ENVIRONMENTAL EFFECT OF IRON ORE MINING OPERATIONS

IN ITAKPE, KOGI STATE

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By

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i

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DECLARATION

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

ABSTRACT

Topsoil stripping, drilling and blasting extraction, waste rock dumping, loading, and unloading, crushing and screening, and materials transport are among other activities involved in iron ore mining. These activities produce fugitive dust that may contain heavy metals which deteriorate the quality of ambient air. They also cause noise and surface water pollution, not to mention their effects on the soil and vegetation. Corrosion is another issue observed in iron ore mining; corroded iron ore and pipes at mining sites affect the environment particularly ground water quality. Therefore, there is a need to take mitigating measures.

Heavy metals are bio-accumulated and biotransferred both by natural and anthropogenic sources. The contamination by heavy metals in water, soil, and plants is one of the major issues to be faced throughout the world and requires attention because heavy metals above their normal ranges are extremely threatening to both plant and animal life. It was therefore of interest to conduct a study to estimate levels of heavy metals in water, plants, and soil in Itakpe area, Kogi State. The location (geographical coordinate) of mines, soil, water and plants samples from Kogi State were determined using geological and topographical maps, satellite images and Global Position System (GPS). Field observations, testing of water, soil, and interviews were conducted to determine the effect of mining activities in and around Itakpe in Kogi State. The data obtained was analyzed in order to assess the presence of deleterious elements from mining activities.

Water samples were collected at random from the tailing disposal unit and the water stream around beneficiation plant at Itakpe Iron mining site and nearby village i.e. Abobo village. About seven (7) soil samples, five (5) water samples and three (3) plants namely *Cynodon dactylon, Plectranthus Scutellarioides,* and *Muhlenbergia rigens* were collected from the same region. Heavy metals for which these samples were analyzed were cadmium, lead, chromium, manganese, copper, cobalt, zinc,

iron, Antimony, Arsenic, and Nickel. Plant samples were analyzed separately for their root and upper part. Atomic Absorption Spectrometer (AAS) was used for analyzing the water samples while X-ray fluorescence (XRF) was used to analyze both the plants and the soil.

Results showed that the concentrations of cadmium, chromium, copper, cobalt, iron and lead in water were recorded above the permissible limits set by Federal Environmental Protect Agency (FEPA) and WHO while zinc was recorded below the permissible limits and manganese was also below the permissible limit only in tailing water 1 and Hand dug well 2. pH of all water samples was recorded below the neutral value. Concentrations of heavy metals in soil and plants were also compared with FEPA and WHO standards for heavy metals and in soil and plants samples, the concentration of heavy metals was recorded above the permissible limits. Also, the concentration of heavy metals in water, soil, and plant samples was also evaluated based on the distance where the sample is taken to the mining site. The sample closer to the mining site had the highest concentration of the heavy metals considered, however, apart from the mining process; other activities can also increase the concentration of heavy metals on any sample outside the mining site.

Keywords: Soil, Water, Plants, pH, heavy metals, Atomic Absorption Spectrometer, XRF, GPS

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Thanks are to God Almighty for making it possible for me to undertake this project successfully.

It would be impossible to acknowledge and name individually all those who contributed in various ways to the success of this study. However, it is again impossible not to mention the contributions of the following people:

DEDICATION

I humbly dedicate this work to God Almighty, and Mary, the ever Blessed Virgin who have made this endeavor fruitful and also to my late father Mr. Cooper K. Lackay Sr, may his soul perfectly Rest In Peace.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AAS……………..Atomic Absorption Spectrophotometer

XRF……………..X-Ray Fluorescence

GPS………………Global Position System

WHO……………..World Health Organization

NIOMCO…………National Iron Ore Mining Company

USEPA……………United State Environmental Protection Agency

TPH………………Tons Per Hour

USDOL…………..United State department of Labor

EIA……………….Environmental Impact Assessment

FEPA…………….Federal Environmental Protection Agency

ISO………………..International Standard Organization

COPD…………… Chronic Obstructive Pulmonary Disease

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Iron ores are rocks and minerals from which metallic iron can be extracted. The ores are usually rich in iron oxides and vary in color from dark gray, bright yellow, deep purple, to rusty red. Iron ore deposits have been found in various locations in Nigeria, but mainly in the north-central, north-east and south-east regions. The deposits in Nigeria typically occur in the following forms: hematite (Fe_2O_3), magnetite (Fe_3O_4), metasedimentary, bands of ferrugino, quartzites, sedimentary ores, limonite, maghemite, goethite and siderite (Min. & Ind. in Nigeria, 1987).

Environmental pollution by heavy metals is very prominent in areas of mining iron ore and old mine sites, and pollution reduces with increasing distance away from mining sites The soil, air, water, and plants can be greatly affected (Peplow, 1999).

Mining is considered to be the principal source of environmental pollution due to heavy metals (Ademoroti, 1996). As waste generated from iron ore mining becomes incorporated into the environment, their heavy metal contents are absorbed by plants, air, soil, and water. When plants are consumed by humans, they can cause a 'silent epidemic' of environmental poisoning while the drinking of water around the iron ore mining site also affects human health. Heavy metal contamination of plants, soil, and water also results in deterioration of the quality of animal products as these toxic wastes can accumulate and interfere with animal organs and pose severe health problems ranging from cancer to heart and voice contamination diseases (Jimoh, 2006).

The study area is the Itakpe Iron Ore Mining Company and its surrounding communities. The company is located within the Lokoja-Okene Geological Survey Area in Nigeria delimited by latitude

7º and 8ºN and longitudes 6º and 7ºE. The area is made up of crystalline basement complex with compositional variability and structural complexity covering over 7,770 sequences consisting of sandstone and mudrocks of cretaceous to tertiary that cover about one-third of the area.

The climatic condition of the study area is tropical and consists of 6 months (May-October) of the wet season and 6 months (November-April) of the dry season. Agriculture is the major activity of the people in this area. They cultivate economic food crops such as melon, groundnut, cassava, yam, tomatoes, and cowpea.

1.2   Problem Statement

The Itakpe iron ore deposit has proven and estimated reserves of 250million, and 400million tons respectively. The deposit is located approximately 16 km northeast of Okene and forms the most impressive of a series of iron-bearing quartzite ridges in the area (Olade, 1978).

About 28 million tons of waste are expected to be excavated from the mine in order to produce 7.28 million tons of run-off-mine ore annually (NIOMCO, 2001). The wastes are disposed of in nearby dump sites thereby exposing them to precipitation and surface runoff. The washing of the un-recovered and associated ores alters the quality of water which percolates through the soil. Blasting massive ore-containing rocks to fragments generates heavy metals of dust in the cloud, which in turn leads to the settling down of the mineral-rich dust. These contaminate the ground water through the dissolution of iron.

Water polluted by heavy metals from iron mining also affects the soil and plants in that area. This may have a metallic taste and can stain surfaces or cause an unpleasant taste of water (Fetter, 1980, Olarewaju et al, 1997). When large concentrations of some heavy metals are ingested, health problems such as gastrointestinal disorder and cancer may be experienced. Aside from water and soil contaminations, there is also a problem of inhalation of dust particles from some iron ores (Pyrite)

which contain sulfur. Such dust can cause respiratory health problems. Water pH also causes the corrosion of metal components used in the industry (Olarenwaju et al 1997). This can also lead to deterioration of domestic utensils.

In addition, blasting in the mining area causes noise pollution, as well as cracking in lands and buildings of nearby villages due to severe vibrations. The key environmental impact of mining iron ore is on wildlife and fishery habitat, the water balance, local climate and the pattern of rainfall and sedimentation. The study will assess the possible effects on the environment and come up with possible adoption of environmentally friendly technology. In addition, the study will provide a baseline data for addressing the environmental effects of the mining activities.

1.3   Objectives of the Study

The objective of this research is to provide data on the levels of contamination for assessing the impact of iron ore mining activities in the localities where the mines are sited. This is in perspective of considering possible implications of heavy metal contamination of water, air, soil and plants in the area, and how they affect the people living in the area who feed on agricultural products. The impact of this pollution on groundwater quality will be evaluated, and measures to mitigate the impact of iron ore mining activities on the environment will be proffered.

CHAPTER TWO

LITERATURE REVIEW

2.1   Iron Ore Deposits

Mineral deposits are natural accumulation or concentrations of metal or minerals of sufficient size that might, under favorable circumstances, have economic value. Economic concentrations of metals or other mineral commodities are known as ore.

In those places where the concentration is sufficiently high that such rocks or minerals can be extracted from the earth at a profit, these deposits are called ores (Howard, 1987). An iron ore deposit is a mineral body of sufficient size, iron content, and chemical composition with both physical and economic characteristics that will allow it to be a source of iron either immediately or potentially (Kennedy, 1990).

Iron ore deposits are formed by three geological processes: direct sedimentation; formation of bedded sedimentary deposits, igneous activity; forming segregation or replacement deposit and enrichment due to surface and near-surface weathering (USEPA, 1994). Geological processes of iron ore deposit formation and the resulting type of ore formed with its principal iron minerals are illustrated in **Table 2.1**.

2.1.1   Process of Iron Ore Formation

Mineral concentration mostly takes place via a chemical process. It entails the dissolution of chemical components of rocks, their transport in solution and the precipitation of those components as ore minerals at some specific sites of deposition, usually controlled by chemical contrast or change in chemical environment. In the process of crystallization from solutions, the heavier iron-bearing mineral segregates by gravity to form an iron-rich deposit. When surface water descends or when underground water ascends through rock strata, iron-bearing minerals may be deposited or gangue

4

minerals such as silica may be leached out (Howard, 1987) from solutions, the heavier iron-bearing

minerals segregate by gravity to form an iron-rich deposit.

Table 2.1: Geological Processes of Iron formation

Geological Type	Principal of Mineral
Sedimentation	
Banded Iron Formation	Magnetite, Hematite, Siderite, Iron silicate
Iron Stones	Chamosite, Limonite, Hematite, Siderite
Igneous Activity	
Magmatic Segregations	Titaniferous, Ilmenite, Magnetit, Iron silicates
Pyrometasomatic	Magnetite
Surface or Near-Surface Weathering	
Secondary enrichments of low-grade deposits	Magnetite, Limonite, Siderite

(Source: USEPA, 1994)

Mechanical processes include erosion, transportation, and deposition of generally dense and insoluble

rich iron weathered rock material. The higher specific gravity of the iron-bearing minerals causes

them to be deposited earlier than other lighter materials. This method of formation is responsible for

certain sedimentary hematite deposits and magnetite beach sand (Robb, 2004).

2.1.2. Classification of Iron Ore deposits

The deposits of iron ore are widespread and have formed in a range of geological environments throughout geological time. These deposits can be divided into four major categories based on their origin (Pratt, 1993), using aspects of previous classifications by Gross, (1970) and Klemic et al (1973).

- ✓ Sedimentary(Banded iron formation, oolitic, placer, swamp);

- ✓ Igneous(Magmatic segregations and skarn);

- ✓ Hydrothermal(Proximal and distal);

- ✓ Surficial enrichment(Laterite and Supergene)

2.2 Types of Minerals in Iron Ore

There are about 300 minerals containing some iron, but only a few are considered to be important iron ore minerals. The major iron ore minerals are presented in **Table 2.2**.

6

Table 2.2: Properties of major Iron Ore Minerals

Mineral	Chemical Formula	Theoretical Iron Ore Content,%	Specific Gravity	Mohs Hardness
Hematite	Fe_2O_3	70	5.1	5-6
Magnetite	Fe_3O_4	72	5.2	5.5-6
Martite	$\alpha\text{-}Fe_2O_3$	70	5.3	5.5-6.5
Goethite	$FeO(OH)$	63	3.3-4.3	5-5.5
Siderite	$FeCO_3$	48	4	4
Chamosite	$(Mg,Fe,Al)_6(Si,Al)_4O_{14}(OH)_8$	45	3.1	3
Pyrite	FeS_2	47	4.9	6-6.5
Limonite	$FeO(OH).n(H_2O)$	63	3-4	5-5.5
Lepidocrocite	$\gamma\text{-}Fe_2O_3.H2O$	60	4.1	5
Greenalite	$Fe_3Si_2O_5(OH)_4$	45	2.9	3
Ilmenite	$FeTiO_3$	37	4.7-4.79	5-6

(Source: Ferenczi, 2001)

Major iron-bearing minerals within the Itapke deposits include: hematite (Fe_2O_3), magnetite (Fe_3O_4), limonite ($2Fe_2O_3.3H_2O$), goethite ($HFeO_2$), turgite-[$Fe_4O_5(OH)_2$], siderite ($FeCO_3$), pyrite (FeS_2), chalcopyrite ($CuFeS_2$) and iron silicate that may include chloropal ($H_6Fe_2Si_3O1_2.2H_2O$) (Encycl.Sc. and Tech., 1997).

2.2.1   Type of Iron Minerals

Iron occurs mainly in iron-oxide ores. Some ores are a mixture of minerals rich in iron. Other iron ores are less rich and have a large number of impurities. The most important iron ore forming minerals (BCS, Inc, 2002) are:

✓ Magnetite (Fe_3O_4) forms magnetic black iron ore.

✓ Hematite (Fe_2O_3) is a red iron ore. Hematite occurs in almost all forms, from solid rock to loose earth. It is the most plentiful iron ore and occurs in large quantities throughout the world.

✓ Goethite ($Fe_2O_3.H_2O$), a brown ore, contains iron.

✓ Limonite- ($Fe_2O_3.H_2O$) is a yellow-brown iron ore. Limonite is a collective term for impure goethite and a mixture of hydrated iron oxides.

2.3. Iron ore Mining Practices

The two main mining techniques used to extract iron ores from their deposits are surface and underground methods. The decision to employ underground or surface mining techniques depends on the proximity of the ore body to the surface (US EPA, 1994).

Surface mining is the predominant mining technique adopted globally. It consists of the open-pit and open-cut methods. Open-pit and open cast mining account for about 96% of non-metal minerals, 87% of metallic ores and 60% of coal production in the world. Surface mining is the most common exploitation method with production accounting for nearly 85% of all minerals, excluding petroleum and natural gas. Surface mines of iron ore extract 0.5-30 mt/year.

Underground methods are employed when the depth of the deposit, the stripping ratio of overburden to ore or both become excessive for surface exploitation. Underground mining of iron ore is still being carried out in a few large, well-established deposits in some parts of the world, for example in Kiruna Mine in Sweden (Ferenczi, 2001) and Kumba's Thabazimbi in South Africa (Howard, 1987).

2.4. Iron Ore Processing

Iron ore is converted into iron through processes of beneficiation and extraction. Most high-grade iron ores can be sent directly to iron extraction plants without beneficiation activities other than crushing and washing, but low-grade ores must be beneficiated to upgrade the iron content. Methods

of ore and mineral treatment generally involve mechanical and chemical processes. Mechanical methods include hand-picking, wet concentration, dry concentration, amalgamation, magnetic separation, electrostatic separation and flotation (Ferenczi, 2001).

Chemical methods include smelting and the use of solutions of chemical agents to dissolve valuable minerals from ore material. Beneficiation improves both physical and chemical characteristics of the final iron concentrate.

The ore excavated from the mine site is usually crushed using different types of crushers, followed by screening to obtain three basic products as follows:

(1) 1-4cm size fraction, which is used as lump ore in blast furnaces,

(2) An intermediate fraction (<1cm) for sintering, and

(3) Fine, below 150 μm size, that is either rejected or used to make pellets, often after beneficiation to increase the iron content to over 65%, since the gangue in iron ore gets concentrated in the 'fines' fraction (Ghosh and Chatterjee, 2008).

2.4.1 Crushing and Grinding

Grinding mills with spherical ball charges are used in mineral processing plants to grind coarse concentrates and middling. Final concentrates and tailing are separated after the grinding mill and fed with material that has already been ground and treated in one or more processing steps. In the grinding mill, relatively small sized balls are used. They can be operated in both open and closed circuit. The purpose of grinding and regrinding is to reduce the ore to a size small enough to liberate and recover the valuable minerals. Closed circuit grinding minimizes over grinding of very friable ore normally found in the ore bodies in India. The more the recirculation load the less is the over grinding of particles. The grinding process achieves two goals, first, the particles are crushed to achieve the

liberation size for upgrading and second the particles must be fine enough such that after combining them with the deslimed minus 0.150 mm fraction, the product will have blaine needed for the pelletizing (Taylor et al., 1997).

2.4.2   Concentration Methods

There are many methods normally used to separate iron-oxide from gangue minerals such as the gravity method, magnetic separation, and reduction roasting followed by magnetic separation, flotation, and electrostatic separation. In addition to these methods, some degree of concentration can be achieved by washing (Devaney et al., 1985). The concentration of valuable minerals from gangue involves exploitation of the differences in the mineral properties of the ore after effective comminution (Olubambi and Potgiete, 2005).

2.4.2.1   Washing

Sometime ores can be enriched by the simple process of washing such ores that consist of coarse and fine particles of clean ore minerals mixed with either barren sand or clay. In general, clay minerals increase the alumina in iron ore which is easily reduced by washing. Separation of clay minerals consists of a simple scrubbing operation in a log washer or classifier followed by a screening operation to remove the coarser iron ore particles, whereas the overflow usually is the waste products (Ferenczi, 2001).

2.4.2.2   Gravity Separation

The common iron oxides are usually heavier than the waste minerals, so they can be separated by their differences in specific gravity. Jigging is one of the oldest methods of gravity concentration in which the feed is kept in motion by water pulsing vertically through it. The heavier grains move downwards to the bottom of the bed and are removed. Since the weight of the grain is governed by its size as well as its density, it is necessary for the feed to be sized within close limits (Devaney et al, 1985).

Many kinds of jigs exist according to the size and the nature of the ore. For fine ore with a particle size of 1-1.5mm, Humphrey's spirals are now largely used and have taken the place of the shaking tables; because they have a relatively high capacity and also low maintenance requirements. The ore is washed down a spiral launder with a curved bottom to get the fine valuable out (Mular et al, 2002).

2.4.2.3 Magnetic Separation

Magnetic separation technologies are used to take advantage of the difference in the magnetic properties for separating iron ore from the non-magnetic associated gangue materials. Magnetic separation can be conducted in either a dry to wet environment, although wet systems are more common (Mular et al., 2002).

Magnetic separation operations can also be categorized as either low or high-intensity. Low-intensity separators use magnetic fields in which the magnetic induction is between 1000 to 3000 Tesla. Low-intensity techniques are normally used on magnetite ore as an inexpensive and effective separation method. High-intensity separators employ fields as strong as 20,000 Tesla. This method is used to separate weakly magnetic gangue materials. Other factors important in determining which type of magnetic separator system is used include particle size and the solids content of the ore slurry feed (Mular et al., 2002).

Typically, magnetic separation involves three stages of separation namely (i) cobbling, (ii) cleaning/rough, and (iii) finishing. Each stage may employ several drums in a series to improve separation efficiency. Each successive stage works on finer particles as a result of the removal of oversized particles in earlier separations. Cobblers work on larger particles and reject substantial percent of feed as tailing (Mular, 2002).

2.4.2.4   Froth Flotation

Froth flotation is a selective process and can be used to achieve specific separation from complex ores. This process utilizes the differences in physicochemical surface properties of particles of various minerals. After treatment with reagents, such differences in surface properties between the minerals within the flotation pulp become apparent and, for flotation to take place, an air-bubble must be able to attach itself to a particle and lift it to the water surface.

Froth flotation can effectively be used to upgrade low-grade iron ores to high iron ore concentrates. In this case, the particle size should be at least 250 μm. Fatty acids or petroleum sulfonates can be used as a collector in anionic flotation to float fine iron oxides, such as magnetite, hematite, or siderite away from waste minerals such as quartz or chert. Cationic flotation may be used to upgrade fine concentrate by floating the mineral away from the iron minerals (Kelly and Spottiswood, 1989).

The efficiency of the froth flotation process decreases when slime is apparent. Magnetic separation and flotation are the most widely accepted technologies for concentrating iron ore particles, however, these processes result in iron concentrate with a high amount of very fine and/or interlocked silica particles (Kelly and Spottiswood, 1989).

2.4.2.5   Electrostatic Separation

Electrostatic separation is limited to relatively few ores. The major process makes use of the differences in electrical conductivity between iron oxides and gangue minerals. It works best on crystalline, non-magnetic iron oxides finer than about 1.7mm and coarser 75 μm. The mineral surfaces should be free from slime or dust coating (Devaney et al., 1985). Electrostatic separating is most often used in the process of sorting mineral ore, it is an industrial process used to separate large amounts of material particles. This process can help remove valuable material from ore.

2.4.2.6   Fine Iron Ore Processing

Fine iron ores are not suitable as direct feed to the blast furnace because they tend to pack into a non-permeable bed or their fine particles are likely to be carried away as dust by the high gas flow rates. Fine iron ores must, therefore, be agglomerated into larger particles that will improve permeability of the furnace burden, increase throughput, and reduce the amount of material blown out of the furnace as dust (Pietsch, 2008).

2.4.2.7   Agglomeration

Agglomeration is a size enlargement process which involves combining small size particles to create productions with new larger particle sizes. The development of this technique of mining and concentrating taconite led to the introduction of the iron ore pellet. Pellets are comprised of ore that has been agglomerated into balls. The pellet is the major form of introducing iron into steelmaking blast furnaces. The effect of pelletizing taconite iron has been to encourage mines throughout the world to grind, concentrate and pelletize otherwise low-grade ores. Another form of agglomeration commonly used is briquetting (U.S Dept.Int., 2001).

2.5   Iron Ore Beneficiation at the National Iron Ore Mining Company (NIOMCO), Itakpe.

The basic objectives of iron ore beneficiation are to eliminate quartz and silicates, and lower phosphorous and sulfur contents. Laboratory, pilot and industrial trial tests carried out revealed the amenability of the pre-Cambrian metamorphic iron ores to beneficiation for the production of sinter and pellet feed grade of 63 - 64% Fe and 67%Fe, respectively,(Aldennan, 2002).

The Itakpe iron ore has been successfully beneficiated by gravity and magnetic separation techniques. The flow sheet adopted for the upgrading involves Reichert cones as primary concentrators and Low-Intensity Magnetic Separators as Secondary beneficiation units for the cone rejects. Final concentrate assaying 65% with a recovery of 80% is obtained after grinding to 1.6mm. The flow sheet for the

super concentrate production is expected to assay 67-69% and a recovery of 83% after regrinding to minus 0.08mm of the concentrate, using reverse flotation. (Aldennan, 2002)

2.6. Processing Description in Itakpe

A simplified overall flow sheet of the National Iron Ore Mining Company in Itakpe beneficiation process is shown in **Figure 2.1**. The industrial beneficiation plant for upgrading the ore quality comprises various compartments linked together by conveyor belts as follows:

✓ The Crushing Line, consisting of a 54" by 74" 2000 Tons per Hour (TPH) Gyratory Crusher from where minus 200mm products are transported via a Jaw Secondary Crusher, Belt conveyors and a Stacker to the Blending yard. The Blending yard comprises two homogenization stockpiles, each with a holding capacity of 273,000 tons of minus 200mm crushed iron ore. (Aldennan, 2002).
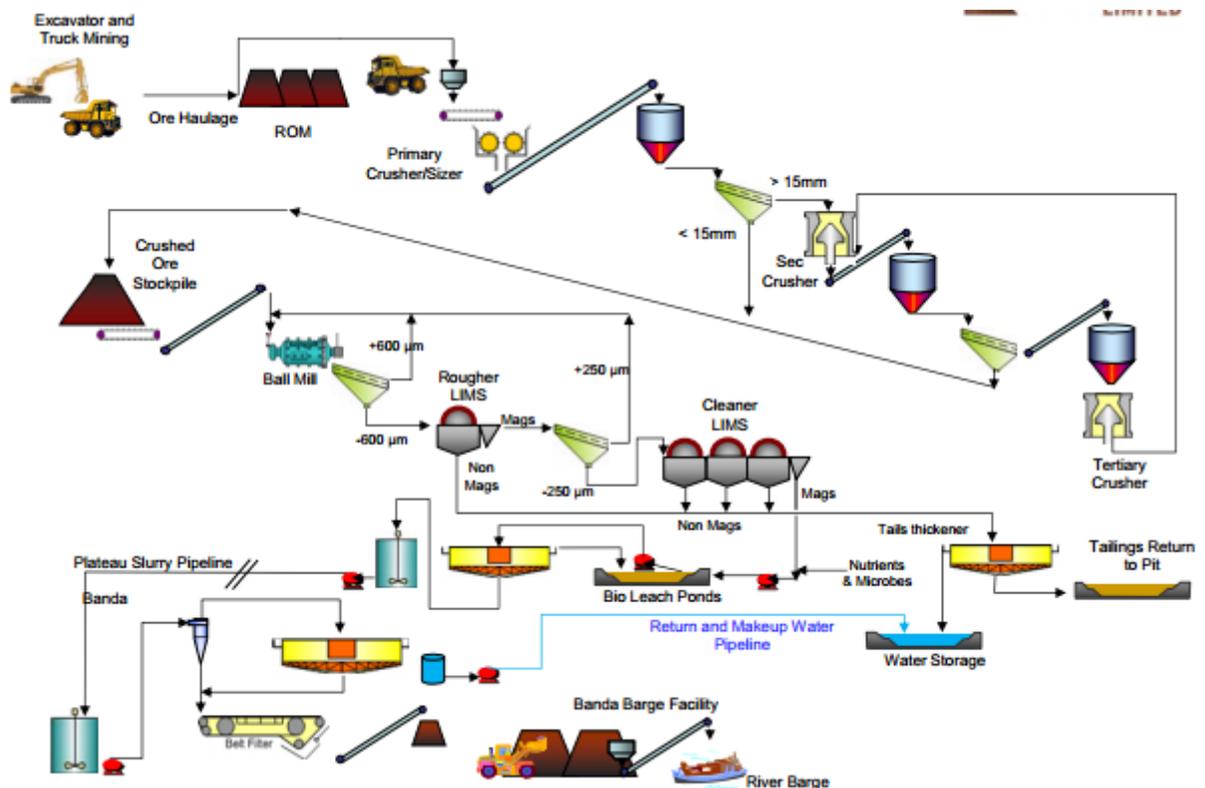
Figure 2.1: Simplified process flowsheet of Itakpe iron ore processing plant (Aldennan, 2002)

- ✓ The Reclaiming Chain, consisting of a Bucket Wheel Reclaimed which reclaims stockpiled crushed ore which is further transported by means of conveyor belts to the 2500 tons capacity Repartition Bin at the base of which are three vibratory feeders that feed the three grinding mills via belt conveyors BC10, BC11, BC12.(Aldennan, 2002).

- ✓ The Grinding Section consists of three Autogenous Grinding Mills (2.4 meters in length, 7.2 meters in diameter) powered by a 2,700kw drive motor and having nominal feed capacity of 292 TPH. The products from the mills go to the Wet Screens with 1.6mm openings.

- ✓ The Wet Screening Section comprises of 8^0 north fourteen (14) square meters screen from where grinding mills output materials below 1.6mm are further sent to the beneficiation plant where magnetic and gravity separation take place to produce the required concentrate. (Aldennan, 2002).

- ✓ The beneficiation plant consists of the Cycloning Section (Classifying and Thickening Hydrocyclones), Gravity Concentration (rough, cleaning and recleaning spiral stages,) a solid-Water Section (11°North Horizontal 20square meter) belt filters equipped with two types of vacuum Pumps for Concentrate and Tailing filtration.

- ✓ Some common units of the three completed production lines include the 60-meter diameter slimes Thickener, Concentrate Storage Yard (40,000T capacity), the 2000TPH train loading Station, Tailings disposal system, Weighing Systems, Automatic Samplers and the Central Control Room. (Aldennan, 2002).

2.7.   Iron Ore Gangue

Iron ores have impurities that are called gangue. The presence of small amounts of gangue can have either bad or good effect on the characteristics of an iron ore or on the operation of a steel plant. Flux is normally added to iron ore feed in the blast furnace to increase the furnace efficiency, while other

chemicals are added to improve the end product qualities. Ideally, iron ore contains only iron and oxygen, but typically, iron ore contains a lot of elements which are often unwanted in modern steel. There are four main slag-forming constituents in iron ores, which include the acidic oxide silica (SiO_2) and the basic oxide lime (CaO) and magnesia (MgO) as well as the neutral alumina (Al_2O_3). Most iron ores have an excess of SiO_2 and Al_2O_3 and the ash of the coke used for fuel is mainly composed of these oxides, so a basic flux, e.g. limestone must be added (Taylor et al., 2001).

Some of the iron ores contain silica, which is normally removed in the form of slag during the smelting process. Silica is reduced to silicon above 1300^0C, which forms an alloy with iron. The major effect of silicon is to promote the formation of gray iron, which is less brittle and easier to finish than white iron and thus preferred for casting purposes. The presence of silica has been reported to reduce shrinkage and the formation of blowholes, lowering the number of bad castings (Strassburger et al., 1969).

2.8.   Ore Tailings

Tailings are the materials left over after the process of separating the valuable fraction from the uneconomic fraction (gangue) of ore. Mine dumps are distinct from overburden, which is the waste rock or other material that overlies an ore or mineral body and is displaced during mining without being processed. The amount of tailings can be large, ranging from 90-98% for some copper ores to 20-50% of the other(less valuable) minerals (Davies and Rice, 2001).

The effluent from the tailings produced by the mining of sulfidic minerals has been described as "the largest environmental liability of the mining industry". These tailings contain large amounts of pyrite (FeS_2) and iron (II) sulfide (FeS) that are rejected from the sought-after ores. These minerals are reactive toward air in the presence of a microorganism, leading to acid mine drainage (Nagaraj, 2007).

2.9.   Thickening/Filtering

Thickening/filtering removes most of the liquid from both slurried concentrates and mill tailings. Thickened tailings are discharged to a tailings pond and the liquid is usually recycled to a holding pond for reuse in the mill. Chemical flocculants such as aluminum sulfate, lime, iron, calcium salts, and starches, may be added to increase the efficiency of the thickening process. A distributor is required to feed each filter from the concentrate thickener. The most efficient filter i.e. pressure filter is now replacing older technology filters. At a Blaine of $1800cm^2/g$ on specular hematite ore pressure, filter/disc filter produces close to 100dmt/ hr. at moisture at $10\%H_2O$ (http:www.vtcorpindia.com/ 2008).

2.10.   Environmental Effect of Iron Ore Mining Activities

Like other creatures, humans should create a difference in the environment, otherwise they cannot live, but unlike the others, human should choose the type and amounts of these changes. (Evernden, 1992).

Heavy metals are naturally occurring elements that have atomic weight and a density at least five (5) times greater than that of water. Their multiple industrial, domestic, agricultural, medical and technological applications have led to their wide distribution in the environment; raising concerns over their potential effects on human health and the environment. Their toxicity depends on several factors including the dose, route of exposure and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals in the iron ore mining area. Because of their high degree of toxicity, arsenic, cadmium, chromium, lead, and mercury rank among the priority metals that are of public health significance. These heavy metals are considered systemic toxicants that are known to induce multiple organs damage, even at lower levels of exposure. They are also classified as human carcinogens (known or probable) according to the U.S. Environmental Protection Agency, and the International Agency for Research on Cancer (Sutton et al., 2002).

2.11 The Effects of Heavy Metals

Heavy metals from iron ore mining activities occur as natural constituents of the earth crust, they are persistent environmental contaminants since they cannot be degraded or destroyed. To some extent, they enter the body system through soil, air, water and plants and bio-accumulate over a period of time (Lenntech, 2004; UNEP/GPA, 2004). In rocks, they exist as their ores in different chemical forms. Heavy metal ores include sulfides, such as iron, arsenic, lead, lead-zinc, cobalt, gold silver and nickel sulfides; oxides such as aluminum, manganese, gold, selenium and antimony. Some exist and can be recovered as both sulfide and oxide such as iron, copper, and cobalt.

Ore minerals tend to occur in families whereby metals that exist naturally as sulfides would mostly occur together, likewise for oxides. Therefore, sulfides of lead, cadmium, arsenic and mercury would naturally be found occurring together with sulfides of iron (Pyrite, FeS_2) and copper (Chalcopyrite, $CuFeS_2$) as minors, which are obtained as byproducts of various hydrometallurgical processes or as part of exhaust fumes in pyrometallurgical and other processes that follow after mining are left behind as tailings scattered in open and partially covered pits; some are transported through wind and flood, creating various environmental problems. Heavy metals are basically recovered from their ores by mineral operations (Peplow, 1999 Lenntech, 2004; UNEP/GPA, 2004; United State Department of Labor (USDOL, 2004).

2.11.1 Effects on Plants and Soil

Plants have the ability to accumulate "essential" metals (Ca, Co, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Se, V, and Zn) from the soil solution. Plants need different concentrations for growth and development. This ability also allows plants to accumulate other "non-essential" metals (Al, As, Au, Cd, Hg, Pb, Pd, Pt, Sb, Te, TI, and U) which have no known biological function (Djingova and Kuleff, 2000). Moreover, metals from iron ore mining activities cannot be broken down and when concentrations inside the plant cells exceed the threshold or optimal levels, it can cause direct toxicity by damaging

cell structure (due to oxidative stress caused by the reaction of oxygen species) and inhibit a number of cytoplasmic enzymes. In addition, it can cause indirect toxic effects by replacing essential nutrients at cation exchange sites in plants (Taiz and Zeiger, 2002). Iron ore mining activities also make heavy metals present in minute quantities to become more abundant in the soil. As wastes from mines become incorporated into the soil, their heavy metal contents are absorbed by plants and when those plants are consumed by man, they expose him to the 'silent epidemic' of environmental poisoning. Heavy metals are absorbed by plants and as forage by animal and find their way into the bodies where they accumulate, interface with the working order of the system and pose severe health problems ranging from cancer to heart diseases (Ademororti, 1996; Jimoh, 2006).

2.11.2   Water Pollution

Environmental pollution by heavy metals is very prominent in areas of iron ore mining and old mine sites. Pollution reduces with increasing distance away from the iron ore mining sites (Peplow, 1999). These metals are leached out and in sloppy areas, they are carried by acid water downstream or run-off to the sea. During iron ore mining activities, water bodies are most emphatically polluted. The potential for contamination is increased when iron ore mining exposes metal-bearing ores rather than natural exposure of ore bodies through erosion (Garbarino et al., 1995), and when mined ores are dumped on the earth surfaces in mineral dressing processes. Through the rivers and streams, the metals are transported as either dissolved species in water or as an integral part of suspended sediments, (dissolved species in water have the greatest potential of causing the most deleterious effects).They may then be stored in river bed sediments or seep into the underground water thereby contaminating water from underground sources, particularly wells; and the extent of contamination will depend on the nearness of the well to the iron ore mining sites.

2.11.2.1   Surface Water Pollution

Water pollution is a major problem in iron ore mining operations. When the ore is to be washed or processed in its slurry form for enrichment, the tailings, after extraction of the useful mineral are rejected and stored in big ponds. These ponds may overflow during the rainy season or they may even breach their banks, carrying huge quantities of suspended and dissolved solid into surrounding areas (Manjunath and Pearson, 2006).

The silt may get deposited in water courses or agricultural lands. Such waters may become unfit for direct usage and to make this water fit for consumption, elaborate treatment has to be done at additional cost. The spill-over of toxic material like heavy metal is a major problem in the iron ore mining sites were water becomes turbid (Manjunath and Pearson, 2006).

2.11.2.2   Ground Water Pollution

Ground water pollution may arise when the top soil/loose material contains certain chemical constituents and heavy metals and can be leached away with precipitation and percolate to ground water. The concentration of heavy metals like zinc, cadmium, lead, manganese, iron and copper are very low and will have a significant adverse impact on the groundwater quality (Bell, 2000).

The percolation of toxic from iron ore waste and storage yards in iron ore mining areas causes' ground water pollution. As a result, land also gets polluted (Manjunath and Pearson, 2006).

2.11.3   Climate and Air Pollution

Iron ore mining activities are responsible for some of the largest releases of heavy metals into the environment of the mining industry. Iron ore mining activities release other air pollutants including sulfur dioxide and nitrogen oxides, in addition to leaving behind tons of waste tailings, and acid drainage. Occupational and environmental exposure to heavy metals, silica, and asbestos can occur

during mining and milling operations. The smelting process (extracting the metal from the ore) is associated with highest exposures and environmental releases. (ILO, 2011).

The activities of iron mining caused hazards to human health caused by exposure to heavy metals including lead, cadmium, and mercury. These are associated with a range of neurological deficits in both children and adults in addition to a range of other system effects. Exposure to airborne silica and asbestos can cause lung cancer, pneumoconiosis, voice contaminations and numerous other health effects. (Eckley et al, 2011).

While pollution controls can minimize exposure to workers and surrounding communities, these safeguards are often absent in mining and smelting operations in developing countries, for example in Nigeria. In most mining sites in Nigeria, iron ore mining activities have been operational leading to indiscriminate dumping of industrial waste. Agricultural practices have been the main occupation of inhabitants around the mining site. The main staple foodstuff grown in the area like root tubers, cereal and vegetables are being irrigated from streams and dams in the mining area. Heavy metals have been found in food crops and have potential health hazards to man through the pathway in Nigeria (Obiajunwa et al., 2005). In view of the hazards posed to man, especially through the ingested and inhalation pathway, their concentrations and disposition pattern cannot be neglected in order to properly access the overall body burden.

The environmental policy of Nigeria covers the legislations, standards, regulations and administrations adopted to control activities with potentially damaging effects on the country's environment. Environmental laws have been formulated to deal with a variety of environmental pollutants, such as toxic chemical, noise, etc. control of particular activities, such as iron ore mining, power generation, etc.; and protecting basic natural resources such as air, soil, plants, soil and water (Eneh, 2010).

The environmental laws of Nigeria consist of framework environmental legislation and sectoral legislation. A framework environmental legislation is a single law which contains a comprehensive system of laws for environmental legislation this includes the Harmful Waste (Special Criminal Provisions) Act 1988 Cap 165 LFN1990; Federal Environmental Protect Agency (FEPA) Act 1988 Cap 131 LFN 1990; Environmental Impact Assessment (EIA) Act 1992 and Nigerian Urban and Regional Planning Act 1992. The sectoral legislation addresses specific aspects of the environment and human activities and includes the Mineral Act 1956(Eneh, 2010).

Even relatively efficient iron ore mining operations result in enormous waste, emission to air and water, and a legacy of environmental contamination in nearby communities. Around the world, unsafe iron ore mining sites and smelting practices have been responsible for a continuing series of environmental and human health disasters, which cause great human tragedy and undermine social stability, economic development, and sustainability goals. (Eckley et al., 2011).

2.11.4 Noise and Vibration Pollution

Iron ore mining activities usually generate noise during different states of mining and handling of ores. In open cast mines, noise is due to drilling, blasting, excavation, sizing and transportation of ores. In the case of processing, noise is due to operations like crushing, screening, washing, storage and dispatch of ores. These noise generation sources can be grouped into two categories: fixed plant and mobile plant sources. Fixed plant sources include crushers, grinders, screens, conveyors, etc., which generate noise and vibration. Similarly, the mobile plant used on-site associated with drilling, blasting, loading, haulage or service operations cause noise. (Pal et al., 1990).

Table 2.3. The noise levels in the iron ore mining and other associated activities shall not exceed the following limits:

S. No	Parameter	Noise Limits	
		Daytime (6:00am to 10:00pm)	Nighttime (10:00pm to 6:00am)
1.	Noise level-leq	75Db(A)	70d(A)

(Source: Pal et al, 1990)

2.12   Health Effect of Iron Ore Mining on Humans

Iron ore mining presents significant health effects to both workers in the mining site and those who live in the communities near the mine site. In addition to threatening the viability of watersheds and purity of drinking water, iron ore mining and processing releases heavy metals and silicate particles into the air. This air pollution can exacerbate lung diseases like asthma and Chronic Obstructive Pulmonary Disease (COPD) (Hemphill, 2007).

Miners and processing workers are at risk of silicosis and mesothelioma (Hemphill, 2007). Digging ore in open pits and then grinding the ore during processing into pellets increases the release of three known heavy metals into the environment: Arsenic (As), Lead (Pb) and Mercury (Hg). Mercury turns into methyl mercury in water and bio-accumulates in fish, leading to high levels of mercury toxicity in people who consume fish. Inorganic arsenic is a known human carcinogen associated with cancers of the lung, liver, bladder, kidney, prostate, and skin. Non-cancerous effects of chronic arsenic exposure include skin thickening and discoloration, as well as gastrointestinal symptoms of stomach pain, nausea with vomiting and diarrhea as well as numbness in hands and feet, partial paralysis and blindness (Hemphill, 2007).

Arsenic, Lead, and methyl mercury are also potent neurological toxicants that can cross the blood-brain barrier and the placenta during pregnancy. The three contaminants are particularly dangerous to the fetus and developing nervous systems of children under six years of age. They can cause permanent damage to cognitive thinking (measure in IQ), memory, motor coordination, language development and behavior, and are now implicated in behavior problems, primarily aggression and hyperactivity.(Rosenmem and Reilly, 2011).

CHAPTER THREE

METHODOLOGY AND MATERIALS

3.1 Study Area

The National Iron Ore Mining Company (NIOMCO) mining area is located South of Abuja, in Itakpe, Kogi State. Its local boundaries are with Abuja to the North, Nassarawa State to the North-East, Benue State to the East and Enugu State to the South-East as it is shown in **Figure 3.1**.
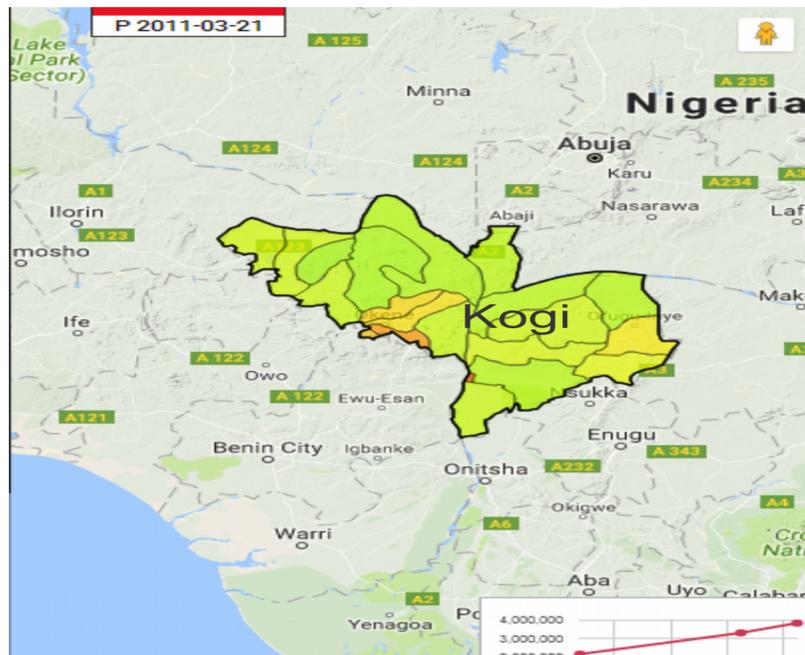
Figure 3.1: Map of Nigeria showing the location of the National Iron Ore Mining Company (NIOMCO) concession area (Source: WCNF, 1997).

3.2   Location and Access

The area of Itapke and environs is a rural area in Okene Local Government area of Kogi State in central Nigeria. It lies within latitudes $7^0 36$'N to $7^0 39$'N and longitudes 6^0 17'E to 6^0 22'E. Itapke is northeast of Okene and is about 10km along the Okene - Lokoja road. **Figure 3.2** shows the location of the study area access and its geographic features.

Figure 3.2: Map of Itakpe, Kogi State where water samples were collected from the base on their coordinates.
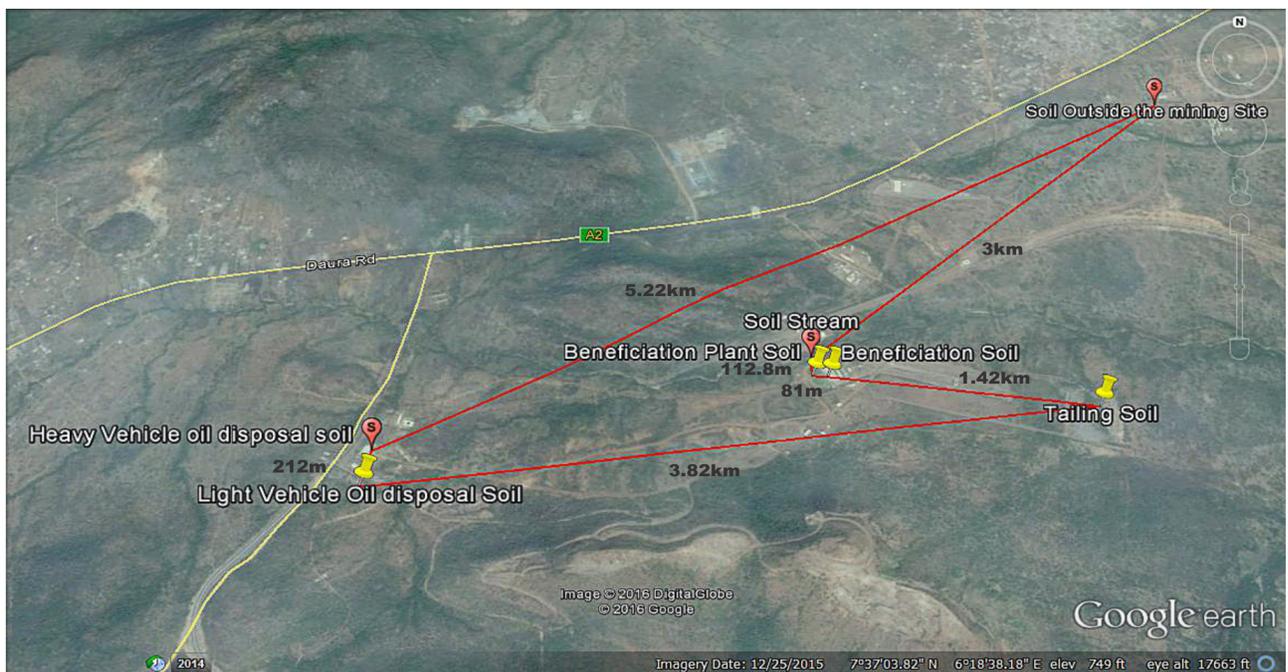
Figure 3.3: Map of Itakpe, Kogi State where Soil samples were collected from the base on their coordinates.

Figure 3.4: Map of Itakpe, Kogi State where plants samples were collected from the base on their coordinates.

3.3 Climate and Vegetation

The climate condition in Itakpe, Kogi State is similar to that of other parts of the Middle Belt of Nigeria with rainfall stretching for about seven (7) months, from April to October and dry season lasting for five months from November to March (N.S.D.A 1976). The mean annual precipitation at Itakpe is 1,200 mm. The peak period of rain is between July and September with a short break experienced in August. Rainfall decreases to 10 mm-15 mm in December and January. Harmattan or cool Northeastern winds blow in the area for the most part of the dry season. This is specifically intense in January and February. This is characterized by dust from the Sahara. Relative air humidity varies from 80% between July and August to 60% between January and February. The monthly average temperature ranges from 28^0-29^0C in July and August to 34^0-36^0C in February and March. The vegetation of the area is characteristic of the forest Savanna with bush scattered low trees, grass and shrubs.

3.4 **Research Methodology**

The study was carried out in the following steps:

Step 1: Field observation of the mining area and detection of the geographical position of the mine and sample locations using a Global Position System (GPS).

Step 2: Sampling of water, soil, and plants in order to detect and establish the presence of deleterious elements (heavy metals). The water, soil, and plant samples were collected from different locations as presented in **Tables 3.1**, **3.2** and **3.3** respectively.

Step 3: Data analysis using X-ray fluorescence (XRF) and Atomic Absorption Spectrophotometer (AAS) for analysis of probable heavy metal contamination in the samples. The pH of each sample was measured in order to test its acidity in the water sample.

3.5 **Experimental Procedure**

Soil, water, and plants were sampled from within and around the iron ore mining site in order to identify heavy metals contained in these samples. The field observation was carried out and the position of each sample was recorded using a Global Position System (GPS).

In total, seven (07) samples of soil, five (05) samples of water and three (03) samples of plants were collected. Each sample of soil was made of one (1) Kg collected from one (1) cm under the earth surface. The soils were collected by composite sampling (Random collection of soil in the area) and mixed up with a distance of fifty (50) meters from each soil sample collected, with their coordinate location using the GPS recording as shown in **Table 4.2**.

One hundred milliliter (100 ml) water samples were collected from underground, surface, stream, borehole and tailing water sources. These water samples were collected via the composite sampling

technique with a distance of fifty (50) meters from each water sample coordinate location using the GPS recording detailed in **Table 4.1**. The water was stored in containers and later kept in the freezer for just a day. Afterward, two drops of Hydrochloride Acid (HCl) were added to each sample, prior to laboratory analysis.

Grass (*Cynodon dactylon*) and vegetable plant (*Plectranthus scutellarioides*) samples were collected by random sampling with a distance of fifty (50) meters from their coordinate locations with the GPS.

3.5.1　　　　Laboratory Analysis

All reagents used were of analytical grade. Standard solutions were prepared using these reagents in a laboratory apparatus (glass) which had been appropriately washed with distilled water, cleaned and dried to prevent contamination.

3.5.1.1　　　　X-Ray Fluorescence Analysis Of Soil

Name of equipment: SKYRAY INSTRUMENT and type of Equipment Model No: EDX3600B X-ray fluorescence spectrometer applies XRF technology to conduct a fast and accurate analysis of complex composition. The system detects elements between Sodium (Na, Z=11) and Uranium (U, Z=92) with high resolution and fast analysis.

Sample preparation: For non-homogeneous samples, samples were be pulverized to fine homogeneous size and then pelletized.

Procedure for analysis:

1. Registration of samples for analysis.
2. Sample preparation: the soil samples were crushed in an agate mortar to obtain some degree of uniformity in size, after which, the samples were pelletized and send to the Laboratory for testing.

3. Sample testing: EDXRF equipment and the computer system interface were turned on and allowed to initialize for 45 minutes, after which the samples were run.

The equipment was calibrated using the pure silver sample to confine the efficiency of the equipment before testing the unknown samples. Each of the samples were loaded and tested on the equipment and the data was saved before unloading the sample from the equipment.

3.5.1.2 X- Ray Fluorescence (XRF) For Plants Analysis

Name of equipment: SKYRAY INSTRUMENT and type of Equipment Model No: EDX3600B X-ray fluorescence spectrometer applies XRF technology to conduct a fast and accurate analysis of complex composition. The system detects elements between Sodium (Na, Z=11) and Uranium (U, Z=92) with high resolution and fast analysis.

Sample preparation: For a non-homogeneous sample, the sample was pulverized to fine homogeneous size and then pelletized.

Procedure for analysis:

1. Registration of samples for analysis.

2. Sample preparation: the upper parts and roots of the plant samples (Cynodon dactylon, Plectranthus scutellarioides and Muhlenberg rigens) were crushed in an agate mortar to obtain some degree of uniformity in size, after which, the samples were pelletized and sent to the Laboratory for testing.

3. Sample testing: EDXRF equipment and the computer system interface were turned on and allowed to initialize for 45 minutes.

The equipment was calibrated using the pure silver sample to confine the efficiency of the equipment before testing the unknown samples. Each of the samples were loaded and tested on the equipment and the data was saved before unloading the sample from the equipment.

3.5.1.3 Water Samples Analysis

Surface, underground, tailing, stream and borehole water samples were collected from five (5) different locations, each location being 50 meters apart within the mining sites, as shown in **Table 2**. The samples were stored in clean plastic bottles, to which 5 ml of concentrated hydrochloric acid was added to 250 ml of each water sample and evaporated to 25 ml. The concentrate was filtered using a cellulose membrane (0.45µm) and transferred to a 50 ml flaskand50 ml of 0.1M HCl, after which it was diluted to mark with distilled water. Heavy metals (Mg, Cd, Pb, Cr, Mn, Cu, Co, Zn and Fe) were determined using an Atomic Absorption Spectrometer (AAS) Model AA500F and Manufacturer Analytic Jena.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

The result of the elemental concentrations of heavy metals in water samples is presented in **Table 4.1** and **Figure 4.1**. The concentration in soil samples are also presented in **Table 4.2** and **Figure 4.2**, while the concentration in the upper part and roots of plants are presented in **Table 4.3** and **4.4**, and **Figure 4.3**.

The mineral phases content in the ore are presented in **Table 4.5** and **Figure 4.4**; the elemental contents of the iron ore are also presented in **Table 4.6** and Figure **4.5**.

Table 4.1: Total elementals concentrations (mg/l) of heavy metals in a water sample.

Water Samples	Description/Locations	GSP Coordinates	pH	Cd	Pb	Cr	Mn	Cu	Co	Zn	Fe
Tailings Water 1	Tailing Disposal Unit/Itakpe Iron Ore Mining Site/L04CKL	N 07° 36' 51.6" E 006° 19' 55.4"	7.07	0.03	0.82	0.26	0.03	0.20	0.23	0.04	1.30
Tailings Water 2	Tailing Disposal Unit/Itakpe Iron Ore Mining Site/L05CKL	N 07° 36' 51.4" E 006° 19' 55.3"	2.49	0.04	0.37	0.20	7.12	0.17	0.24	0.09	11.57
Stream Water	Water Stream Around Beneficiation Plant/Itakpe Iron Ore Mining Site/L12CKL	N 07° 37' 00.8" E 006° 19' 06.7"	2.81	0.04	0.27	0.16	4.27	0.19	0.41	0.12	0.89
Hand Dug Well 1	Outside Mining area/ Abobo Village 500m/L13CKL	N 07° 38' 18.3" E 006° 20' 11.9"	2.64	0.03	1.07	0.22	0.07	0.17	0.20	0.05	0.11
Hand Dug Well 2	outside Mining area /Abobo Village 520m/L14CKL	N 07° 38' 22.5" E 006° 20' 12.3"	3.04	0.11	0.72	0.14	0.03	0.16	0.12	0.06	0.06
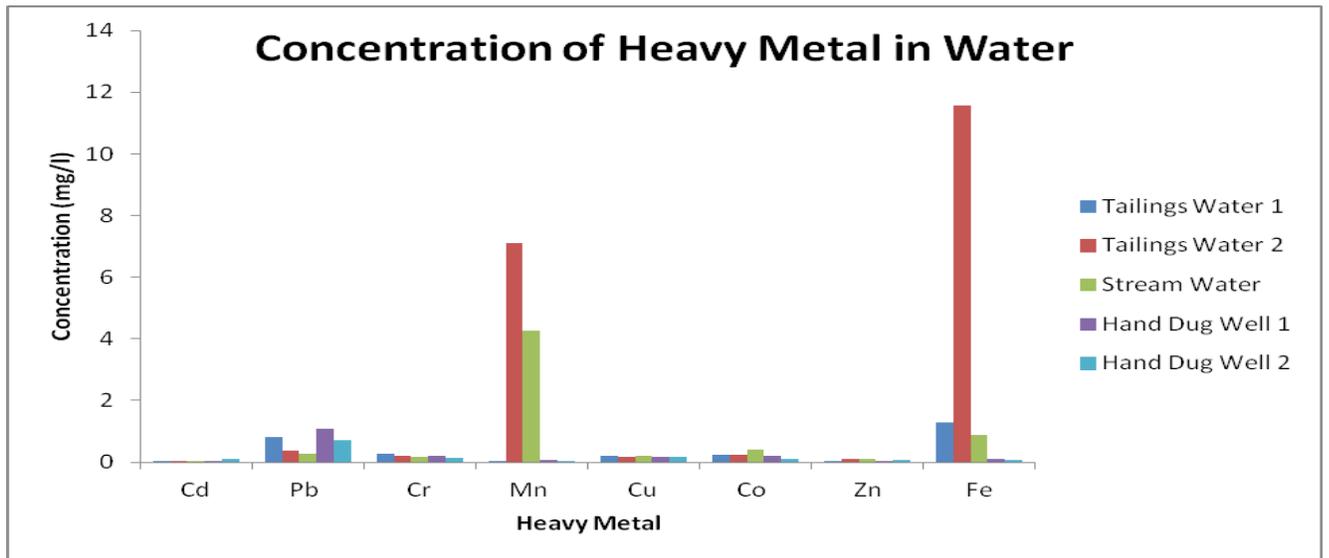
Figure 4.1: Total elementals(mg/L) of heavy metal in Water samples against the   elementals concentration

Table 4.2: Total elementals concentrations (mg/kg) of heavy metals in a Soil sample.

| Soil Samples	Description/Locations	GPS Coordinates	Mn	As	Sb	Ni	Pb	Cr	Co
Light Vehicle oil disposal Soil	Maintenance Workshop Spent Point/Itakpe Iron Ore Mining Site L01 CKL	N 07° 36' 34.5" E 006 17' 51.8"	512	176	9713	751	1173	162	380
Tailing Soil	Tailing Disposal Unit/Itakpe Iron Ore Mining Site L06CKL	N 07° 36' 51.3" E 006 19' 55.3"	8225	0	5383	860	188	515	3658
Beneficiation Soil	Around the gravity and Lim Separating plant/Itakpe Iron Ore Mining Site L09CKL	N 07° 36'57.0" E006° 19' 09.4"	934	0	4824	438	496	500	6027
Beneficiation Plant Soil	Gravity and Lim(Close to water thickener)/Itakpe Iron Ore Mining Site L10CKL	N 07°36' 57.2" E 006° 19' 06.8"	846	0	7103	6050	355	357	5008
Soil Stream	Stream in the mining Site /Itakpe Iron Ore Mining site/L11CKL	N 07° 37' 00.9" E 006° 19' 06.8"	1495	0	7775	587	0	127	1098
Soil Outside the mining Site	Miners Residential Quarters/Outside Itakpe Iron Ore Mining site/L15CKL	N 07° 38' 04.9" E 006 20' 21.1"	1210	0	6914	563	0	170	1544
Heavy Vehicle oil disposal soil	Heavy Duty Equipment(Plant Workshop point/L02CKL	N 070 36' 41.4" E006 17' 52.9"	1568	104	5496	548	976	696	3855
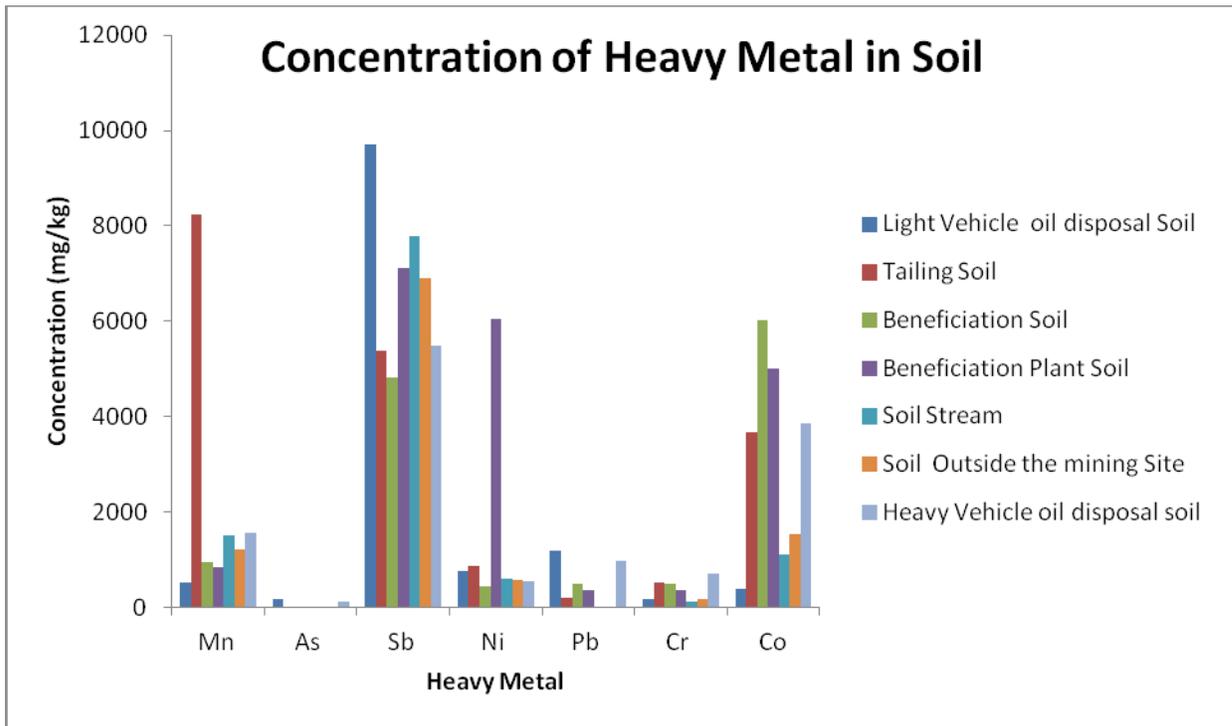
Figure 4.2. Total elementals(mg/Kg) of heavy metal in Soil samples against the elementals concentrations

Table 4.3: Total elementals concentrations (mg/kg) of heavy metals in the Upper part of the plant samples.

Samples of Plants	Descriptions/ Locations	GPS LOCATIONS	Parts of the Plants	Mn	Cr	Co	Pb	Ni	Zn	Sb	Fe
Cynodon dactylon (upper)	Tailing site in the Mining area/L07CKL	N 07° 36' 51.4" E 006° 19' 55.4"	UPPER	11272	150	434	138	783	2756	6961	122725
Plectranthus scutellarioides (upper)	Tailing Site in the mining area/L08CKL	N 07° 36' 50.9" E 006° 19' 55.4"	UPPER	17740	173	648	0	696	1819	4668	138132
Muhlenbergia rigens (upper)	Mining Residential Quarter/L15CKL	N 07° 38' 04.9" E 006 20' 21.2"	UPPER	1733	790	1847	0	455	1160	3834	158679

36

Table 4.4. Total elementals concentrations (mg/Kg) of heavy metals in Roots of the plant sample.

Samples of Plants	Descriptions/ Locations	GPS Locations	Parts of the Plants	Mn	Cr	Co	Pb	Ni	Zn	Sb	Fe
Cynodon dactylon (Roots)	Tailing site in the Mining area/L07CKL	N 07° 36' 51.4" E 006° 19' 55.4"	ROOTS	15457	401	2944	341	698	856	494	1141
Plectranthus scutellarioides (Roots)	Tailing Site in the mining area/L08CKL	N 07° 36' 50.9" E 006° 19' 55.4"	ROOTS	23023	173	2006	161	714	1096	5034	274579
Muhlenbergia rigens (Roots)	Mining Residential Quarter/L15CKL	N 07° 38' 04.9" E 006 20' 21.2"	ROOTS	2788	388	2251	97	453	1315	2746	291158
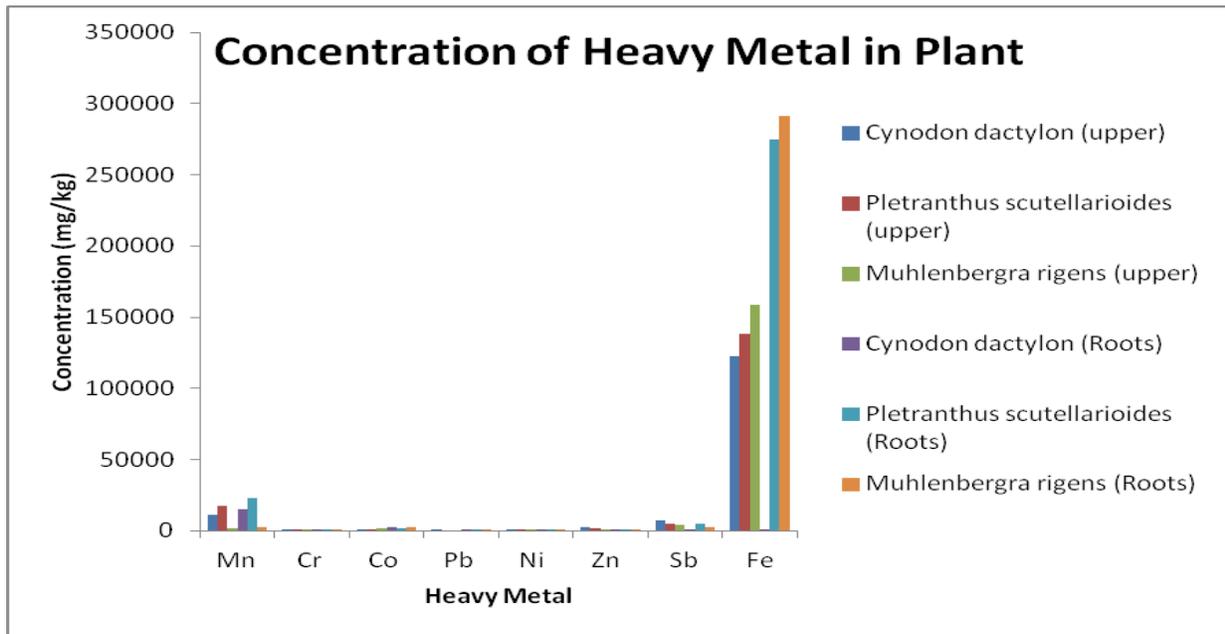
Figure 4.3: Total elementals (mg/Kg) of heavy metal in Plant samples against the elemental

Concentrations

Table 4.5: Percentage of Iron minerals in the Sample

Minerals	Chemical formula	Iron Ore content,%
Hematite	(Fe_2O_3)	69.2
Magnetite	(Fe_3O_4)	72
Martite	$(Fe_2O_3)/(Fe_3O_4)$	70.1
Goethite	$FeO\{OH\}$	62.2
Siderite	$FeCO_3$	48
Chamosite	$Fe_3MgAlO_{12}\{Si\}(OH)$	29.4
Pyrite	FeS_2	46.5
Limonite	$FeO(OH).n(H_2O)$	59.1
Lepidocrocite	$\gamma\text{-}Fe_2O_3.H_2O$	22.4
Chalcopyrite	$CuFeS_2$	30.2
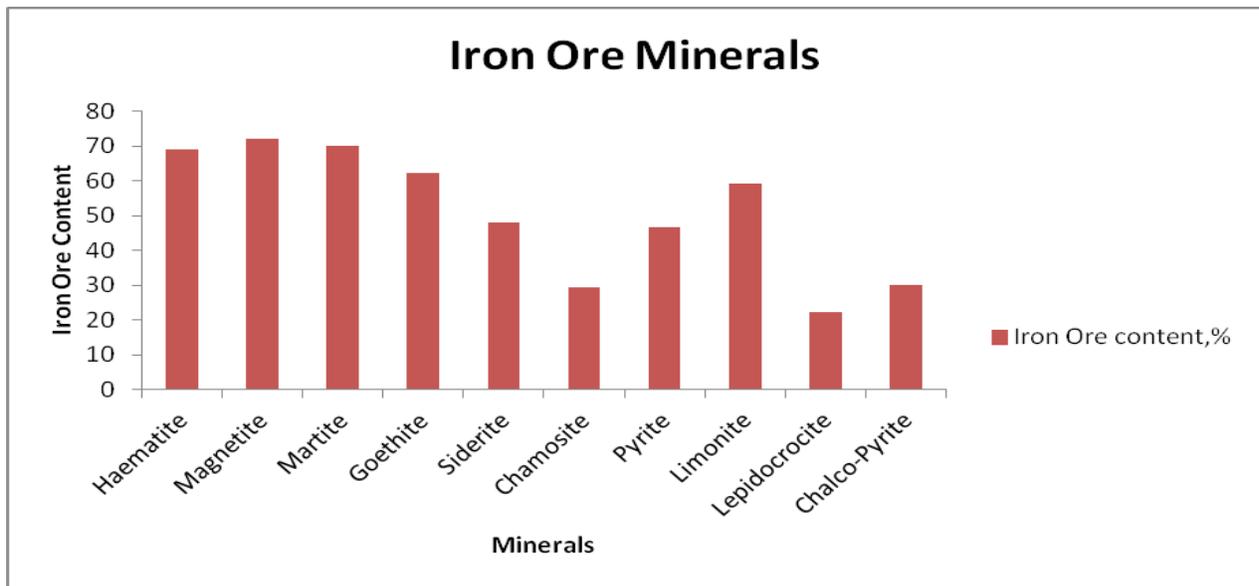
Figure 4.4: Percentage of Iron Ore content in the Sample

Table 4.6: Elemental Composition of the Ore in Itakpe

38

Elements	Elemental % in the Ore
Antimony (Sb)	0.2881
Cadmium (Cd)	0
Cobalt (Co)	1.2323
Lead (Pb)	0.4261
Chromium (Cr)	0.1918
Nickel (Ni)	0.1483
Manganese (Mn)	0.2584
Copper (Cu)	0.0531
Zinc (Zn)	0.0858
Iron (Fe)	66.0288
Arsenic (As)	0
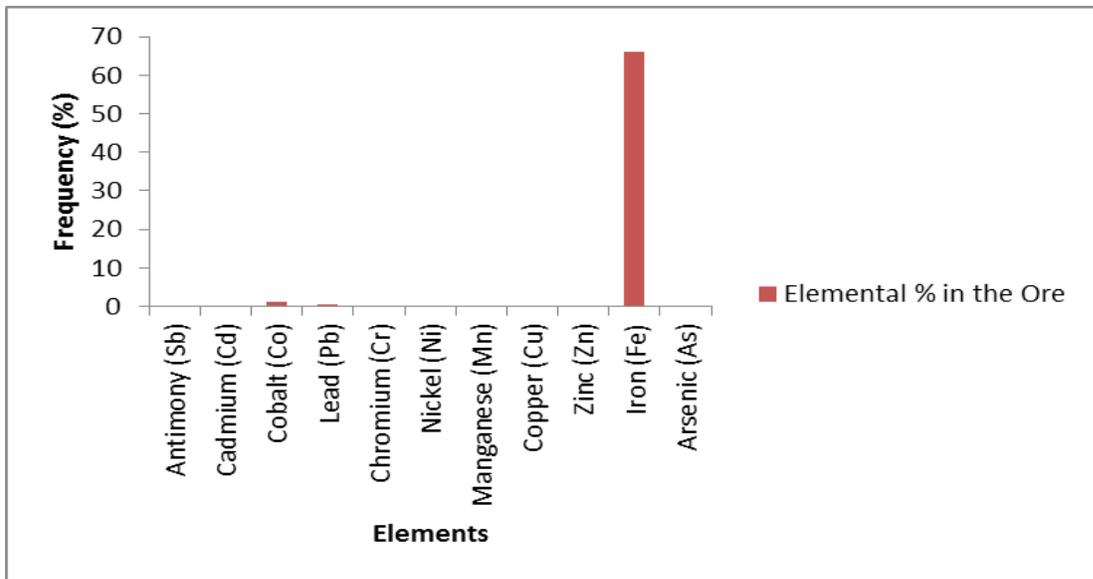
Figure 4.5: Elemental composition the Ore in Itakpe

4.2   **Discussion**

The present study was conducted in order to assess the heavy metal contamination of soil, plants, and water of Itakpe, Kogi State. As water pollution is dangerous for both aquatic and human health, it is, therefore, needful to assess the water quality of rivers and dams. For this purpose, five (5) water samples including tailing disposal unit, water stream around beneficiation plant and the Abobo Hand dug well were collected. Also, three plants including *Cynodon dactylon, Plectranthus scutellarioides, and Muhlenbergia rigens* from the upper part and the root were considered. Soil samples were collected both within and outside the mining site. The water, soil, and plants were subjected to heavy metal analysis from which the following were formed to be present, viz, Cd, Pb, Cr, Mn, Cu, Co, Zn and Fe.

4.2.1   **Level of Cadmium (Cd) in Water, Plants, and Soil**

The concentration of cadmium in water samples ranged between 0.0335 to 0.1097mg/l (**Table 1**). This is above the permissible limits of 0.01mg/l and 0.005mg/l set by the regulatory agencies including Federal Environmental Protection Agency (FEPA, 1999) and WHO, 1998, respectively. The concentration of Cd in the water sample also varied based on distance to the mining site. Cd was more concentrated in Hand Dug Well 2 than the other sample. Apart from the distance from the mining site, volcanic activities such as weathering of rocks and minerals and erosion can also increase the concentration of Cd in water. The elemental composition of the ore in Itakpe from **Table 4.6** mining site showed that Cd was below the sample ranged, therefore, iron ore mining may not be the cause of Cd in the mining habitat; the presence of Cd in the water may be from other sources like the reagents used to concentrate the iron ore or waste in the mining area.

The permissible limit of cadmium in plants (*Cynodon dactylon*, *Plectranthus scutellarioides, and* Muhlenberg *rigens*) and soil recommended by FEPA and WHO are 0.02mg/kg and 0.003mg/kg

respectively. In all the collected samples for both soil and plants samples in **Table 4.2**, **4.3** and **4.4**, there were no concentrations of cadmium found.

Absorption of cadmium compounds is dependent on the solubility of the compounds. Cadmium accumulates primarily in the kidneys and has a long biological half-life in humans of 10-35years (Melse, 2003). There is evidence that cadmium is carcinogenic by the inhalation route, and the International Agency for Research on Cancer (IARC) has classified cadmium and cadmium compounds in Group 2A. However, there is no evidence by the oral route and no clear evidence for the genotoxicity of cadmium. The kidney is the main target organ for cadmium toxicity. Several epidemiological investigations have demonstrated the relation between risk for cardiovascular disease, growth retardations reproductive failure, and other health problems and hardness of drinking water or its content of magnesium (Galan et al. 2002).

4.2.2 Level of Lead (Pb) in Plants, Water, and Soil

The permissible limit in plants recommended by (FEPA, 1999) is 2mg/kg. At the roots of the plants (*Cynodon dactylon, Plectranthus scutellarioides* and *Muhlenbergia rigens*), the concentration of lead was above the permissible limit as it ranged from 97 to 341 mg/kg. In the upper part of the *Cynodon dactylon,* it was also above the permissible level. However, in the upper part of *Plectranthus scutellarioides* and *Muhlenbergia rigens,* there was no lead found. According to (FEPA,1991) and (WHO,1998) standards, the permissible limit of lead in water is 0.05mg/l and in all the collected water samples, the concentration of lead was above the permissible limit since it's ranged between 0.2703 to 1.0705 mg/l. The concentration of lead in the soil sample was recorded to be range between 355 to 1173 mg/kg. In all the collected soil samples, there was no presence of Lead in the soil stream and soil outside the mining site, while the concentration of lead in the remaining five (5) soil samples was recorded above the permissible limit set by FEPA, 1999 and ISO, 2009 which is 15mg/kg. The concentration of Pb in water, soil, and plants also varied based on the distance where the sample is

taken to the mining site. Hand Dug Well 1, Light Vehicle Oil Disposal Soil and *Cynodon dactylon* has the highest concentration of Pb in water, soil and plant sample respectively. The sample closer to the mining site was expected to have the highest concentration of Pb, however, disposal of sewage and other activities could also increase the concentration of Pb in any sample outside the mining site.

The elemental composition of the ore in Itakpe from **Table 4.6** mining site shows that lead is above the sample ranged, therefore, iron ore mining activities may be a major cause of lead in the mining area.

Lead as a soil contaminant has a widespread issue; It accumulates with age in the bone aorta, and kidney, liver, and spleen. It can enter the human body through uptake of food (65%), water (20%) and air (15%) (Afzal et al 2011). Lead is known for its toxicity and negative impacts on human health. Absorption of swallowed lead may have a severe danger to public health. Some long lasting negative impacts of lead toxicity includes colic, constipation, and anemia (blood-related disorder) (Bolger et al, 2000). Children show weakness toward lead (Pb) noxiousness and that Pb results in harm to the central nervous system, in severe cases death may occur (Nicklow et al. 1983).

Lead in soils has been testified to prevent plant's progress in growth, uptake of nutrients, physiological and metabolic process. It also affects chlorosis, harm to roots tips, minimized water and uptake of nutrients and impairment to enzymes (Sanità and Gabbrielli, 1999).

In plants, lead is highly toxic at a comparatively low amount. The heavy metal poisonousness is the product of a multifaceted interaction of chief noxious ions with other vital or non-essential ions. Lead can be a source of decrease in the hydrolysis products, α-amylase, phosphatase, RNAs, and proteins. They disturb the enzyme activities by substituting metal ions from the metals-enzymes and prevent various physiological developments of plants (Agrawal, 1999).

4.2.3   Level of Chromium (Cr) in Plants, Water, and Soil

The permissible limit of chromium for plants is 1.30mg/kg recommended by (FEPA, 1999) and WHO (Zaigham et al, 2012). The values of **Cr** in all the upper part and the roots of the plant samples ranged between 150 to 790mg/kg and 173 to 401mg/kg respectively. In the three plants (*Cynodon dactylon, Plectranthus scutellarioides* and *Muhlenbergia rigens*), the concentration of chromium was above the permissible limit. The maximum permissible limit for **Cr** in water by FEPA, 1999 and WHO, 1999 is 0.1mg/l and 0.05mg/l. In all the collected water samples, the concentration of chromium was recorded above the permissible limit since it ranged between 0.1365 to 0.2638mg/l in the five (5) samples. In the soil samples, the concentration of chromium ranged between 127 to 696mg/kg which was also above the permissible limit of 12mg/kg set by FEPA, 1999 and ISO, 1998. The concentration of Cr in water, soil, and plants also varied based on the distance where the sample was taken to the mining site. Tailing water 1, Heavy Vehicle Oil Disposal Soil and *Muhlenbergia rigens* had the highest concentration of Cr in water, soil and plant sample respectively. The sample closer to the mining site was expected to have the highest concentration, however, apart from the mining process, other activities could have also increased the concentration of Cr in any sample outside the mining site.

The elemental composition of the ore in Itakpe from **Table 4.6** mining site show that chromium is above the samples ranged, therefore, iron ore mining, therefore, the mining activities may contribute extensively to Cr pollution in the mining environment.

4.2.4   Level of Manganese (Mn) in Water, Soil, and Plants

The permissible limit of manganese for water is 0.05mg/l (FEPA, 1999 and WHO, 2006). The values of **Mn** in all water samples ranged between 0.0256 to 7.1177mg/l in the five (5) samples. In the collected water samples, the concentration of Tailing water sample and Hand dug well was below the permissible limit while the other three (3) samples were recorded above the permissible limit. In soil, Mn ranged between 512 to 8225mg/kg which is above the permissible limit of 12mg/kg (FEPA, 1999). Also, in the plants, including the upper and roots part, the concentration of Mn was above the

permissible limit of 200mg/kg. The concentration of Mn in water, soil, and plants also varied based on the distance where the sample was taken to the mining site. Tailing water 2, Tailing Soil and *Plectranthus scutellarioides* had the highest concentration of Mn in water, soil and plant samples respectively. The sample closer to the mining site was expected to have the highest concentration, however, apart from the mining process, other activities could have also increased the concentration of Mn on any sample outside the mining site. The elemental composition of the ore in Itakpe from **Table 4.6** mining show that manganese is above the samples ranged, therefore, iron ore mining practices and thus may act as the cause of Mn pollution in the mining area and its environs.

4.2.5   Level of Copper (Cu) in Water, Soil, and Plants

The permissible limit of copper for plants is 10mg/kg recommend by FEPA, 1991 and WHO (Zighan Hassan et al 2012). In all the collected samples of upper parts and roots of plants, no concentration of copper was found.

The maximum permissible limit of **Cu** in water by FEPA, 1999 and WHO, 1998 is 0.05mg/l. The concentration of copper in all the collected water samples was recorded in the range 0.1582 to 0.2032, which was above the permissible limit. The concentration of Cu in water also varied based on the distance from where the sample was taken to the mining site. Tailing water 1 had the highest concentration of Cu in water. As expected, the sample closer to the mining site had the highest concentration Cu. The elemental composition of the ore in Itakpe from **Table 4.6** mining site show copper is above the samples of water ranged, therefore, iron ore mining activities may contribute extensively to Cu pollution in the mining environments.

Contamination of drinking water with high levels of copper may lead to chronic anemia (Asma Iqbel et al 2011). Copper accumulates in the liver and brain. Copper toxicity is a fundamental cause of Wilson's disease (Samuel Zerabruk et al 2011).

4.2.6 Level of Zinc (Zn) in Water, Soil, and Plants

The element zinc is one of the most important trace elements that play a vital role in the physiological and metabolic process of many organisms. The higher concentrations of zinc can be toxic to the organisms. It plays an important role in protein synthesis and is a metal which shows fairly low concentration in surface and underground water due to its restricted mobility from the place of rock weathering or from the natural sources. The concentration of zinc in water samples ranged between 0.04 to 0.1151mg/l. The permissible limit of zinc in water according to FEPA and WHO standards is 5mg/l. In all the collected water samples concentration of zinc was recorded below the permissible limit. In the soil sample, Zn was not found. In the upper part and the roots of plants, it ranged between 1160 to 2756mg/kg and 856 to 1315mg/kg respectively which were above the permissible limit of 50mg/kg. The concentration of Zn in water and plants also varied based on the distance from where the sample was taken to the mining site. Stream water and *Cynodon dactylons* had the highest concentration of Zn in water and plant samples respectively. The sample closer to the mining site was expected to have the highest concentration, however, apart from the mining process, other activities could also have increased the concentration of Zn on any sample outside the mining site. The elemental composition of the ore in Itakpe from **Table 4.6** show that zinc is above the samples of plants ranging in at 856mg/kg, therefore, iron ore mining activities and may, therefore, be a major cause of Zn in the mining habitats.

4.2.7 Level of Iron (Fe) in Water, Soil, and Plants

Iron is present in drinking water as Fe^{2+} or Fe^{3+} in suspended form. The element causes staining in clothes and imparts a bitter taste. It comes into the water from iron ore mining sites discharge and also from byproducts. The increase of iron more than 10mg/kg causes a rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension, and drowsiness. The maximum allowed concentration of iron in drinking water by FEPA, 1991 and WHO, 1998 is 1.0mg/l. In all the collected water samples, the concentration of iron was above the permissible limit in Tailing water I and II while

it was below the limit in the remaining water sample. The FEPA, 1999 and WHO recommended a level of iron in plants is 20mg/kg (Afzal Shal et al 2011). In the upper parts and the roots of *Cynodon dactylon, Pletranthus scutellarioides* and *Muhlenbergia rigens,* ranged between 122725 to 158679mg/kg and 1141 to 291158mg/kg respectively which was above the permissible limit. The concentration of Fe in water and plants also varies based on the distance where the sample is taken to the mining site. Tailing water 2 and *Muhlenbergia rigens* had the highest concentration of Fe in water and plant samples respectively. The sample closer to the mining site was expected to have the highest concentration of Fe, however, apart from the mining process, other activities could have also increased the concentration of Fe. The elemental composition of the ore in Itakpe from **Table 4.6** mining area show that Fe is above the samples ranged for both plants and water, therefore, iron ore mining activities may be the main cause of Fe pollution in the mining site.

4.2.8   Level of Cobalt (Co) in Water, Soil and Plants

The permissible limit for a plant is 0.05mg/kg (Kabata-Pendias and Piotrowska, 1984). The values of **Co** in all plant samples ranged between 434mg/kg to 2944mg/kg in the three samples (*Cynodon dactylon, Plectranthus Scutellarioides, and Muhlenbergia rigens*) which was recorded above the permissible limit. The permissible limit for water by FEPA, 1999 and WHO, 2006 is 0.001mg/l. The values of **Co** in all water samples ranged between 0.124 to 0.4114mg/kg which was recorded above the permissible limit. The permissible limit for soil is 12mg/kg (ISO, 1998). The values of **Co** in all soil samples ranged between 380 to 6027 mg/kg, which was also recorded above the permissible limit of International Standard. The concentration of Co in water, soil, and plants also varied based on the distance from where the sample was taken to the mining site. Stream water, beneficiation soil, and *Muhlenbergia rigens* had the highest concentration of Co in water, soil and plant sample respectively. The sample closer to the mining site was expected to have the highest concentration, however, apart from the mining process, other activities could also increase the concentration of Co on any sample

outside the mining site. The elemental composition of the ore in Itakpe from **Table 4.6** mining area show that **Co** is above the samples ranged, therefore, iron ore mining may contribute majorly to the cause of Co pollution in the mining environment.

4.2.9 Level of Nickel (Ni) in Water, Soil, and Plants

The permissible limit for soil is 100mg/kg (ISO, 2009).The values of **Ni** in all soil samples ranged between 438 to 6050mg/kg, which was recorded above the permissible limit of International Standard. There was no trace of Ni found in the water sample.

The permissible limit for a plant by FEPA, 1999 and WHO (Zaigham Hassan et al, 2012) is 10mg/kg. The values of **Ni** in the upper part and roots of all plant samples ranged between 455 to 783mg/kg and 453 to 714mg kg respectively in the three plants (*Cynodon dactylon, Plectranthus Scutellarioides,* and *Muhlenbergia rigens*) which were recorded above the permissible limit. The concentration of Ni in soil and plants also varied based on the distance from where the sample was taken to the mining site. Beneficiation Plant Soil and *Cynodon dactylon* had the highest concentration of Ni in soil and plant samples respectively. The elemental composition of the ore in Itakpe from **Table 4.6** mining site show that Nickel is above the samples of some soil and completely above the samples of plants in their ranges, therefore iron ore mining activities may contribute to Nickel pollution in the mining environment.

4.2.10 Level of Arsenic in Water, Soil, and Plants

The permissible limit for soil is 1mg/kg (ISO, 1998). The values of **As** in the Light and Heavy vehicle oil disposal soil are 104mg/kg and 176mg/kg respectively which was recorded above the permissible limit. However, it was not detected in the remaining five (5) samples. The element Arsenic was not found in both plants and water samples. The concentration of **As** in soil also varied based on the distance from where the sample was taken to the mining site. Light Vehicle Oil Disposal Soil had the highest concentration of **As** in soil sample. As expected, the sample closer to the mining site had the

highest concentration. The elemental composition of the ore in Itakpe from Table **4.6** mining site show that Arsenic is below the sample ranged and was not even find in the ore, therefore, iron ore mining activities are not the cause of As in the mining environment, it was from difference sources like the waste or the reagents they used to concentrate the iron ore.

4.2.11 Level of Antimony (Sb) in Water, Soil, and Plants

The permissible limit by FEPA and WHO of Sb in soil is 36mg/kg. The values of **Sb** in all soil samples ranged between 4824 to 9713mg/kg, which was recorded above the permissible limit. The permissible limit for plant ranges between 5-10mg/kg (Kabata and pendias, 1984). The values of **Sb** in the upper part and roots of the plant samples (*Cynodon dactylon, Plectranthus Scutellarioides,* and *Muhlenbergia rigens*) ranged between 3834 to 6961mg/kg and 494 to 5034mg/kg respectively which was above the permissible limit. There was no Antimony found in the water sample. The concentration of Sb in soil and plants also varied based on the distance from where the sample was taken to the mining site. Light Vehicle Oil Disposal Soil and *Cynodon dactylon* had the highest concentration of Sb in soil and plant samples respectively. As was expected, the sample closer to the mining site had the highest concentration of Sb. The elemental composition of the ore in Itakpe from **Table 4.6** mining site show that Antimony is below the sample ranged, therefore, iron ore mining activities are not the cause of Sb in the environment, it can be from other sources like the reagent being used to concentrate the iron ore or waste in the mining area.

4.3   General Observation

When water samples were collected and analyzed for heavy metals (Cd, Pb, Cr, Mn, Cu, Co, Zn and Fe), it was found that the concentrations of heavy metals i.e. cadmium, lead, chromium, copper, cobalt, and iron were beyond the maximum permissible limits set by the regulatory agencies including FEPA and WHO while that of zinc and manganese were below the permissible limit most especially in tailing water 1 and Hand dug well 2. The study revealed that most of the heavy metal content in water of Itakpe was beyond the normal range and extremely dangerous for human consumption. The pH of the tailing water 1 was neutral (i.e. 7.07) while other water samples were strongly acidic (i.e. 2.49-3.04), which is also harmful to be consumed except tailing water sample 1. Similarly, in all soil samples, the concentration of all the heavy metals was recorded above the permissible limit set by FEPA and WHO. The concentration of all the heavy metals was also found to be above the permissible limit in the upper part and roots of plants (*Cynodon dactylon, Plectranthus scutellarioides, and Muhlenbergia rigens*).

The reason for this extremity in values found in the water samples, soil and plants might be due to the addition of civic waste and industrial effluents as the sewage of the city is directly discharged into the river along with the industries which are also discharging their effluents directly into the river. This is, in turn, deteriorating the water quality making it unsuitable for both aquatic and human life. Performing irrigation with the contaminated water exposes the soil and plants to harmful heavy metals. Also, major iron-bearing minerals within the Itakpe deposits were included in this study: hematite (Fe_2O_3), magnetite (Fe_3O_4), Martite (Fe_2O_3), limonite ($2Fe_2O_3.3H_2O$), goethite ($HFeO_2$), siderite ($FeCO_3$), Chamosite ($Fe_3MgAlO_{12}\{Si\}(OH)$), pyrite (FeS_2), Lepidocrocite ($\gamma\text{-}Fe_2O_3.H_2O$) and chalcopyrite ($CuFeS_2$). It shows that the iron ore consists more of magnetite than any other minerals. There are about 300 minerals containing some iron, but only a few are considered to be important iron ore minerals. The major iron ore minerals were presented in **Table 4.5**. After the investigation of the elemental composition of Itakpe Ore, as was expected, iron made up 66% of the element in the ore.

From **Table 4.6**, it was observed that many of the heavy metals namely **Pb, Cr, Mn, Cu, Zn, Fe, Co and Ni**, present in the ore are more than the values in the water, soil or plants or a combination of three of these heavy metals in the environment would, therefore, be expected to have emanated from the mining activities. In the same vein, some of the heavy metals namely **Cd, As** and **Sb** are low in the iron ore and the presence in quantities above the permissible levels may come from sources other than the mining activities themselves.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1   Conclusion

This research work provides data on the levels of contamination for assessing the impact of iron ore mining activities in the localities where the mines are sited. The effect of water, soil, and plants contaminated by heavy metals was possible through the use of X-ray Fluorescence and Atomic Absorption Spectrometer. A total of seven (7) soil samples, five (5) water samples, and three (3) plants were collected from the same region. Heavy metals for which these samples were analyzed were Cd, Pb, Cr, Mn, Cu, Co, Zn, Fe, Sb, As and Ni. Plant samples were analyzed separately for their root and upper part. The results revealed that the concentrations of Cd, Cr, Co, Fe and Pb in water were recorded above the permissible limits set by FEPA and WHO, while Zn and Cu were recorded below the permissible limits and Mn was also below the permissible limit only in tailing water 1 and Hand dug well 2. pH of all water samples was recorded below the neutral value except tailing water 1. Concentrations of heavy metals (Mn, Cr, Co, Pb, Ni, Zn, Sb, Fe, As) in soil and plants were also compared with FEPA and WHO standards for heavy metals and in soil and plants samples. Observed concentration of heavy metals was above the permissible limits set by FEPA and WHO. Also, the concentration of heavy metals in water, soil and plants sample was also evaluated based on the distance from where the sample was taken to the mining site. The sample closer to the mining site had the highest concentration of the heavy metals considered. Also, the high concentrations of the studied heavy metals clearly indicate that the major source of pollution comes from the activities occurring in the iron ore mining activities in Itakpe, Kogi State. The human body is a complex structure; therefore, the accumulation of heavy metals can cause toxic effects such as affecting the kidney, spleen, lungs and liver in the body.

The work observed that many of the heavy metals are high in the ore than in the habitat materials analyzed while some are lower. It may, therefore, be concluded that mining activities contribute majorly to the presence of the heavy metals in water, soil, and plants in the area while the heavy metals with low content in the ore may be introduced into the water, soil and plant from sources other than mining activities. These other sources may be in the reagents used in concentrating the ore or dumps from the environments.

5.2   Recommendation

1. Monthly evaluation of the health status of the iron ore mining workers should be carried out.

2. Monitoring by state environmental agencies so as to check the operations in the mining site and protect the environment from hazardous pollutants.

3. There is a need for replacing periodic studies (every two years) on the effect of the iron ore mining on the environment.

4. Research work should be carried out to study the accumulation of heavy metals in the crops which are irrigated by the stream water.

5. Research work should be carried out to study the effect of heavy metals on the people of Kogi State especially in Itakpe whose agricultural lands are irrigated by the contaminated water.

6. Awareness should be developed in the people so as to prevent them from disposing of their agricultural waste in the stream.

7. The government should pay attention to improve the water quality of Itakpe. It should also consider the presence of heavy metals in the area so that soil and plants are minimally exposed to these metals.

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