Impact of Zinc-Lead Mining on Groundwater and Surface Water at Agalagu Alike in Ikwo LGA of Ebonyi State

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Abstract
Physicochemical and heavy metals analyses were carried out on water samples from four different sampling points to evaluate the effect of Lead/Zinc mining on water quality. The location of the sampling points was Agalagu Alike in Ikwo LGA of Ebonyi State. Water samples collected were labeled SW, BH1, BH2 and Control. The samples collected were examined for Temperature, pH, Chemical Oxygen Demand, Total Dissolved Solids, Dissolved Oxygen, Biological Oxygen Demand, Total Suspended Solids, Electrical Conductivity, Microbial Load, and lead/zinc as the heavy metal of major interest. The result was subjected to relevant statistical analysis like Analysis of variance (ANOVA) and t–Test, and significantly different means were separated using F-LSD at 5% level of probability. The analyses indicated that there are some levels of contaminations in the water. From the result of this research, for physicochemical parameters, it was observed that levels of temperature, pH, EC, TDS, TSS, Alkalinity, Cl, Mg, and BOD were all recorded within the acceptable limits in all the samples, with the exception of samples BH1 and BH2 which also had a pH of 5.8 and 6.0 respectively during the dry season of 2019. Turbidity and COD were found to be very high in almost all the samples tested, ranging between 9.3mg/L – 98.2mg/L for Turbidity, and 145.0mg/L – 738.0mg/L for COD. All the samples showed high concentration of Pb with a range of 0.02mg/L – 0.21mg/L across the samples. The concentration of Zn was found to have the range 0.10mg/L to 0.36mg/L, which is within the standard of the regulatory body. The Researcher strongly recommend thorough efforts by the mining companies licensed to operate in that area and the government agencies to provide alternative sources of well treated drinking water, since most of the tested water samples are already contaminated.

Keywords: *Heavy metals, Water quality, Microbial load, Artisanal mining, Water pollution*

1.0. INTRODUCTION

Water is a fundamental element to all forms of life for various functions such as drinking, cleaning, as a reproductive medium and as habitat for aquatic organisms and for irrigation purposes (Ninhoskinson, 2011). The Earth's surface comprises of 70% water, making it one of the most valuable natural resources on earth (Krantz, 2011). Water makes up 50 to 90% of the body weight of most living organisms. It is also essential as a transport mechanism and for metabolic processes of most living organism, (Aremu *et al*., 2011).

Water pollution is a substantial issue of the world which requires periodic assessment and amendment of water asset strategies at all levels. Water pollution is overall leading reason for deaths and diseases. According to WHO (2016), such diseases account for an estimated 4.1% of the total disability-adjusted life year (DALY) global burden of disease, and cause about 1.8

million human deaths annually with unsafe water supply, sanitation and hygiene being the major causes. Water contamination is an intense issue in both developed and developing countries who keep on struggling on this issue.

Water is typically referred to as polluted when it is impaired by anthropogenic contaminants and either does not support a human use, such as drinking water, or undergoes a marked shift in its ability to support its constituent biotic communities, such as fish. Natural phenomena such as volcanoes, algae blooms, storms, and earthquakes also cause major changes in water quality and the ecological status of water. The specific contaminants leading to pollution in water include a wide spectrum of chemicals, pathogens, and physical changes such as elevated temperature and discoloration. While many of the chemicals and substances that are regulated may be naturally occurring (calcium, sodium, iron, manganese, etc.) the concentration is often the key in determining what is a natural component of water and what is a contaminant. High concentrations of naturally occurring substances can have negative impacts on aquatic flora and fauna.

The first step towards controlling water pollution is to know its causes and effects. Once the causes are known proper mitigation steps can be taken to control these factors. It is also essential to study the impacts of pollution on water quality. We need to know how water quality is affected due to all these factors and how will the water quality affect life and operations. For that the different essential physical and chemical parameters need to be studied.

Mining is one of the major causes of water pollution. Mining activities are also responsible for many other shares of environment degradation. Main sources of water pollution from mines are mine water drainage, flow or leakage of mineral exposed water to the water sources nearby, acid mine drainage and water from spoil heaps. These sources also result in pollution via heavy metal contamination and leaching, erosion and sedimentation. Even tailings from the mineral processing plants affect the surface and ground water quality.

Agalagu Alike lead-zinc mining activities is characterized by the indiscriminate dumping of mine tailings, which appear sometimes as elongate ridge trailing parallel to mined out veins. These tailings contain ore and gangue, which like the mineral veins, on weathering release the composing metals to the environment. Metals such as lead (Pb), zinc (Zn), copper (Cu), nickel (Ni) and arsenic (As) which are also associated with lead-zinc (Pb-Zn) mineralization can be released into the terrestrial environment by intensive weathering and podzolisation, polluting soils, surface and underground waters and sediments (Ezeh and Anike 2009).

There are numerous reports on the effects of lead-zinc mining activities on health and environment (Aremu *et al*., 2011). Currently, the activities of artisan mining in the Agalagu Alike lead-zinc mines are on the increase. Despite the effects of such activities on the environment of host communities, there is little or none data on these effects on the soil and water qualities of the host community. Therefore, this work was aimed at evaluating the impact of Lead/Zinc mining activities on water quality in Agalagu Alike, Ikwo LGA

2.0. STUDY AREA

The area of study is Agalagu Alike village in Ikwo Local Government Area in Ebonyi State. Ikwo is the largest Local Government Area in the State. It is situated on the eastern part of Ebonyi State. The study area is referenced geographically on a point location of Latitude 06^{O}10̓29.6̎N and Longitude 08^{O}08̓08.0"E.

Agalagu Alike is in the warm humid equatorial climatic belt. The study area has a tropical climate. This climate is considered to be Aw according to the Köppen-Geiger climate classification. The average temperature in Agalagu Alike is 27.3 °C. The mean temperature in the hottest period of February to April is about 30ºC. Average length of rainy season is between 250 to 270 days in a year. The mean annual rainfall varies between 1750mm and 2250mm. The least amount of rainfall occurs in December (Climate-data, n.d.).

The study area has a land mass of approximately 500km and shares a border with Abakaliki and Ezza Local Government Areas. Regionally, the mapped area is within the Southern end of the Benue trough. The oldest sedimentary rocks in Nigeria are in this trough and they are of lower Cretaceous age. The cretaceous stratigraphic record of the Southern Benue trough is represented by sediments deposited by three main marine depositional cycles: Albian-Cenomanian; Turonian-Santonian and campano-Maastrichtian (Adelakan, 2007). Ikwo LGA, the local government of the study location falls within the Asu-River Geologic Group (Lower Cretaceous), Eze-Aku shale formation and Nkporo Formations. The State is made up mainly of hydromorphic soils which consist of reddish brown gravely and pale coloured clayey soil, shallow in depth, and of shale parent material. The topography is largely a table land; highest point 162m and lowest 15m above sea level. The area is underlain by Cretaceous Sediments of the Asu River Group, a Tertiary to Recent volcanic intrusion (Basement). The topography of the buffer area can be described as comprising irregular ridges and hills with highlands ranging from 80m to 115m and lowlands with average elevation of 30m. These topographical features are controlled by the bedrock geology. Surface drainage in the area is irregular and consists principally of a number of small ephemeral streams. The streams generally follow a west to east course into the Ebonyi River (Ogbodo, 2013).

The study area lies within the cross River Drainage Basin. Major rivers in Ebonyi state are the Eastern and Western Ebonyi Rivers which are tributaries of Cross River. All other rivers and streams are tributaries of these two Ebonyi Rivers. At the project location lies the Ozeroko stream and an artificial British Trench, acting as an artificial means for carrying run-off water in monsoon. Both the Trench and Ozeroko stream empties into Ebonyi River. Existence of groundwater in parts of the state varies and is seriously influenced by the local geology. While the greater part, which includes the Abakaliki Metropolis, Onueke, some parts of Afikpo north and their environs record reduced groundwater yield to hand dug well and boreholes due to the underlying aquiclude (Adelakan, 2007).

Agalagu Alike is located within the partially modified lowland tropical rain forest and wooded grassland derived savannah with a large portion of a large portion of cultivated land. The major characteristic of the vegetation of the project area is the abundant combination of varied plant groups whose branches intertwine to form a continuous canopy of leaves within the Area. The predominant vegetation visible along this area is the grasslands, with scattered forests and woodland areas, as well as tropical rainforest which comprise of tall trees with thick undergrowth and less branches. The area and its surroundings are in the secondary succession Rainforest with a mix of few forest trees. The area is a community of regenerating secondary plants, which has been left to fallow with some pockets of functional and abandoned farmlands, and extensive land being badly eroded. The oil palm (*Elaeis guineesis*) is the dominant tree species. Other species are *Daniella oliveri*, *Milicia excelsa. Lophira lanceolata*, *Vitellaria paradoxa*, *Terminalia spp Naucles spp. Parkia biglobosa*, *Cola gigantea*, *Tectona grandis Azadirachta indica*, *Spondias mombin*, *Ricinodendron heudelotii*, *Gmelina Arborea*, *Treculia Africana* and *Ceiba pentandra.* The dominant grasses along the route are *Andropogon gayanus*, *Androprpgon tectorum*, *Loudetia arundinacea*, *Hyparrehnia rufa*, *Panicum Maximum*, *Chromolaena odorata* and *Schizachyrium sanguineum*.

Ikwo LGA had a total population 154,396 people during the 1991 census, but as at 2006 census, Ikwo had an estimated population of 214,969 people, with a projection of 284,400 in 2016 (City Population, 2016).

Farming is the major occupation of the people of Agalagu Alike with the area known for the cultivation of a variety of crops such as rice, yam, cassava and palm-tree in substantially large quantities. The village is also endowed with a number of mineral resources such as limestone, lead, salt, and laterite. Other important economic enterprises undertaken by residents of the location include mining, trade, and palm wine tapping (Manpower, 2019).

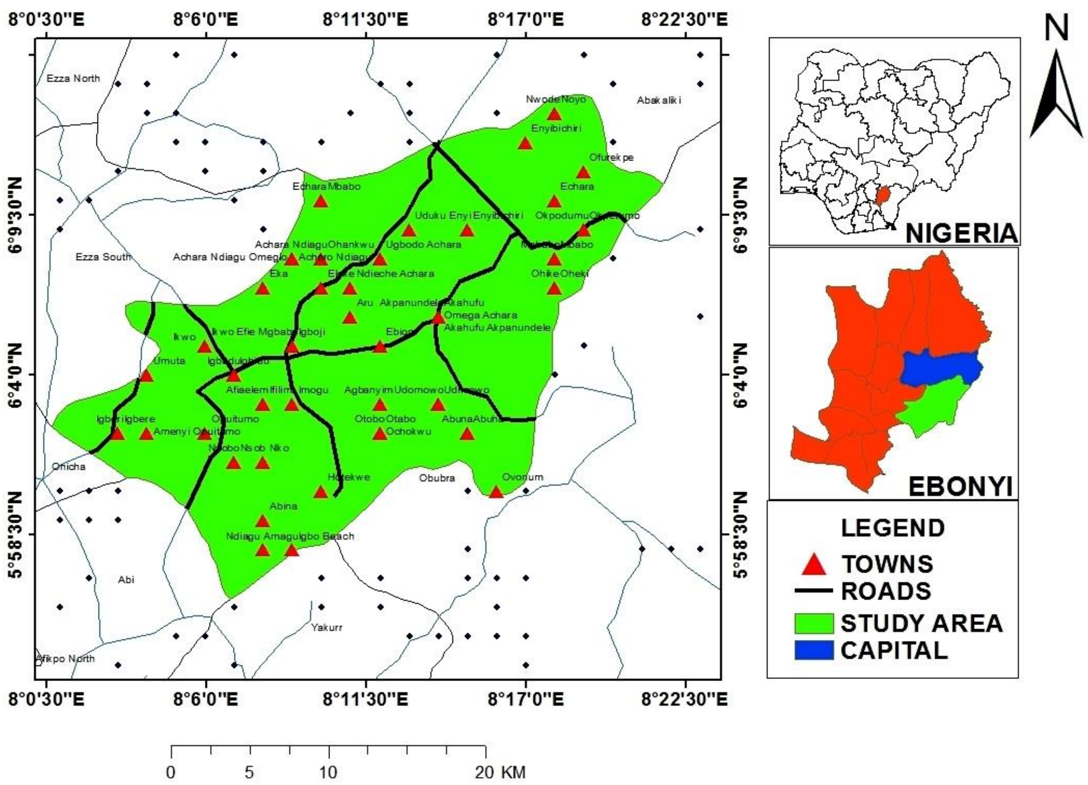

Figure 2: Google Earth view of the study area showing the concession of one of the licensed mining companies in the area.

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, laboratory equipments and the use of statistical techniques.

3.2.2. Secondary Source of Data Collection

The secondary sources of data that were utilized on the course of this study includes textbooks, magazines, maps, population figures, journals, articles, conference papers, as well as published/unpublished thesis, which forms the basis of the literatures.

3.3. Methods and Procedures

3.3.1. Collection of Samples

Three (3) water samples were collected from two (2) daily use boreholes and one (1) surface water for laboratory analysis. The boreholes were designated as BH1 and BH 2, while the surface water was designated as SF. A control was collected from a borehole at Albina, a nearby village that covers a distance of 1.7km away from the facility and designated as

"Control". The collection of the water samples from the study location was done during the dry season of 2019 and rainy season of 2020. The water samples collected were analyzed for physicochemical parameters, heavy metal concentration and microbial analysis.
The sampling bottles were soaked overnight with hydrogen peroxide and then rinsed with distilled water. The cap of the sampling bottle was removed while the bottle was submerged into the water for surface water body, while the tap of the boreholes were cleaned with a cotton wool soaked in 70% alcohol, flamed with spirit lamp and the water allowed to run for 60 seconds before collecting in a 750ml sterile bottle which was carefully covered with its screw cap. All samples collected from all sources were taken to Yematech Consulting and Analytical Services, Aba – Abia State; affiliated to Federal Ministry of Environment (FMEnv) for analysis within eight hours after collection. The sample bottles were labeled with sample codes BH1, BH2, SF and Control respectively.
For microbial count, eight water samples (including the control) were collected for Microbial analysis (2 from each point). Each of the sample bottles was labeled with sample code number and they were thoroughly mixed, before testing.

3.3.2. Sample Preparation and Analysis

In order to achieve the proposed objectives of this study, both field and laboratory works were performed. The field works includes the collection of samples, and in-situ testing of pH and temperature, while the studies and analysis that were carried out in the laboratory involved the evaluation of the physicochemical and bacteriological parameters, and heavy metals concentration of the water samples collected.
The samples were analyzed for Temperature, Alkalinity, Turbidity, Chloride, pH, Electrical Conductivity, Dissolved Oxygen, Total Dissolved Solids, Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solids, Magnesium, Microbial Load, and Heavy Metals concentration. Dissolved Oxygen (DO) was determined using Winkler's Modification Method (Standard Method, 1998) whilst the total suspended solids and total dissolved solids of the samples were determined with Jennway Conductivity meter model 4520. The colour was measured by colour comparator and pH was measured in-situ, using a portable pH meter, Horiba pH Multi-parameter. Metals (such as Lead and Zinc) in the water samples were determined using atomic absorption spectro-photometer (AAS), AAS 220 model. The samples for AAS were digested with nitric acid before analysis. In the laboratory, the acidified samples were filtered using Whatman's filter paper. The 0.45μm membrane filter paper was used because the analyte of interest in this work is the total dissolved metals. The filtered samples and the unfiltered samples were stored in the refrigerator at $4^{o}C$ for further analysis (APHA – AWWA, 1998). Comparisons were made with the standard of National Environmental Standards and Regulations Enforcement Agency (NESREA) an arm of the Federal Ministry of Environment (FMEnv).

3.4. Physicochemical Analyses

The physicochemical properties of the water samples were determined according to standard methods.

3.4.1. Determination of pH:

The pH was carried out in-situ at the site of sample collection using the Hanna microprocessor pH meter. It was standardized with a buffer solution of pH range between 5.5 - 9.

3.4.2. Measurement of Temperature:
This was carried out in-situ at the site of sample collection using a mobile thermometer. This was done by dipping the thermometer into the sample and recording the stable reading.

3.4.3. Determination of Conductivity:
This was done using a Jenway conductivity meter (4510 model). The probe was dipped into the container of the samples until a stable reading was obtained and recorded.

3.4.4. Determination of Total Dissolved Solids (TDS) by Gravimetric Method:
A portion of water was filtered out and 10ml of the filtrate measured into a pre-weighed evaporating dish. Following the procedure for the determination of total solids above, the total dissolved solids content of the water was calculated.

Calculation

Total dissolved solids (mg/l) = (W2-W1) mg x 1000/ ml of filtrate used.

Where W1 = initial weight of evaporating dish, W2 = Final weight of the dish (evaporating dish + residue).

3.4.5. Determination of Total Suspended Solids (TSS)
The total suspended solids were easily obtained by simple calculation, i.e.

Calculation

Total suspended solids = total solid - total dissolved solids.

3.5. Concentrations of Heavy Metals Analyses
Concentration of heavy metals such as lead (Pb), zinc (Zn), iron (Fe), copper (Cu), nickel (Ni), chromium (Cr), cadmium (Cd) and arsenic (As) were measured with Perkin-Elmer atomic absorption spectrophotometer (model 403). The spectrophotometer was checked for malfunctioning by passing standard solutions of all the parameters to be measured; Blank samples (de-ionized water) were passed between every three successful measurements to check for any eventual contamination or abnormal response of the equipment.

3.6. Determination of Microbial Load
All glasswares used for this study were sterilized in a hot box oven at 160^0C for one hour. 9ml of sterile water was transferred into 4 sterile tubes labeled 10^{-1} to 10^{-4}. 1ml of the sample aseptically transferred into the first test tube (10^{-1}) with a sterile pipette and mixed. From the first test tube, 1ml was equally transferred to the test tube labeled 10^{-2} and mixed using fresh pipette. This was repeated until the test tube labeled 10^{-4}. The Pour Plate Technique was used and the culture medium was Nutrient Agar. 1ml of the sample from 10-^{2} test tube was aseptically transferred into sterile Petri dishes using sterile pipette. The Nutrient Agar was prepared according to the manufacturer's instruction and allowed to cool to 45^0C. 20ml of the culture medium was poured into the Petri dish and properly mixed with the sample. This was done in triplicates. A control was equally prepared. The plates were labeled, allowed to solidify, inverted and finally incubated at 37^0C for 24-48 hours. The plates were observed for development of bacterial colonies. Statistical tables were then used to derive the concentration of organisms in the original sample.

4.0. RESULT PRESENTATION

The results obtained were compared with the permissible limits of the National Environmental Standards and Regulations Enforcement Agency (NESREA) which is an arm of the Federal Ministry of Environment (FMEnv) as shown below in Tables 1, 2 and 3 respectively. Table 1 contains results from the Physicochemical analysis, Table 2 shows results of Heavy metals concentration and Table 3 shows results from the Microbial analysis of water samples for both rainy and dry seasons respectively.

Table 1: Results of Physicochemical parameters of Water Samples for two seasons (Rain and Dry).

SAMPLES	SW			BH1			BH2			CONTROL			NESREA (Limit)
SEASONS	Rain	Dry	Mean Value	Rain	Dry	Mean Value	Rain	Dry	Mean Value	Rain	Dry	Mean Value	
PARAMETERS				RESULTS									
Temperature ^{0}C	27.6	30.2	**28.9**	30.8	30.3	**30.6**	29.8	30.8	**30.3**	20.2	30.3	**25.3**	≤32
pH	6.9	6.8	**6.9**	8.3	5.6	**7.0**	7.1	6.0	**6.6**	6.9	6.7	**6.8**	6.5-8.5
EC µs/cm	8.2	30.0	**19.1**	2.8	2.7	**2.8**	9.9	37.2	**23.6**	92.5	6.3	**49.4**	1,000
TDS mg/L	420	500	**460.0**	896	240	**568.0**	540	185	**362.5**	231.0	148	**189.5**	≤1000
Alkalinity mg/L	31.5	57.2	**44.4**	25.0	48.4	**36.7**	46.5	64.0	**55.3**	34.3	54.9	**44.6**	≤200
TSS mg/L	18.5	17.7	**18.1**	0.6	0.2	**0.4**	1.3	2.7	**2.0**	0.2	0.1	**0.2**	30
DO mg/L	10.9	12.3	**11.6**	7.2	6.6	**6.9**	10.6	7.2	**8.9**	10.3	10.1	**10.2**	≤7.5
Turbidity (NTU)	93.6	98.2	**95.9**	31.0	9.7	**20.4**	89.0	9.3	**49.2**	2.90	10.0	**6.5**	≤5.0
Chloride mg/L	0.8	1.0	**0.9**	0.8	6.5	**3.7**	1.2	5.7	**3.5**	0.5	0.8	**0.7**	≤250
Magnesium mg/L	30.0	44.0	**37.0**	65.0	50.2	**57.6**	85.0	67.6	**76.3**	0.7	0.6	**0.7**	≤100
BOD	104.0	56.0	**80.0**	87.0	82.0	**84.5**	367.0	52.1	**209.6**	104.0	34.3	**69.2**	-
COD	293.0	192.3	**242.7**	145.0	150.3	**147.7**	738.0	148.7	**443.4**	293.0	156.1	**224.6**	≤30

Source: *Researcher's Fieldwork, 2020.*

4.1.1. Variation of Temperature, pH and Electrical Conductivity

From Table 1 above, the Temperature at the three (3) sampled locations (SW, BH1 and BH2) ranged from 27.6^{0}C to 30.8^{0}C for the wet season, and 30.2^{0}C to 30.8^{0}C for the dry season.

pH recorded an average mean of range 6.6 to 7.0, with BH1 having the highest mean value of 7.0.

EC values were found to be between 2.7µs/cm to 37.2µs/cm, which is within the standard limit of 1000µs/cm.

4.1.2. Variation of TDS, Alkalinity and TSS (mg/L)

Table 1 above shows the mean concentration of Total dissolved solid to be 460.0, 568.0, and 362.5.

Alkalinity 44.4, 36.7 and 55.3; and for Total suspended solids 18.2, 0.4 and 2.0 for the three (3) samples (SW, BH1 and BH2) respectively during the two seasons (Rain and dry).

4.1.3. Variations of DO, Turbidity and Chloride

Table 1 shows that the least value (6.6mg/L) of DO was recorded in BH1, while the highest value (12.3mg/L) was recorded in SW, both were during the dry season.

Turbidity ranged between 31.0NTU to 93.6NTU during the wet season, and 9.3NTU to 98.2NTU during the dry season.

The least value (0.8mg/L) of Chloride was recorded in SW during the wet season, while the highest value (6.5mg/L) was recorded in BH1 during the dry season.

4.1.4. Variations of Mg, BOD and COD

From Table 1 above, the Mg at the three (3) sampled locations (SW, BH1 and BH2) ranged from 30.0mg/L to 85.0mg/L for the wet season, and 44.0mg/L to 67.6mg/L for the dry season.

BOD recorded an average mean of range 80.0 to 209.6, with BH2 having the highest mean value (209.6).

COD values were found to be between 145.0 to 738.0 across the two seasons (wet and dry).

Table 2: Results of Heavy Metals Concentration of Water Samples for both seasons

Samples	**SW**			**BH1**			**BH2**			**Control**			**NESREA Limit**
Parameters Mg/L	**Rain**	**Dry**	**Mean Value**	**Rain**	**Dry**	**Mean Value**	**Rain**	**Dry**	**Mean Value**	**Rain**	**Dry**	**Mean Value**	
Lead (Pb)	0.21	0.19	**0.20**	nd	0.20	**0.10**	0.02	0.11	**0.07**	0.01	0.15	**0.08**	≤0.01
Zinc (Zn)	0.36	0.18	**0.27**	nd	0.10	**0.05**	0.20	0.60	**0.40**	0.05	0.12	**0.09**	≤3
Iron (Fe)	0.19	0.17	**0.18**	0.27	0.41	**0.34**	0.40	0.32	**0.36**	0.53	0.12	**0.39**	≤0.3
Chromium (Cr)	0.04	0.23	**0.14**	0.05	0.33	**0.19**	0.17	0.22	**0.20**	0.04	nd	**0.02**	≤0.05
Cadmium (Cd)	0.03	0.01	**0.02**	0.06	0.03	**0.05**	0.240	nd	**0.12**	0.02	nd	**0.01**	≤0.003
Copper (Cu)	0.18	0.13	**0.16**	nd	0.10	**0.05**	1.0	0.12	**0.56**	0.09	0.10	**0.10**	≤0.001
Nickel (Ni)	0.08	0.02	**0.05**	0.03	0.08	**0.06**	0.16	0.14	**0.15**	0.08	0.01	**0.05**	≤0.02
Arsenic (As)	0.05	0.02	**0.04**	0.03	0.05	**0.04**	0.14	0.03	**0.09**	0.05	nd	**0.03**	≤0.05

Source: *Researcher's Fieldwork, 2020*
ND = not detected

4.1.5. Variations of Pb and Zn

Table 2 above shows that the values of Lead recorded ranged from 0.02mg/L to 0.21mg/L across the two seasons, with sample BH2 having the lowest value (0.02mg/L), while sample SW recorded the highest value (0.21mg/L), both during the wet season.

For the concentration of Zinc, the lowest value of Zn (0.10mg/L) was recorded in BH1 during the dry season, while the highest value of Zn (0.60mg/L) was recorded in BH2 during the dry season.

Table 3: Microbial Analysis

Parameters	SW		BH1		BH2		Control		NESREA Limit
	Rain	Dry	Rain	Dry	Rain	Dry	Rain	Dry	Nil
E.coli CFU/ml	-	-	-	-	-	-	-	-	Nil
Coliforms CFU/ml	1.0×10^2	-	$0.5x10^5$	-	$1.5x10^3$	-	5.5×10^3	-	Nil
Fecal streptococci	1.0×10^2	-	$0.5x10^6$	-	$1.5x10^6$	-	-	-	Nil

Source: *Researcher's Fieldwork, 2020*

4.1.6. Variations of Microbial Load

Table 3 above shows the microbial counts of the tested water samples. From Table 3, E. Coli was undetected in all the samples, but there were presence of Coliforms and Fecal streptococci. The values of Coliforms (in CFU/ml) were only present during the wet season, and ranged from $0.5x10^5$ to $1.5x10^3$, while Fecal streptococci ranged from $0.5x10^6$ to $1.5x10^6$, and was also only present during the wet season.

5.0. DISCUSSION

5.2.1. Temperature, pH, Electrical Conductivity and Total Dissolved Solids

For water to be acceptable for recreational use, industrial use and other domestic uses, it has to be influenced by physicochemical parameters such as pH, total dissolved solids and conductivity (Oko *et al.*, 2014). From Table 1 it was observed that the temperature of the samples for the two seasons ranged from of 20.2^0C to 30.8^0C, but falls within the acceptable limit of $\leq32^0$C for safe drinking water (NESDRA, n.d.). The values obtained in this research work are similar to the works of Onwughara *et al.* (2013); Obi and Okocha (2007). Cool waters are generally known to be more potable for drinking purposes, since high temperature water may enhance the growth of micro-organisms and as such could influence the taste, odour, colour, and possibly increase corrosion problem (Okogbue and Ukpai, 2013). Thus, the temperature range observed in this work may not impact negatively on the taste and odour of the water (Ayoko *et al.*, 2007), unless it is affected by other non-established factors.

The pH of water is a measure of the acid–base equilibrium and, in most natural waters, is controlled by the carbon dioxide–bicarbonate–carbonate equilibrium system. Although pH usually has no direct impact on water consumers, it is one of the most important operational water quality parameters as it is important in determining the corrosiveness of water. From Table 1 it was observed that samples BH1 and BH2 fell short of the standard of the regulatory body with a pH of 5.8 and 6.0 respectively during the dry season, which is an indication that the two samples were acidic, while other samples (SW and control) were within the permissible limit of 6.5 – 8.5. The results from SW and control were favourable with those reported by some independent such as Oko *et al.* (2014); Agbalagba *et al.* (2011); Adefemi *et al.* (2007). The effects of acids and alkalis on health depend on the strength of the acid or alkali and the concentration. Strong concentrated acids or alkalis are corrosive, whereas dilute and weak acids and alkalis are not corrosive. pH alone is not the primary determinant of adverse effects, and in water, acids and alkalis are normally extremely.

EC is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. The values of EC obtained ranged between 2.76µs/cm – 92.5µs/cm which indicates that the result lies within the tolerable limit of 1000µs/cm. The observed electrical conductivity (EC) values for all samples were low compared to those reported by other researchers like Okereke *et al*. (2014); Agwu *et al*. (2013).

The TDS is used to describe the inorganic salts (majorly chlorides, calcium, sodium, magnesium, sulfates, bicarbonates, and potassium) and small amounts of organic matter present in solution in water. Water containing TDS concentrations ≤1000mg/L is usually acceptable to consumers (WHO, 2011 and NESDRA, n.d.), although acceptability may vary according to circumstances. From the samples collected, the values obtained for TDS varies, but were within the standard of ≤1000mg/L for drinking water; and agree with the work of Adindu *et al.* (2012). The values obtained were however higher than those reported by Agwu *et al.* (2013).

5.2.2. Alkalinity, Total Suspended Solids, Dissolved Oxygen and Turbidity

Alkalinity is a measure of the capacity of water to neutralize acids or hydrogen ions. Alkalinity can sometimes be referred as "Carbonate hardness". From the results of the physicochemical parameters, it was observed that the alkalinity of all the samples for the two seasons are within the safe limit of 20-200mg/L (NESDRA, n.d.), and the values obtained were inline when compared with the work of Christina and Khasim (n.d.).

The TSS refers to solids in water that can be trapped by a standard filter. The result obtained from the experiments shows that the TSS ranged between 0.15mg/L – 18.5mg/L for the rainy season and 0.10mg/L – 2.65mg/L for the dry season, with the SW having the highest value of TSS. The control was found to be significantly lower in TSS compared to other samples. All the tested samples were found to be within the tolerable limit of 30mg/L; but the SW having a fairly high values compared to other samples. This indicates that the surface water (SW) was generally exposed to debris, hence, the higher values of TSS recorded. High value of TSS can affect the living organisms in the water body, which can also influence the level of dissolved oxygen present in the water.

The results from Table 1 shows that the Dissolved Oxygen ranged between 6.6mg/L – 12.3mg/L, with most of the samples having a DO above the tolerable limit (≤7.5mg/L), except for samples BH1 for both seasons and BH2 for dry season which fell within the tolerable limit with values 7.2mg/L, 6.6 mg/L and 7.2mg/L respectively. The SW recorded the highest value of DO. The high rate of DO observed in the SW could vary proportionally with the high values of TSS recorded in the samples.

Turbidity as a measure of the cloudiness (clarity) of water was found to be high in all the samples tested except for the Control in the rainy season which has a turbidity of 2.90NTU. Similar results were reported by Okogbue and Ukpai (2013). The observed high turbidity in most of the samples especially the surface water may be attributed to the mining activities which generally release particles to the water. Although, turbidity may not be a major health concern, but high turbidity can interfere with disinfection and provide a medium for microbial growth.

5.2.3. Chloride, Magnesium, Biochemical Oxygen Demand and Chemical Oxygen Demand

The result obtained for Chlorine for all the samples falls within the permissible limit, with a range of 0.50mg/L – 6.49mg/L. According to WHO, in freshwaters, chloride concentrations are usually lower than 10mg/L and sometimes less than 2mg/L. Although, higher concentrations can occur near sewage and other waste outlets, irrigation drains, salt water intrusions, in arid areas and in wet coastal areas.
For Magnesium which is common in natural waters as Mg^{2+} was found to range between 0.58mg/L – 85.0mg/L, which falls within the permissible range of 1 to 100mg/L of WHO (2006).

Biochemical Oxygen Demand (BOD) which is an approximate measure of the amount of biochemically degradable organic matter present in the water samples was found to range between 34.3mg/L – 367.0mg/L. BOD is often used as a surrogate of the degree of organic pollution of water. The BOD of most of the samples was found to be within the lowest tolerable limit when compared with the US standard of groundwater of value 200mg/L (Biochemical Oxygen Demand, n.d.), except for sample BH2 for the rainy season.
From Table 1 above, the concentrations of COD in all the sampling points were higher than the NESRA value of 30mg/L for freshwaters. The values recorded ranged between 145.0mg/L to 738.0mg/L. Chemical Oxygen Demand (COD) is the oxygen requirement of a sample for oxidation of organic and inorganic matter. According to WHO (2006), the concentrations of COD observed in fresh waters should not be >50mg/L, but all the sampled waters recorded values that exceeded this limit.

5.2.4. Heavy Metal Concentration

Traces of heavy metal concentration such as Pb, Zn, Fe, Cr, Cd, Cu, Ni and As were detected in the water samples (Surface water and groundwater) as presented in Table 2 above. The results obtained shows that Pb was high in varying degrees in most samples, except for Samples BH1 and the Control for the rainy season which were undetected and 0.01mg/L respectively. The high presence of Pb in most of the samples shows some health hazards as accumulative effect has the tendency to lead to lead (Pb) poisoning (Ahmed *et al.*, 2010). The concentrations of Zn were found to be within the tolerable limit of ≤3 except for sample BH1 which was unexplainably undetected for the rainy season. For Fe concentration, samples from SW, BH1 for rainy season and the control for the dry season were found to be within the permissible limit, while other samples were found to be above the tolerable limit. The Cr concentration of the samples for the two seasons were 0.04 and 0.23 for SW, 0.05 and 0.33 for BH1, 0.17mg/L and 0.22mg/L for BH2 and 0.04mg/L and undetected for the control. For Cd concentration, almost all the samples showed Cd levels above the permissible limit except BH2 and the control which were undetected for the dry season. The level of Cu in the samples has a range of 0.09mg/L - 1.0mg/L, which indicates that Cu concentration was above the permissible limit of ≤0.001mg/L, except for the rainy season of BH1 which was undetected. The high concentration of Cu in the surface water could be attributed to the soil weathering being experienced at the study area or as a result of agricultural runoffs as the residents of the study area are well known for engaging in agricultural activities like farming; and for the presence of Cu in the groundwater samples, it could be attributed to the corrosion of pipes/fittings through which the groundwater flows, as there are no reports of the presence of copper ore in the area. The Ni concentrations of most of the samples fail short of the permissible limit of ≤0.02, except for the SW and Control which were measured 0.02mg/L and 0.01mg/L respectively for the dry season.

5.2.4. Microbial Load

Microbial analysis of the water samples were carried out as shown in Table 3 above. The results obtained indicate that none of the water samples analyzed met the guideline limit of WHO. During the period of study, bacteria belonging to the general *Coliforms* and *Streptococcus* were found (Table 3). According to WHO's guideline limit, no form of bacteria must be detected in any sample of clean water intended for domestic use. The presence of general *Coliforms* and *Streptococcus species* from most of the samples show pollution of the water by human activities. These organisms are capable of surviving in the aquatic environment after introduction. The total coliform values recorded are on high side considering the WHO standard limit of 0.00 CFU/ml for drinking water. Since water is essential to life there is need to have unpolluted pure water.

6.0. SUMMARY

The rate of artisanal mining activities going on in Barkin-Ladi area of Plateau State, Nigeria The primary aim of this study was to evaluate the impact of Zinc-Lead mining activities on water quality in Agalagu Alike in Ikwo LGA, in order to ascertain the level of pollution/contamination. This study focused on the impact of Zinc-Lead mining on groundwater (Boreholes) and surface-water for the two seasons (rain and dry).

The parameters examined in this study were Temperature, pH, Chemical Oxygen Demand, Total Dissolved Solids, Dissolved Oxygen, Biological Oxygen Demand, Total Suspended Solids, Electrical Conductivity, Microbial load, and lead and zinc as the heavy metals of major interest.

The study revealed that there were significant differences between the values obtained in the two seasons, as well as variation in results obtained from different sampling points. The study revealed the presence of heavy metals in the samples, with Pb being predominantly above the acceptable limit.

For physicochemical analyses, soil pH, electrical conductivity, phosphorus and total organic matter of the control were higher compared to that of other sampling points, but exchangeable calcium, sodium, magnesium and potassium of most sampling points were lower than the control. For heavy metals concentrations, the control recorded the lowest levels compared to the other sampling points.

The study showed the variations in the concentration of physicochemical parameters, heavy metals and microbial count for the two seasons.

7.0. CONCLUSION

This research investigated the impact of zinc-lead mining on groundwater and surface water quality at Agalagu Alike in Ikwo LGA of Ebonyi State by determining the physicochemical parameters, heavy metal concentration and microbial count of water samples collected from the study area, and comparing the results of the various parameters obtained with those of the regulatory bodies. This study showed that the lead-zinc mining going on in Agalagu Alike in Ikwo L.G.A, Ebonyi State in Nigeria has adverse effects on the environment, as it has introduced heavy metal above the threshold limit to the water, thereby causing severe pollution of the water. As a result of this adverse effect, there is pressing need to come-up with guiding principles to regulate mining activities in this area.

Microbial analysis of the water samples showed that none of the water samples analyzed met the guideline limit of WHO; as the presence of bacteria belonging to the general Coliforms and Streptococcus were found; this makes the waters unsafe for domestic use. Because according WHO's guideline limit, no form of bacteria must be detected in any sample of clean water intended for domestic use.

This study demonstrated that there are seasonal variations across the water samples. The study has as well provided more information to the government, individuals, non-governmental organisations and the public on the extent of water pollution associated with the mining of ore within the study area.

8.0. RECOMMENDATION

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

There is urgent need to make policies that will guide and regulate mining activities especially artisan mining in this area in order to avoid multiple poisoning effects of these metals.

More studies are needed to assess the speciation, mobility and bioavailability of theses metals in the vegetation of the study area, and also the associated health problems of the mining activities to the residents of the community where the mine site is located.

The government (Local, State and Federal) should come up with appropriate guiding principles, and establish policies on the pollution of the environment and its conservation.

The use of artisanal miners should be seriously discouraged to avoid long-term effects in future. The researcher also recommends the need for environmental awareness using enlightenment campaigns on illegal mining and mining activities, control and monitoring techniques in the study location which will be geared towards satisfactory quality environmental conditions.

Also, a regular assessment of the water quality around the mines should be encouraged at all levels, including the government, individuals and organizations to always determine the concentration of the assessed water parameters.

Individual and households in the community should be educated on the need for regular medical checkup owing to the level of water pollution going on in the study area.

More importantly, since most of the water resources in the community have been polluted, there should be thorough efforts by the mining companies licensed to operate in that area and the government agencies to provide alternative sources of well treated drinking water. This exercise should, however, be backed by intensive education so that the people will see the need to utilize them.

The Government of Nigeria, who holds right to all minerals in trust for all Nigerians, in collaboration with the Ministry of Mines and Steel Development should make willful efforts to lessen the level at which lands and rights are granted to mining companies in the country. This is necessary because despite numerous efforts and measures put in place, environmental and health effects of mining activities continue to remain a huge predicament, particularly to those living in the surrounding communities, and to a greater extent, the country at large.

Lastly, there is urgent need for an effective collaboration and co-ordination among governmental agencies such as the FEPA, Ministry of Mines and Steel Development and others so that they can perform their roles effectively in dealing with the environmental and health problems associated with mining activities within the affected communities.

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