INFLUENCE OF MINING ACTIVITIES ON PHYSICOCHEMICAL PROPERTIES OF SOIL AT IFEWARA GOLD MINE SITE DURING DRY SEASON, OSUN STATE, NIGERIA.

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CERTIFICATION

This is to certify that this project was written by **UDA ANTHONY UKPEWU** with the Matric Number **(HND/23/MNE/FT/037)** supervised, read and approved as having satisfied part of the requirements for the award of Higher National Diploma in Mining Engineering Technology by the Department of Mineral and Petroleum Resources Engineering Technology, Kwara State Polytechnic, Ilorin.

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DEDICATION

This project is dedicated to Almighty God that has made my year in school a success one for me. I also express my heart to my beloved parents and guidance that lead to the fulfillment of my Higher National Diploma (HND) both morally and financially may Almighty God grant them all to eat the fruits of their labour.

ACKNOWLEDGMENT

My precious gratitude to Almighty God for his hand upon my life since inception and after the project work.

I also forward hardworking, able and beloved supervisor of the department in person of Engr, Agbalajobi, S.A. may Almighty God shower you with more blessing and grant you all your heart desire over your children and you shall not lack any good things (Amen).

My appreciation also goes to all the lecturers in the department of Mineral and Petroleum Resources Engineering, Kwara State Polytechnic and the Director of the institute I am indeed grateful for your moral instruction.

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ABSTRACT

Mining has recently become a significant economic activity in southwestern Nigeria; however, existing studies have largely overlooked its potential impact on the soil quality of surrounding communities. This study focused on the effect of mining on the physicochemical properties of soil at the Ifewara Gold Mining site, Osun State, Nigeria. A total of ten soil samples were randomly collected from both within the mining site and the surrounding community areas outside the site. Soil samples collected were analyzed for both physical and chemical properties that influence soil productivity. This physicochemical study of soil is based on various parameters, including pH, electrical conductivity (EC), temperature, soil organic matter, total dissolved solids (TDS), sodium, potassium, magnesium, calcium, sulphate, chloride, and total organic carbon (TOC). Additionally, concentrations of heavy metals such as Fe, Co, Zn, Ni, Pb, Cr, and Cd were analyzed using standard analytical methods. The pH values ranged from 5.1 to 6.9, electrical conductivity (EC) ranged from 1131 to 1502 μS/cm, and total dissolved solids (TDS) ranged from 186 to 319 ppm. Concentrations of sodium (Na^{+}) ranged from 10.56 to 43.83 mg/kg, potassium (K^{+}) from 12.59 to 38.27 mg/kg, magnesium (Mg^{2+}) from 13.64 to 32.41 mg/kg, calcium (Ca^{2+}) from 21.48 to 52.36 mg/kg, sulphate (SO_4^{2-}) from 18.26 to 57.36 mg/kg, chloride (Cl^{-}) from 3.81 to 10.46 mg/kg, and total organic carbon (TOC) ranged from 1.57% to 2.28%. Heavy metal analysis (in mg/kg) showed the following concentration ranges: Fe (8.768 – 10.58 mg/kg), Co (0.005 – 0.515 mg/kg), Zn (3.411 – 3.679 mg/kg), Ni (0.054 – 1.407 mg/kg), Pb (0.001 – 0.001 mg/kg), and Cr (0.053 – 0.124 mg/kg), Cd (0.001 – 0.088 mg/kg). The results showed significant changes in soil physicochemical properties and elevated heavy metal concentrations in samples collected within the mine perimeter, which may be attributed to mining activities and waste generated from the mine. The contamination level indices for the heavy metals in the samples could not be accurately determined due to sampling during the dry season and the leaching of contaminants.

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CHAPTER ONE

INTRODUCTION

1.1 EFFECT OF MINING ACTIVITIES ON SOIL

Processing minerals contaminate the land, water, and air, causing health problems. The environmental impact of mining includes erosion, formation of loss of biodiversity, and contamination of soil, under-groundwater and surface water by mining processes. Contaminants can modify or disturb microorganisms, thus modifying nutrient availability, causing a loss of vegetation in the area. Cultivated crops might be a problem near mines. Most crops can grow on weekly contaminated sites, but yield is generally lower than it would have been in regular growing conditions (Younis, 2018). Mining can be any of the many ways of taking minerals out of the ground, which implies excavations, trenching and pitting activities that denote unavoidable negative impacts on the environment, including removal of rocks, gravel, sand and other building materials. Moreover, if appropriate measures are not adopted in time, during the process of mining, serious occupational problems will emerge the mining process which led to environmental damage, the goal should be to minimize the extend of the impacts. The gold mining sector in Sudan is predominantly artisan in nature. 85 - 90 per cent of output comes from artisan mines. Poor educational and development services have left miners with little other choice, and inadequate health services have exacerbated the health consequences of gold mining and processing.

Artisanal mining practices are common in Africa, and many researchers have investigated their attributes. For example, Hilson (2001) provides information about the workings of the small-scale mining industry in the Ghana, and argued that initiatives have recently been taken to regularize and formalize the activities of the industry, with the intention of reducing the associated environmental impacts and land-use conflicts. Except for the recent efforts by the Ministry of Mine and Steel Development, gold mining in Nigeria is largely uncontrolled, and the majority of the operators are unlicensed (Oramah, Richards, Summers, Garvin, and McGee, 2015). Studies have indicated mine sites are around farmlands where chemicals may accumulate in fruits and leaves of arable and cash crops, and that soil contamination in mine sites can cause severe heavy metal contamination of water sources and poisoning of humans and animals, if ingested (Bartrem *et al*., 2014; Lo *et al*., 2012; Oramah *et al*., 2015; Plumlee *et al*., 2013). Poisoning by materials associated with mining has been associated with increased cases of kidney pain, respiratory problems, dizziness, and miscarriages in women, and deaths in many residents of communities where mining activities are carried out (Twerefou, Tutu, Owusu-Afriyie, and Adjei-Mantey, 2015).

1.2 AIM AND OBJECTIVE OF THE RESEARCH WORK

1.2.1 Aim of the Research

The aim of this project is to investigate on the Influence of Mining Activities on physicochemical properties of soil at Ifewara gold mine site during dry season, Osun State, Nigeria.

1.2.2 Objectives of the Study

The main objectives of the study are to:

i. determines the physical and chemical parameters such as, soil pH and temperature, Electric Conductivity (EC), Total Dissolved Salt (TDS), chlorine ion, sulphide ion and nitrite ion, Mg^{2+}, Na^{2+}, K^{+}, Ca^{2+}, Also, some heavy metals contaminants such as Cobalt (Co), Cadmium (Cd), Zinc (Zn), Cr (Chromium) and Lead (Pb).

ii. ascertain the effect of mining activities of Ifewara gold mine site, Osun State on the soil quality.

1.3 SCOPE OF THE RESEARCH WORK

The study of soil sample will be collected from the mining site and adjourning undisturbed area. They physicochemical properties of the sample collected will be analyzed using standard procedures and the results will be compared with World Health Organization (WHO) and understand threshold limit.

1.4 STATEMENT OF PROBLEM

The Influence of mining activities on soil properties can damage the soils on which crops are grown and also the environmental contamination of soil can pose a significant threat to human health and aquatic life.

1.5 JUSTIFICATION

The results of this study will be recommended to the Government's Ministry of Environment at all levels to adopt a good management approach to the incessant and inadequate mining activities going on in the study location.

CHAPTER TWO

LITERATURE REVIEW

2.1 PREVIOUS OF STUDY

The exploitation of mineral resources has been developed in sub-Saharan Africa since the 19th century. It is characterized by the coexistence of large-scale exploitation scale practiced by large companies and constitutes a significant source of revenue for the State and small-scale exploitation (Butaré and Keita, 2010). Mining activities are important sources of contamination of the environment (Mitchell, 2009). Mining operations use water for mineral processing, metal recovery, dust control and supply of water needs of workers on site (Lottermoser, 2010). In the locality of Wakaso (Adamawa, Cameroon), an artisanal semi-mechanized gold exploitation is carried out and the extraction of gold can negatively impact water resources. In the world, physicochemical characterization studies have been carried out to assess the water and sediment quality. Kaizer and Osakwe, (2010) have studied the physicochemical characteristics and heavy metal content of the various river systems with a view of accessing the effects of land use on the quality of rivers.

Industrial development is associated worldwide with the extraction and distribution of mineral substances from their natural deposits. In mining-impacted sites, arsenic is generally measured at elevated levels that cause health and ecological hazards. Abandoned metal mines are one significant source of arsenic contamination of the environment, as the activities of heavy rainfall and strong winds facilitate arsenic transportation via downstream movement from the vicinity of mining sites, leading to the release of massive quantities of arsenic into paddy fields through irrigation water contaminated by mining and smelting operations.

The climate is characterized by tropical wet and dry climate in the rainforest ecological region. Mean annual temperature varies between 26°C and 28°C, while relative humidity over the area varies from 60 to 80%. Average rainfall is about 140 cm per year. The geology is characterized by Amphibolites rocks, and the soils belong to the Itagunmodi Association of the southwest Nigeria (Smyth and Montgomery, 1962). The vegetation characteristics vary with land-use types. An assessment of the vegetation characteristics indicated that more plant species occupied the relatively undisturbed forested region than either the mine sites or the farm plots. The lower frequency of climbers, shrubs, and tree species in the abandoned mine site can be attributed to the destruction of the vegetal properties around the site during the processes of soil excavations for gold. In terms of the human geography, Itagunmodi is a typical rural area with high records of migrants that work on the mine fields. A cursory interaction with the workers at about two major sites revealed that about 80% are migrants from the northern region of the country. The migrant workers include have, however, been settled (mostly temporarily) in the area.

The mining activity has been connected with an array of environmental consequences. For example, Haddaway *et al*., (2019) claimed that mining is a driver of the climate change that has been ravaging the world. The mechanism of the environmental impact of mining was particularly argued by Naibbi and Chindo (2020), Obasi *et al*., (2021) and Idowu (2022). The initial process of mining involves a disruption of the ecosystem with environmental-depleting practices such as deforestation, bush burning, habitat displacement and loss of biodiversity (Naibbi and Chindo, 2020). In addition, during the actual mining process, the mines are predisposed to cause disturbance to healthy living among the residents of their host communities (Idowu, 2022). They also inadvertently release greenhouse gases and emissions which result in increased temperature and reduced living conditions (Obasi *et al*., 2021). This subjects the locals to untoward environmental hazards, constituting a drag on their health trajectories (Idowu, 2022). These streams of environmental impact of mining have made researchers call for formidable government regulation and supervision of mining activities in any mineral-rich locality (Ogunleye *et al*., 2022; Aliu *et al*., 2022).

A Tour of the Related Literature Ogbonna *et al*., (2015) conducted an environmental assessment of coal mining in Akwuke and Iva mine communities in Enugu, Nigeria. The authors were interested in collating and analysing views of locals in the selected communities regarding the impact of coal mining on their health, means of livelihood and environment. A semi-structured questionnaire was designed by the authors. This was combined with personal observation to aid the data collection process. As reported by the respondents, the authors found that some trees and animals had gone extinct due to intensive coal mining in the host communities. In addition, many members of the communities had faced serious health hazards including blindness, cancer and heart diseases. Most importantly, the mining process has made the roads of the host communities degraded with incessant land pollution which had remained unabated. In their conclusive remarks, Ogbonna *et al*., (2015) argued that coal mining has been a major source of burden, rather than gain, for the environment of the sampled communities. Similarly, Adeoye, (2016) assessed the effect of gold mining on land degradation in gold-rich communities of Ijesaland, Osun state, Nigeria. Spatial data on the patterns of land use were collected and analysed relative to the occurrence of land degradation in thirty-seven mining sites in ten mining communities.

The opinions of the participants suggested that the mining activities have caused mixed impact in their communities. On the one hand, mining was linked with improved socio-economic status of the residents of the communities. This was described as positive spill-over impact of the mining activity. On the other hand, the respondents declared that mining was the harbinger of the major adverse effects they have experienced on their environment. In particular, where the mines are not closely monitored by the government authorities, they tend to predispose their host communities to unpleasant land pollution and other environmental hazards (Adeoye, 2016). Omotehinse and Ako (2019) investigated the environmental impact of mineral exploration in Nigeria. The researchers were particular about the effects of tin and coal exploration in Jos and Enugu, respectively. Data were collected using a mixed approach including field survey, documentary analysis, direct mapping and observations. Findings indicated that the environment of the selected locations have been degraded by contaminants generated during the mining processes. This had threatened the ecosystem within the host communities as the authors observed that their vegetation has been rendered unusable for nutritional and health purposes. These environmental consequences have persistently taken new forms because the compliance of the mining companies with the mining laws is very limited, making their environmental behaviours unchecked (Omotehinde and Ako, 2019). Similar findings were further confirmed by Adesipo *et al*., (2020) in their analysis of the relationship between floristic composition and mining activity. In specific terms, Adesipo *et al*., (2020) stated that deforestation and exposure of the forest soils to direct sunlight have greatly stressed the environmental balance of the mining communities.

CHAPTER THREE

MATERIALS AND METHODS

3.1 SAMPLE DESCRIPTION

The material that was mainly used for the research was soil which was collected at the subsurface of the earth crust. The samples were collected at the mine at Ifewara, Atakumosa Local Government Area, Osun State, Nigeria. It lies within latitude 07° 03’ 13” N to 07° 03’ 22” N and longitude 04° 11’ 09” E to 04° 12’ 22” E (Figure 3.1) lies about 35 km west of Ilesa town. The area is a developing resident’s layout towards the east side of the Ifewara Township. The residents of the area are of different tribes living in their own houses. The remaining parts of the open fields, apart from the gold mining pits, are used mainly by the residents for farming and cash crop (cocoa). The topography of the area in undulating, drained by river and its tributaries, it is underlain by the rocks typical of the Basement Complex of southwest Nigeria and characterized by the tropical rain forest climate. The artisanal miners haphazardly select Artisanal Gold Mine (AGM) pit sites, where gold-bearing saprolitic layers are panned (Figure 3.3) to extract gold and associated heavy minerals. Locally fabricated sluice boxes are also employed in the beneficiation of the saprolite slurries where carpets, which act as traps, are placed in these boxes while the slurries are run over them (Figure 3.2) and Figure 3.4 and Figure 3.5 Site Location with group picture with the project students and miners.

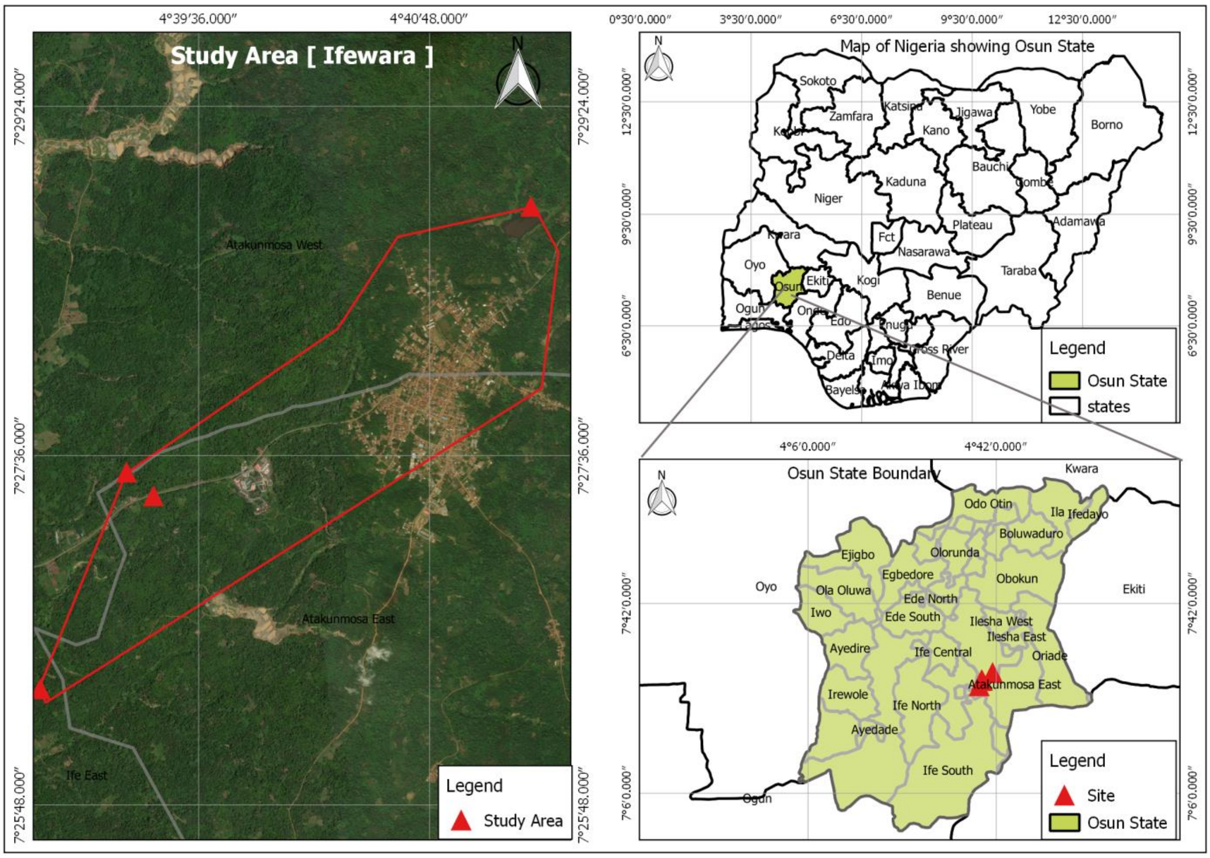

Figure 3.1: Map of the Study Area Location Ifewara, Atakumosa Local Government Area, Osun State, Nigeria.

Plate 3.1: Typical Artisanal Small-Scale Gold Mining Process in the Study Area using a Sluice Box

Plate 3.2: The artisanal miners haphazardly select Artisanal Gold Mine (AGM) pit sites, where gold-bearing saprolitic layers are panned.

Plate 3.3: Site Location with group picture with the project students and miners

Plate 3.4: Site Location with group picture with the project students and miners

Plate 3.5: Site Location with group picture with the project students

3.2 SAMPLE COLLECTION

Soil samples were randomly collected at ten (10) different points within mine perimeter whiles the sixth, seventh and eighth location was 500m away from the mine. Ten samples were taken randomly at each sample location at a depth of 30cm with the aid of hand auger drill and were rigorously mixed together in a polythene bag. At the end of the samples collection, ten set of samples were available for laboratory analysis.

3.3 SAMPLE PREPARATION

The analyses of the soil sample to determine the composition of heavy metals were carried out. The samples collected from the surface and subsurface soil of each sampling point were later mixed to form composite sample for each sampling location. The collected samples were dried, grinded to fine powder using ball milling machine and sieved with 150µm mesh size. The sieved samples were stored in the polythene bag and labelled accordingly prior to analysis, and the residue samples were discarded.

Organic carbon was determined by dichromate oxidation method of Walkley and Black procedure (Neson and Sommers 1982), wet oxidation, and corrected to soil organic matter by multiplying with a correction factor of 1.724, particle size analysis of the soil was determined using the Bouyoucos hydrometer method. The soil samples were analyzed for the following physicochemical parameters: pH, Electrical conductivity (EC), available phosphorus, exchangeable calcium, potassium, sodium, total organic matter. Heavy metal concentrations of the sample were also determined using Atomic Absorption Spectrophotometer (ASS) for the following heavy metals: Fe (iron), Cobalt (Co), Zinc (Zn), Chromium (Cr), Nickel (Ni), Lead (Pb), and Cadmium (Cd). Available phosphorus was extracted using Bray II extractant as described by Bray and Kurtz (1945). Exchangeable Calcium, Magnesium, Sodium and Potassium were extracted with ammonium actateethylenediaminetetraacetic acid (NH_4OAC-EDTA). Calcium and Magnesium were determined using Ethylene Diamine Tetra-acetic Acid disodium salt (EDTA) titration method while Potassium and Sodium were determined by flame photometer (Rhoades, 2002). Cation exchange capacity was determined titrimetrically using 0.01N NaOH. Exchangeable acidity was determined titrimetrically using 0.05N NaOH. Bulk density was determined on the core samples by core method as described by Anderson and Ingram (2013).

3.4 PHYSICOCHEMICAL ANALYSIS

All the soil samples were subjected to tests at the Central Research Laboratory, University of Ilorin, Kwara State. The physicochemical properties of the soil samples were determined according to standard methods. Soil pH was determined using digital pH meter according to the method described by Bates (2004). Soil electrical conductivity was determined using conductivity meter according to the method outlined by Godson *et al*., (2002). Calcium and magnesium in soil samples were determined by versenate titration method as outlined by Piper, (1966). Potassium was determined by flame photometrically after extracting the soil with neutral normal ammonium acetate (Jackson, 2003). Available phosphorus was extracted using Bray II extraction as described by Bray and Kurtz (2015). Sodium in soil samples was determined turbidometrically. The intensity of turbidity was measured using spectrophotometer at 420nm of wavelength as outlined by Piper, (1966). Total organic matter was determined according to the method outlined by Osuji and Adesiyan, (2005).

3.4.1 Measurement of Physicochemical Parameter

During sampling, some immediate probing referred to as physical investigation was carried out on the samples in-situ by a portable water kit before the samples were sent to the laboratory for analyses. The measured physico-chemical parameters include the pH, Temperature, Electrical conductivity and Total Dissolved Solid (TDS).

3.4.2 Electrical Conductivity (EC)

Electrical conductivity is a good measure of salinity hazard to crops as it reflects the TDS in water and soil. Electrical conductivity of natural waters is determined by the presence of substances, which dissociate into cations and anions. Measurement of EC can be used to monitor and determine the degree of water pollution. The value of EC may serve as an appropriate index of the total content of the dissolved substances for the bodies of waters, which have been subjected to considerable influence run-off waters, to establish the origin and distribution of various waters in the body of water and delineation pollution zones.

The measurement of electrical conductivity in microsiemen per centimeter (us/cm) was determined using portable field conductivity meter for each of the water samples. Conductivity is a measure of the ability of water to conduct an electric current. It increases as the amount of the dissolved minerals (ions) increases.

3.4.3 pH Test

The pH of water is a measure of hydrogen ion concentration in water. It ranges from 0 to 14, with neutral water at 7. While lower of it is acidic and pH greater than 7 is known as basic. Drinking water with a pH ranging from 6.5 to 8.5 is generally considered satisfactory. It is noticed that water with low pH tends to be toxic and with high degree of pH tastes bitter. The pH of the studied water samples was measured by dipping the electrode of the pH meter into the bowl of the water samples.

3.4.4 Temperature

The temperature of the water is one of the most important characteristics which determines, to a considerable extent and tendencies of changes in the quality of water. It is taken with the aid of multifunction water kit, and measured in degree Celsius. The water temperature was taken before the other water measurements, because the temperature tends to change very rapidly after a sample is collected.

3.4.5 Total Dissolved Solid (TDS)

The concentration of impurities is often termed Total Dissolved Solid (TDS). It is often measured in ppm or mg/l and can be determined using conductivity method or TDS meter. Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulphates etc. these minerals produced unwanted taste and diluted colour in appearance of water which may be injurious to animals and plants.

3.4.6 Major Ions

The major ions analyzed in the water samples are of two groups, which are;

1. Cations
2. Anions

The major cations analyzed include sodium (Na^+), potassium (K^+) and calcium (Ca^{2+})$^.$ The major anions analyzed include chloride (C^-) and sulphate (SO_4^{2-}).

3.4.7 Determination of Sodium and Potassium Using AAS

100mls of the water sample was measured into a clean 250mls digestion flask. 15mls of conc. nitric acid ($HNO_{3)}$ and 5mls of conc hydrochloric acid (HCL) were added into the sample in digestion flask. The solution inside digestion flask was heated on a hot plate until all the brownish fumes (nitrogenous compound) expelled out, which confirmed that the water sample is digested and it was allowed to cool at room temperature, 2mls of distilled water was added. Then, the mixture was filtered into 50mls standard flask and it was transferred into plastic reagent bottle for Atomic Absorption Spectrometry (A.A.S) at Central Research Laboratory University of Ilorin for determination of Na^+ and K^+.

3.4.8 Determination of Calcium Ion Using Muroxide as Indicator

25mls of the water sample was measured into a clean conical flask, then 2mls of dilute NaOH was added into the sample and 2 – 3 drops of muroxide indicator were added into the solution, and then titrated against 0.01m of EDTA (titrant) until a pinkish color appeared as equation 3.1.

$$Ca^{2+}(mg/l) = \frac{\text{Titre Value x Molarity x Molar Mass}}{\text{Volume of Sample}} \text{ x } 1000 \qquad \text{equation 3.1}$$

3.4.9 Determination of Magnesium Ion (Mg^{2+}) Using Erichrome as Indicator

Total hardness is due to the presence of both calcium and magnesium ions so that the sum of calcium and magnesium is determined readily using erichrome as indicator. Direct titration method was used in which 25mls of the water sample was buffered to pH 10 (i.e. 5mls of ammoniacal buffer). It was then titrated against 0.01m EDTA, the end point was noted when the solution changes from purple to pure blue. Note, the mg^{2+} was determined by subtracting the already known Ca^{2+} from the total hardness as in equation 3.2 and 3.3.

$$\text{Total hardness (mg/l)} = \frac{\text{Titre Value x Molarity x Molar Mass}}{\text{Volume of Sample}} \text{ x } 1000 \qquad \text{equation 3.2}$$

$$Mg^{2+}(mg/l) = \text{Total Hardness} - \text{Calcium Ion} \qquad \text{equation 3.3}$$

3.4.10 Determination of Sulphate ($SO4^{2-}$) Using Precipitation Method

10mls of the sample was poured into a beaker, 5mls of barium chloride was added into the solution. The initial weight of the beaker together with the solution was weighed. The solution was heated on a burse burner until white precipitate formed. The beaker was removed from the burner and allowed to cool. Then, its final weight was taken in equation 3.4.

$$SO4^{2-}(mg/l) = \frac{\text{Change in Weight}}{\text{Volume of Sample}} \text{ x } 1000 \qquad \text{equation 3.4}$$

3.4.11 Determination of Chloride Ion (Cl^-) Using Mohr Method

25mls of water sample was measured into a conical flask and placed on a white tile surface. 1ml of potassium chromate solution ($K_2Cr_2O_4$) as an indicator was added and a light-yellow solution appeared; it was then titrated against silver nitrate solution ($AgNO_3$) with constant stirring until lightest reddish coloration persists at the end point as in equation 3.5.

$$Cl^-(mg/l) = \frac{\text{Titre Value x Molarity x Molar Mass}}{\text{Volume of Sample}} \text{ x } 1000 \qquad \text{equation 3.5}$$

3.5 DETERMINATION OF HEAVY METALS

The concentrations of heavy metals in all the samples were determined using the BUCK Scientific ACCUSYS (Model 203) Atomic Absorption Spectrophotometer. One grams of each sample was introduced into a digesting tube then 10 ml of concentrated HNO_3 was added. The samples were placed in the digester for 8 hours at 96^{o}C with alternating turning. When the digestion has completed, the samples were filtered into 100 ml volumetric flask using what man filter paper. Samples were made up to 100 ml mark in the volumetric flask using distilled deionised water. The concentration of Iron (Fe), Cobalt (Co), Zinc (Zn), Nickel (Ni), Lead (Pb), Chromium (Cr), and Cadmium (Cd) in the solution were determined using Varian Spectra AA 600 Atomic Absorption Spectrophotometer (AAS) with air acetylene flame connected to it.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Physicochemical Analysis of the Samples

In this study, ten samples were collected within the mine perimeter at 100meter interval while a control sample was collected at 500m away from the mine parameter. The samples were labelled sample LS1, LS2, LS3, LS4, LS5, LS6, LS7, LS8, LS9 and LS10 with the control sample being labelled sample LS10. In order to understand the soil capability to retain heavy metals, geochemical soil characteristics such as pH, carbon content, electric conductivity were performed on the sample. Table 4.1 shows the results of the Physiochemical analysis of the samples.

Table 4.1: Results of physiochemical Analysis of the soil samples from the study site during dry season

Sample Codes	Ph	EC (µS/cm)	TDS (ppm)	Temp^o (^{o}C)	Na^{2+}	K^+	Mg^{2+}	Ca^{2+}	SO_4^{2-}	Cl^-	TOC %
LS 1	6.1	1157	186	31.8	21.42	12.59	15.29	21.48	18.26	7.40	2.11
LS2	6.3	1388	287	32.1	24.08	17.84	13.64	44.81	52.09	6.83	1.76
LS3	5.4	1502	319	35.2	43.83	33.93	19.14	52.36	57.36	9.51	2.19
LS4	6.9	1437	299	32.3	34.79	38.27	13.61	48.99	48.99	8.23	1.98
LS5	5.6	1131	178	31.3	17.41	14.60	16.48	25.63	25.63	9.16	1.99
LS6	5.6	1191	199	35.6	20.06	15.14	19.72	33.39	33.39	8.94	1.70
LS7	6.9	1265	235	34.6	19.94	21.95	28.67	39.74	39.74	10.46	2.28
LS8	5.5	1414	259	35.9	13.28	24.42	32.41	36.63	36.63	5.31	1.86
LS9	5.3	1335	218	33.8	10.56	28.04	25.37	31.31	31.31	5.611	2.11
LS10	5.1	1243	286	35.6	12.71	26.56	29.51	29.25	29.25	3.81	1.57

Range	5.1 – 6.9	1131 – 1502	186 – 319	31.3 – 35.6	10.56 – 43.83	12.59 – 38.27	13.64 – 32.41	21.48 – 52.36	18.26 – 57.36	3.81 – 10.46	1.57 – 2.28

4.1.2 Variation of pH and Electrical Conductivity

Table 4.1 show the soil pH at the eight (8) locations (LS1, LS2, LS3, LS4, LS5, LS6, LS7, LS8. LS9, LS10/control) to be 6.1, 6.3, 5.4, 6.9, 5.6, 5.6, 6.9, 5.5, 5.3, and 5.1 respectively during the dry season. The recorded values of samples value collected within the proximity of the site are lower than the pH recommended value range of 6.6 to 7.5 for optimum plant growth (Queensland Department of Environment and Heritage Protection (QDEHP), 2019), but the control sample is within the recommended limit. The results of the Electricity conductivity range from 1131 to 1502 µs/cm. The EC was observed to be higher in the sample within the mine (LS2, LS3, LS4, LS7, LS8, LS 9 and LS 10) while it was observed to be low in LS1, LS5 and LS6 which are flowing river samples. Since the EC is a measure of level of salts content in the soil and it is understood that if the EC value in soil sample increases, then more dissolve ion was being deposited from a source which could be from the mine (Yasir and Alain, 2016).

4.1.3 Variations of Potassium, Sodium, Calcium and Magnesium (mg/kg)

The results of potassium for the dry season were recorded with range from 12.59 to 38.27, potassium is not an integral part of any major plant component but it plays a key role in a vast array of physiological process vital to plant growth from protein synthesis to maintenance of plant water balance (Sumithra *et al*., 2013). Potassium is found in its mineral form and affect plants division, carbohydrate formation, translocation of sugar, various enzyme actions and resistance to certain plant disease (Jain *et al*., 2014). For Sodium the recorded value was between 10.56 – 43.83 for dry season and magnesium ranged between 13.64 – 32.41 during the dry season, the Calcium content in the soil samples was observed to be between 21.48 to 52.36 with control sample possessing the lowest calcium content value 21.48.

4.1.4 Variations of Total Organic Matter, Chlorine, and Sulphide (mg/kg)

The total organic matter (TOC) ranged from 1.57% to 2.28% as shown in Table 4.2 from the result, it could be seen that all the samples within the mine perimeter have high carbon content LS10/control sample. Soil organic carbon is a key attribute in assessing soil health, generally correlating positively with crop yield (Bennett *et al*., 2010). The soil organic carbon affects important functional processes in soil like the storage of nutrients, mainly nitrogen, and water holding capacity (Silva and Sa-Mendonca, 2007).

The content of chlorine in the sample ranged from 3.81 to 10.46 with the control sample having the lowest CI content. This implies that the mining activities could have contributed to increment. Increase in chlorine content in the soil indicated high rate of CI in take by immediate plants which could reduce the crop yield (Onipede *et al*., 2020).

The results of the sulphide content ranged from 57.36 to 18.26 while the LS1 sample has value of 13.80. High waste generation in the mine could be attributed to the high level of sulphide content within the mine perimeter. Though, sulphide content in soil may be advantageous for optimal plant growth so far, the threshold limit as specified by (NCHRP, 2009) is not exceeded.

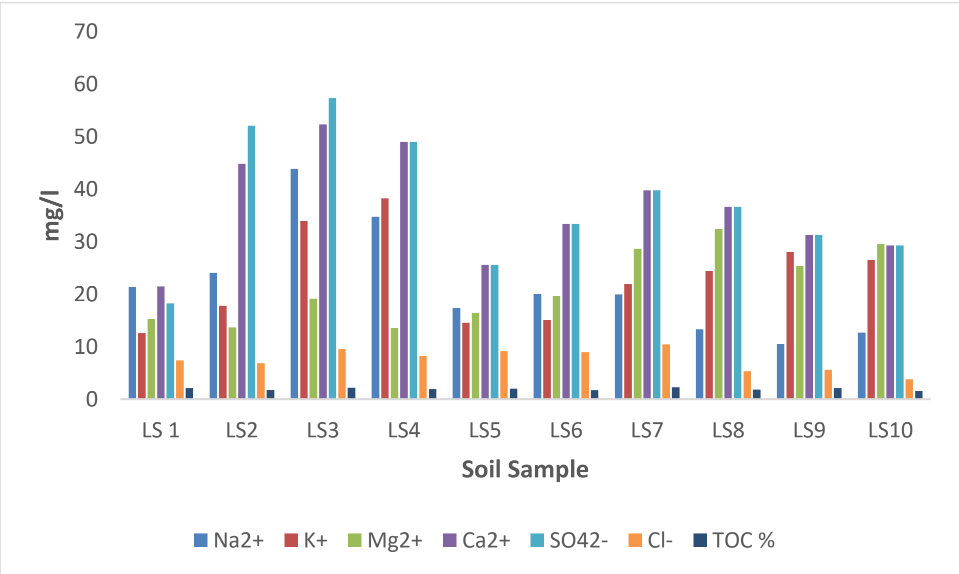

Figure 4.1: Concentrations of Metallic Elements in Soil Samples around the mine

4.1.5 Heavy Metal Concentration of Samples

The results of the heavy metal concentration of the sample are shown in Table 4.2. The average concentration of Fe present in the sample ranged from 10.508 (LS 4) to 8.789 (LS 9). The content of Fe was observed to be high in all the samples within mine perimeter with the control sample. This could also be observed in other heavy metals such as Co, Zn, Ni, Pb, Cr, and Cd with average results ranging from 0.515 (LS 3) to 0.005 (LS7); 3.679 (LS 4) – 3.411 (LS 6); 1.407 (LS 2) – 0.054 (LS 3); 0.001 – 0.001 (Constant); 0.124 (LS 2) – 0.053 (LS 5); and 0.088 (LS 4) – 0.001 (LS 2,6,7,9) respectively.

Table 4.2: Result of Heavy Metal Concentration in Samples (mg/kg) during the dry season

Sample Code	Fe		AVE	Co		AVE	Zn		AVE	Ni		AVE	Pb		AVE	Cr		AVE	Cd		AVE
LS 1	9.608	9.608	9.608	0.495	0.495	0.495	3.663	3.663	3.663	1.237	1.237	1.237	0.001	0.001	0.001	0.090	0.090	0.090	0.001	0.001	0.001
LS 2	9.752	9.752	9.752	0.514	0.514	0.514	3.550	3.550	3.550	1.407	1.407	1.407	0.001	0.001	0.001	0.095	0.152	0.124	0.013	0.013	0.013
LS 3	10.243	10.243	10.243	0.515	0.515	0.515	3.634	3.634	3.634	0.054	0.054	0.054	0.001	0.001	0.001	0.086	0.086	0.086	0.001	0.001	0.001
LS 4	10.508	10.508	10.508	0.0811	0.111	0.096	3.679	3.679	3.679	0.195	0.195	0.195	0.001	0.001	0.001	0.070	0.070	0.070	0.088	0.088	0.088
LS 5	9.173	9.173	9.173	0.016	0.016	0.016	3.545	3.545	3.545	0.135	0.135	0.135	0.001	0.001	0.001	0.077	0.029	0.053	0.022	0.022	0.022
LS 6	9.763	9.763	9.763	0.052	0.052	0.052	3.411	3.411	3.411	0.223	0.223	0.223	0.001	0.001	0.001	0.008	0.008	0.008	0.001	0.001	0.001
LS 7	10.383	10.383	10.383	0.005	0.005	0.005	3.467	3.467	3.467	0.325	0.325	0.325	0.001	0.001	0.001	0.038	0.038	0.038	0.001	0.001	0.001
LS 8	10.365	10.365	10.365	0.041	0.041	0.041	3.587	3.587	3.587	0.034	0.034	0.034	0.001	0.001	0.001	0.115	0.115	0.115	0.044	0.044	0.044
LS 9	8.789	8.789	8.789	0.001	0.001	0.001	3.501	3.501	3.501	0.109	0.109	0.109	0.001	0.001	0.001	0.088	0.081	0.085	0.001	0.001	0.001
LS 10	9.619	9.619	9.619	0.136	0.136	0.136	3.484	3.484	3.484	0.168	0.168	0.168	0.001	0.001	0.001	0.054	0.054	0.054	0.083	0.083	0.083

It could be observed that heavy metals concentration was high in the entire sample within the mine perimeter than that of the control samples in Figure 4.1, Figure 4.2 and Figure 4.3 respectively. It could be connoted that the mining activities have influences in the accumulation of heavy metals in the soil.

Table 4.3: Results of the Average heavy metals concentration in the sample (mg/kg) soil during the dry season

Sample Code	Fe (mg/kg)	Co (mg/kg)	Zn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Cd (mg/kg)
LS 1	9.608	0.495	3.663	1.237	0.001	0.090	0.001
LS 2	9.752	0.514	3.550	1.407	0.001	0.124	0.013
LS 3	10.243	0.515	3.634	0.054	0.001	0.086	0.001
LS 4	10.508	0.096	3.679	0.195	0.001	0.070	0.088
LS 5	9.173	0.016	3.545	0.135	0.001	0.053	0.022
LS 6	9.763	0.052	3.411	0.223	0.001	0.008	0.001
LS 7	10.383	0.005	3.467	0.325	0.001	0.038	0.001
LS 8	10.365	0.041	3.587	0.034	0.001	0.115	0.044
LS 9	8.789	0.001	3.501	0.109	0.001	0.085	0.001
LS 10	9.619	0.136	3.484	0.168	0.001	0.054	0.083
Range	8.768 – 10.58	0.005 – 0.515	3.411 – 3.679	0.054 – 1.407	0.001 – 0.001	0.053 – 0.124	0.001 – 0.088

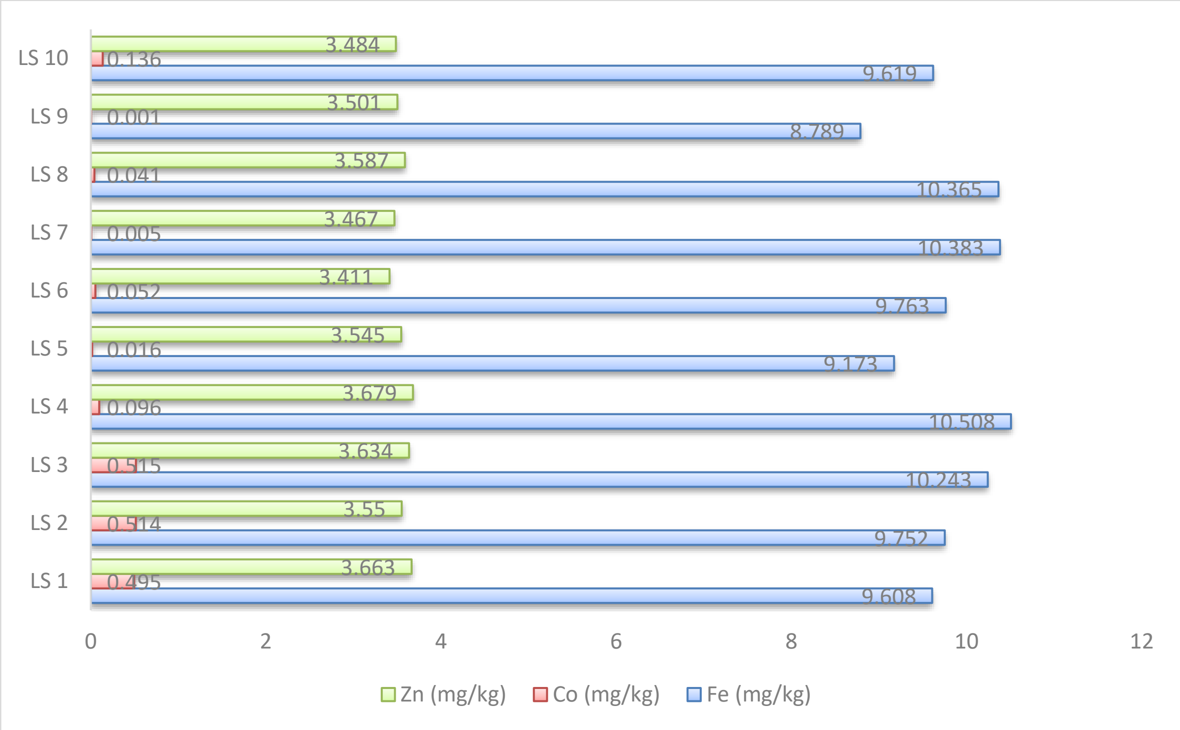

Figure 4.1: Heavy Metals Concentration of the Sample (mg/kg)

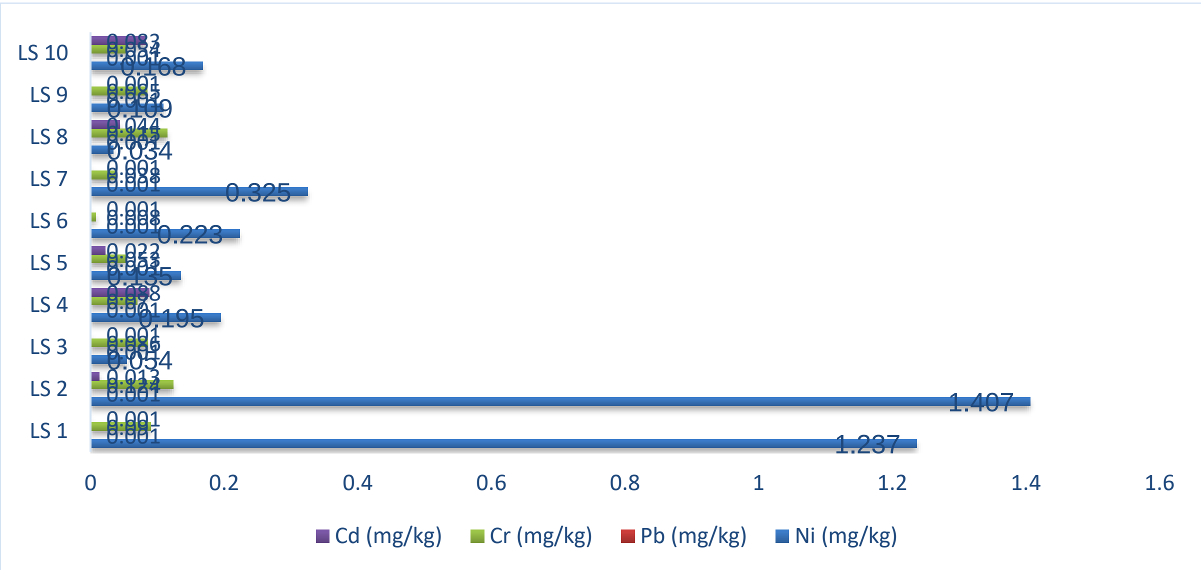

Figure 4.2: Heavy Metals Concentration of the Sample (mg/kg)

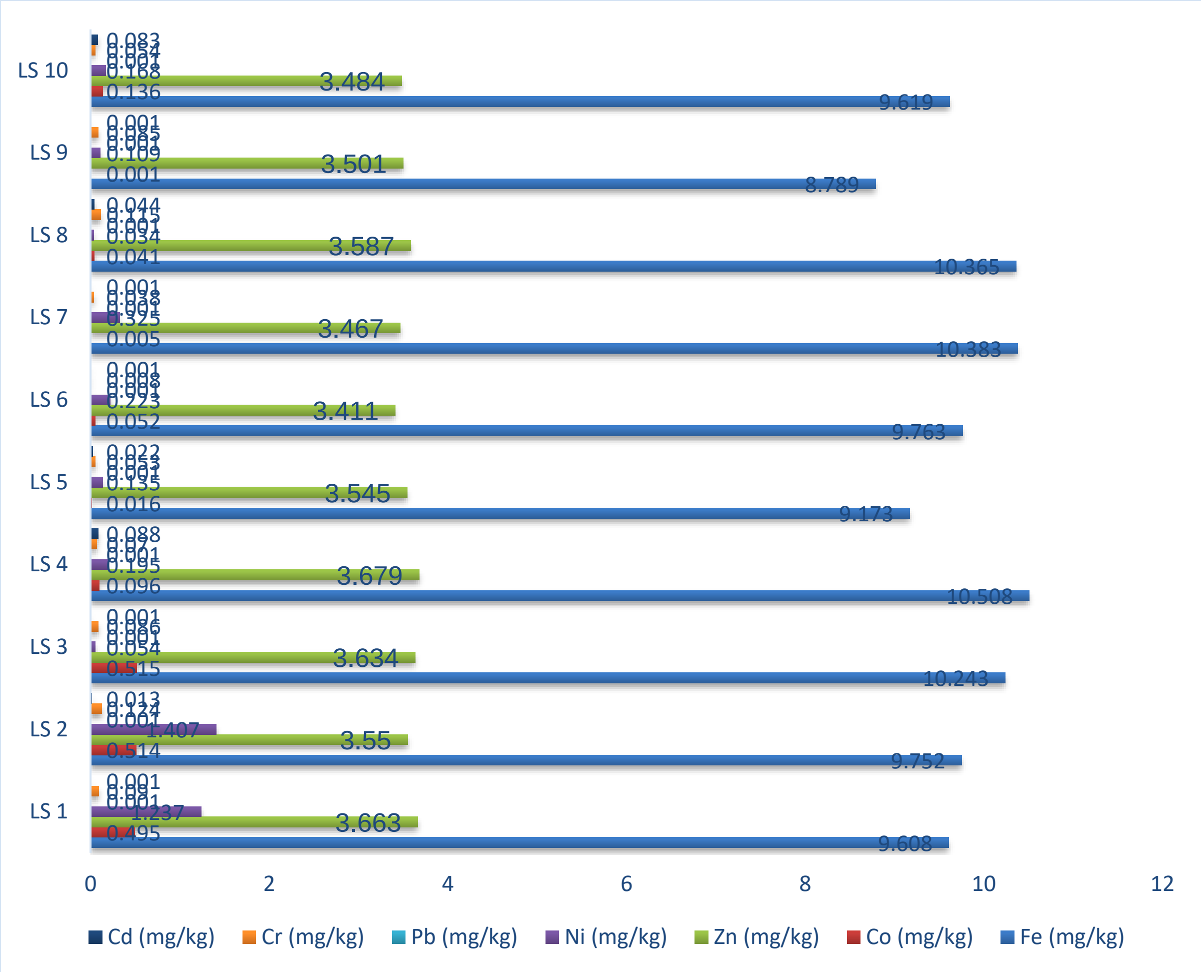

Figure 4.3: Heavy Metals Concentration of the Sample (mg/kg) for all the Soil Samples

4.2 IMPACT OF MINING ON METALLIC ELEMENTS IN THE SOIL

Plants require metallic elements, such as calcium (Ca), potassium (K), magnesium (Mg), Iron (Fe), and Zinc (Zn) as nutrients to grow and develop (Tripathi *et al*., 2014). Disturbance or contamination of the soil could negatively impact the availability of these metals and affect the suitability of the soil for sustainable agriculture. Therefore, it is imperative to assess the impact of mining activities on the metallic elements in soil samples at the different locations around the mine are in Figure 4.1. Ca, K, and Mg are macronutrients that plants need in large quantities for growth. The concentrations of these macro-nutrients in the soil samples are interpreted using Table 4.4.

Table 4.1 presents different concentrations of macronutrients in soil (Hazelton and Murphy, 2016). Ca concentrations in all the soil samples in all the location are below the moderate concentration of Ca required for agricultural soils (Table 4.4). Ca deficiency in soil could affect the ability of legume plants to associate with nitrogen-fixing bacteria. Soil K is essential for plant growth and development and the plant's mobility of nutrients (Adams and Shin, 2014). The Mg concentrations are below the typical concentration required for plant growth. Similarly, Onifade *et al.*, 2020 reported a low average Mg concentration of 13.64 mg/kg around the mining site in Komu, South-western Nigeria. Generally, it can be observed that many researchers have reported the impact of mining activities on soil macronutrients (Afeni and Ibitolu, 2018; Oladipo *et al.*, 2014; Onifade *et al.*, 2020; Mensah *et al.*, 2015; Wang *et al.*, 2021). In addition, the low concentrations of these macronutrients in the soil samples could be linked to the acidity of the soil samples; macronutrients are less available in acidic soil samples; macronutrients are less available in acidic soil (Gondal *et al.*, 2021).

Sodium concentration in the soil has little effect on plant growth, but a too-high concentration can affect plant growth and crop productivity (Maarguis, 2014; Essandoh *et al.*, 2021). The sodium concentrations in all the Soil samples, which range from 10.56 to 43.86 mg/kg, are within the low range recommended for agricultural purposes (Table 4.4). A similar range of sodium concentration was also found in the soil of a mine site in Dunkwa East municipality of Ghana (Essadoh *et al.*, 2021). In a mining site at Komu south-western Nigeria, Onifade *et al.*, (2020) reported a lower average sodium concentration of 10.56 mg/kg.

Table 4.4: Concentration levels of macronutrients in Soil (adapted from Hazelton and Murphy, 2016)

Elements (mg/kg)	Low	Moderate	High
Ca	400 – 1000	1000 – 2000	2000 – 4000
K	78 – 117	117 – 273	273 – 780
Mg	36 – 120	120 – 360	360 – 960
Na	23 – 69	69 – 169	169 – 460

Iron and zinc are micronutrients because they are needed in small quantities for plant growth. Nevertheless, high concentrations of these micronutrients or their deficiencies can affect plant metabolism and growth (Chatzistathis, 2014). Iron and zinc concentrations in all the soil samples in and around the mining site are below the recommended concentrations of 100 and 20 mg/kg respectively (Epstein, 1965). Low concentrations of Fe and Zn may also relate to low soil pH in and around the mining site, as a low pH enhances the solubility of heavy metals (Arogunjo, 2007). The region's low concentration of Fe and Zn in the studied area seems peculiar. Onifade *et a*l., (2020) obtained a low average concentration of Fe (8.768 mg/kg) and Zn (3.411 mg/kg) from the mining site at Komu, south-western Nigeria. The study revealed relative concentration of heavy metal in the soil during the dry season at Ifewara mine site in the following order: Fe>Zn>Pb>Ni>Cr>Cd. The Iron and Zinc content of the soils was extremely low but they are needs to analysis the soil during dry season to ascertain degree of contamination assessing the trace element pollution risk evaluation and calculation of contamination factor index and potential ecological risk index.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSIONS

This study revealed that mining activities in Ifewara, Osun State, Nigeria, have negatively impacted the soil by introducing heavy metals above threshold limits and altering its physicochemical properties; thereby causing severe pollution of the soil, which negatively impacts agricultural productivity and poses serious health risks to nearby communities. Given the significant risks associated with heavy metal contamination, it is imperative to establish comprehensive regulatory guidelines, particularly targeting artisanal mining activities in this region, to mitigate their harmful environmental and health impacts. In addition, further studies are needed to evaluate the extent of contamination through both physicochemical analysis and heavy metal concentration measurements during the dry and wet seasons. This will help in assessing the quality and uptake of these metals in plants and humans, as well as in understanding the associated health risks posed by mining activities to the inhabitants of the studied area.

5.2 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

1. Intermittent monitoring of soil quality around mines should be encouraged at both governmental and organizational levels to consistently assess the concentration of key soil parameters
2. There is an urgent need to develop guiding principles to regulate mining activities particularly artisanal mining in this area to prevent the numerous toxic effects of heavy metal contamination.
3. Further research should focus on the assessment, monitoring, and control of heavy metal contamination in airborne dust, surface water, and sediments.

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