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 **BABATUNDE BUSAYO ROTIMI** with the Matric Number **(HND/23/MNE/FT/022)** 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 years in this school a successful one for me. I also express my heart to my beloved parent that line to the fulfillment of my Higher National Diploma (HND) both morally and financially may Almighty God grant them all to eat the fruit of their labour (Amen).

ACKNOWLEDGMENT

My precious gratitude to Almighty God for his hand upon my life since inception and after the project work. I also forward my acknowledgment to my amiable, wonderful, hardworking, a father figure and beloved supervisor in person of Engr, Agbalajobi, S.A., may Almighty God shower you with more blessing and grant you all your heart desire over year children and you shall not any good things (Amen).

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ABSTRACT

Indiscriminate and unrestrained mining activities can lead to significant negative environmental impacts, including pollution of land and water bodies. This pollution affects soil quality, reduces soil fertility, causes land degradation, and alters the natural landscape. Therefore, this study was conducted to assess the impact of mining activities on the physicochemical properties of soil at Ifewara Gold Mine, Osun State during the dry season, and to evaluate the current status of soil physicochemical properties and heavy metal concentrations in the study area. In the study, ten soil samples labelled LS1 to LS10 were collected from both within and outside the mine site for analysis. The samples were tested and analyzed for physicochemical parameters—including pH, electrical conductivity (EC), total dissolved solids (TDS), sodium (Na^{+}), potassium (K^{+}), magnesium (Mg^{2+}), calcium (Ca^{2+}), sulfate (SO_4^{2-}), chloride (Cl^{-}), and total organic carbon (TOC%) during the dry season only. Additionally, heavy metal concentrations of Fe, Co, Zn, Ni, Pb, Cr, and Cd were also determined. The study revealed that the relative concentrations of heavy metals in the soils at the Ifewara mining site followed the order: Fe > Co > Zn > Ni > Pb > Cr > Cd. It is recommended that the Ministry of Environment at all levels of government adopt effective management strategies to address the ongoing and unregulated mining activities in the study area. The contamination and pollution levels could not be accurately determined because the samples were analyzed only during the dry season.

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CHAPTER ONE

INTRODUCTION

1.1 MINING ACTIVITIES

Mining has recently (since 2000) become an important economic activity in southwestern Nigeria but existing studies on their implications have mostly overlooked their capacity to impact the microclimate of neighbouring communities. Mining as a primary activity, has been in existence from ages, and so are its impacts on the ecosystem, including humans. The core-periphery concept of Friedman (Onakerhoraye and Omuta, 1994; Akinbode *et al*., 2008) that distinguishes an area into 'core', which often the most developed part of a region that equates the present day capital cities or local government headquarters in a Nigerian state; periphery, which often suffers from inadequate resource allocation, relative under-development and under-population; and resource-base, which is home to natural resources (including forests, minerals, crude oil, among others (Akinbode *et al*., 2008; Eludoyin *et al*., 2017). Communities that are rich in natural resources are generally opened to exploitation, and their environment typically become vulnerable to degradation.

Many researches have been carried out to explain that almost, if not all the countries in Africa is active in one or more possession and production of minerals as well as their economic importance on the wellbeing of the community (Aigbedon *et al*., 2007; Ingram *et al*., 2011; Oladipo *et al*., 2014; Ralph *et al*., 2018; Omotehinse and Ako, 2019; Adesipo *et al*., 2020). However, over 95% of the mining activity is artisanal and another 95% of this portion is illegal (Mallo, 2012). Studies (Orimoogunje, 2010; Eludoyin *et al*., 2017; Oyebamiji *et al*., 2018) have carried out many researches on Southwestern Nigeria and with the aim of assessing the various multifaceted impacts illegal and artisanal mining activities can have on a community. Their results reveal that illegal and small-scale mining activity often takes place in areas that are rural and undeveloped. Though, mining has its positive impacts on the economy (Ingram *et al*., 2011; Soderholm and Svahn, 2015) yet, most of its discussed effects in studies (Klukanova and Rapant, 1999; Aryee *et al*., 2003; Balling *et al*., 2014; Eludoyin *et al*., 2017; Oyebamiji *et al*., 2018; Ralph *et al*., 2018; Adesipo *et al*., 2020; Bradley, 2020) have been disastrous to the environment.

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 PROBLEM STATEMENT

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 BACKGROUND OF STUDY

Ifewara, a rural area in Atakunmosa west local government in Osun State, Nigeria, is known for artisanal gold mining. Ifewara and some other close villages have undergone many researches in times past focused on the impact of the mining activities on soil, plants and water, which have shown that the area is negatively impacted by the mining operations. However, most of these researches have overlooked the capacity of activities around the mining sites to impact significant changes in the microclimate of neighbouring communities. Apart from the emission of CO_2 from large diesel trucks and loaders in large-scale mining activities, mining activities, which invariably would include removal of vegetation in the mine sites contribute to the emission of heat. Vegetation removal and use of generator sets on the field are contributors to the potential variability in the microclimate of the region.

As much as anthropogenic activities such as mining takes place, it continues to alter an area's environmental balance (Ingram *et al*., 2011; Adelere *et al*., 2018). In developed countries, measures are being employed to mitigate the adverse effects of mining activities, though may be inadequate (Hentschel *et al*., 2003; Balling *et al*., 2014; Soderholm and Svahn, 2015). However, in underdeveloped and developing countries as Nigeria, the effect of artisanal mining affects the environment strongly. Researchers have revealed the adverse effect of mining to the environment (Salami *et al*., 2003; Orimoogunje, 2010; Eludoyin *et al*., 2017; Oyebamiji *et al*., 2018; Omotehinse and Ako, 2019; Adesipo *et al*., 2020; Bradley, 2020). Such include its effect on soil, flora and fauna, water and chemical compositions. However, there has been little or no research on the effect of this small-scale primary activity on the microclimate of mine sites and neighbouring communities, probably because of the poor awareness of thermal comfort in the Nigerian environment.

The mining sector contributes to the economic development of any country through foreign exchange earnings, employment and improved standard of living. Gold mining in Nigeria could be dated back to 1913; but the production peak was experienced between 1933 and 1943 during which around 1.4 t of gold were produced (Australian Mine Limited, 2011; Gee, 2011). The gold production declined during the World War II period as mines were abandoned by the colonial companies. The Nigerian Mining Corporation, however, started exploring gold in the early 1980s but failed to be sustained due to lack of funds (MMSD, 2010). The discovery of petroleum as the mainstay of the country's economy also contributed to the lack of attention giving to gold mining despite its promising potentials (Paul, 2014). The Ijeshaland gold mining activities are mainly carried out by artisanal small-scale miners who worked with crude tools and equipment (Bradshaw, 1997; Gbadebo and Ekwue, 2014). Their activities include mining of gemstones (tourmaline, beryl, amethyst, aquamarine and garnet) and precious minerals (diamond and gold). These activities potentially result into environmental damages, social disruption and conflicts (Ako *et al*., 2014). Gold mining and processing operations (milling, grinding, concentrating ores) and disposal of tailings, along with mine/mill waste water are emission sources of environmental pollutants. Other environmental problems of gold mining include: land degradation, devegetation, loss of aquatic animals, soil pollution, water pollution and air pollution (Adriano, 1986). Apart from the environmental concerns of gold mining, the health problems of gold mining are numerous due to use of gravity concentration methods such as panning and sluicing during the processing operations (Adriano, 1986). Generally, metal contaminations may be linked directly to mineral exploitation, ore transportation, smelting and refining, disposal of the tailings and waste waters around the gold mines. Studies on health impacts of artisanal gold mining had been severally reported (Basu *et al*., 2015; Cobbina *et al*., 2015; Rajaee *et al*., 2015; Obiri *et al*., 2016). These studies revealed artisanal gold mining as the major exposure route to mercury. Artisanal mining releases 1000 t of mercury into the environment every year, which accounts for 30 to 40% of global mercury emissions (Basu *et al*., 2015). Mercury, cadmium, chromium and arsenic are metals of health concerns among the communities of gold miners (Obiri *et al*., 2016).

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 - 3.6 Site Location with group picture with the project students and miners.

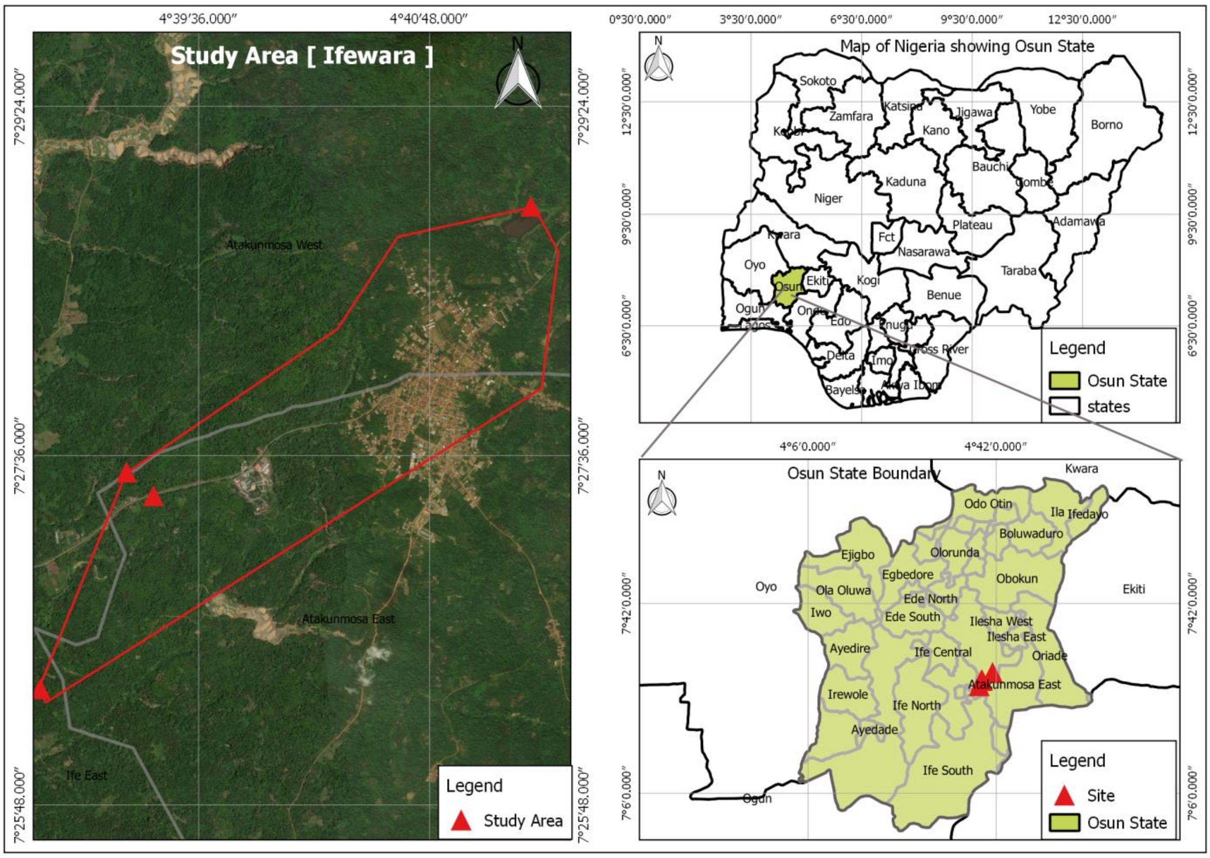

Figure 3.1: Map of the Study Area Location Ifewara, Atakumosa Local Government Area, Osun State, Nigeria.

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

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

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

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

Plates 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^{l-}) 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.

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

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.

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

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

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.

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

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.

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

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 de-ionised 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° (°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.

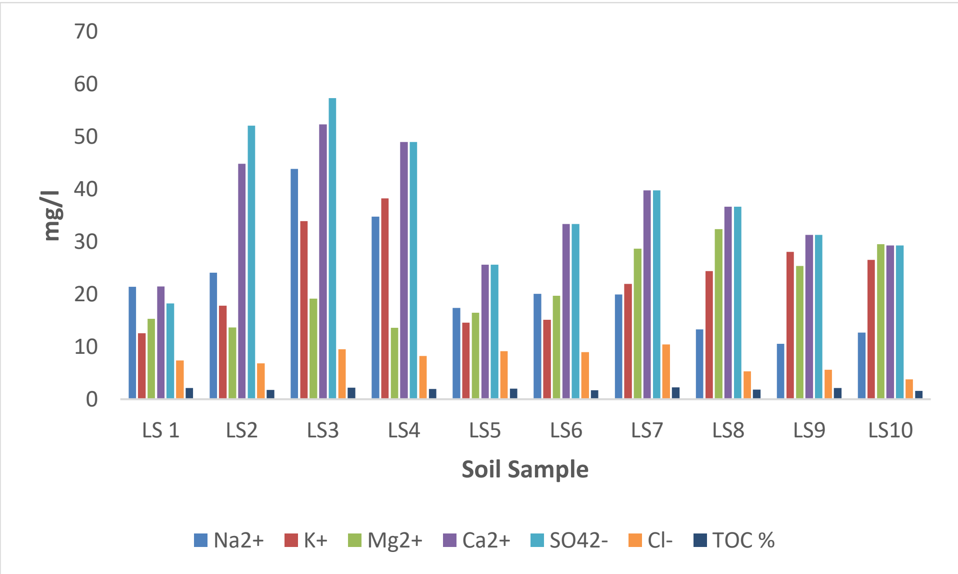

Figure 4.1: Concentrations of Metallic Elements in Soil Samples around the mine

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) 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

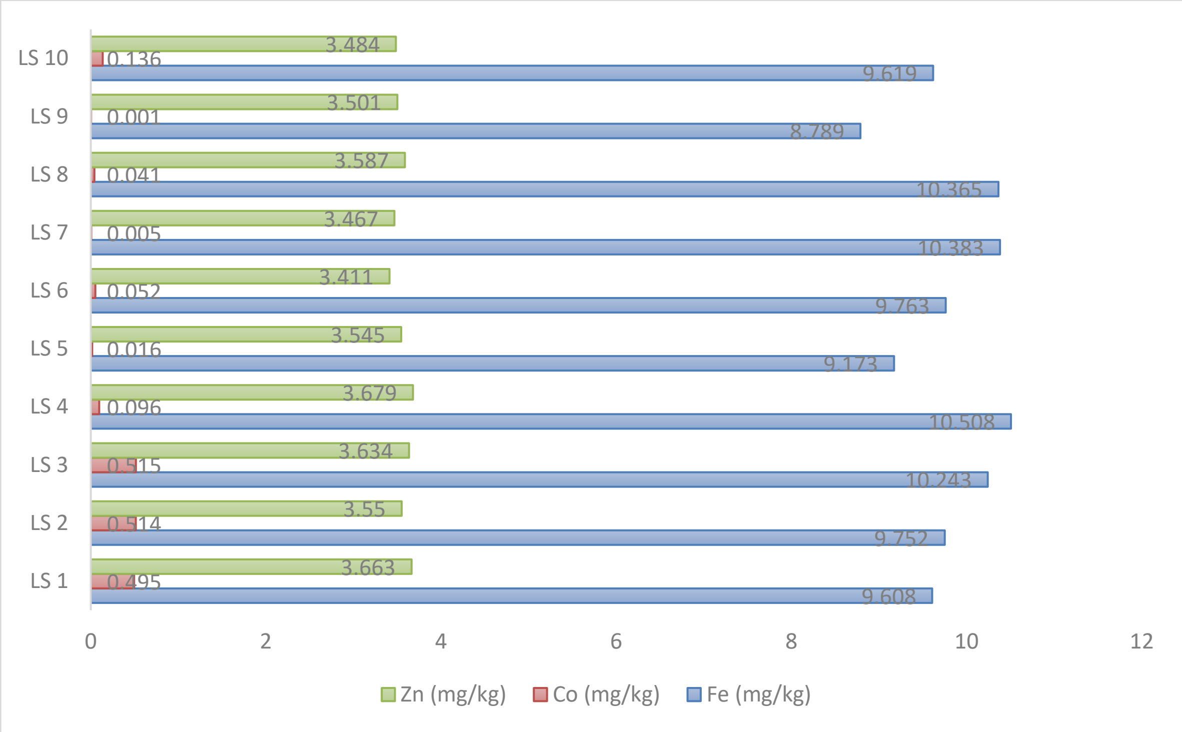

Figure 4.1: Heavy Metals Concentration of the Sample (mg/kg)

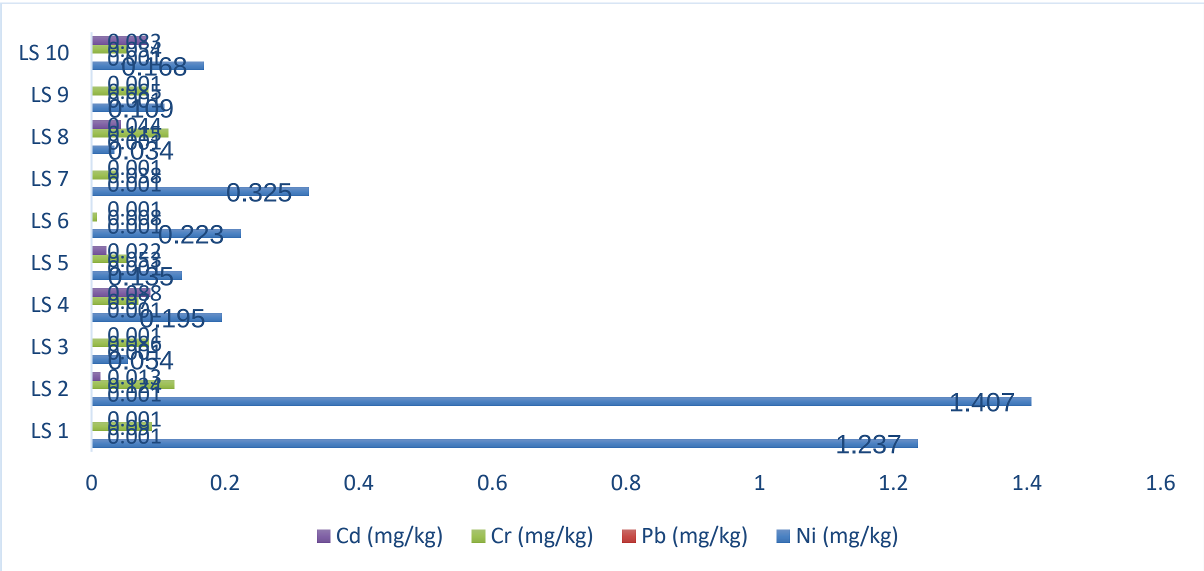

Figure 4.2: Heavy Metals Concentration of the Sample (mg/kg)

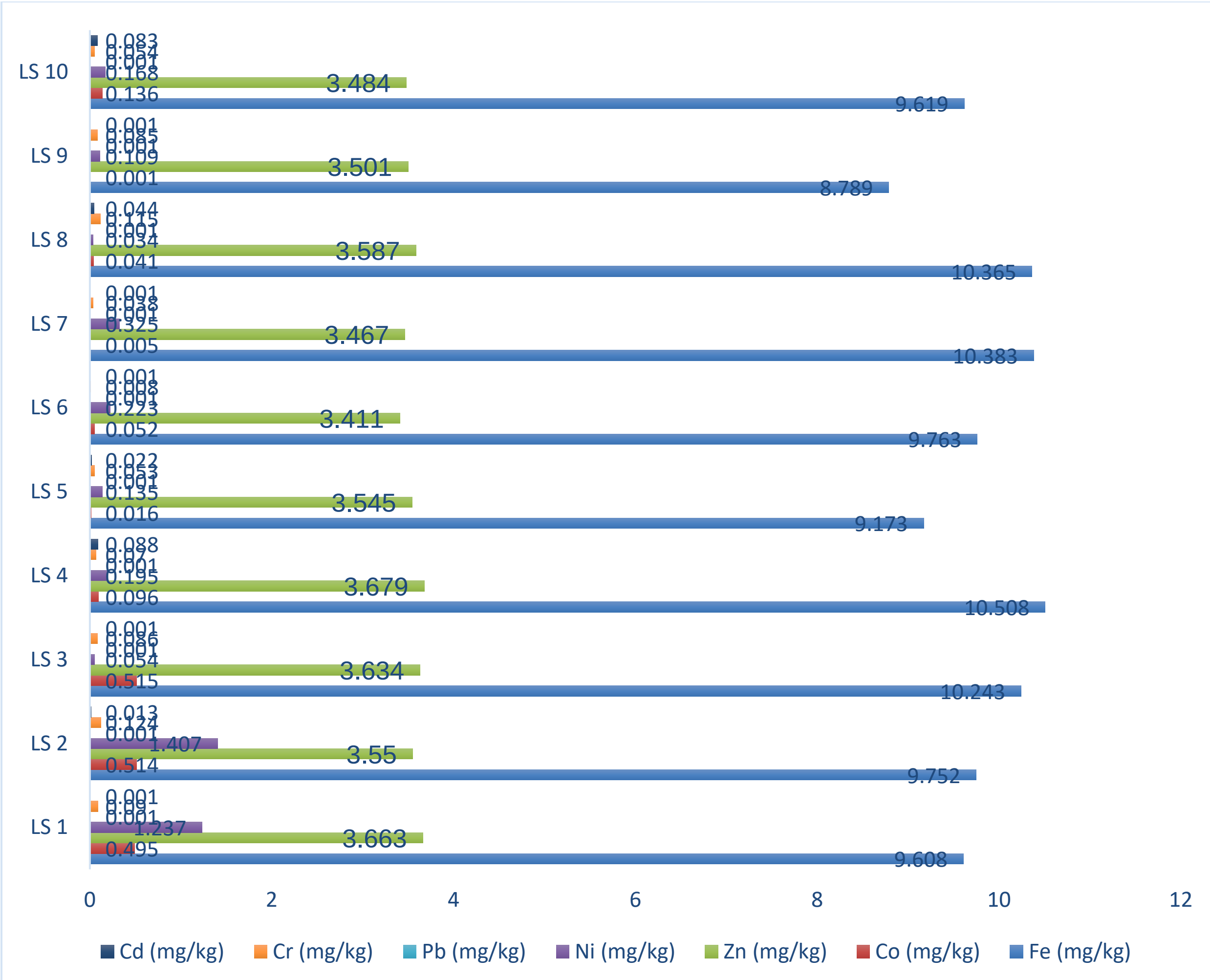

Figure 4.3: Heavy Metals Concentration of the Sample (mg/kg) for all the Soil Samples

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

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This study revealed that mining activities in Ifewara, Osun State, Nigeria, have a detrimental impact on the soil by introducing heavy metals above threshold limits and altering the soil's physicochemical properties, thereby causing severe soil pollution. There is an urgent need to develop guiding principles to regulate mining activities particularly artisanal mining in this area, in order to prevent the numerous toxic effects caused by heavy metal contamination. In addition, further studies are needed to evaluate contamination levels through physicochemical analyses and heavy metal concentrations during both the dry and wet seasons. This will help assess the accumulation of these metals in plants and humans, as well as the associated health risks of mining activities to the inhabitants of the studied area.

5.2 RECOMMENDATIONS

Based on the conclusion of this study, the following recommendations are made:

1. The contamination of soils by heavy metals in the area is increasing, and this situation calls for effective measures to prevent further pollution of the ecosystem.
2. All mining activities at the Ifewara gold site should be closely monitored to ensure that gold extraction and related operations do not pollute the soil or the environment.
3. The study also recommends increasing environmental awareness through enlightenment campaigns focused on illegal and artisanal mining activities.
4. Additionally, implementing control and monitoring techniques in the study area will help achieve satisfactory environmental quality.

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