INFLUENCE OF MINING ACTIVITIES ON PHYSICOCHEMICAL PROPERTIES OF WATER 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 OPEYEMI BARAKAT** with the Matric Number **(HND/23/MNE/FT/038)** supervised, read and approved as having satisfied part of the requirements for the award of Higher National Diploma (HND) 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 who had been my helper through my HND program .

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I give thanks to Almighty God, the only one who has knowledge of attitude, to him be the glory, for His mercy and goodness throughout my project work.

I also forward my acknowledgment to my wonderful handsome and hardworking supervisor Engr. Agbalajobi, S. A for his knowledge used to input lightness in my darkness. May Almighty God continue to be with you (Ameen).

My gratitude also goes to my trusted and able parents in person of Mr. and Mrs. Babatunde and other lecturers in the department.

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ABSTRACT

This study was conducted in Ifewara, Osun State, Nigeria, to identify potential hotspots of water contamination for future treatment efforts. Water quality analyses were conducted based on physicochemical properties and heavy metal concentrations in surface and groundwater samples collected from the study community. A total of ten water samples were collected in February, 2025 and analyzed using standard procedures. Heavy metal concentrations were determined using Atomic Absorption Spectrophotometry (AAS). Results showed that water samples within the gold mining community of Ifewara are contaminated, and the hydrochemistry reflects the influence of both natural factors and mining activities. The values of pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS) during the dry season of sampling ranged 5.48 – 6.99, 81.3 – 361 μS/cm, 54 – 180 ppm respectively and phosphate, calcium, potassium, sodium, magnesium was within the stipulated limits set by the Nigerian Standard for Drinking Water (NSDWQ) and World Health Organization (WHO) standard. heavy metal concentrations in groundwater are generally higher compared to surface water in the mining area. The values of Fe, Co, Zn, Ni, Pb, Cr and Cd for both surface and groundwater ranged from 0.240 – 9.468 mg/L, 0.001 – 0.090 mg/L, 0.345 – 3.172 mg/L, 0.001 – 0.068 mg/L, 0.001 – 0.001 mg/L, 0.025 – 0.105 mg/L, and 0.001 – 0.030 mg/L respectively. Most of the listed metals have values within the international and natural recommended limits, but it's recommended that the research be repeated during the dry season to ascertain the safety intake of the water resource and public health within the mining community.

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CHAPTER ONE

INTRODUCTION

1.1 MINING COMMUNITIES

Nigeria is richly endowed with minerals. There are over 40 different types of minerals in commercial quantity and economically viable spread across metallic and nonmetallic divides. Iron ore, zinc, lead, barium and gold top the metallic minerals, while the main non-metallic minerals are granite, marble, limestone, and bentonite (Dema, 2014: 8). The country has also produced a variety of other industrial minerals such as gypsum, barite, diatomite, and bentonite in the 1900s and gemstones of comparable size to the metallic and industrial minerals (NEITI, 2016).

This development witnessed the establishment of several mining companies and corporations such as the Nigerian Mining Corporation, Makeri Smelting Company Ltd, Aluminium Smelting Company, Nigerian Machine Tools Company, Ajaokuta Steel Rolling Mill Ltd, Katsina Steel Rolling Mill Ltd, Osogbo Steel Rolling Mill Ltd, Delta Steel Rolling Mill Ltd, National Iron Ore Mining Company, Nigerian Coal Corporation, and Nigerian Tin Company Ltd. The boom in industrial mining saw several legislations and regulatory frameworks, including the Mineral Ordinance of 1946, the Coal Ordinance of 1950, the Explosives Act of 1964, and the Explosives Regulations, 1967. This was followed by the immediate and manifest decline in mining activities which was precipitated by the discovery and exploitation of oil and the dominance of other sectors of the economy. Coupled with the indigenization policy of government in the 1970s which was further compounded by the economic crisis of the 1980s (including the fall in the price of tin) that climaxed in the adoption of the Structural Adjustment Programme (SAP), mining in Nigeria witnessed a downturn leading to the withdrawal of foreign investments and consequent job losses. Indeed, the efforts to rescue the sector prompted the enactment of new minerals and mining policies, laws, and regulations in 1999, 2007, and 2011 respectively

Water is a universal solvent to man for various activities such as drinking, cooking, industrial and agricultural processes, waste disposal and human recreation. The two main problem men contend with are the quantity (source and amount) and quality of water in Nigeria (Adeniyi, 2004). In view of the occurrence and distribution pattern, water is not easily available to man in the desirable amount and quality. This is a problem experienced in most cities and town in the developing nations not to mention their rural settings. These factors have led to the growing rate of water borne diseases like typhoid fever and cholera experienced in this part of the world.

River channels are an important component of the ecosystem that promotes life, particularly agricultural activities in the world. River channels in urban areas, across developing countries now have become very useful in all year-round agricultural activities, Nigeria inclusive. Such agricultural activities include the cultivation of cereals, tubers, fruits, vegetables, fishers, as well as livestock. These are based on availability of water and rich organic materials that make such agricultural products flourish in these areas (Olatunji and Ajayi, 2016; Bruce *et al*., 2021). During raining season because of the increase in surface runoff. The rivers receive large amount of sediment and as the energy of the river flow reduces, sediments get deposited at the levee of the rivers. In the course of these events, elements from both geogenic (underlying bedrock) and anthropogenic sources also sink into these sediments both in river bed and floodplain (Adepoju and Adekoya, 2013); Odukoya and Akande, 2015; Asowata and Akinwuniju, 2021).

Sediment in river beds often serve as repositories for the accumulation of trace elements that are weathered and transported form the drainage area underlying bedrock and other man-induced activities (Alonso-Casyilo *et al*., 2013; Hup *et al*., 2015). Such trace element includes As, Cu, Pb, Zn, Ni, Co, Mn, Th and V among others, Moeinaddini *et al*., (2019); Asowata and Akinwumiju, (2021). Some of these trace elements for example Zn, Ni, Co and Cu, at a tolerable level, are biologically relevant as essential nutrients in food commodities. Whereas other elements such as As, Pb, La and Th have no biological relevance to living organism, (Olatunji, *et al*., 2018; Kolawole *et al*., 2022a). These elements can be toxic to the human body in particular and in plants and animals at a relatively higher concentration beyond tolerable limit, through bioaccumulation in the environment. Attention has only been placed on the effect of gold mining of the Ifewara and objectives of the work include influence of mining activities on physicochemical properties of water at Ifewara gold mine site during dry season, Osun State, Nigeria.

1.2 AIM AND OBJECTIVE OF THE RESEARCH WORK.

1.2.1 Aim of the Research

The aim is to investigate the Influence of mining activities on physicochemical properties of water at Ifewara gold mine site during dry season, Osun state, Nigeria.

1.2.3 Objective of the Project

i. determines the physical and chemical properties of water with heavy metal such as pH, Temperature, Electric conductivity, TDS, chlorine ion, sulphide ion and nitrite ion. Also, some heavy metals contaminants such as Codmium (Co), Cadmium (Cd), Zinc (Zn) and Lead (Pb).

ii. assessment of the impact of mining activities on the water of Ifewara gold mining site, Osun State, Nigeria.

1.3 SCOPE OF THE RESEARCH WORK

This study will be assessed on how mining activities influenced the level and distribution of some physicochemical properties and heavy metals in water;

1.4 STATEMENT OF PROBLEM

The physicochemical properties of water in the Ifewara gold mining area have not adequately studied despite the potential risks posed by the mining activities to water quality. This knowledge gap raises concerns about the potential impact of mining on the environment and public health of the community.

1.5 JUSTIFICATION

This study is justified because it will provide valuable information and data on the impact of mining on water quality in the Ifewara gold mining site. The finding will help identify potential sources of water pollution and inform strategies for mitigating the effects of mining on the water resources. The study will also contribute to the existing body of knowledge on the environmental impact of mining in Nigeria.

CHAPTER THREE

LITERATURE REVIEW

2.1 ARTISANAL AND SMALL-SCALE GOLD MINING IMPACT ON SOIL AND AGRICULTURE

Small-scale gold mining has served as a substantial means of subsistence for rural communities worldwide Hilson and Hilson, (2015). Research indicates that around 15 million people have engaged in gold mining as a result of the widespread desire to become wealthy quickly Seccatore *et al*., 2024; Ros-Tonen *et al*., 2021; Akabzaa and Yidana, (2011). Artisanal gold extraction has played a substantial role in the economies of many developing countries Akabzaa and Yidana, (2011) and Brottem, and Ba, (2019). According to Seccatore *et al*., (2024), artisanal gold mining is primarily driven by poverty and is widespread in the remote rural areas of Africa and Asia. Scientific research has shown that artisanal gold mining has negative impacts on essential soil properties, which in turn poses a threat to the already depleted vegetation resources in tropical countries Hilson, Hilson, and Pardie, (2007); Alvarez-Berríos and Mitchell, (2015). Extensive deforestation in Ghana's mining communities has led to a decline in biodiversity and genetic resources, as documented by Ofosu, *et al*., (2020).

Artisanal and small-scale mining (ASM) is distinguished by its dependence on manual labor and its use of basic technology for extracting and processing minerals (Hilson, 2016); (Adu-Baffour *et al*., 2021). ASM operations primarily employ a workforce composed of individuals with limited specialized skills, leading to a decrease in the unemployment rate, particularly among young people living in rural mining communities. Kumi-Boateng and Stemn, (2018) found that this phenomenon results in a reduction in occurrences of armed robbery and social vices. Furthermore, multiple studies (Arthur, *et al.*, 2016; O'Connor, *et* *al.*, 2016) have identified positive externalities associated with artisanal and small-scale mining (ASM). These factors encompass the widespread occurrence of child labor, bias based on gender, the deterioration of land quality, the disappearance of wildlife species, the presence of harmful substances in the air, and the pollution of sediments, surface water, and groundwater with toxic heavy metals. Ghana's arable land is exposed to adverse climatic conditions, such as elevated temperatures, erosion, and strong winds, due to the substantial loss of forest and vegetation. Several governments have enacted a range of laws and policies to reduce the negative effects caused by artisanal and small-scale mining (ASM), especially those that harm the environment.

The lack of sufficient data on the role and impact of small-scale gold mining operations in Nigeria's socioeconomic development has led to differing viewpoints and discussions on the actual extent of small-scale mining's contribution to socioeconomic progress. The employment opportunities resulting from artisanal and small-scale mining (ASM) activities are clearly advantageous for marginalized rural inhabitants who rely primarily on agriculture for their livelihood despite the adverse environmental consequences associated with these activities (Adu-Baffour, *et al.*, 2021); Conteh and Maconachie, 2021). The present circumstances are highly alarming as the considerable consequences of recent variations in weather patterns have greatly affected rural farmers, especially those engaged in small-scale production. The increase in illegal mining activities can be attributed to mining regulations implemented by the government that prioritize the protection of commercial mining companies at the expense of small-scale mining operations.

2.2 ASSESSMENT OF GOLD MINING IMPACT ON THE VEGETATION

Mining occurs when there is an extraction of minerals or other geological materials from the earth's crust; which forms the mineralized package of economic interest to the miner (Oluwafemi, 2018, Oyinloye, 1992). However, mining activities also impact negatively on the waters, landscape, vegetation and the atmosphere at the mine sites (Oyinloye, 1992; Ako *et al*., 2013). Gold with the chemical symbol (Au) coined from the Latin word aurum falls into the categories of transition metals. It can occur as nuggets or grains, in rocks veins or alluvial deposits. According to Hawas *et al*., (2013), environmental consequences of gold mining can be devastating, particularly in fragile tropical ecosystems because toxic substances like cyanide and

mercury is usually involved in its extraction. Several studies exist on the impact of mining on the environment both at micro and macro levels (Schueler, *et al*., 2011; Oyinloye, 1996; Ako *et al*., 2014; Hawas *et al*., 2013). For instance, Sima, *et al*. (2008) observed that both natural and socioeconomic activities are impacted qualitatively and quantitatively as a result of mining activities in the Certej River Catchment, Western Carpathians, Romania. Few studies, (Hawas *et al*., 2013; Oyinloye, 1996; Ako *et al*., 2014) especially in the field of Geoinformatics, have examined mining and its impact on the geomorphology and social wellbeing in a comparative manner.

Traditionally, the effects of gold mining have long attracted the interest of geomorphologists both in terms of their landforms, vegetation alteration and biodiversity response to change. An important goal in mapping and assessment process is to extract hidden relationships and effects between some variables. In recent year, there has also been a wider growing recognition of human impacts on the earth's global systems (Adediji and Oluwafemi, 2007). Surface mining, for example, removes vegetation and soils, interrupts ecosystem service flows, and results in inevitable and often permanent farmland loss. Gold mining activities also frequently result in toxic waste that causes water pollution and health problems. Studies have also shown that mining at both small and large scale has great impact on vegetation and soil, land use, livelihood foundations and geomorphology of African countries. Monitoring vegetation from space can provide relevant information quickly, repeatedly and at regular intervals of time. Since 1970s, satellite remote sensing has been commonly used for understanding the cumulative influence of man on landscape and vegetation (Wickware and Howarth, 1981). Kushwaha *et al*., (2011) used remote sensing data in mapping the forests Kaziranga National Park for determining habitat changes that occurred after the flood event. Gautam and Chenniah (1985) analysed Tripura vegetation using Landsat imagery data. In Nigeria, Mesubi *et al*. (1999) and Ako *et al*., (2014) studies on extraction of gold from Igun gold ore deposit in Atakumosa West Local Government Area, Osun state, and environmental impact of artisanal gold mining in Luku, Niger state respectively. The metamorphism is mainly evident in the amphibolite facies, but locally in greenschist facies (Oke *et al*., 2013; Oyinloye, 2011). At the eastern axis of the fault (the Iperindo catchment) quartzite is dominant, occurring together with quartz schist, quartzo-felspathic-gneiss, and minor iron-rich schist (Oke *et al*., 2013; Oyinloye, 2011). The deciduous rainforest of the study area can be sub-divided into three types. These include the disturbed rainforest, the light forest, and the patches of thick forest. The disturbed rainforest is the anthropogenically impacted rainforest with many randomly distributed open spaces as a result of human activities such as agriculture, mining, lumbering, and fuelwood harvesting. The light forest is an emerging forest at the stage of secondary succession that is common on the slightly weathered rocks. The patches of thick forest are the few natural rainforests of the Southwestern Nigeria that are relatively protected from encroachment. These include the forest reserves and traditionally preserved forests that are consecrated to some traditional religions and festivals in Yoruba Land (Orimoogunje, Oyinloye, and Momodou, 2009; Oluwafemi, 2018). The wet season in the area is normally characterized by two maximal rainfalls with peaks occurring in July and September or October. The rainfall record of Itagunmodi between 1975-2000 indicates that annual rainfall varies from 923mm-2116mm with a mean of 1389.29mm, and the temperature is generally high (Olayiwola and Aguda, 2009). The range of temperature during the dry season especially between December and April is between 21^oC and 30^oC. Also, as observed by Olayiwola and Aguda (2009) the mean daily minimum and maximum temperature in the area is 20^oC and 33^oC respectively.

CHAPTER THREE

MATERIALS AND METHODS

3.1 DESCRIPTION OF STUDY AREA AND SAMPLING POINTS

Ten sample stations were established at different locations of the gold-mining community 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). The mine locations are within one of the six (6) classes of the Basement complex rock that is form slightly migmatised to non-migmatised, meta-sedimentary and meta-igneous rock or simply called the Schist belt. The study area is a part of Ilesa-Ife schist belt (Ademeso *et al*., 2013).

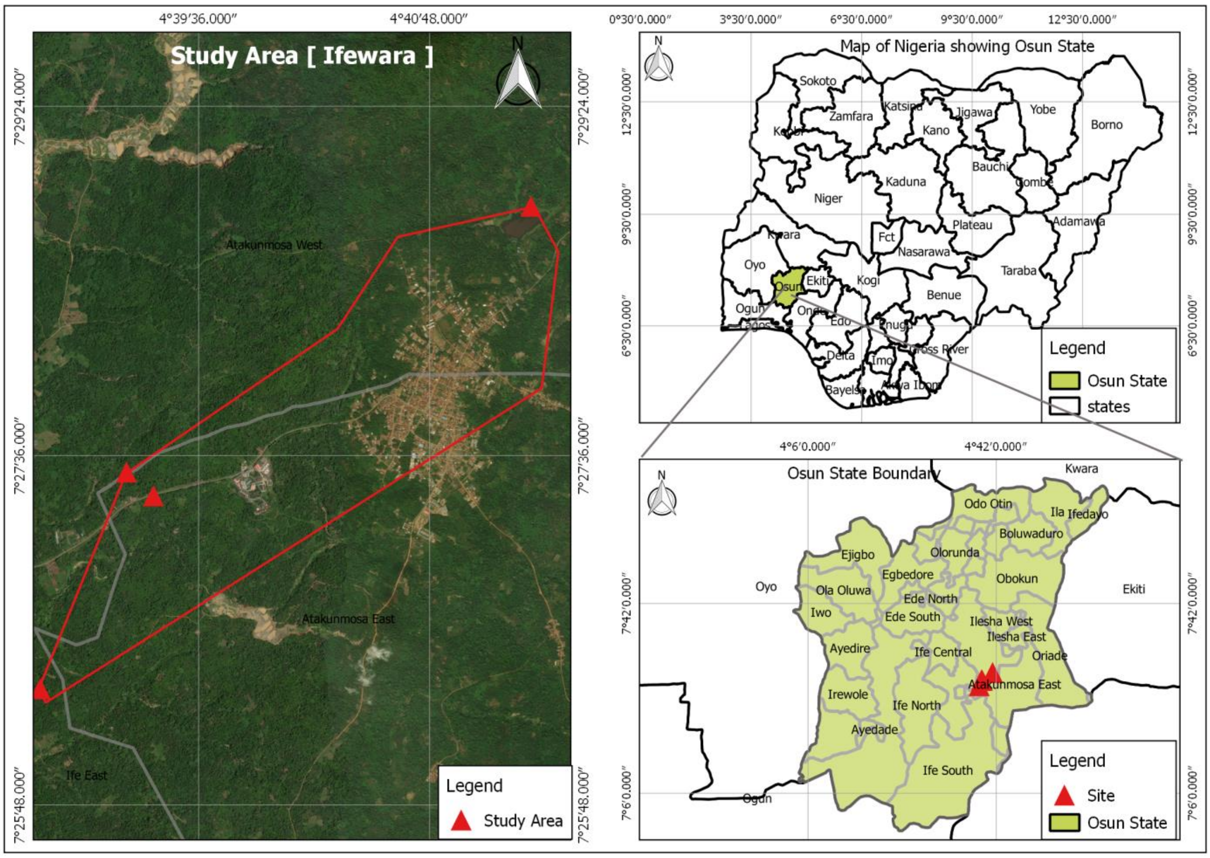

Figure 3.1: Map of the Study Area Location Ifewara, Atakumosa Local Government Area, Osun State, Nigeria.

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 FIELD INVESTIGATION AND WATER SAMPLING

Ifewara area was selected for this study primarily due to the presence of gold mining activities in the community. Seven surface water and three groundwater sampling point were selected and their coordinates located using a Global Positioning System, GARMING 45XLS. The sampling was done in 1st of February, 2025 dry season. A total of 10 water samples were collected from both surface and ground water samples in the study area. Water samples were collected with 2.5 Litre plastic bottles, which have been rinsed thoroughly with double sample water. During sampling, relevant information like the ambient temperature, date of sampling, time of sampling and seasons of the year were recorded. Collected samples were preserved and stored in an ice-chest at temperature of 4°C and transported to the laboratory for analyses. Samples were taken in separate containers for physicochemical and trace heavy metal analysis respectively. Samples for trace metal analysis were each preserved with 0.5 ml of concentrated nitric acid before transporting to the Central Research Laboratory, University of Ilorin for analysis.

3.3 SAMPLE ANALYSIS

The methods of laboratory analysis used were those specified in International analytical standards such as APHS for water quality. All equipment were duly calibrated with standard samples were analysed. All test and laboratory analyses were carried out at the Central Research Laboratory, University of Ilorin for analysis.

3.3.1 Determination of Physico-chemical Parameters

Water, pH, temperature, Electrical Conductivity (EC), TDS were analyzed in-situ during sampling using pH/TDS/Conductivity meter. Samples for water soluble anions (sulphate, nitrate, phosphate and chloride) were determined with Ion Chromatography System (ICS) model Dinonex ICS 2000. Samples for cationic water-soluble constituents (calcium, magnesium and potassium) were analysed with Dionex DX 500. Details of analytical procedures of both anions and cationic species can be found in (Taiwo, 2013; Gashi *et al*., 2013).

3.3.2 Sample Digestion for Heavy Metal Analysis

Samples for determination of cobalt, cadmium, chromium, copper, lead, manganese, nickel and zinc were collected with 500ml plastic bottles, since such metal may be adsorbed on the wall of glass bottles. About 3ml of concentrated Nitric acid was added and the samples were refrigerated at 4°C before digestion. The water samples (100 ml) were digested with 10 ml concentrated HNO_3. Digestion can be carried out primarily through two methods: either through open or closed systems (Hu and Qi, 2013). Open acid digestions were carried out on a lab hotplate for 20 min in a beaker (USEPA, 1989). The samples were placed in the fume hood for a few hours to allow for digestion. Strong oxidizing acids were also added to the sample and heated throughout the wet digestion process to allow the organic components to break down (Mohd *et al*., 2019). BUCK Scientific ACCUSYS 230 Atomic Absorption Spectrophotometer (AAS) at Central Research Laboratory University of Ilorin for determination of Pb, Fe, Ni, Co etc.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Physical and Chemical Parameters

Table 4.1 show the data collected for individual surface and ground water samples and parameters with respective WHO/NSDWQ standard. The samples were labelled sample LW1, LW2, LW3, LW4, LW5, GW6, LW7, LW8, GW9 and GW10. Surface Water (LW) and Ground Water (GW) samples at the dry season in Ifewara, Osun State, Nigeria.

Table 4.1: Physicochemical Parameter

Sample Codes	Ph	EC (µS/cm)	TDS (ppm)	Temp° (°C)	Chloride (mg/L)	Calcium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Mg^{2+} (mg/L)	SO_4^{2-} (mg/L)
LW1	5.90	81.3	68	28	4.22	12.15	7.53	10.51	5.74	12.41
LW2	6.29	140	156	32	3.07	8.30	4.29	7.68	8.81	10.13
LW3	6.5	184	132	37.3	5.32	5.11	9.74	9.24	9.47	7.20
LW4	6.47	124	137	36.6	3.99	6.34	6.43	10.02	8.81	8.23
LW5	5.48	361	180	27.9	4.06	18.23	4.71	9.63	4.91	11.55
GW6	6.32	168	83	26.2	5.81	4.46	5.95	6.17	9.62	7.27
LW7	6.55	165	89	30.2	4.50	8.02	7.81	9.84	6.73	9.46
LW8	5.81	106	54	28.9	3.93	6.15	9.49	11.52	8.55	12.09
GW9	6.99	251	125	30.4	4.38	5.26	4.36	14.81	7.49	15.13
GW10	6.23	134	68	29.8	4.65	10.08	8.44	11.47	6.42	8.46
Range	5.48 – 6.99	81.3 – 361	54 – 180	26.2 – 37.3	3.07 – 5.81	4.46 – 18.32	4.29 – 9.74	6.17 – 14.81	4.91 – 9.62	7.20 – 15.13
WHO STANDARD	**6.5 - 8.5**	**1000**	**500**		**3.00**	**75**	**12**	**200**	**150**	

The measured pH gives the general indication that the water samples range from neutral to alkaline for dry season and the highest desirable level for pH stipulated for drinking and domestic purposes is within the range of 6.5 to 8.5 (WHO, 2004). Electrical conductivity values in all the water samples varied from 81.3 µS/cm (LW1) to 361 µS/cm (LW5) for dry season, all other water samples are within the permissible limit of 1000 µS/cm for EC in drinking water (WHO, 2004). TDS values in the sampled water bodies range from 54 mg/L (LW8) to 180 mg/L (LW5) for dry season samples while the values in the ground water, concentrations of TDS varied from 68 mg/L (GW10) to 125 mg/L (GW9). The TDS values recorded for ground and surface water samples in both seasons are within the WHO limit of 500 mg/L (WHO, 2004). Mg^{2+} concentration varied from 4.91 mg/L (LW5) to 9.47 mg/L (GW5) during the dry season for ground water and from 6.42 mg/L (GW10) to 9.20 mg/L (GW6) all exceeding the recommended limit of 0.2 mg/L set by the Nigerian Standard for Drinking Water Quality (SON, 2007). SO_4^{2-} concentrations in the surface water samples range from 7.20 mg/L in LW3 to 12.41 mg/L in LW1 (dry season) and ground water range from 7.27 mg/L in GW6 and GW10 to 15.13 mg/L in GW10 (dry season), within the WHO limit of 3.00 mg/L (WHO, 2004). There is no WHO guideline value to compare the measured Na and K values. Physico-chemical parameter values in both surface and ground water samples during the dry season in Ifewara.

4.2 Heavy Metal Concentration of Water 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 0.240 at (GW9) to 9.468 at (LW2). 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 0.001 (LW1) to 0.090 (LW2); 0.345 (GW10) – 3.172 (LW5); 0.001 (LW5) – 0.068 (LW5); 0.001 – 0.001 (Constant); 0.025 (GW6) – 0.105 (GW9); 0.001 (LW1-7,10) – 0.030 (LW8,9); 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
LW1	1.687	1.779	1,733	0.001	0.001	0.001	2.935	2.935	2.935	0.016	0.016	0.016	0.001	0.001	0.001	0.051	0.051	0.051	0.001	0.001	0.001
LW2	9.468	9.468	9.468	0.090	0.090	0.090	2.656	2.656	2.656	0.097	0.097	0.097	0.001	0.001	0.001	0.071	0.038	0.055	0.001	0.001	0.001
LW3	1.070	1.070	1.070	0.033	0.033	0.033	2.993	2.993	2.993	0.009	0.009	0.009	0.001	0.001	0.001	0.013	0.039	0.026	0.001	0.001	0.001
LW4	4.791	3.511	4.151	0.002	0.002	0.002	2.943	2.943	2.943	0.006	0.006	0.006	0.001	0.001	0.001	0.031	0.031	0.031	0.001	0.001	0.001
LW5	1.447	1.447	1.447	0.030	0.030	0.030	3.172	3.172	3.172	0.001	0.001	0.001	0.001	0.001	0.001	0.056	0.056	0.056	0.001	0.001	0.001
GW6	0.784	0.784	0.784	0.034	0.034	0.034	3.063	3.063	3.063	0.002	0.002	0.002	0.001	0.001	0.001	0.025	0.025	0.025	0.001	0.001	0.001
LW7	2.814	1.901	2.3575	0.049	0.049	0.049	3.061	3.061	3.061	0.001	0.001	0.001	0.001	0.001	0.001	0.059	0.059	0.059	0.001	0.001	0.001
LW8	1.173	1.173	1.173	0.014	0.014	0.014	3.163	3.163	2.162	0.068	0.068	0.068	0.001	0.001	0.001	0.094	0.094	0.094	0.030	0.030	0.030
GW9	0.240	0.240	0.240	0.001	0.001	0.001	0.381	0.381	0.381	0.056	0.056	0.056	0.001	0.001	0.001	0.105	0.105	0.105	0.030	0.030	0.030
GW10	0.443	0.443	0.443	0.005	0.005	0.005	0.345	0.345	0,345	0.034	0.034	0.034	0.001	0.001	0.001	0.059	0.059	0.059	0.001	0.001	0.001

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 and Figure 4.2 respectively. It could be connoted that the mining activities have influences in the accumulation of heavy metals in the water.

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

Sample Code	Fe (mg/L)	Co (mg/L)	Zn (mg/L)	Ni (mg/L)	Pb (mg/L)	Cr (mg/L)	Cd (mg/L)
LW1	1.733	0.001	2.935	0.016	0.001	0.051	0.001
LW2	9.468	0.090	2.656	0.097	0.001	0.055	0.001
LW3	1.070	0.033	2.993	0.009	0.001	0.026	0.001
LW4	4.151	0.002	2.943	0.006	0.001	0.031	0.001
LW5	1.447	0.030	3.172	0.001	0.001	0.056	0.001
GW6	0.784	0.034	3.063	0.002	0.001	0.025	0.001
LW7	2.3575	0.049	3.061	0.001	0.001	0.059	0.001
LW8	1.173	0.014	2.162	0.068	0.001	0.094	0.030
GW9	0.240	0.001	0.381	0.056	0.001	0.105	0.030
GW10	0.443	0.005	0.345	0.034	0.001	0.059	0.001
Range	0.240 – 9.468	0.001 – 0.090	0.345 – 3.172	0.001 – 0.068	0.001 –0.001	0.025 – 0.105	0.001 – 0.030
WHO Guideline	**0.3**		**5.0**		**12**		

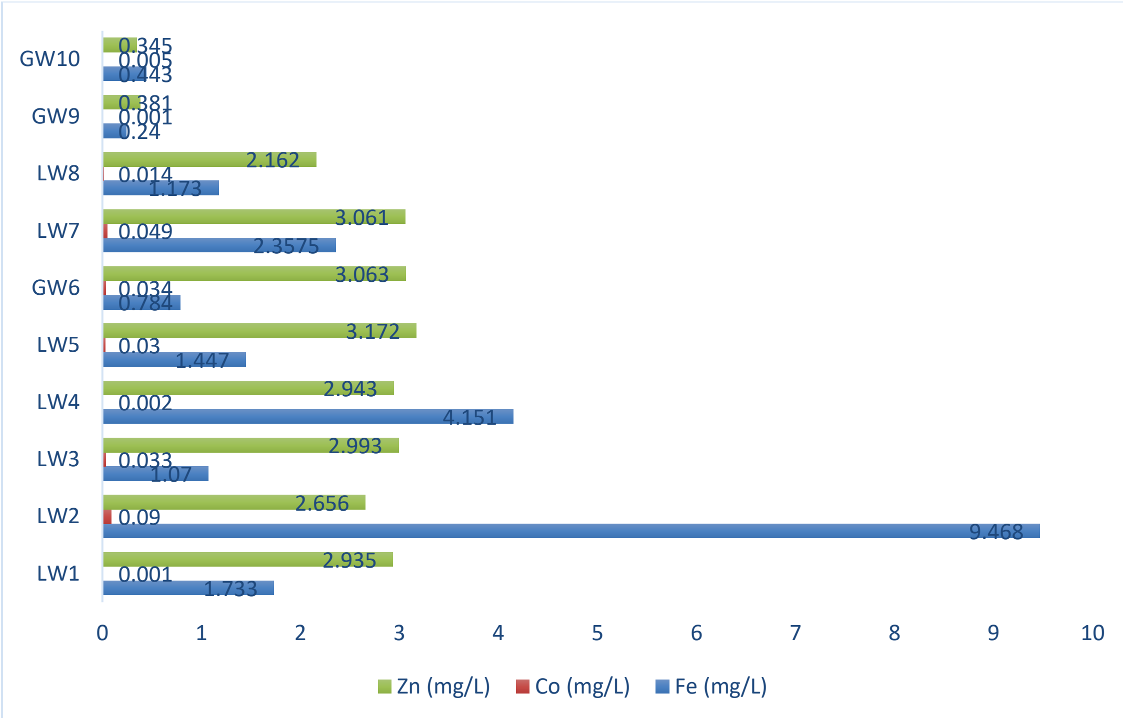

Figure 4.1: Heavy Metals Concentration of the Sample (mg/kg)

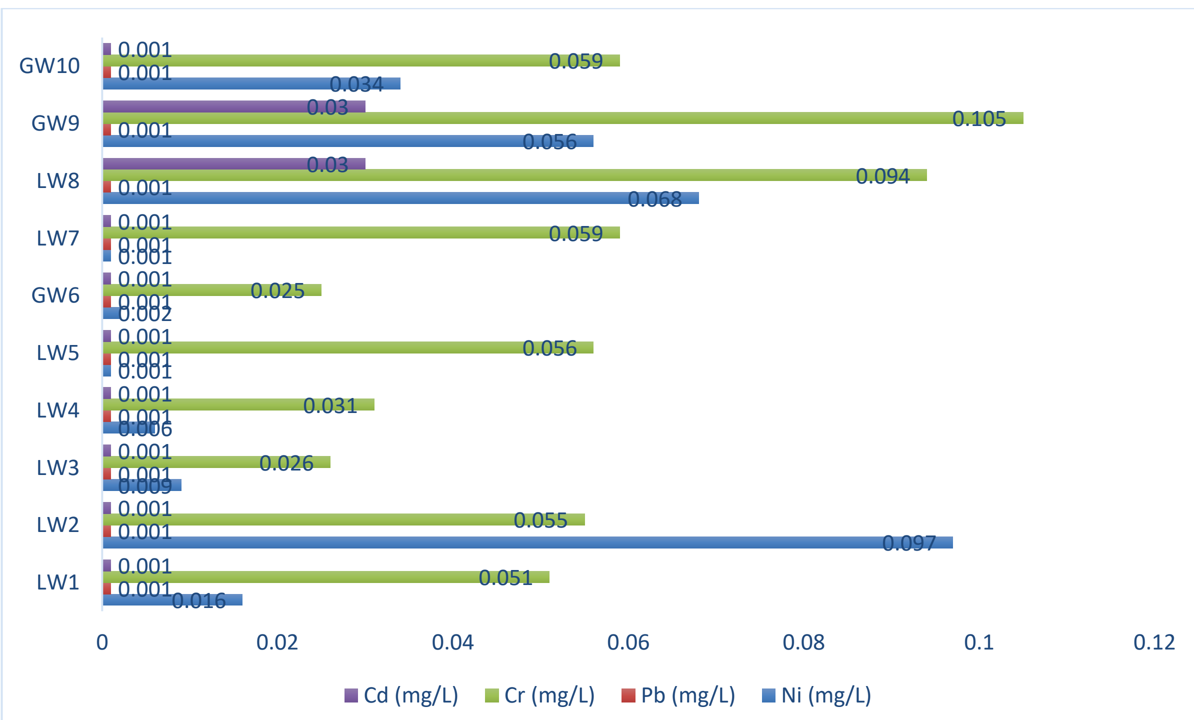

Figure 4.2: Heavy Metals Concentration of the Sample (mg/kg)

Cadmium (Cd) occurs naturally with zinc and lead in sulphide ore. Cd concentrations in unpolluted natural waters are usually below 1.0 mg/L. In this study, Cd concentrations in surface and groundwater at dry season are higher than the permissible limit. The guideline value for cadmium is given as 0.003 mg/L in drinking water by both the World Health Organization (WHO, 2004) and the Nigerian Standard for drinking water quality (SON, 2007). Previous studies show maximum levels in groundwater to be 0.003 mg/L (Kortatsi, 2004, Armah *et al*., 2010) and 0.06 mg/L (Oluwasanya and Martins, 2006). Maximum levels in surface water were less 0.05 mg/L (Kuma and Younger, 2004; Yem *et al*., 2013). The observed cadmium values show that water quality in the mine area is questionable and unfit for human consumption. As a practical measure, the guideline is set as 0.05 mg/L, which is considered to be unlikely to give rise to significant risks to health (WHO, 2004). Maximum levels in groundwater have been shown to be 0.014 mg/L, (Kortatsi, 2004; Marcovecchio, *et al*., 2007) and 0.06 mg/L (Oluwasanya and Martins, 2006) and in surface water to be 0.49 mg/L (Kuma and Younger, 2004, Marcovecchio, *et al*., 2007). Lead (Pb) is possible human carcinogen and it is also cumulative poison so that any increase in the lead burden should be avoided. The Pb value in this study revealed clear expediencies relative to the permissible limit of 0.001 mg/L set by the WHO. Previous studies also show maximum levels in groundwater to be 0.03 mg/L (Kortatsi, 2004, Armah *et al*., 2010) and in surface water to be <0.05 mg/L (Kuma and Younger, 2004; Yem *et al*., 2013). A provisional tolerable daily intake is set as 3.5 μg of lead per kg of body weight for infants. Hunan health concerns associated with lead intoxication in children include brain damage, behavioural problems, anaemia, liver and kidney damage and hearing loss (Gohar and Mohammadi, 2010; Rajaganapathy *et al*., 2011) whereas in adults poor muscle coordination, nerve damage to the sense organs, increased blood pressure, hearing and vision impairment, reproductive problems and retarded fatal development. In this respect, the lead content in the surface and groundwater within the mine area are dangerous for human health and aquatic life. Nickel (Ni) concentrations in drinking water are normally below 20 μg/L, although levels up to several hundred micrograms per litre in groundwater and drinking water have reported (Obriri *et al.*, 2010). The concentrations of nickel observed in the present study are above the permissible limit of 0.07 mg/L for WHO standard and 0.02 mg/L of NSDWQ for domestic water (SON, 2007). The observed nickel values also exceed the finding of Kortatsi (2004), Oluwasanya and Martins (2006) who found maximum levels in groundwater to be 0.08 mg/L and 0.34 mg/L respectively. The presence of nickel in the mine study area is a chemical hazard to both aquatic biotas of the river as well as for human consumption. Zinc (Zn) concentration of the surface water sampled during the dry season are within the recommended limit of 3 mg/L set by WHO and NSDWQ while value from sampling point. Zinc is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes (Edema *et al.*, 2001; WHO, 2003). Iron concentrations are well above the recommended WHO limit of 1.0 mg/L (Highest desirable) and 3.0 mg/L (maximum desirable) except for LW2 and LW4. Fe forms rust-coloured sediment, stains laundry, utensils and fixtures reddish brown. Objectionable for food and beverage processing, can promote growth of certain kinds of bacteria that clog pipes and well openings (Kortatsi, 2007).

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The main goal of this study was to assess the influence of mining activities on water quality at the Ifewara gold mine during the dry season. The study results showed that both surface and groundwater resources within the vicinity of the study area are contaminated. The hydrochemistry of both surface and groundwater shows variations, likely due to natural geological differences and the impact of mining activities. The results also indicated that most of the observed physicochemical parameters in the water samples fall within the standards set by the WHO. Heavy metal concentrations generally exceed the WHO recommended limits, indicating a threat to public health.

5.3 RECOMMENDATIONS

The findings of this study hold several implications for water quality management and policy. Previously, most mining communities depended on surface water as drinking water source. However, contamination of surface water particularly via mining activities made it imperative for government and other non-state stakeholders to resort to groundwater (Armah *et al*., 2010). Results from this study and other studies (Obiri *et al*., 2010) have shown that the quality of groundwater is similarly, questionable. The results identifying many water quality hazards also revealed that the surface and groundwater extracted from the vicinity of the mine cannot be considered safe for particularly drinking and other domestic purposes. Policy makers need to be aware for appropriate regulations that would make it mandatory to analyze drinking water for physical and chemical parameters in mining communities on a regular basis. Where water sources have been tested, communities should be notified of contaminant levels so as to inform apt household or communal treatment solutions and daily decision-making regarding access to safe drinking water.

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