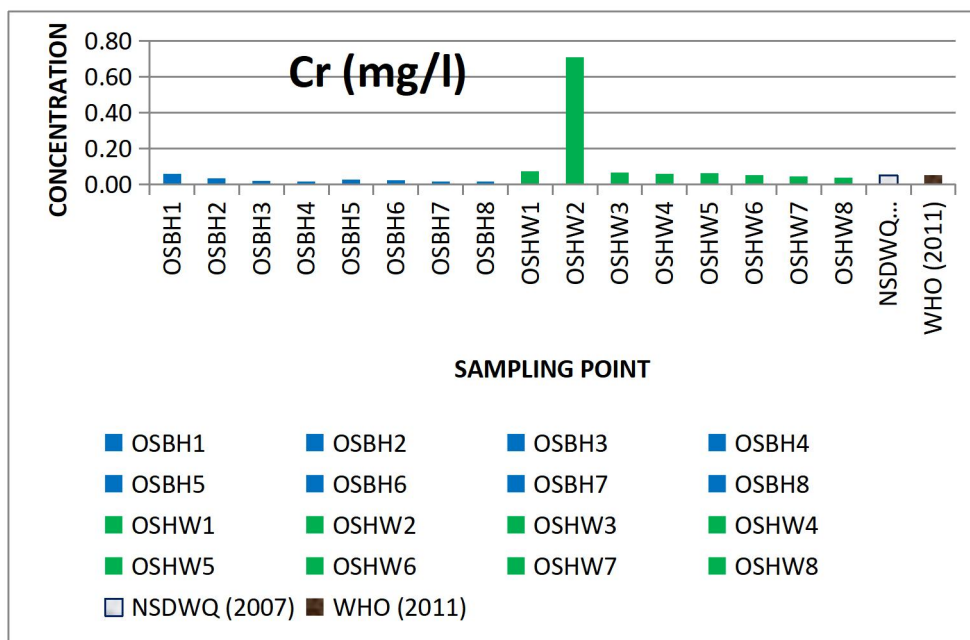


Figure 4.14: Comparative Chromium values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.5.5 LEAD

Lead is the commonest of the heavy metals and several stable isotopes of lead exist in nature. The values recorded for lead in groundwater samples within the study area ranged from 0 to 0.02mg/l in borehole samples and 0.02 to 0.03mg/l in hand-dug wells. The mean and standard deviation recorded for lead is 0.01/0.01mg/l and 0.02/0mg/l in borehole and hand-dug well locations (Table 4.4). The highest value of lead concentration recorded was observed in sample OSHW2 while the lowest value of lead concentration recorded was observed in sample OSBH2 (Table 4.3). Most of the groundwater samples exceed the NSDWQ and WHO drinking water standard limit except OSBH1, OSBH2, OSBH7 and OSBH8. The distribution of lead concentration in groundwater within the study area is presented in figure 4.15.

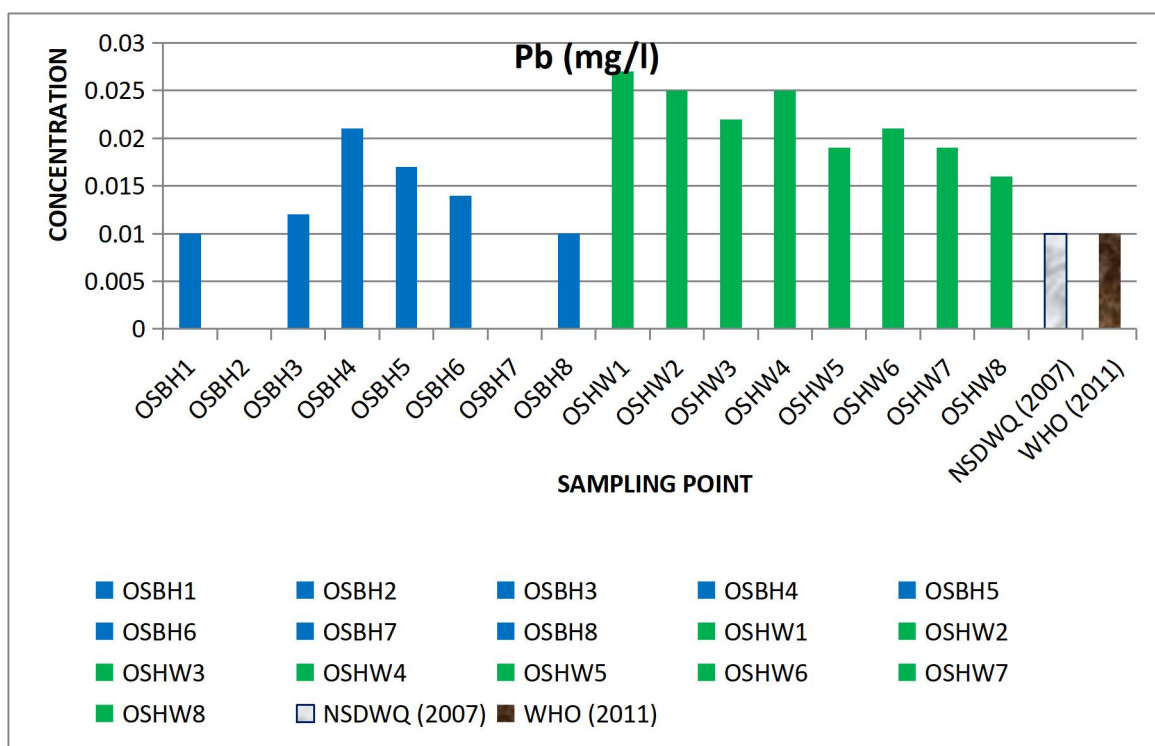


Figure 4.15: Comparative Lead values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.5.6 ZINC

Zinc occurs in small amounts in almost all igneous rocks. The values recorded for zinc in groundwater samples within the study area ranged from 0.13 to 0.19mg/l in borehole samples and 0.15 to 0.36mg/l in hand-dug wells. The mean and standard deviation recorded for zinc is 0.16/0.02mg/l and 0.21/0.07mg/l in borehole and hand-dug well locations (Table 4.4). The highest value of zinc concentration recorded was observed in sample OSHW1 while the lowest value of zinc concentration recorded was observed in sample OSBH5 (Table 4.3). The entire groundwater samples fall within the NSDWQ and WHO drinking water standard limit. The distribution of zinc concentration in groundwater within the study area is presented in figure 4.16.

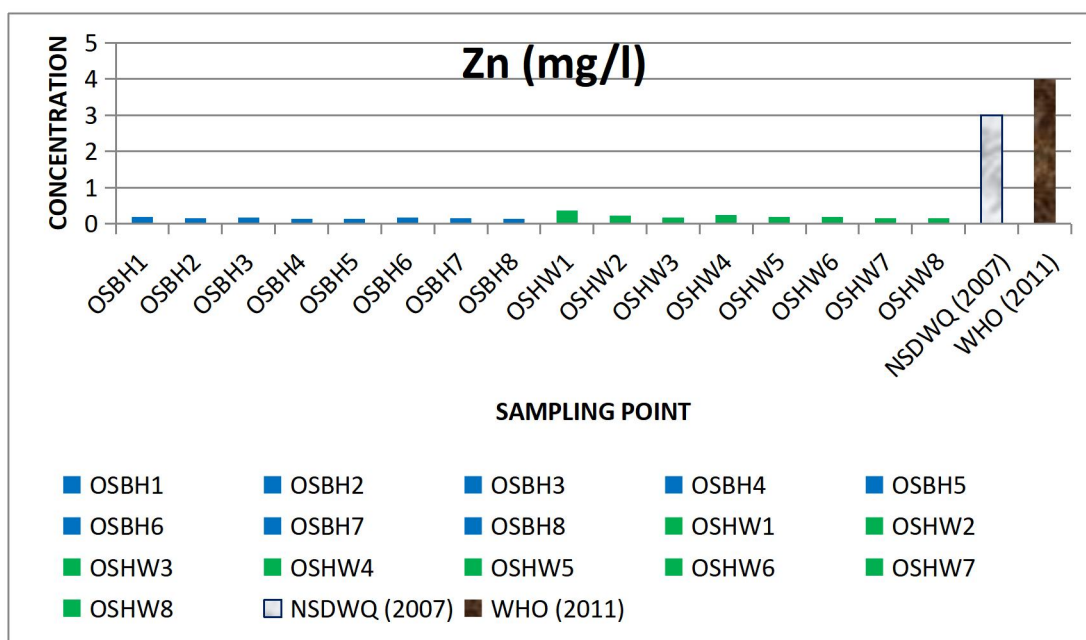


Figure 4.16: Comparative Zinc values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.5.7 COPPER

Copper is an essential element for human beings and it exists in aquatic environment. The values recorded for copper in groundwater samples within the study area ranged from 0.04 to 0.23mg/l in borehole samples and 0.06 to 0.11mg/l in hand-dug wells. The mean and standard deviation recorded for copper is 0.09/0.06mg/l and 0.08/0.02mg/l in borehole and hand-dug well locations (Table 4.4). The highest value of copper concentration recorded was observed in sample OSBH6 while the lowest value of copper concentration recorded was observed in sample OSBH8 (Table 4.3). The entire groundwater samples fall within the NSDWQ and WHO drinking water standard limit. The distribution of copper concentration in groundwater within the study area is presented in figure 4.17.

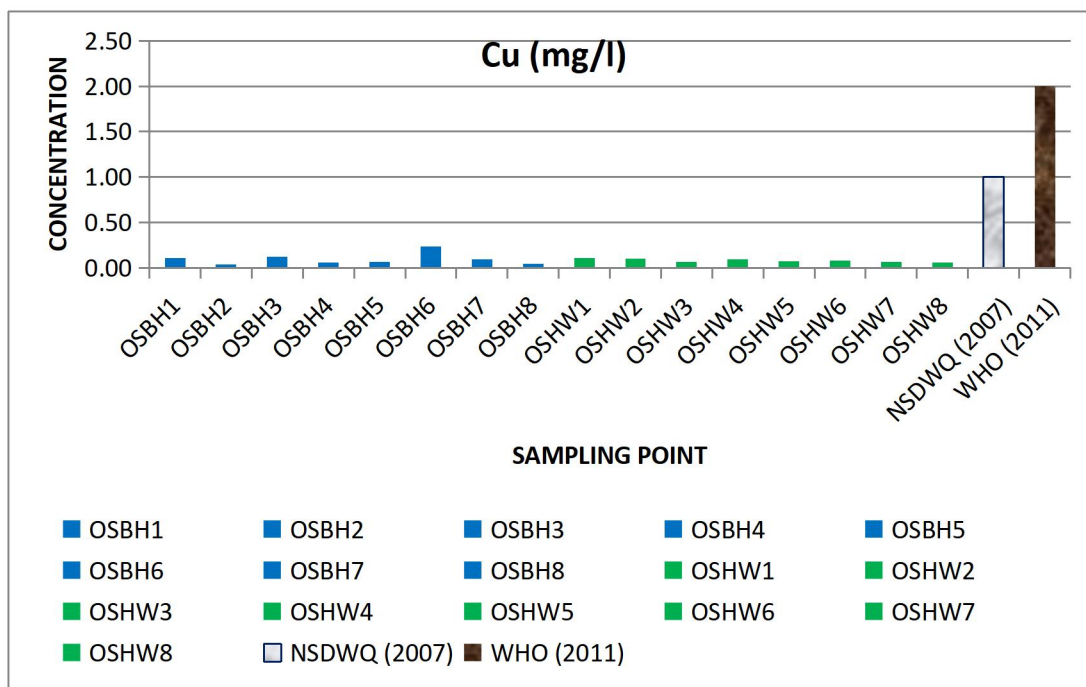


Figure 4.17: Comparative Copper values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.5.8 NICKEL

Nickel is a lustrous white, hard, ferromagnetic metal and occurs naturally in five isotopic forms. The values recorded for nickel in groundwater samples within the study area ranged from 0 to 0.059mg/l in borehole samples and 0.06 to 0.10mg/l in hand-dug wells. The mean and standard deviation recorded for nickel is 0.039/0.018mg/l and 0.08/0.02mg/l in borehole and hand-dug well locations (Table 4.4). The highest value of nickel concentration recorded was observed in sample OSHW8 while the lowest value of nickel concentration recorded was observed in sample OSBH8 (Table 4.3). The groundwater samples except OSBH8 exceed the NSDWQ limit of 0.02mg/l but falls within the WHO drinking water standard limit of 0.07mg/l. The distribution of nickel concentration in groundwater within the study area is presented in figure 4.18.

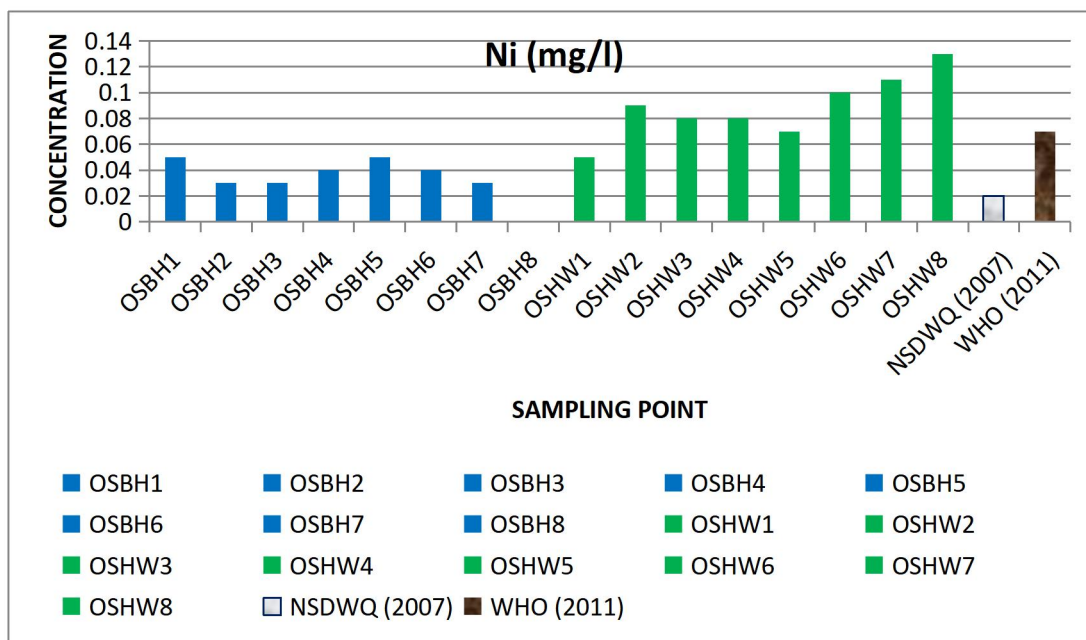


Figure 4.18: Comparative Nickel values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.6. BACTERIA CHARACTERISTICS

4.6.1 FAECAL COLIFORM BACTERIA

Coliform is a sub-group of coliform bacteria which appears in great quantities in the intestines of humans and animals. The values recorded in groundwater samples within the study area ranged from 8 to 18cfu/ml in borehole samples and 36 to 48cfu/ml in hand-dug wells. The mean and standard deviation recorded for nickel is 13/3.55cfu/ml and 43.13/4.29cfu/ml in borehole and hand-dug well locations (Table 4.4). The highest value of nickel concentration recorded was observed in sample OSHW8 while the lowest value of nickel concentration recorded was observed in sample OSBH8 (Table 4.3). The entire groundwater samples except OSBH7 and OSBH8 exceeds the NSDWQ limit of 10cfu/ml but falls short of the WHO limit which stipulates a coliform count value of zero (0) per 100ml. However, the presence of coliform bacteria in water indicates that the water has been contaminated with the faecal material of humans, animals and or, sewage. Hence the entire groundwater in the study area isn't safe for drinking. The distribution of nickel concentration in groundwater within the study area is presented in figure 4.19.

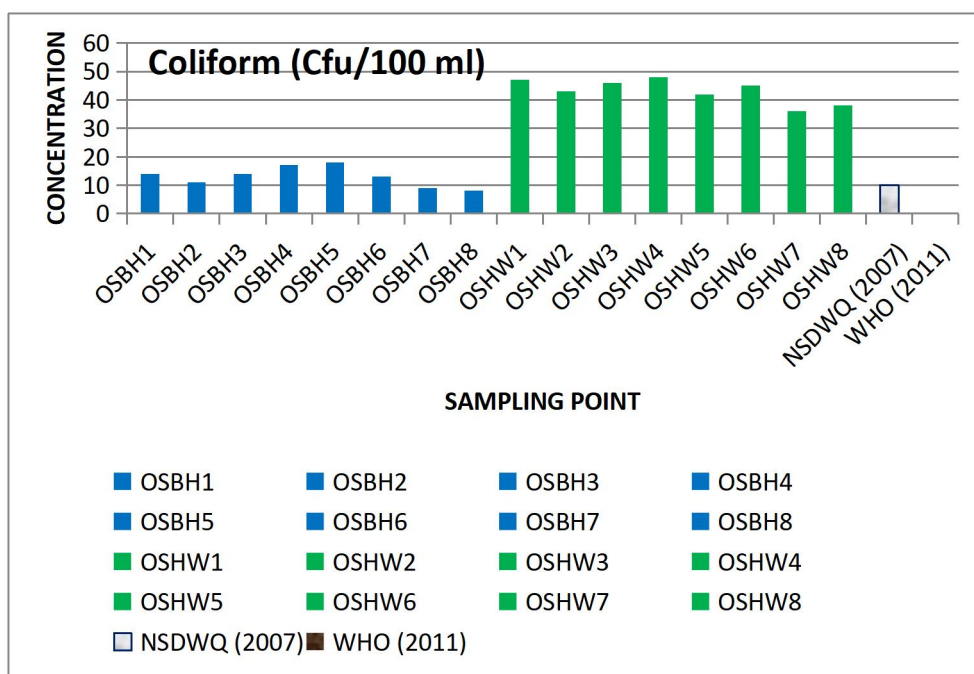


Figure 4.19: Comparative Coliform values with NSDWQ and WHO limit of borehole and hand-dug well locations within the study area.

4.6.2 SOIL

PHYSICOCHEMICAL PARAMETERS OF THE DUMPSITE SOIL

PARTICLE SIZE DISTRIBUTION

The particle size distribution of the dumpsite soil and the control site is presented in Table 4.1. The result shows that the study areas were sandy with the textural class being predominantly sandy loam with the control site being Sandy loam. The soil particle size distribution was observed to be a mixture of sand, clay and silt in all the sites investigated. High sand fractions ranged from 76.2 – 88.4% in the topsoil while subsoil range from 72.1 – 85.2% was observed. Silt fractions were low in all the soil samples ranged from 5.6 – 15.0% in the topsoil while 3.4 – 13.8% in the subsoil and that of clay were also low ranged from 7.0 – 9.1% in topsoil for the dumpsites while 4.3 – 8.6% in sub soil and the control 88.4% sand, 6% clay and 5.6% silt (Figures 4.1). It was observed that the soil textural class of the dump sites studied was mostly sandy soil. Sandy soil are permeable and could allow large quantities of leachates from the wastes to invade the deposited refuse and finally to the groundwater

resources. High clay fractions/concentrations greater than 31% encourage surface water flooding and pollution.

4.6.3 PHYSICAL CHEMICAL CHARACTERISTICS

4.6.4 HYDROGEN POTENTIAL

Hydrogen potential concentration was observed to range between 2.6 and 5.7 at topsoil of depth 0 – 15cm while it ranged between 2.3 and 6.2 at subsoil of depth 15 – 30cm. The mean observed was recorded as 4.36 at topsoil and 4.32 at subsoil of depth 0.15 – 0.3 m. The mean recorded for control is 4.7 at topsoil of depth 0 – 15 and 3.9 at subsoil of depth 15 – 30cm. The distribution of hydrogen potential in soil across the study area is presented in figure 4.20.

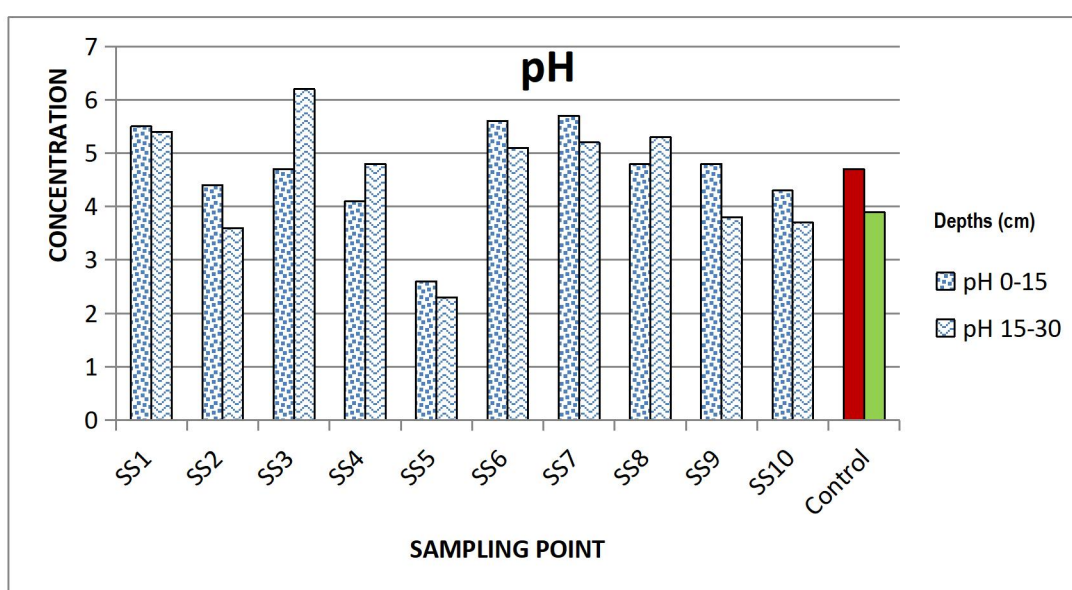


Figure 4.20: Comparative pH concentration and Control of soil samples within the study area.

4.6.5 ELECTRICAL CONDUCTIVITY

The means observed for Electrical conductivity concentration in soil samples were recorded as 1354.55 μ S/cm at topsoil depth of 0 – 15cm and 1379.09 μ S/cm at subsoil depth of 15 – 30cm. The means observed for control were recorded as 2050 μ S/cm at topsoil depth of 0 – 15cm and 2100 μ S/cm at subsoil depth of 15 – 30cm. The distribution of Electrical conductivity in soil across the study area is presented in figure 4.21.

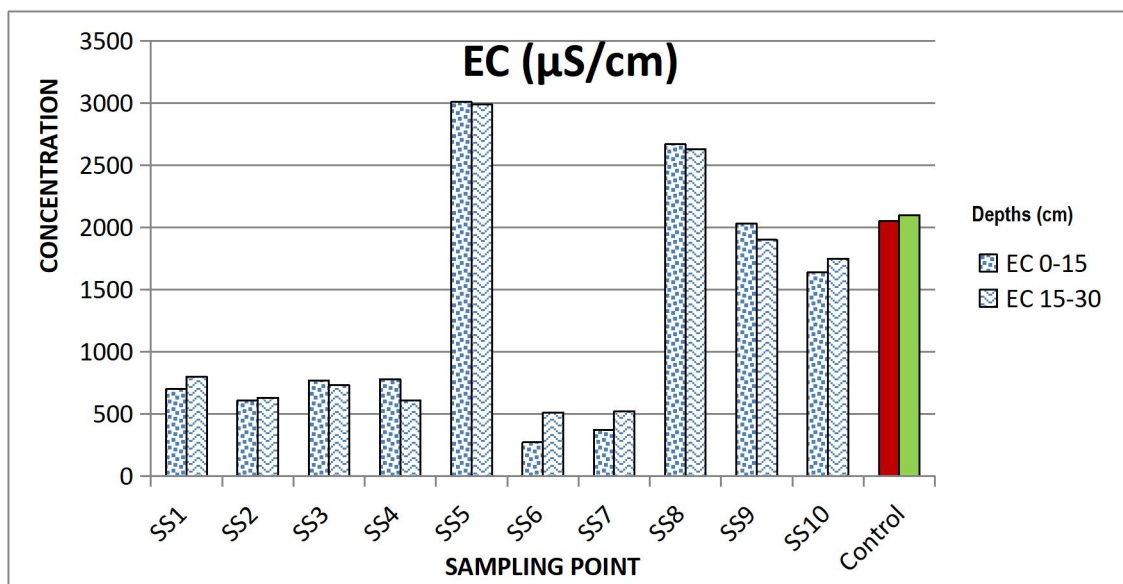


Figure 4.21: Comparative Electrical Conductivity concentration and Control of soil samples within the study area.

4.6.6 ORGANIC MATTER

Values of Organic matter ranged between 0.93 and 5.83 % at top soil depth of 0 – 15cm and 0.52 – 5.44 % at subsoil depth of 15 – 30cm. At topsoil, the highest value recorded was observed in sample SS5 while the lowest value recorded was observed in sample SS3. This trend was repeated in subsoil samples. The control mean values recorded for topsoil and subsoil are 3.5 and 2.49 % respectively. The distribution of Organic matter concentration across the study area is presented in figure 4.22.

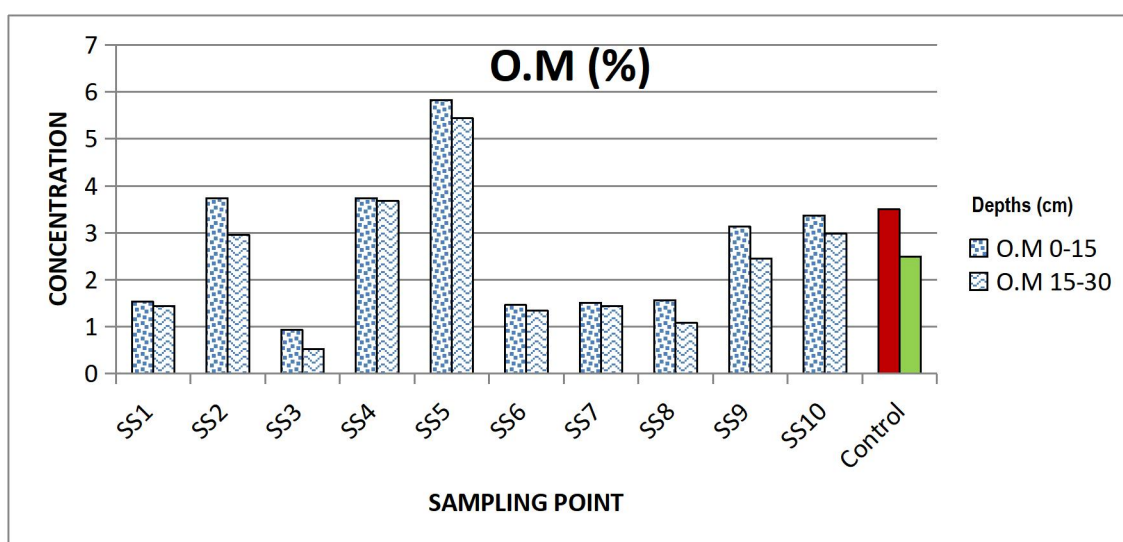


Figure 4.22: Comparative Organic Matter concentration and Control of soil samples within the study area.

4.7.1 CATIONS

4.7.2 SODIUM

Values of Sodium concentration ranged between 9.4 and 15.6 mg/kg at topsoil depth of 0 – 15cm and 7.7 – 13.1 mg/kg at subsoil depth of 15 – 30cm. At subsoil, the highest value recorded was observed in sample SS8 while the lowest value recorded was observed in sample SS3. This trend was repeated in topsoil samples. The control mean values recorded for topsoil and subsoil are 9.9 and 9.6 mg/kg respectively. The distribution of Sodium concentration across the study area is presented in figure 4.23.

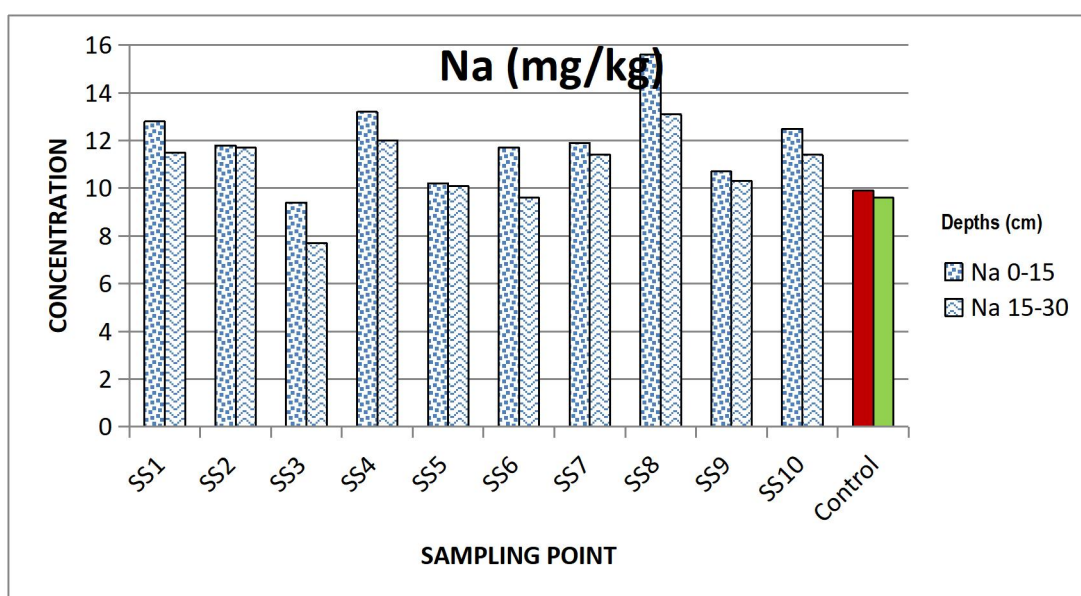


Figure 4.23: Comparative Sodium concentration and Control of soil samples within the study area.

4.7.3 POTASSIUM

The means observed for Potassium concentration in soil samples were recorded as 8.05 mg/kg at topsoil depth of 0 – 15 cm and 6.80 mg/kg at subsoil depth of 15 – 30cm. The means observed for control were recorded as 8.7 mg/kg at topsoil depth of 0 – 15 cm and 4.4mg/kg at subsoil depth of 15 – 30cm. At subsoil, the highest value recorded was observed in sample SS4 while the lowest value recorded was observed in sample SS3. This trend was repeated in topsoil samples. The distribution of Potassium in soil across the study area is presented in figure 4.24.

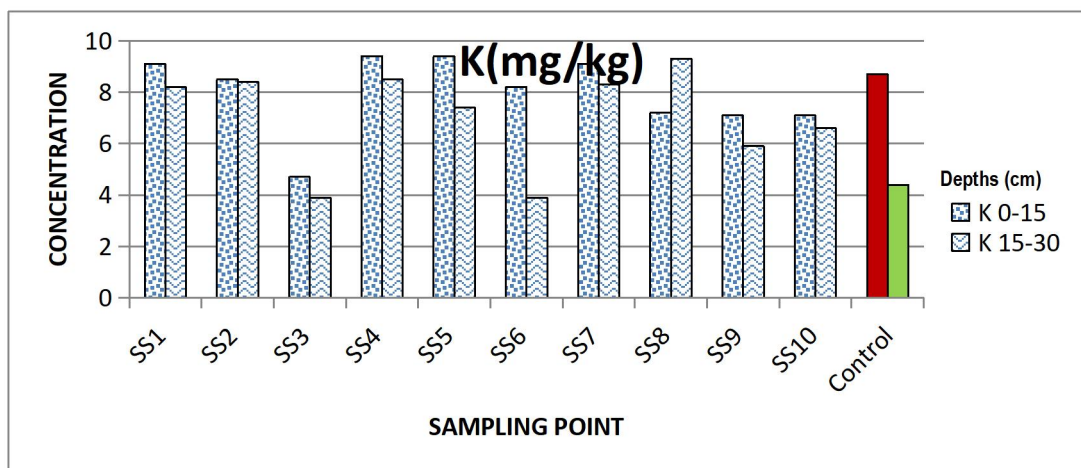


Figure 4.24: Comparative Potassium concentration and Control of soil samples within the study area.

4.7.4 MAGNESIUM

The mean, minimum and maximum values for Magnesium in topsoil depth of 0 – 15 cm are recorded as 10.57 mg/kg, 8.1mg/kg and 14.9mg/kg respectively while in subsoil depth of 15 – 30cm they were recorded as 10.03 mg/kg, 6.3mg/kg and 13.2 mg/kg respectively. The maximum and minimum values recorded in both topsoil and subsoil was observed in sample SS8 and SS3 respectively. The mean value recorded for control at topsoil and subsoil is 10.8 and 6.3 mg/kg respectively. The distribution of Magnesium concentration across the study area is presented in figure 4.25.

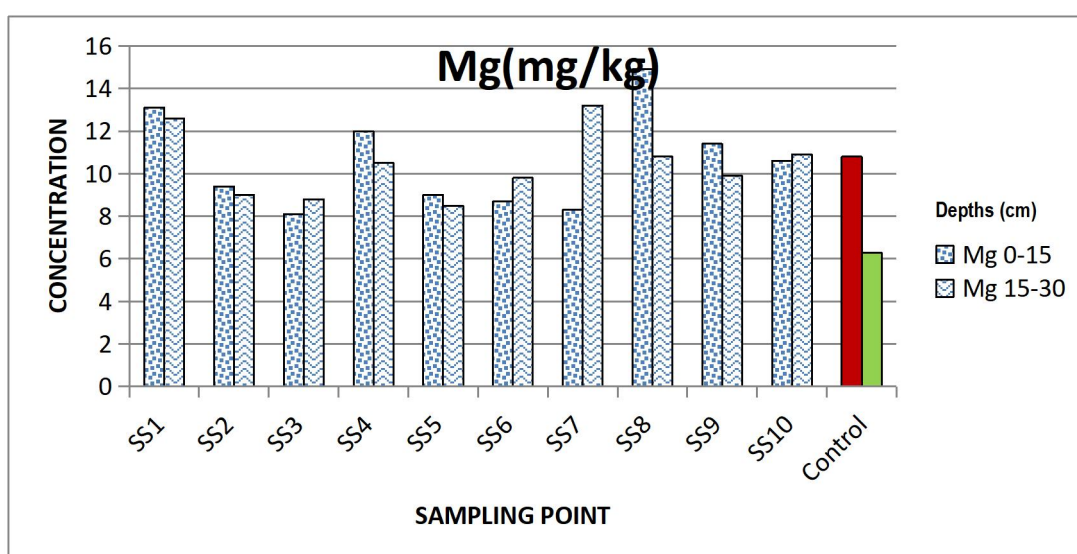


Figure 4.25: Comparative Magnesium concentration and Control of soil samples within the study area.

4.7.5 CALCIUM

Calcium concentration was observed to range between 10.5 and 17.3 mg/kg at topsoil of depth 0 – 15 cm while it ranged between 8.6 and 15.2 mg/kg at subsoil of depth 15-30cm. The mean observed was recorded as 13.57 mg/kg at topsoil and 12.22 mg/kg at subsoil of depth 15 – 30cm. The mean recorded for control is 13.33 mg/kg at topsoil of depth 0 – 15 cm and 12.22 mg/kg at subsoil of depth 15 – 30 cm. The distribution of Calcium in soil across the study area is presented in figure 4.26.

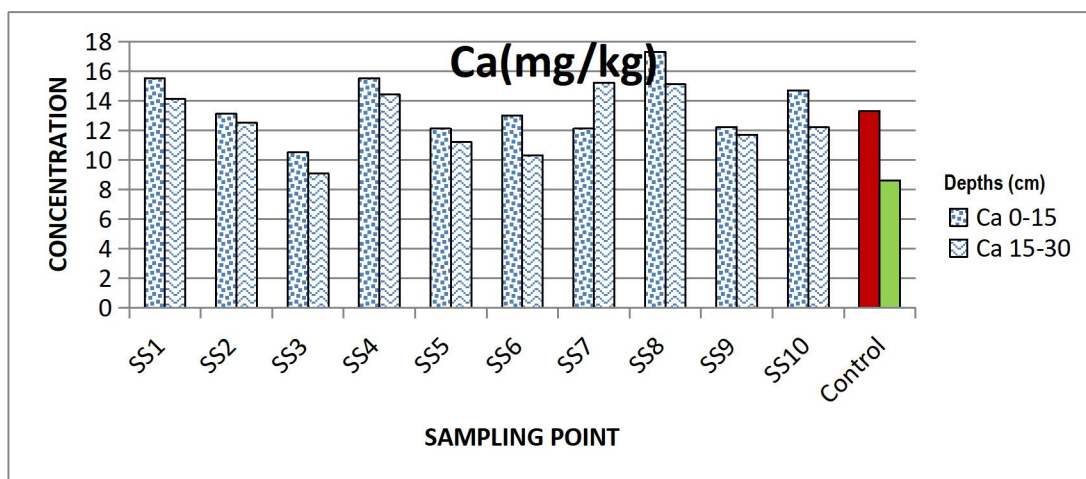


Figure 4.26: Comparative Calcium concentration and Control of soil samples within the study area.

4.7.6 HEAVY METALS

4.7.7 ARSENIC

Values of Arsenic concentration ranged between 11.56 and 23.4 mg/kg at topsoil depth of 0 – 15 cm and 10.58–21.2 mg/kg at subsoil depth of 15 – 30cm. At subsoil, the highest value recorded was observed in sample SS2 while the lowest value recorded was observed in sample SS6. The same trend was observed at topsoil. The control mean values recorded for topsoil and subsoil are 11.56 and 10.58 mg/kg respectively. The distribution of arsenic concentration across the study area is presented in figure 4.27.

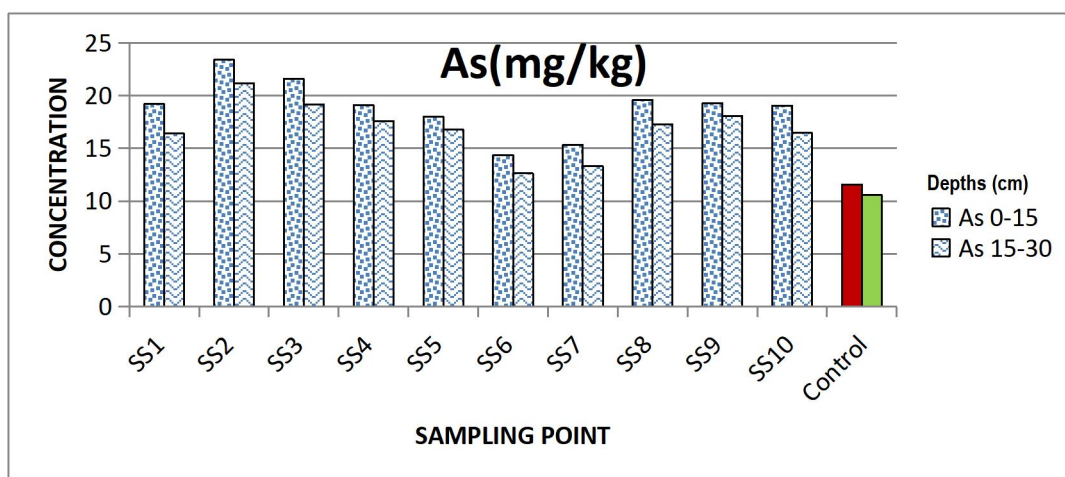


Figure 4.27: Comparative Arsenic concentration and Control of soil samples within the study area.

4.7.8 MANGANESE

Values of Manganese concentration ranged between 1.46 and 3.58mg/kg at topsoil depth of 0 – 15 cm and 1.42–3.52 mg/kg at subsoil depth of 15 – 30cm. At subsoil, the highest value recorded was observed in sample SS4 while the lowest value recorded was observed in sample SS2. Also at topsoil, the highest value recorded was observed in sample SS4 while the lowest value recorded was observed in sample SS2. The control mean values recorded for topsoil and subsoil are 1.46 and 1.42 mg/kg respectively. The distribution of Manganese concentration across the study area is presented in figure 4.28.

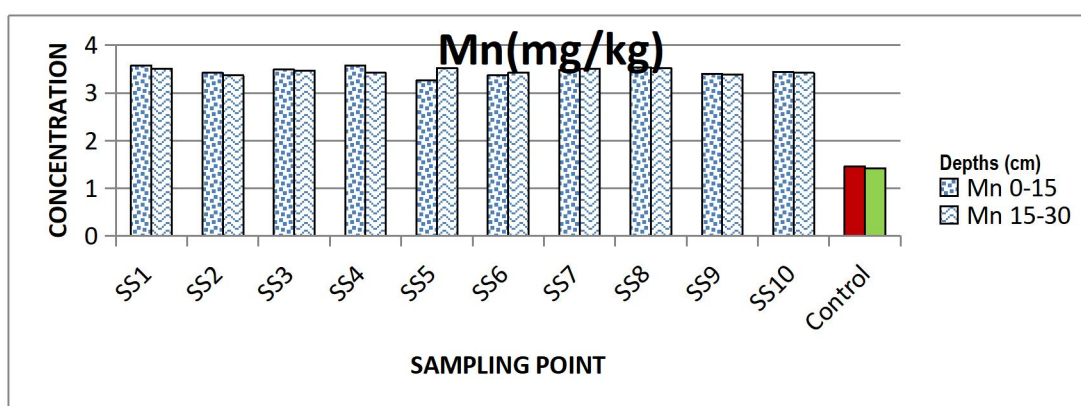


Figure 4.28: Comparative Manganese concentration and Control of soil samples within the study area.

4.7.9 CADMIUM

Concentration of Cadmium in soil samples ranges between 1.08 and 3.46 mg/kg in topsoil of depth 0 – 15 cm and ranges between 1.06 to 3.43 mg/kg in subsoil of depth 15 – 30cm. Mean values recorded for Cadmium was 2.26 mg/kg in subsoil and 2.24 mg/kg in topsoil.

The minimum and maximum values were recorded in sample SS9 and SS8 respectively in subsoil while it was recorded in sample SS9 and SS8 respectively in topsoil. Means recorded for control were 1.06 mg/kg in subsoil and 1.08 mg/kg in topsoil. The distribution of Cadmium concentration across the study area is presented in figure 4.29.

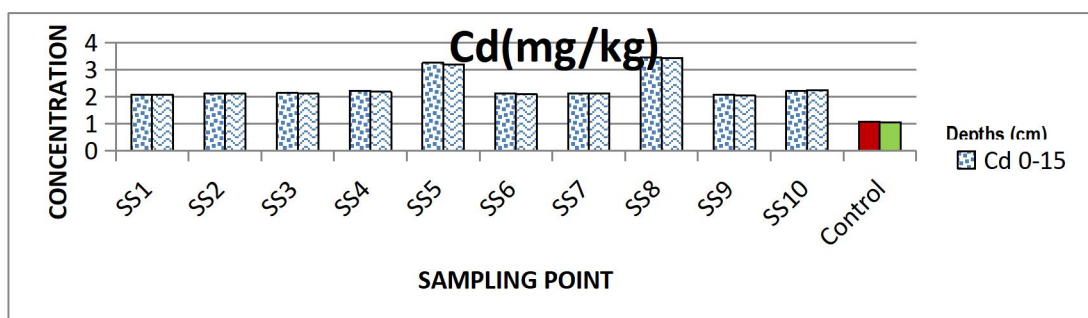


Figure 4.29: Comparative Cadmium concentration and Control of soil samples within the study area.

4.7.10 CHROMIUM

Chromium concentration was observed to range between 1.64 and 4.52 mg/kg at topsoil of depth 0 – 15 cm while it ranged between 1.61 and 4.55 mg/kg at subsoil of depth 15 – 30cm. The mean observed was recorded as 3.53 mg/kg at topsoil and 3.50 mg/kg at subsoil of depth 15 – 30cm. The mean recorded for control is 1.64mg/kg at topsoil of depth 0 – 15 cm and 1.61 mg/kg at subsoil of depth 15 – 30 cm. The distribution of Chromium in soil across the study area is presented in figure 4.30.

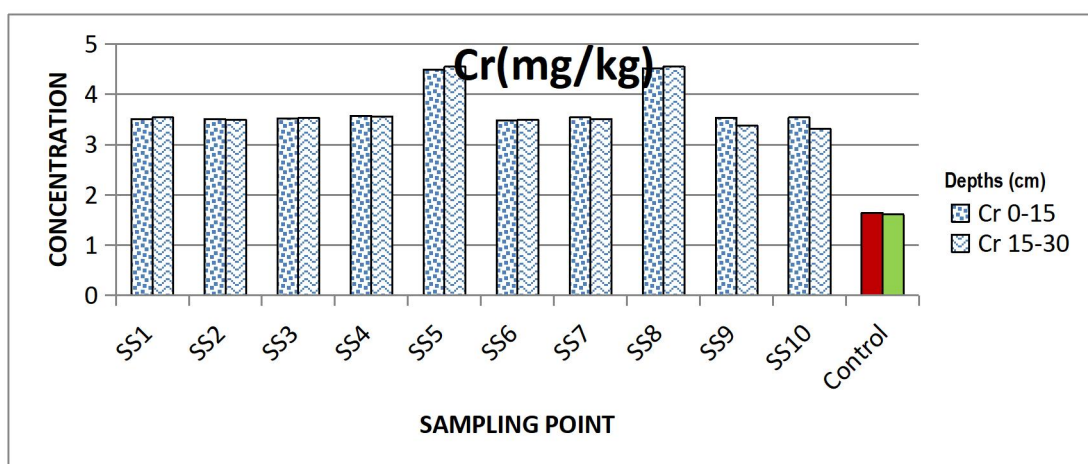


Figure 4.30: Comparative Chromium concentration and Control of soil samples within the study area.

4.7.11 LEAD

Values of Lead concentration ranged between 2.14 and 3.69mg/kg at topsoil depth of 0 – 15 cm and 2.11 – 3.71 mg/kg at subsoil depth of 15 – 30cm. At subsoil, the highest value recorded was observed in sample SS4 while the lowest value recorded was observed in

sample SS7. The same trend was observed at topsoil. The control mean values recorded for topsoil and subsoil are 2.14 and 2.11 mg/kg respectively. The distribution of Lead concentration across the study area is presented in figure 4.31.

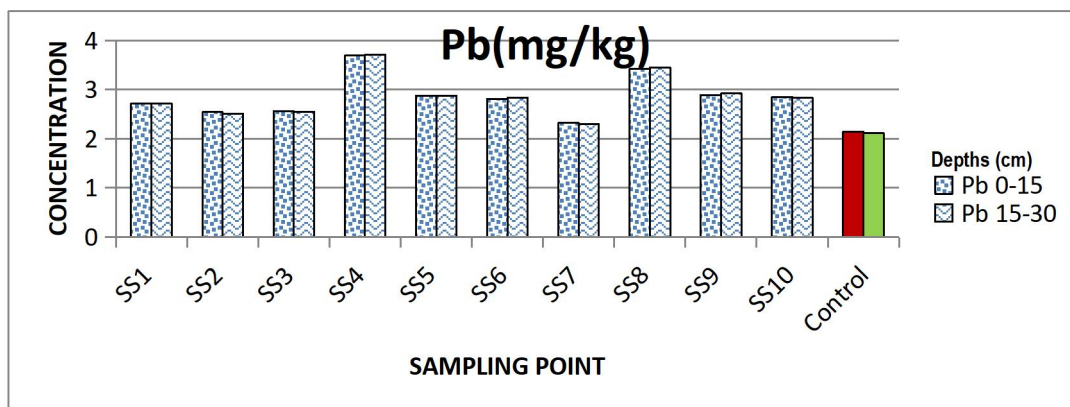


Figure 4.31: Comparative Lead concentration and Control of soil samples within the study area.

4.7.12 ZINC

The means observed for Zinc concentration in soil samples were recorded as 9.99mg/kg at topsoil depth of 0 – 15 cm and 10.27 mg/kg at subsoil depth of 15 – 30cm. The means observed for control were recorded as 5.79 mg/kg at topsoil depth of 0 – 15 cm and 5.77 mg/kg at subsoil depth of 15 – 30cm. The distribution of Zinc in soil across the study area is presented in figure 4.32.

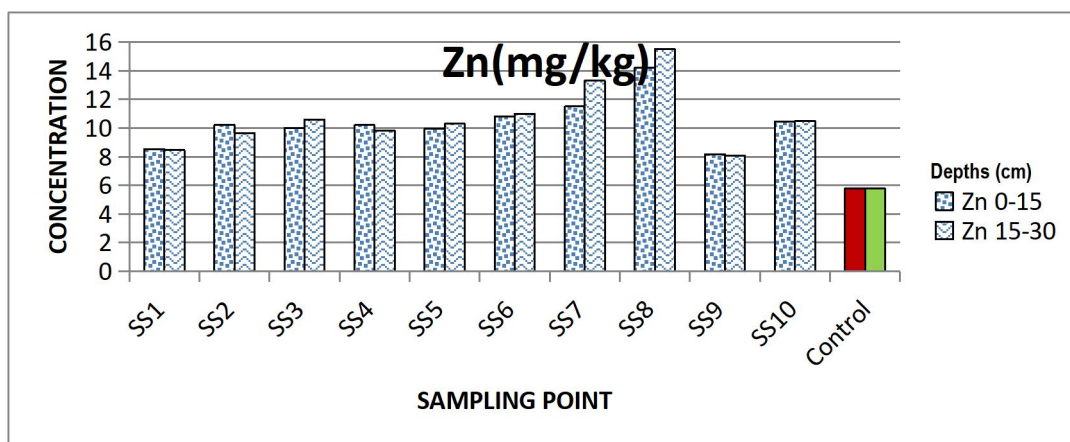


Figure 4.32: Comparative Zinc concentration and Control of soil samples within the study area.

4.7.13 COPPER

Copper concentration was observed to range between 1.86 and 3.23 mg/kg at topsoil of depth 0 – 15 cm while it ranged between 1.69 and 3.17 mg/kg at subsoil of depth 15 – 30cm. The mean observed was recorded as 2.48 mg/kg at topsoil of depth 0 – 15 cm and

2.20 mg/kg at subsoil of depth 15 – 30cm. The mean recorded for control is 1.86mg/kg at topsoil of depth 0 – 15 cm and 1.69 mg/kg at subsoil of depth 15 – 30 cm. The distribution of Copper in soil across the study area is presented in figure 4.33.

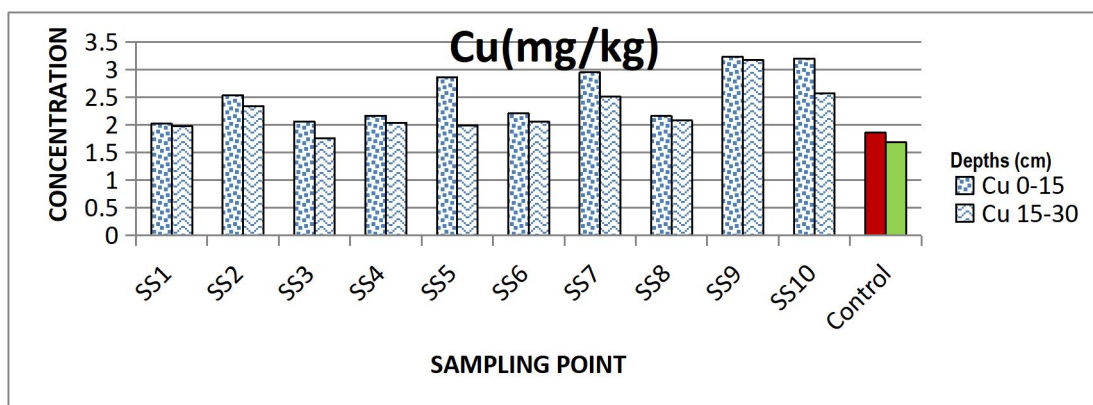


Figure 4.33: Comparative Copper concentration and Control of soil samples within the study area.

4.7.14 CYANIDE

Concentration of Cyanide in soil samples ranges between 0 to 0.005 mg/kg in topsoil of depth 0 – 15 cm and ranges between 0 to 0.006 mg/kg in subsoil of depth 15 – 30cm. Mean values recorded for cyanide was 0 mg/kg in subsoil and 0 mg/kg in topsoil. The minimum and maximum values were recorded in sample SS7 and SS6 respectively in subsoil while it was recorded in sample SS2 and SS9 respectively in topsoil. Means recorded for control were 0 mg/kg in subsoil and 0 mg/kg in topsoil. The distribution of cyanide concentration across the study area is presented in figure 4.34.

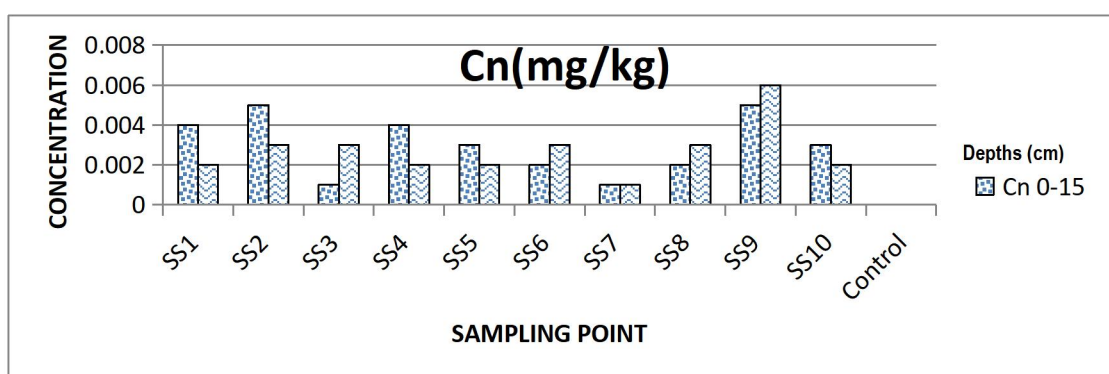


Figure 4.34: Comparative Cyanide concentration and Control of soil samples within the study area.

4.7.15 NICKEL

The means observed for Nickel concentration in soil samples were recorded as 2.94 mg/kg at topsoil depth of 0 – 15 cm and 2.77 mg/kg at subsoil depth of 15 – 30cm. The means observed for control were recorded as 1.35mg/kg at topsoil depth of 0 – 15 cm and 1.31 mg/kg at subsoil depth of 15 – 30cm. The distribution of Nickel in soil across the study area is presented in figure 4.35.

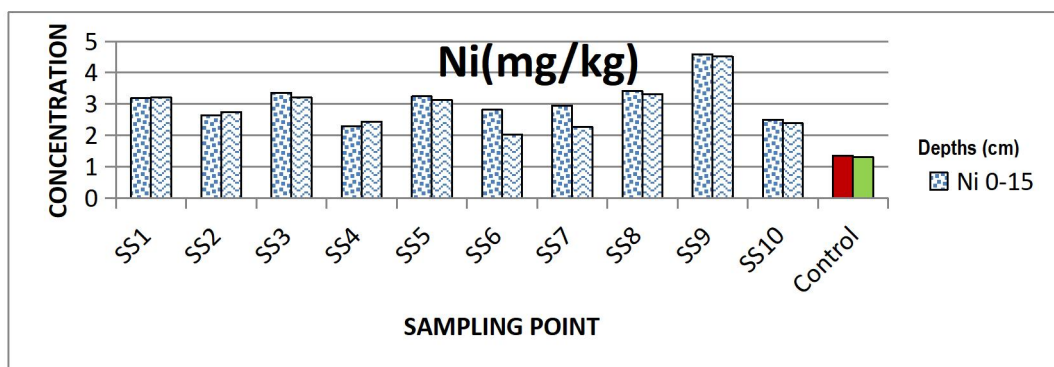


Figure 4.35: Comparative Nickel concentration and Control of soil samples within the study area.

4.7.16 VANADIUM

Concentration of Vanadium in soil samples ranges between 1.24 and 3.81 mg/kg in topsoil of depth 0 – 15 cm and ranges between 1.26 to 3.95 mg/kg in subsoil of depth 15 – 30cm. Mean values recorded for Cadmium was 2.81 mg/kg in subsoil and 2.83 mg/kg in topsoil. The minimum and maximum values were recorded in sample SS8 and SS7 respectively in subsoil while it was recorded in sample SS8 and SS7 respectively in topsoil. Means recorded for control were 1.24 mg/kg in subsoil and 1.26 mg/kg in topsoil. The distribution of Cadmium concentration across the study area is presented in figure 4.36.

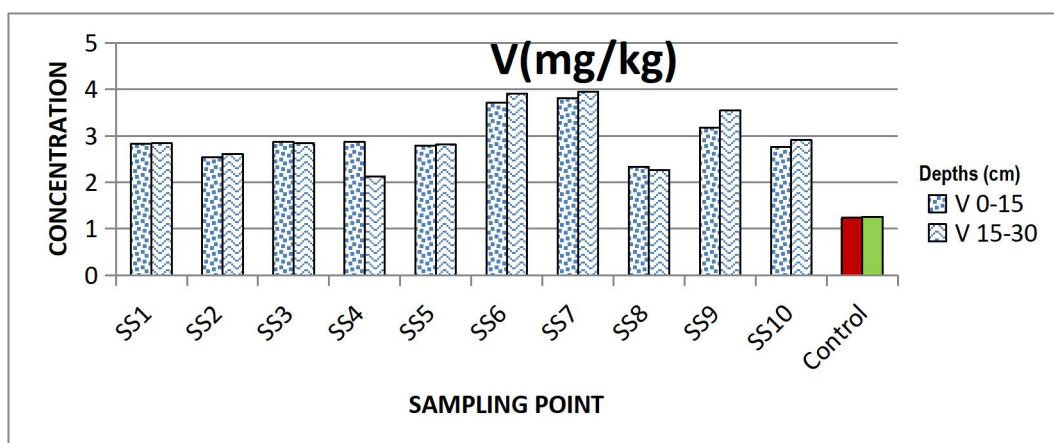
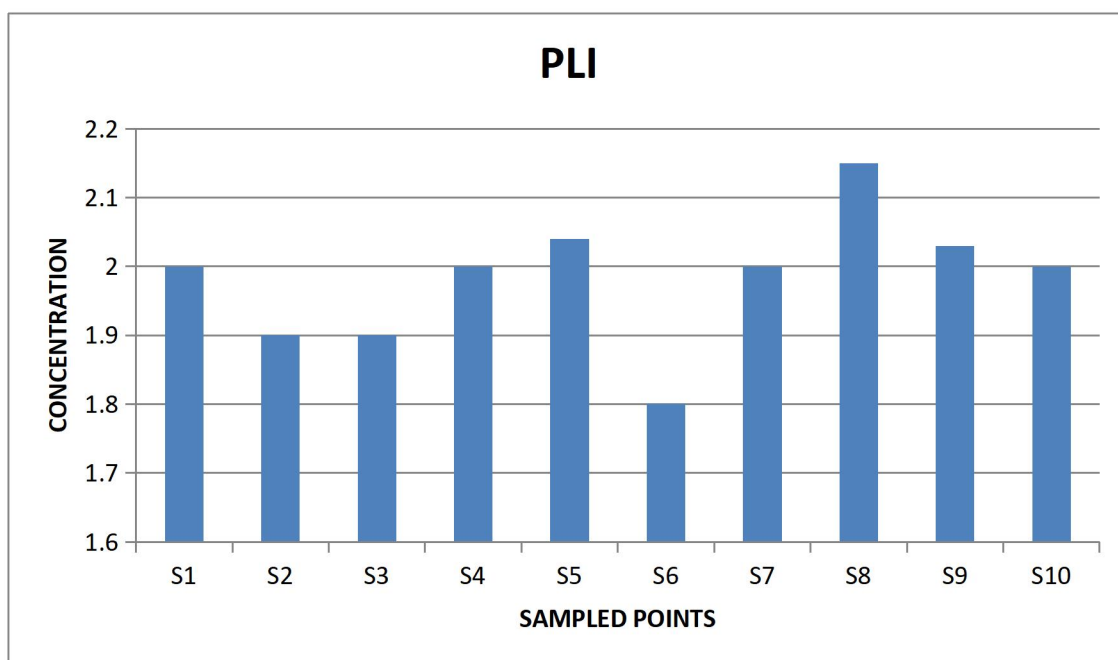


Figure 4.36: Comparative Vanadium concentration and Control of soil samples within the study area.

4.8 POLLUTION LOAD INDEX

Pollution severity and its variation along the sites were determined with the use of pollution load index. This index is a quick tool in order to compare the pollution status of different places/locations. Results of the present study show that the CF values of most of the metals such as Mn, V, Cr, Ni, Cd, Zn, As, Pb, and Cu in the study area are moderately contaminated (<3) (Table (4.9)). But, CF values for metals like Mn, V, Cr, Ni, and Cd showed higher CF values (>2) probably due to the influence of external discrete sources or other anthropogenic inputs. The values of Pollution Load Index (Table (4.9)) were found to be generally moderate (>2) in all the studied locations. The difference in indices results due to the difference in sensitivity of these indices towards the sediment pollutants. These confirmed the soil in the study area is facing probable environmental pollution especially with dangerous heavy metals (Mn, V, Cr, Ni, Cd, As, Zn, Pb, Cu and Pb) which result from increased rate of non-treatment industrial waste which are discharged in the Osubi dumpsite. The pollution load index (PLI) revealed that location SS8 had maximum pollution load index of 2.15 and a minimum pollution load index value of 1.80 was obtained at location SS6 (Table 4.9). The order of pollution load index per location for the sediments was as follows: SS8 > SS5 > SS9 > (SS4=SS7=SS10) > SS2 > SS3 > SS6. While the order of contamination factor (CF) revealed among the heavy metals is as follows: Mn > V > Cr > Ni > Cd > Zn > As > Pb > Cu. Based on Thomilson *et al.*, 1980 indices, locations SS8, SS5, SS9, SS2, SS3, and SS6 have shown progressive site deterioration while, SS4, SS7 and SS10 had only baseline level of pollutants present with respect to the measured nine (9) heavy metals. The very high values of the CFs (>1) in all the metals can be due to influence of dumpsite activities such as indiscriminate disposal of metal containing compounds such as batteries, paints and pipes, steel scrap, vehicle spare parts, etc. The results of contamination index show that the quality of soil in the study area are moderately contaminated with respect to the control site which acts as a normalizer.



Fi

g 4.37 Pollution load index classification for soils in the area.

4.9 ANOVA

Table 4.7 shows the P-Values of the ANOVA used to compare control collected for soil samples. There was highly significant difference between control and Hydrogen potential, Sodium, Arsenic, Copper, and Cyanide in topsoil depths of 0-15 cm and 15-30cm.

Also there was significant difference between control values and Calcium in topsoil depths of 0-15 cm and 15-30cm. There was no significant difference between control and Electrical conductivity, Organic Matter, Potassium, Magnesium, Manganese, Cadmium, Chromium, Lead, Zinc, Nickel and Vanadium.

4.10 CORRELATION

Spearman's correlation coefficient matrix was carried out on the physicochemical data collected from groundwater in the study area. It is used to establish relationship between two parameters. It helps to determine how one parameter predicts the other. Correlation matrix for groundwater is presented in table 4.6.

4.11 CORRELATION IN GROUNDWATER

The Hydrogen Potential in hand-dug wells correlated very strongly negatively at $p < 0.01$ with the Turbidity in borehole samples; and correlated strongly negatively with Copper in the borehole samples at $p < 0.05$

Temperature in hand-dug wells correlated very strongly positively with Magnesium at $p < 0.01$, strongly positively with temperature, Manganese, and Potassium at $p < 0.05$; and very strongly negatively with Arsenic at $p < 0.001$ in borehole samples.

Turbidity in hand-dug well correlates very positively with Zinc in borehole samples at $p < 0.05$.

Strong positive correlation at $p < 0.05$ was observed between Biochemical Oxygen Demand of hand-dug wells with Vanadium and Coliform of borehole samples.

Strong positive correlation between Chemical Oxygen Demand of hand-dug wells was observed with Turbidity and Copper of borehole samples at $p < 0.05$.

Sulphate in hand-dug wells correlated strongly negatively with temperature and Potassium at $p < 0.05$; very strongly negatively with Magnesium at $p < 0.01$; very strongly positively with Sodium at $p < 0.01$ and strongly positively with Zinc at $p < 0.05$ in borehole samples.

Strong positive correlation was observed between Sodium in hand-dug wells with Biochemical Oxygen Demand, Sulphate and Cadmium in borehole samples at $p < 0.05$; and correlated very strong positively with Lead at $p < 0.01$.

Potassium in hand-dug wells correlated strongly negatively and positive with Total Dissolved Solids and Sulphate respectively in borehole samples at $p < 0.05$.

Manganese in hand-dug wells correlated strongly negatively with Chemical Oxygen Demand; strongly positively with Nickel and Coliform in borehole samples at $p < 0.05$.

Strong negative correlation at $p < 0.05$ was observed between Cadmium in hand-dug wells; and strongly positively correlated with Electrical conductivity & Nickel in borehole samples.

Chromium in hand-dug wells correlated strongly negatively with Sodium, and strongly positively with Arsenic & Chromium at $p<0.05$; very strongly positively correlated with Vanadium in borehole samples at $p<0.01$.

Very strong negative correlation at $p<0.01$ was observed between Lead in hand-dug wells with Temperature, Phosphate, Magnesium; strongly negatively correlated with Sodium, Potassium, Manganese at $p<0.05$; and very strongly positively correlated with Arsenic at $p<0.01$ in borehole samples.

Zinc in hand-dug wells correlated strongly negatively with Temperature & Sulphate at $p<0.05$; very strongly positively correlated with Arsenic at $p<0.01$ in borehole samples.

Copper concentration in hand-dug wells correlated strongly negatively with Sulphate; and strongly positively with Arsenic in borehole samples at $p<0.05$.

Very strong negative correlation at $p<0.01$ was observed between Nickel in hand-dug and Temperature; at $p<0.05$ strong negative correlation was observed with Sulphate, Magnesium, Sodium, Potassium; very strong positively correlated with Arsenic at $p<0.01$; and strongly positively correlated with Vanadium at $p<0.05$ in borehole samples.

Vanadium in hand-dug wells correlated strongly positively with Temperature, Phosphate, Magnesium, Sodium, Potassium at $p<0.05$; very strong positively correlated with Arsenic at $p<0.01$; and strongly positively correlated with Vanadium at $p<0.05$ in borehole samples.

Escherichia Coli in hand-dug wells correlated strongly negatively with Temperature, Sulphate, Magnesium, Sodium, Potassium at $p<0.05$; and very strongly positively with Arsenic at $p<0.01$ in borehole samples.

Very strong negative correlation at $p<0.01$ was observed between Coliform in hand-dug wells and Temperature in borehole samples; Coliform correlated strongly positively with Biochemical Oxygen Demand & Arsenic; strongly negatively with Sodium in borehole samples at $p<0.05$.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The study has shown that there is high concentration of heavy metals which exceeded both the NSDWQ, (2007) and WHO, (2011) limit in most of the groundwater samples, and both the groundwater and soil samples are acidic. The hand-dug wells were more contaminated than the borehole water samples. This could be attributed to either atmospheric gases dissolved during rainfall or the shallowness of the well which led to heavy metals depositing into the wells. The particle size distribution of the dumpsite soil and the control site as presented shows that the study areas were sandy with the textural class being predominantly sandy loam. Sandy soil are permeable and could allow large quantities of leachates from the wastes to invade the deposited refuse and finally to the groundwater resources. High clay fractions/concentrations greater than 31% encourage surface water flooding and pollution. The pollution load index (PLI) revealed that location SS8 had maximum pollution load index of 2.15 and a minimum pollution load index value of 1.80 was obtained at location SS6. The order of pollution load index per location for the sediments was as follows: SS8 > SS5 > SS9 > (SS4=SS7=SS10) > SS2 > SS3 > SS6. While the order of contamination factor (CF) revealed among the heavy metals is as follows: Mn > V > Cr > Ni > Cd > Zn > As > Pb > Cu. Based on Tomlinson *et.al*, 1980 indices, locations SS8, SS5, SS9, SS2, SS3, and SS6 have shown progressive site deterioration with respect to the measured ten (10) heavy metals analyzed. The correlation result between the analyzed parameters in hand-dug wells and borehole samples, revealed positive and negative correlation coefficients at $r(0.01)$ and $r(0.05)$ indicating strong association between them, which probably reflects their related or common source and contamination. The ANOVA result indicated highly significant difference between pH and control, sodium, arsenic, copper, and cyanide in soil samples at depths of 0-15 cm and 15-30 cm at $p < 0.01$. While at $p < 0.05$, there was significant difference between control and calcium at depths of 0-15 cm and 15-30 cm. By extrapolating from the results, it is concluded that the natural topsoil quality around the dumpsite is not in a pristine state which is a reflection of anthropogenic contribution from the disposal of solid wastes in the dumpsite.

5.2 RECOMMENDATION

The study assessed the physico chemical and trace metal levels in groundwater and sediments in the study area. Consequently, the following are hereby recommended:

- The groundwater in the study area is acidic and should be treated with the addition calcium carbonate or lime and intensive aeration, oxidation, chlorination followed by filtration to neutralize the pH, remove magnesium, trace metals, and eliminate bacteria respectively.
- The levels of Mg, As, Mn, Cd, Cr, Pb, Ni, Coliform and other trace metals in the groundwater should be continuously monitored to check on their concentration. The levels of the aforementioned trace metals in the groundwater of the study area is already beyond the NSDWQ, (2007) and WHO, (2011) recommended maximum limit, as these metals are dangerous to health.
- A further study should be done to determine other anthropogenic sources of contamination of groundwater in the study area. Owing to the fact that, the correlation result revealed different relationships/source among the physico-chemical and trace metals analyzed in the groundwater samples.
- Efforts should be intensified to discourage the practice of open dumpsites close to residential areas. Hence the dumpsite should be closed as this is already contaminating the groundwater through the soil.
- Finally, modern waste disposal facilities should be acquired by relevant authorities and appropriate waste disposal sites be chosen to avoid the injurious effects of indiscriminate disposal of wastes.

REFERENCES

- Adeleken, B. and Abegunde, K. (2011).** Heavy metal contamination of soil and ground water at automobile mechanic village in Ibadan, Nigeria. *International Journal of the Physical Sciences*, 6(5): 1045-1058.
- Adesida. A.A., Reijers, T.J.A., and Nwajide, C.S., (1997).** Sequence stratigraphic framework of the Niger Delta. Paper presented at the AAPG international conference and exhibition, Vienna, Austria.
- Ajibade, O.M., Omosanya, K.O. and Odunsi, G.O. (2011),** “Groundwater potability and flow direction of Urban Aquifer, Ibadan, Southwestern Nigeria”, *Water Resources*, Vol. 21, pp. 38-60.
- Akujieze and Idehai (2014).** Physiochemical Assessment of Landfill Generated Leachates in Lagos, Nigeria. *International Journal of Science and Engineering*, 7(2),113-123.
- Akujieze CN (2004).** Effect of Anthropogenic Activities on Urban Groundwater System and Aquifer Vulnerability Assessment in Benin City, Edo State Nigeria. PhD Thesis University of Benin,Benin City, Nigeria.
- Akujieze, C.N., (2006).** Remedies of soil and groundwater pollution: An overview. *Afr. Sci.* 7(2):61-68.
- Akujieze, C.N., Ezomo FO (2010).** Permeable reactive and Aquifer Remediation. *J. Civ. Environ. Syst. Eng.* 11(2):48-63.
- Akujieze, C.N., Oteze GO (2007).** Deteriorating Quality of Groundwater in Benin City, Edo State, Nigeria: *Water Resources. J. Niger. Assoc. Hydrogeol.* 17:17-23.
- Alloway, B.J. (1996).** Heavy metals in soils, Halsted Press, John Wiley and Sons Inc. London, UK. pp. 240.
- Anna, L.B., and Piotr, B., (2014).** The Effect of Industrial Heavy Metal Pollution on Microbial Abundance and Diversity in Soils — A Review, pp 760-783.
- APHA (2005):** Standard methods for examination of water and wastewater”. American Public Health Association, 21th Edition, Washington DC pp.4-144.
- Asuen G. O., Ihenyen A. E., and Ugboyibo U. J (2005).** The Level of Heavy Metal Pollution of Roadside Sediments and Soils in Auchi Municipality, Edo State, Nigeria. *Journal of Research in Physical Sciences*, Volume 1, Number 1, 2005.

- Benkhelil, J., (1987).** The origin and evolution of the Cretaceous Benue Trough (Nigeria). J. Afr. Earth Sci. 8:251-282.
- Benkhelil, J., (1989).** Structural frame and deformations in the Benue Trough. Bull. Cent. Rech. Explor. Prod. Elf-Aquitaine, 7: 349-359.
- Calbard, E.B., and Johnson, L.R., (1984).** An assessment of arsenic in housedust and garden soils from South-East England and their implication for human health. P.276-281. In: Environmental contamination. CEP. Edinburgh.
- Culbard E B; Thornton I; Walt J; Moorcroft S and Brooks K (1983).** Sources and distribution of lead and cadmium in United Kingdom dusts and soils. P.426-429. In: proc.of 4th Int. Conf. On Heavy Metals in the environment, CEP. Edinburgh.
- Delteil, J.R., Valery, P., Montadert, L., Fondeur, C., Patriat, P. and Mascle, J., (1974).** The continental margin in the northern part of the Gulf of Guinea. In: C.A. Burk and C.L. Drake (Editors), Geology of Continental Margins. Springer-Verlag, New York, N.Y., pp. 297-311.
- Doust, H., Omatsola, E., (1989).** Niger Delta. AAPG Memoir 48:201–238.
- Egai, A.O., and Imasuen, O.I., (2015).** Assessment of soil quality in a crude oil impacted site in Aguobiri, Bayelsa State. Scientia Africana, Vol. 14 (No.1), June 2015. Pp 1-11.
- Ejedawe, J.E., (1989).** The Eastern Niger Delta: geological evolution and hydrocarbon occurrences. SPDC Internal Report, Exploration Note 89. 002.
- Ekwumemgbo, P.A., Omoniyi, K.I. and Sanni, H.A. (2013).** Geochemical partitioning of some heavy metals in dumpsite soils in Kaduna metropolis, Nigeria. International Journal of Research in Chemistry and Environment. 3(3) : 125-131.
- Etu-Efeotor, J.O. and Akpokodje, E.G., (1990).** Aquifer Systems of the Niger Delta. Journal of Mining and Geology, 26, pp.279 – 294.
- Evamy, B.D., Haremboure, J., Kameling, P., Knaap, W.A., Molloy, F.A., and Rowlands, P.H., (1978).** Hydrocarbon habitat of tertiary Niger Delta. AAPG Bull 62:1–39.
- Hakanson, L., (1980).** An ecological risk index for aquatic pollution control: A sedimentological approach. Water Res. 14(8), 975–1001.
- Harmsen, K., (1977).** Behaviour of Heavy Metals in Soils Centre for Agricultural Publishing and Documentation pg.157 Technology and Engineering.
- Ihenyen A E (1988a).** Assessment of heavy metal pollution in roadside sediments in Benin City, Nigeria. Geologia. Tom Zeszut 3 (Poland) 187-197.

- Ihenyen A E (1992).** Trace metals in bottom sediments of the harbour of Lagos, Nigeria. *Environmental monitoring and Assessment* 16; 259- 264.
- Ihenyen A E (1998b).** Heavy metal pollution studies on roadside sediments in Metropolitan Lagos, Nigeria. *Environmental Science*, MY Tokyo, 6; 1-6.
- Ihenyen,A.E., &Aghimien, A.E., (2002).** A study of trace heavy metal levels in Warri soils and vegetables, Southern Nigeria. *Afr. J. Environ. Pollut. Health* 1 (1): 72-82.
- Imasuen, OI; Omorogieva, OM (2013).** Comparative study of heavy metals Distribution in Mechanic Workshop and Refuse Dumpsite in Oluku and Otofure, Edo, South-Western Nigeria. *J.Appl. Sci. Environ .Manage.* 3 (17) pp425-430.
- Jire, P. N., and Imeokparia, E.G., (2018).** Statistical Evaluation of The Heavy Metals in the Sediments of Warri River and Environs. *Advances in Image and Video Processing*, Volume 6 No 3, June (2016); pp: 1-16.
- Kar, D. Sur, P. Mandal, S. Saha, T. and Kole, R. (2008).** Assessment of heavy metal pollution in surface water. *International Journal of Science and Technology*; 5:119-124.
- Lar, U.A., Uriah, L.A., and Shehu, U. (2014).** Environmental risk assessment of heavy metals content of municipal solid waste used as organic fertilizer in vegetable gardens on the Jos Plateau, Nigeria.*American Journal of Environmental Protection*, 3(6-2): 1-13.
- Marshal, E. (1995).** Analytical study to evaluate associations between dumpsites and birth effects. *ATSDR Co Ltd: Atlanta.* pp. 48-54.
- Medina, M. (2002).** Globalization, development and municipal solid waste management in third world cities. Tijuana, Mexico: El Colegio de la Frontera Norte. pp. 30-48.
- Misra, S. and Mani, D. (2009).** Soil pollution. New Delhi, India: S. B Nangia APH Publishing Corporation. pp. 29-59.
- Murat, R.C. (1972).** Stratigraphy and paleogeography of the Cretaceous and lower Tertiary in southern Nigeria. In: T.F.J. Dessauvage and A.J. Whiteman (Editors), *African Geology*. Ibadan University Press, Ibadan, pp. 251-266.
- NSDWQ (2007).** Nigerian Standard for Drinking Water Quality. Nigerian Industrial Standard, NIS: 554: 13-14.
- Ojeshiria, O.A. (1999).** Sanitary and hazardous waste: Landfill as a waste Disposal stage for Nigeria settlement. A paper presented at FEPA 10th year anniversary, in Nigeria.

- Onyeobi, TUS; Akujieze, CN (2014).** Characteristics of Soil and Sediment Parameters of Jisik-Izombe Upper Aquifer System for Assessment of the Potential of Groundwater Pollution. *J. Appl. Sci. Environ. Manage.* Vol 18 (4) pp 677-683.
- Onyeonwu, R.O., (2000).** Manual for Waste/Wastewater, Soil/ Sediment, Plant and Fish analysis. Benin City: MacGill Environmental Research Laboratory Manual. 81 pp.
- Parry G D R Johnson M S and Bell R M (1981).** Trace metal survey of soils as a component of strategic & Local Planning policy development. *Environmental Poll. Ser. P.* 2:97 – 107.
- Petters, S.W., (1981).** Paleoenvironments of the Gulf of Guinea. *Oceanol. Acta Proc.* 26th Int. Geol. Congr. on Geology of Continental Margins Symposium, Paris, July 7-17, 1980, pp.81-85.
- Petters, S.W., (1985).** Foraminiferal biofacies in the Nigerian rift and continental margin deltas. In: M.N. Oti and G. Postma (Editors), *Geology of Deltas.* A.A. Balkema, Rotterdam, pp.219-235.
- Puyate, Y. T., Rim-Rukeh, A., and Awatefe, J. K. (2007).** Metal pollution assessment and particle size distribution of bottom sediment of Orogodo River, Agbor, Delta State, Nigeria. *Journal of Applied Science Research*, 3(12), 2056-2061.
- Reijers, T. J. A., Peters, S. W., and Nwajide, C. S., (1997).** The Niger Delta Basin. In: R. C. Selley, Ed., *African Basin-Sedimentary Basin of the World 3,* Elsevier Science, Amsterdam, pp. 151-172.
- Reyment, R.A., (1965).** Aspects of the Geology of Nigeria. Ibadan University Press, Ibadan, pp.145.
- Roger, W, (1982).** Groundwater and Rural Homeowner Pamphlet. US Geological Survey.
- Shayley H., McBride M, and Harrison E. (2009).** Sources and Impacts of Contaminants in Soils. Cornell Waste Management Institute. pp.1-6.
- SON (2007): Nigerian Standard for Drinking Water Quality.** ICS 13.060.20, Approved by Standards Organization of Nigeria (SON) Governing Council, Lagos and Abuja, Nigeria.
- Tijjani, M.N., Kenneth .J, and Yoshinar, H. (2004).** Environmental impact of heavy metals distributions in water and sediments of Ogunpa River, Ibadan Area, South Western Nigeria. *Journal of Mining and Geology*, 40(1): 73 - 83.

- United Nations Environmental Protection, UNEP., (2005).** Solid Waste Management. United Nations Environmental Programme.
- United States Environmental Protection Agency, USEPA., (2006).** Solid Waste Disposal.pp.21-28.
- Weber, K.J., (1972).**Sedimentological aspects of oil fields in the Niger Delta. *Geologie en Mijnbouw* 50:559–576.
- Whiteman, A., (1982).** Nigeria: its petroleum geology, resources and potential. Graham and Trotman, London, 381 pp.
- WHO (2011):** Guidelines for Drinking-Water Quality, Volume 1, Recommendations 1st Addendum to 3rd edition. World Health Organization, Geneva (Electronic version). http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.ht_ml Accessed on the 14/02/2009.
- Wigwe, G.A., (1975).** The Niger Delta Physical Geology, Nigeria in *Maps: Eastern States* (pp 38 – 40). Benin: Ethiope Publ. House.



PLATE 1.0: RESEARCHER COLLECTING SEDIMENT AT DEPTH 0-15CM



PLATE 1.1: RESEARCHER COLLECTING WATER SAMPLE FROM A HAND DUG WELL