Heavy Metal Concentration of Surface Water and Groundwater within an Abandoned Artisanal Tin Mining Site in Barkin-Ladi LGA, Plateau State, Nigeria

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Abstract
The outrageous level of environmental degradation caused by the cruel mining activities accompanied by the unguided and incessant activities of artisanal miners instigates this researchwork. This study was conducted with the aim of assessing the extents of heavy metals contamination on surface water and groundwater resulting from abandoned tin mining paddocks in Barkin-Ladi Local Government Area of Plateau State. Three surface water (upstream, downstream and mine pond) and three groundwater from mined well constitutes the obtained water samples. The samples were tested and analyzed for heavy metals concentration such as Pb, Cr, As, Zn, Cd, Cu, and Fe. The result obtained of the surface water and groundwater samples were compared with the Federal Ministry of Environment water quality suitability standard for domestic use to ascertain implication of the findings. Findings from the study revealed that the heavy metal concentrations of all the water samples are within the limit set by the regulatory body for Pb, Cd, Zn, Cu, Cr, Ar and Fe. The study recommends among others that; the use of artisanal miners, especially children must be seriously discouraged to avoid long-term effects in the future.

***Keywords**: Heavy Metals, Water Pollution, Artisans, Water Quality and Environmental Degradation.*

1.0. INTRODUCTION

Artisanal mining (also called *small scale mining*) has been on the rise as an imperative means of basic livelihood activity for some poor populations in Nigeria, residing in areas with natural resources. The sector now functions as an important social safety net and in some cases, the sector provides the only source of income in employment constrained economies, helping many poor families survive during increasingly uncertain times. While these artisanal or small scale mining activities provide jobs, they are also linked to the release of heavy metals into the mainstream environment causing environmental pollution (Bansah *et al.*, 2018).

According to United Nations Educational, Scientific and Cultural Organisation (UNESCO) (1998), although water resources are abundant on Earth, but about 97.5% of the water on the Earth is salt-water, with only 2.5% fresh-water. Furthermore, about two-thirds of the earth's fresh-water is frozen in glaciers and polar icecaps (United States Geological Survey (USGS), 2016). The remaining unfrozen fresh-water is mainly found as groundwater with only a small percentage existing as water on the earth's surfaces such as rivers, lakes, etc., and as water in the atmosphere (United Nations World Water Development Report (UN-WWDR), 2006; USGS, 2016). Consequently, the demand for fresh-water generally exceeds supply in many parts of the world (USGS, 2016). Increasing population sizes with the accompanying expansion in the uses of water further increase the pressure on existing fresh-water sources (World Health Organisation (WHO), 2019). The situation is aggravated by the reduction of the quantity and quality of available water resources by human activities and natural forces WHO estimated that by 2025, about half of the world's population will live in water-stressed areas (WHO, 2019). These disturbing realities have driven efforts to increase public awareness on the need to better manage and protect water resources over the years.

Generally, mining is one of the human activities which affect the quality of water sources adversely, especially surface water, including water in rivers, lakes, and wetlands (WHO, 2019). Undeniably, mining has contributed significantly to various economies because of the high earnings from its products (Walser, 2000; Ntori, 2017). The Republic of Nigeria is one of the countries whose economy benefits from the export of mineral resources. Despite the economic contribution from mining activities, its adverse effects on the ecosystem cannot be overlooked.Artisanal mining is a practice that involves basic techniques of mineral extraction characterized by highly dangerous manual processes, hazardous working conditions, and negative human and environmental health impacts (Hilson, 2002). Artisanal mining has often led to discharge and run-off of mining waste into rivers, ponds, streams, wells, and boreholes and has resulted in severe heavy metal contamination (Bortey-Sam *et al.*, 2015). Nigeria has suffered severe environmental degradation from mining activities especially those from artisanal mining. Many rivers have been contaminated by artisanal mining activities with adverse effects on rural communities established along these rivers. Inhabitants of such communities depend on the water bodies for their livelihoods. To this fact, this research was aimed at assessing the heavy metal concentration of surface water and groundwater within an abandoned artisanal tin mining site in Barkin-Ladi LGA, Plateau State, Nigeria.

2.0. STUDY AREA

Barkin-Ladi Local Government Area lies Northwest of Plateau State on a geographic point of 9°32′00″N 8°54′00″E. Barkin-Ladi LGA has an area of 1,032km² and a population of 175,267 as at the 2006 census (Basil, 2014). The abandoned mine paddock is situated in the District of Barakin Gangare, and referenced geographically on a point location of Latitude 9° 32.878'N; and Longitude 8° 53.614'E, covering about 1.5km^2.

The climate of the study area is typical of Jos-Plateau. "It is characterized by two distinct seasons; the dry and wet seasons. The dry and the wet seasons are usually very critical in determining the different types of features observed in the area. The dry season is characterized by lack of rainfall, low relative humidity, dry and dusty winds. This often results in poor visibility hence putting life to risk" (Yenne, 2004). "The dry season spans between November and March. Although, in the past few years, this trend seems to have changed possibly as result of global warming" (Awuchi *et al.,* 2020).

The wet season stretches between April and October, and gets to its peak towards the end of August. It is marked by heavy rainfall and high relative humidity. The heavy downpour may also reduce visibility but it is not as bad as that experienced during the dry season. The mean annual temperature ranges between 22^0C to 27^0C with the highest peak in April and the lowest in January. This temperature is very typical of high altitudes observed on the Plateau.

Barkin-Ladi LGA lies within the basement complex rock formation. Its typical characteristics are the Younger Granites and intrusion of volcanic rocks covering most parts of the area. “The general geology of the area is predominantly underlain by banded gneiss” (Goki *et al.*, 2010). The area falls within the immediate transition zone of the Jos Plateau uplifted area and the low land area in the eastern part of Plateau State. “The area is generally rugged and dominated by relief with elevations ranging from 500-700m above mean sea level. River Wase being the major drainage in the area is a father to a whole lot of streams and empties into the River Benue” (Peter *et al.*, 2014).

The soil of the study area is conditioned by the geological parent rock. Generally, the soils are acidic (PH values mostly < 5.5) and lateritic (Ogunmola *et al.*, 2014). The study area lies within the North of Guinea Savannah vegetation zone, which is an open woodland with tall grasses, extensively altered in recent time by human activities (Ogunmola *et al.*, 2014).

The area is predominantly habited by the Berom ethnic group and other speaking tribe such as Ryom, Hausa, as well as few Igbos and Yorubas whose major occupation are trading, farming and small scale mining (Blench *et al.*, 2003).

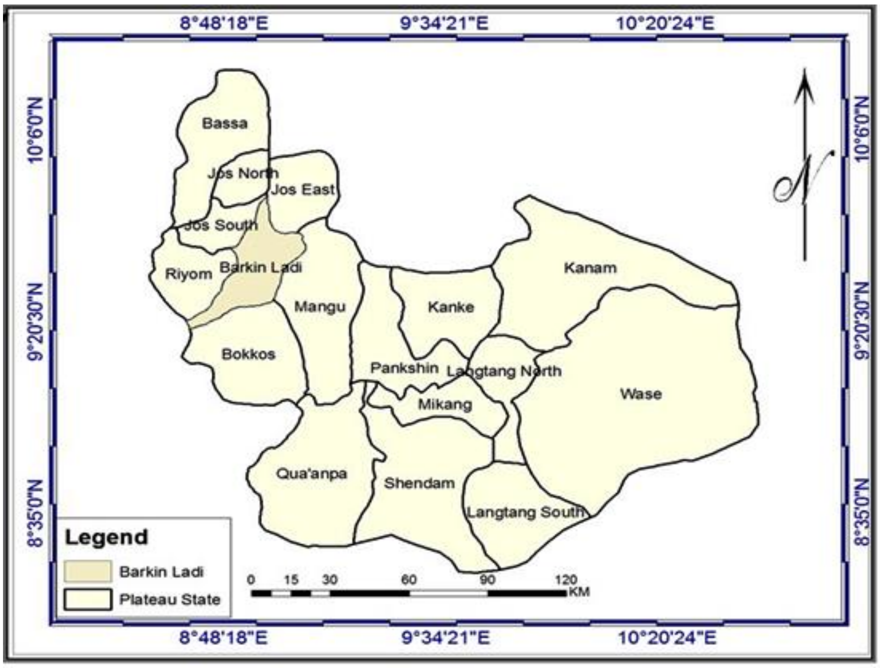

Figure 1: Map of Plateau State showing Barkin Ladi the study area

3.0. METHODOLOGY

3.1. Research Design

The research design of this study was exploratory and on-the-spot measurements. The procedure involved field data measurements with the use of portable instruments, laboratory equipments and the use of statistical techniques to analyze the data from which conclusions were drawn.

3.2. Sources of Data

The data used in this study were obtained through primary source and secondary sources.

3.2.1. Primary Source of Data Collection

The primary sources of data for this study were obtained using various approaches such as observation, portable instruments and laboratory equipments.

3.2.2. Secondary Source of Data Collection

The secondary sources of data that were adopted in this study include textbooks, magazines, maps, population figures, journals, articles, conference papers, as well as published/unpublished thesis which form the basis of the literatures.

3.3. Methods and Procedures

3.3.1. Collection of Samples

Three surface water (upstream, downstream and mine pond) and three groundwater from mined well constitutes the obtained water samples. The samples were collected in a nitric acid washed plastic bottles, properly marked and labelled after the source of water. After collection, nitric acid (0.2%) was added as a preservative, and the samples were preserved in ice-block containing plastic coolers and transported to the laboratory for analysis. The collection of the water samples from the study location was done during the dry season of 2021.

Table 1: Points of soil samples collection

Parameter	Latitude	Longitude
Surface water	9.547770°	8.893205°
	9.548870°	8.892314°
	9.547554°	8.894165°
Groundwater	9.548565°	8.893360°
	9.548218°	8.894185°
	9.547554°	8.894165°

Source: *Researchers' Fieldwork, 2021.*

3.3.2. Water Samples Analyses

All analysis were done using Aanalyst100 (Perkin-Elmer) spectrophotometer located at the Analytical Laboratory of the National Metallurgical Development Agency, Jos Nigeria.

While in the laboratory, each of the collected samples was filtered using membrane papers to remove all solids. The pH of the filtrate was then set to 2+0.2 with 1M nitric acid and stored at 4^{0}C until time of analysis. In making sure that the water samples were not contaminated, all the glassware and plastic containers used for the analyses were treated with nitric acid and rinsed with distilled water. Quality assurance and control was performed according to the method of Soylak *et al.* (2002).

3.3.2.1. Concentrations of Heavy Metals Analyses

Heavy metals' analyses were carried out using atomic absorption spectroscopy (AAS) with electrothermic atomization in graphite furnace for the determination of the total content of Pb, Cr, As, Zn, Cd, Cu, and Fe. The instrument used was Aanalyst100 (Perkin-Elmer) spectrophotometer located at the Analytical Laboratory of the National Metallurgical Development Agency, Jos Nigeria. The machine was equipped with an HGA-800 furnace and an AS-72 auto sampler. All lamps used were hollow cathode multi-element lamps, except for As, Cd and Pb.

The result obtained of the surface water and underground water samples were compared with the Federal Ministry of Environment water quality suitability standard for domestic use to ascertain implication of the findings.

Figure 2: Map of Sampling Point
Source: *Researchers' Fieldwork, 2021.*

4. RESULT PRESENTATION AND DISCUSSION

The laboratory result of the sampled surface water and groundwater were compared with the standard for water quality as propounded by the Federal Ministry of Environment (FMEnv). This was done to establish the extents of heavy metal contamination on water resources at the artisanal mining area of Barki-Ladi, Jos.

4.1. Analyzed Surface Water and Groundwater Results

The laboratory analysis of surface water and groundwater samples was concentrated on heavy metals such as lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), and iron (Fe) respectively. The surface water samples were collected from three points (upstream, downstream, and mine pond), likewise, the groundwater samples (abandoned burrow) as presented in Table 2 and3.

4.1.1: Result of Heavy Metal parameters of Surface Water

Traces of heavy metals concentration such as Pb, Cr, Ar, Zn, and Fe were detected in the surface water samples (up-stream, down-stream and mined pond), with the exception of Cd and Cu as presented in Table 2.

Table 2: Result of SurfaceWater Samples

Parameters (units in mg/L)	**Surface Water**						**FMEnv**
	US	**Remark**	**DS**	**Remark**	**MP**	**Remark**	**SL**
Lead	0.16	Permissible	0.09	Permissible	0.23	Permissible	<1
Chromium	0.28	Permissible	0.01	Permissible	0.29	Permissible	<1
Arsenic	0.15	Permissible	0.13	Permissible	0.24	Permissible	<1
Zinc	0.02	Permissible	0.01	Permissible	0.06	Permissible	<1
Cadmium	ND	Permissible	ND	Permissible	ND	Permissible	<1
Copper	ND	Permissible	ND	Permissible	ND	Permissible	<1
Iron	0.37	Permissible	0.19	Permissible	0.22	Permissible	1.5

Source: *Researchers' Fieldwork, 2021.*
Note: US= upstream, DS= downstream, MP= mine pond.

The analysis result of the heavy metals reveal that surface water samples both up-stream and down-stream collected from the receiving drainage system where wastewater from the abandoned mine site empties are within the permissible limit as prescribed by the FMEnv of Nigeria. However, the concentration of the trace heavy metals decreases along the flow direction, with the farther away from sources of pollution, the concentrations of heavy metals decreased considerably from the up-stream to the down-stream. Similar outcome of the decrease of heavy metals from source points along flow direction of surface water was reported by Ning, Liyuan, Jirui and Xugui (2011) in gold mining field of Linglong province in China (Ning, Liyuan, Jirui and Xugui, 2011). Furthermore, trace metals detected in the abandoned mine pond are also within permissible limit set by the FMEnv of Nigeria. However, the concentration of trace metals in the pond is greater than the concentration of the receiving river.

The concentration of Pb in the surface water is 0.16mg/L, 0.09mg/L, and 0.23mg/L in the up-stream, downstream and mined pond respectively. Despite the trace level of lead is within the FMEnv set permissible limit, its presence pose serious health concern because lead is a persistent, toxic metal that can be harmful to human health even at low exposure levels and it can bio-accumulate in the body over time, if consume directly by humans through drinking water, foods such as sea animals or irrigated plants. Traces of Cr (0.28mg/L, 0.00mg/L, and 0.29mg/L) detected in the sampled surface water (up-stream, down-stream and abandoned mine pond) is fits to the required limit of the FMEnv of Nigeria. While Cr can play significant role in food and dietary supplements essential for normal glucose, protein, and fat metabolism in human body system, in excess, Cr produces harmful effects such as lung tumors (Jinwal *et al.*, 2009).

As, and Cd are known to be persistent environment contaminant metals and toxic to most form of life (Jinwal *et al.*, 2009), their concentration in the surface water samples is within the FMEnv permissible limit for Ar (0.15mg/L, 0.13mg/L, 0.24mg/L), while no traces were detected for Cd. Intake of Ar in high level is detrimental for vulnerable group such as children and pregnant women where low birth weight and fetal loss may occur and there is concern that the infants' growth may be affected (Tofail *et al.*, 2009). The concentration of Zn (0.02mg/L, 0.01mg/L, and 0.06mg/L), Fe (0.37mg/L, 0.22mg/L, and 1.5mg/L), are within the FMEnv permissible for water quality in all the surface water samples. The concentration of Cu metal was not detected. However, this condition may not be healthy for aquatic life, because Cu possesses content of haemoglobin, so it is very necessary for all living organism but in excess promote iron bacteria in water.

Figure 3: Surface water Flow

Figure 4: Mined Pond

4.2.2: Result of Heavy Metal Parameters of Groundwater

Three groundwater samples were collected from abandoned burrowed pit where mining operation has taken place. Result of the analysis is presented in Table 3.

Table 3: Result of Groundwater Samples

Parameters	Groundwater						FMEnv
	BP_1		BP_2		BP_3		SL
Lead	0.08	Permissible	0.22	Permissible	0.16	Permissible	<1
Chromium	0.58	Permissible	0.78	Permissible	0.10	Permissible	<1
Arsenic	1.28	Not Permissible	1.23	Not Permissible	1.17	Not Permissible	<1
Zinc	1.10	Not Permissible	1.10	Not Permissible	1.01	Not Permissible	<1
Cadmium	ND	Permissible	ND	Permissible	ND	Permissible	<1
Copper	ND	Permissible	ND	Permissible	ND	Permissible	0.1
Iron	1.64	Not Permissible	1.67	Not Permissible	1.71	Not Permissible	1.5

Source: *Researchers' Fieldwork, 2021.*
Note: BP= burrow pit, SL= standard limit.

Long-term storage of tailings and improper management of waste water and sediments from abandoned mine site containing dissolved heavy metals can leaked into surrounding aquifers and contaminate local groundwater (Nuss, and Eckelman, 2014). The result of groundwater samples collected from burrowed mine pit shows varying concentration of heavy metals, with the exception of cadmium and copper, which were not detected in all the sampled groundwater (Table 3). While Cu in small quantity is essential for living organisms, including humans, Cd is potentially carcinogenic in humans. The accumulation of Cd in the kidney being its target organ of toxicity has a significant health effect (World Health Organization (WHO), 2010).

Cr contaminants as detected in the three-groundwater samples (0.58mg/L, 0.75mg/L, and 0.10mg/L) are within the permissible limit of the FMEnv (Nigeria). While Ar contaminant (1.28mg/L, 1.23mg/L, and 1.17mg/L) exceeds the permissible limit set by the FMEnv (<1) in all three-source points. The traces of Ar and Cr in the groundwater samples of the three source points indicate the occurrences of metal ions. This condition is a threat to health (United Nations International Children's Emergency Fund, 2008). It is considered by some researchers to have more serious health repercussions than any other environmental contaminant (Smith and Steinmaus, 2007).

Fe is a secondary priority chemical, naturally found in groundwater due to large deposits in the earth's surface; however, anthropogenic activities is capable of release large amount of Fe into surround groundwater, thus, the FMEnv (Nigeria) sets a limit of 1.5mg/L as standard. The concentration of Fe is distinctly above the standard limit of the FMEnv in the three-sampled groundwater (1.64mg/L, 1.67mg/L, and 1.71mg/L). Similarly, Zn concentration was also above the permissible limit of the FMEnv, given its concentration as 1.10mg/L, 1.10mg/L, and 1.01mg/L in the three-groundwater samples. Under normal condition, drinking water seldom contains the concentration of Zn above 0.1mg/L; however, Zn imparts an undesirable astringent taste to water at concentrations exceeding this limit (Oyem *et al.*, 2015).The use of groundwater for drinking is in many cases is also limited by the presence of dissolved iron. These give the water an unpleasant metallic taste, and stain food, sanitary wares and laundry (UNICEF, 2008). Therefore the results obtained for the Fe and Zn content of the groundwater in this study suggests poor water quality with reference to the metals under study; especially as values recorded are all far above the FMEnv permissible limit (Nigerian Industrial Standard (NIS), 2007)

The concentration of Pb in the three sampling points (0.08mg/L, 0.22mg/L, and 0.16mg/L) are within the permissible limit of the FMEnv (<1). Thus, cases of lead exposure because of contact with the water either through drinking or bathing will not be minimal.

In general, abandoned mines with concentration of trace metals that produce AMD have the potential to discharge heavy metals from a variety of sources to both surface drainage system as well as groundwater in areas of shallow aquifers through seepage. Heavy metals are transported in leachate from tailings, waste rocks, and contaminated soils or may be discharge from mine workings such as portals, shafts, and adits which is the major system adopted by artisans (Daniel *et al.*,2014). Heavy metals in tailings are mobilized, migrate to the surroundings, and cause severe and widespread contamination of surface, and groundwater (Labbe, 2008).

5. SUMMARY OF RESEARCH FINDINGS

The rate of artisanal mining activities going on in Barkin-Ladi area of Plateau State, Nigeria has created an imbalance in the natural ecosystem of the area. Recently, artisanal tin mining activities have gained more drive because of the present economic hardship in the country. To this fact, this research was carried out to assess the heavy metal concentration of surface water and groundwater within an abandoned artisanal tin mining site in Barkin-Ladi LGA, Plateau State, Nigeria.

Three surface water (upstream, downstream and mine pond) and three groundwater from mined well constitutes the obtained water samples and were tested for heavy metal concentration such as Pb, Cr, As, Zn, Cd, Cu, and Fe.

The obtained results were compared with the Federal Ministry of Environment water quality suitability standard for domestic use to ascertain implication of the findings. Although the result of this study shows that traces of heavy metals concentration such as Pb, Cr, Ar, Zn, As and Fe were detected in the surface water samples, with the exception of Cd and Cu, but the tested water samples are within the tolerable limit set by the regulatory bodies.

The concentration of Pb in the surface water are 0.16mg/L, 0.09mg/L, and 0.23mg/L; Cr recorded 0.28mg/L, 0.01mg/L, and 0.29mg/L in the sampled surface water; Ar recorded 0.15mg/L, 0.13mg/L, 0.24mg/L; Zn recorded 0.02mg/L, 0.01mg/L, and 0.06mg/L; Fe recorded 0.37mg/L, 0.22mg/L; and 1.5mg/L; while As recorded 0.15mg/L, 0.13mg/L and 0.24mg/L as its values, in the up-stream, downstream and mined pond respectively.

The heavy metal concentration in the groundwater are as follows: Pb are 0.08mg/L, 0.22mg/L, and 0.16mg/L; Cr are 0.58mg/L, 0.75mg/L, and 0.10mg/L; While Ar contaminants are

1.28mg/L, 1.23mg/L, and 1.17mg/L; Zn was recorded as 1.10mg/L, 1.10mg/L, and 1.01mg/L; Fe recorded 1.64mg/L, 1.67mg/L, and 1.71 mg/L while As recorded 1.28mg/L, 1.23mg/L and 1.17mg/L as its values.

6. CONCLUSIONS

The study assesses heavy metal concentration of surface water and groundwater within an abandoned artisanal tin mining site in Barkin-Ladi LGA, Plateau State, Nigeria using Aanalyst100 (Perkin-Elmer) spectrophotometer.

Based on the findings of the study, the results obtained showed traces of Pb, Cr, Ar, Zn, As and Fe in the surface water and groundwater samples, with the exception of Cd and Cu, but the values obtained from the tested water samples are within the allowable limits set by the regulatory body (FMEnv).

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