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# Determination of the levels of heavy metals and physicochemical properties of borehole water within selected mining sites in Ebonyi state, Nigeria

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**Abstract**
The level of heavy metals (Pb, Cd, As, Cr, Ni, Co, Zn) and physicochemical parameters in borehole water sources within selected mining sites in Ebonyi State, Nigeria were determined using FS240AA Atomic Absorption Spectrophotometer (AAS) according to the method of American Public Health Association (APHA). Water samples were collected from Enyigba mining site, Ikwo mining site, Ameri Amekamining site, Izza mining site, Mkpume Akwatakwa mining site and Mpume Akwaokuku mining sites. Composite water samples were collected within the mining locales and 500 metres away from the mining locations using two liters plastic jars. Similarly, the control samples were taken from Abakaliki (about 15 km away from mining area) where there was no evidence of mining activity. A total of 14 sub-samples were collected for this study. Generally, the levels of heavy metals in the borehole water samples were higher than the values recommended by the World Health Organization (WHO). This however suggests a possible mobility of the metals from mining sites into the groundwater sources through leaching. The findings from this study have revealed the need to purify borehole water within mining areas prior to industrial and domestic use.

**Keywords:** heavy metals, physicochemical, borehole, mining site, Ebonyi

## Introduction

Water is an inorganic, transparent, tasteless, odorless, and nearly colorless chemical substance, which is vital for sustaining global socio-economic development and all known forms of life [1]. It has been established that water covers approximately 70.9% of the Earth's surface, mostly in seas and oceans. Water can be categorized into two main sources *viz* groundwater sources and surface water sources. Groundwaters are beneath the land surface and include boreholes, springs and wells; while surface waters are above the land surface and include streams, creeks, wetlands and reservoirs [2]. Small portions of water occur as groundwater (1.7%), in the glaciers and the ice caps of Antarctica and Greenland (1.7%), and in the air as vapor, clouds (consisting of ice and liquid water suspended in air), and precipitation (0.001%) [3]. Heavy metals often contaminate rivers thereby making them unfit for domestic, agricultural and industrial purposes [4, 5]. Due to the unique characteristics of heavy metals (high toxicity at low concentrations, poor biodegradability and bioaccumulation), they pose a serious health threat to humans when ingested [5, 6]. In Nigeria, borehole water sources are considered the main source of potable drinking water due to the collapse of public pipe-borne water scheme [7, 8, 9]. The borehole water resources are usually accessed through the drilling of boreholes and with the help of pumping machines are subsequently pumped out through pipes and then stored in tanks for domestic and industrial use [10]. According to Ibe *et al.* [10], majority of the boreholes within urban and sub-urban areas are constructed close to waste dumpsites, latrines, vicinity of metal scrap yards, mining sites etc., hence rendering the groundwater sources vulnerable to contamination. There are extensive reports that groundwater resources in developing countries like Nigeria are appreciably polluted due to anthropogenic activities such as mining [11, 12]. A study conducted by Duru *et al.* [13] attributed the poor water quality in groundwater samples collected in Orji to high cadmium concentration caused by anthropogenic activities. This study is very important owing to the fact that residents within the mining sites depend solely on borehole water resources for their household water requirements; hence the need to regularly monitor borehole water resources within the mining sites to ascertain the quality of the water. Also, this study is vital owing to the paucity of data on the level of heavy metals in borehole water resources within the study area. The present study, therefore, is aimed at ascertaining the level of heavy metals in borehole as well as the physicochemical properties of the water. The report of this study would, therefore, create the necessary awareness and consciousness amongst the inhabitants, town planners, and other relevant government agencies that will lead to the planning towards the supply and development of future sustainable water schemes in the area.

## Materials and Methods

### Study area

The study was conducted in six mining sites, namely: Enyigba, Ikwo, Ameri-Ameka, Izza, Mkpume-Akwatakwa, Mpume-Akwaokuku, and the control site (Abakaliki town). The Enyigba mining site is one of the significant communities where mining is vigorously done. It is situated in the south of Abakaliki; 14 km south of Abakaliki town of Ebonyi State [14, 15, 16]. Previous investigations at the examination area zeroed in on the effect of heavy metal tainting on deserted mine pits, underground water sources, waterways, streams and counterfeit lakes [11, 17]. Ikwo is located on the eastern part of the state. The territory is plentiful in mineral assets and progenitors of the present occupants created bronze projecting methods in excess of 500 years prior. Ameri-Ameka is situated in the south of Abakiliki town. It comprises of cretaceous dregs of the Asu stream bunch, predominantly shales, silty shales, limestone and volcanic rocks. They are one of Africa's most notable lead-zinc mineralized region [11, 18]. The Izza south mining site is situated in the south of Abakiliki town. There are various kinds of soil around there, specifically: lateritic mud soil, sandy soil with mudstone and clayey shaly soil. The soil is gotten predominantly from the old sedimentary rocks. The Mkpume-Akwaokuko and Akwatakwa mining sites are situated in the north of Abakiliki town. The vegetation is overwhelmed by grasses, bushes and trees such as palm trees, coconut, mango and orange trees [11, 19, 20].

**Table 1:** Sampling site and their coordinates

| Sampling sites | Coordinates |
| --- | --- |
| Enyigba mining site | N: 06$^{o}$ 11.642’ E: 008$^{0}$ 08.380’ 263.4ft |
| Ikwo mining site | N: 06$^{o}$ 10.590’ E: 008$^{0}$ 07.438’196.8ft |
| Ameriamekamining site | N: 06$^{o}$ 11.042’ E: 008$^{0}$ 06.110’ 149.3ft |
| Izza mining site | N: 06$^{o}$ 09.929’ E: 008$^{0}$ 06.625’ 161.9ft |
| MkpumeAkwatakwa mining site | N: 06$^{o}$ 23.588’E: 008$^{0}$ 09.784’ 192.8ft |
| MpumeAkwaokuku mining site | N: 06$^{o}$ 30.268’E: 008$^{0}$ 16.352’ 226.6ft |
| Control (Abakaliki town) | N:06$^{0}$19.163’E:008$^{0}$06.559’142.8ft |

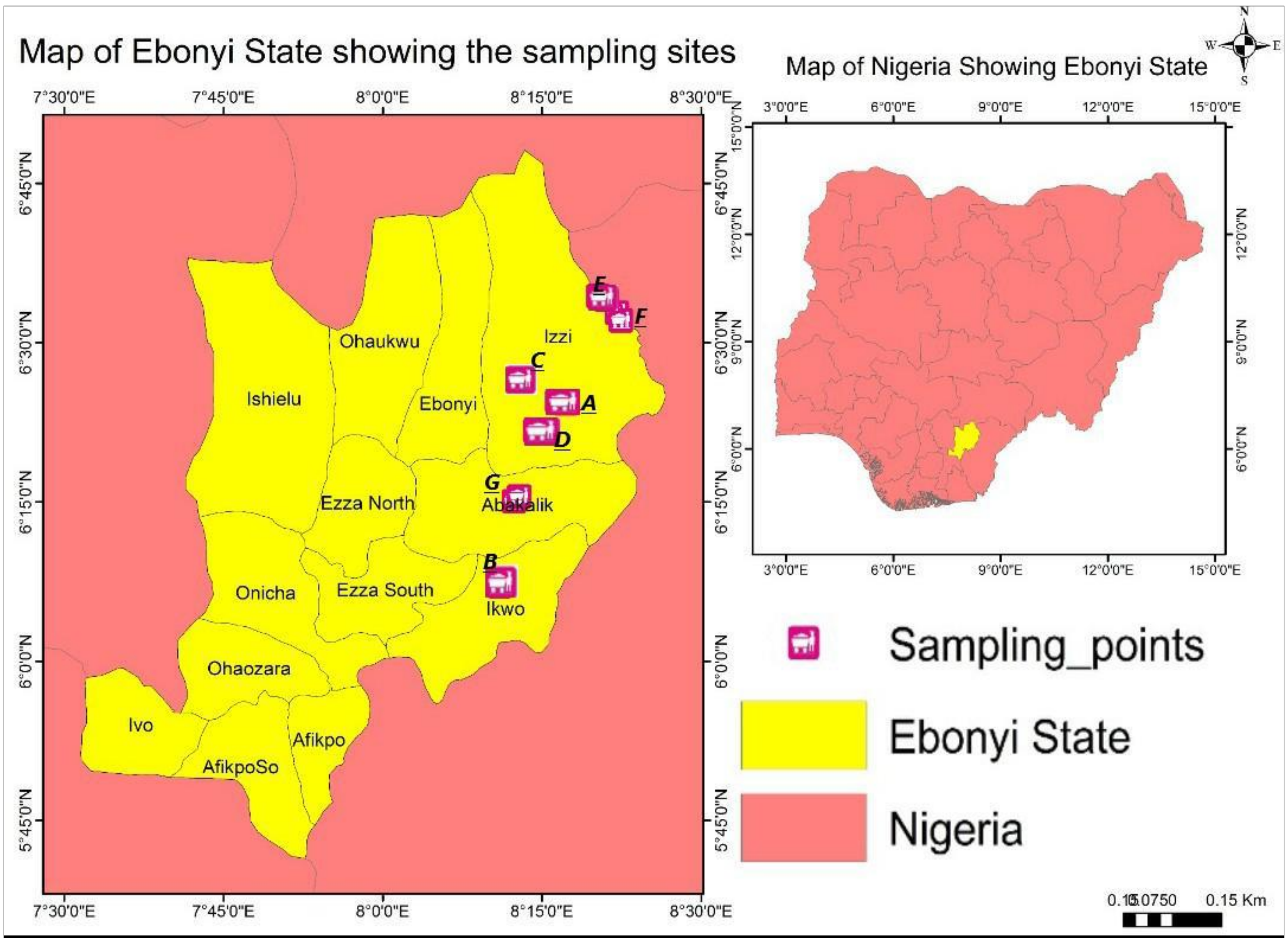


**Fig 1:** Map of Ebonyi State showing the sampling sites

## Samples Collection and Preparation

In this study, six sampling locations were arbitrarily selected for borehole water sampling using a global positioning system (Model, GARMIN etrex 20). The sampling locations are: Enyigba mining site, Ikwo mining site, Ameri-Ameka mining site, Izza mining site, Mkpume-Akwatakwa mining site and Mpume-Akwaokuku mining site. Composite water samples were collected using two liters plastic jars within the mining locales and 500 metres away from the mining locations [11]. Prior to filling the jars, each was washed thrice with the water from the borehole before sampling. One ml of nitric corrosive was added to 1 litre of the plastic can which was utilized for cation and anions investigation.

The control samples were taken from Abakaliki (about 15 km away from the study area) where there was no evidence of mining activity. A total of 14 sub-samples were collected for this study. The samples were promptly moved to Springboard Research Laboratory, Awka, for analysis.

**Assessment of Physicochemical Properties of the Water Samples**

The collected water samples were analyzed according to the method prescribed by the American Public Health Association, APHA [21, 22]. The pH and electrical conductivity (µs/cm) of the samples were measured *in situ* using pH meter and conductivity meter respectively [22]. Total dissolved solvent (TDS) was determined using APHA [22] while temperature and turbidity were determined using APHA [21]. Hardness (NTU) was conducted by EDTA titrimetric method [22]. Chloride ($Cl^-$) and fluoride ($F^-$) were estimated using the Argentometric method [21]. Nitrate ($NO_3^-$) was estimated using the procedures given by APHA [22].

**Methods of Heavy Metal Analysis of Water Samples**

Heavy metal analysis was conducted using FS240AA Atomic Absorption Spectrophotometer according to the method of American Public Health Association [21]. The samples were thoroughly mixed by shaking, and 100ml of it was transferred into a glass beaker of 250 ml, to which 5ml of concentrated nitric acid was added and heated to boil till the volume is reduced to about 15-20ml. 5ml of concentrated nitric acid was added periodically until all the residues were completely dissolved. The mixture was cooled, transferred and made up to 100 ml using metal free distilled water. The sample was aspirated into the oxidising air-acetylene flame. When the aqueous sample was aspirated, the sensitivity for 1% absorption was observed. The instrument setting and operational conditions were done in accordance with the manufacturers' specifications. Following the same protocol as the samples, standard reference material (SRM 2783) filter from National Institute of Standards and Technology (NIST) was analysed for elemental concentrations and compared with their certified values to validate the analyses and results were found within ±5% of the certified values [19, 23, 24].

**Data Analysis**

The data analysis for the data reported in this study was done using Ms-Excel.

**Results and Discussions**

**Result of physicochemical parameters in water samples**

The results obtained in Izza mining site indicated that all the physicochemical properties of the water samples collected within the mining sites varied significantly from the water samples collected 500 m away from mining site. For Ikwo mining sites, nitrate and hardness did not vary from samples collected 500 m from mining sites. In Akwatakwa mining sites, pH and Hardness did not vary significantly from samples collected 500 m from mining site ($p>0.05$). From samples collected from Ameri ameka mining site, no variation was observed between pH and TDS in comparison with the control sample. From Mpume akwaokuku, there was no variation between hardness and fluoride in comparison with samples collected 500 m from the mining site. It is worth noting that pH of the borehole water samples were acidic (5.25−6.37). Eze *et al.* [23] stated that daily ingestion of water with low pH could lead to peptic ulcer. The values reported for chloride and fluoride were below the WHO [30] and the NSDWQ acceptable limits. However, the presence of $Cl^-$ and $F^-$ in the borehole water samples are a sign of pollution due to human activities [23]. The result of the physicochemical parameters assessed in the water samples collected around the mining sites and 500 m from mining site are shown in Table 2.

**Table 2:** Physicochemical properties of water samples from the selected mining sites

| Parameters | Enyingba | Enyingba (500 m away) | Izza south | Izza south (500m away) | Ikwo | Ikwo (500 m away) | Akwatakwa | Akwatakwa (500 m away) | Ameri Ameka | Ameri Ameka (500 m away) | Mpume-Akwaokuku | Mpume-Akwaokuko (500 m away) | Control |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 5.39 | 6.18 | 5.62 | 6.37 | 5.64 | 5.90 | 5.51 | 5.25 | 5.94 | 5.85 | 5.63 | 5.74 | 6.44 |
| Temperature (ºC) | 28.40 | 29.37 | 29.2 | 27.73 | 27.40 | 28.53 | 28.3 | 26.57 | 27.4 | 28.27 | 18.90 | 29.33 | 28.40 |
| Conductivity (us/cm) | 190.963 | 68.83 | 170.04 | 66.27 | 83.72 | 64.33 | 62.65 | 57.30 | 52.393 | 86.63 | 66.05 | 86.27 | 45.53 |
| Turbidity (NTU) | 12.70 | 4.37 | 10.67 | 5.80 | 12.83 | 3.63 | 16.4 | 3.57 | 11.5 | 3.6 | 14.80 | 4.43 | 2.00 |
| Chloride (mg/l) | 174.80 | 113.43 | 159.97 | 93.10 | 163.96 | 104.93 | 141.97 | 71.98 | 133.36 | 82.977 | 123.43 | 104.79 | 122.56 |
| Fluoride (mg/l) | 1.25 | 0.06 | 1.34 | 0.16 | 1.063 | 0.16 | 1.82 | 0.44 | 1.55 | 0.347 | 1.34 | 0.17 | 0.25 |
| Nitrate (mg/l) | 9.93 | 8.69 | 5.28 | 4.54 | 6.676 | 6.37 | 5.55 | 3.48 | 5.51 | 4.123 | 11.57 | 3.47 | 4.41 |
| TDS (mg/l) | 123.33 | 88.67 | 123.33 | 105.33 | 79.33 | 65.67 | 104.67 | 55.00 | 73.63 | 92.00 | 91.33 | 81.67 | 93.00 |
| Hardness (mg/l) | 144.33 | 113.67 | 133.33 | 106.00 | 89.00 | 126.33 | 72.00 | 143.33 | 79.00 | 106.66 | 78.33 | 107.00 | 67.72 |

Furthermore, the low nitrate concentrations recorded in the borehole water samples indicates a low possibility of the development of methaemoglobinaemia in children (infants). In this study, the results reported for the physicochemical parameters were higher than that reported by Duru *et al.* [13] and Ibe *et al.* [25].

**Result of heavy metal concentration in water samples**

The result of heavy metal concentration (Table 3) showed a higher level of lead in all the mining sites with Enyigba mining site having the highest concentration of 4.71 mg/l which is followed by Akwatakwa mining site (3.64 mg/l), Izza south (3.40 mg/l), Ikwo (2.75 mg/l), Mkpume-Akwaokuko (2.62 mg/l) and AmeriAmeka (1.56 mg/l). Lower concentrations of lead were detected in the water samples collected 500 m from the mining site with Akwatakwa having the highest concentration of 0.24 mg/l. Generally, low concentration of the heavy metals were detected in both the control samples and the samples collected from the mining sites.

**Table 3:** Heavy metal analysis of water samples within the selected mining sites.

| Heavy metals | Enyingba | Enyingba (500 m away) | Izza south | Izza south (500m away) | Ikwo | Ikwo (500 m away) | Akwatakwa | Akwatakwa (500 m away) | Ameri Ameka | Ameri Ameka (500 m away) | Mpume-Akwaokuko | Mpume-Akwaokuko (500 m away) | Control |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lead (mg/l) | 4.713 | 0.078 | 3.400 | 0.065 | 2.754 | 0.061 | 3.635 | 0.236 | 1.560 | 0.055 | 2.619 | 0.065 | 0.122 |
| Cadmium (mg/l) | 0.408 | 0.00 | 0.257 | 0.00 | 0.355 | 0.023 | 0.201 | 0.017 | 0.156 | 0.015 | 0.133 | 0.025 | 0.055 |
| Arsenic (mg/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Chromium (mg/l) | 0.0377 | 0.00 | 0.038 | 0.00 | 0.022 | 0.00 | 0.032 | 0.00 | 0.161 | 0.00 | 0.035 | 0.00 | 0.00 |
| Nickel (mg/l) | 0.358 | 0.02 | 0.13 | 0.014 | 0.28 | 0.021 | 0.108 | 0.025 | 0.145 | 0.023 | 0.351 | 0.027 | 0.034 |
| Cobalt (mg/l) | 0.00 | 0.022 | 0.00 | 0.017 | 0.00 | 0.027 | 0.00 | 0.014 | 0.00 | 0.027 | 0.00 | 0.019 | 0.00 |
| Zn (mg/l) | 6.0135 | 6.249 | 4.875 | 4.361 | 5.686 | 6.889 | 7.087 | 4.327 | 6.8 | 3.722 | 8.615 | 2.645 | 2.654 |
| Sum | 11.5302 | 6.369 | 8.7 | 4.457 | 9.097 | 7.021 | 11.063 | 4.619 | 8.822 | 3.842 | 11.753 | 2.781 | 2.865 |

In addition, most of the heavy metals detected recorded higher concentration in samples from the mining site when compared to the samples collected 500 m away from mining site and control sample; except for cobalt which was had higher concentrations in samples collected 500 m away from mining site.

The result of the current study is comparable to the study of groundwater samples near waste dumpsite conducted by Nnaji *et al*. [2]. Eze *et al*. [23] stated that lead causes diseases of the kidney, fetal brain, and damage to the circulatory and nervous system. However, Calo and Parise [26] in their related study reported concentrations of Cd, As, Co, Ni and Pb lower than the results of the current study.

## Assessment of Pollution status of water samples

### Contamination factors of heavy metals in water

As shown in Table 4, lead (Pb) recorded the highest contamination factor in all the mining sites; cadmium was higher in Enyigba (7.41) and Ikwo (6.45) mining sites, nickel was higher in Enyigba (10.53), Ikwo (8.24) and Mpume akwaokuku (10.32) mining site. However, the results showed a significantly higher contamination around the mining site in comparison with samples 500 m away from the mining site. A moderate to low contamination factor were detected in water samples 500 m away from mining site. This was in agreement with the study conducted by Wongsasuluk *et al*. [27] and Mishra *et al*. [28].

**Table 4:** Contamination factors of heavy metals in water samples from the studied mining sites

| Parameters | Enyingba mining Vs. 500m from mining site | Izza south mining Vs. 500m from mining site | Ikwo mining Vs. 500m from Mining site | Akwatakwa mining Vs. 500m from mining site | Ameri ameka mining Vs. 500m from mining site | Mpume-Akwaokuko mining Vs. 500 from mining site |
|---|---|---|---|---|---|---|
| Lead (mg/l) | 38.63* 0.64 | 27.87* 0.53 | 22.57* 0.50 | 29.80* 1.93 | 12.79* 0.45 | 21.47* 0.53 |
| Cadmium (mg/l) | 7.41* 0.00 | 4.67 0.00 | 6.45* 0.42 | 3.65 0.31 | 2.84 0.27 | 2.42 0.45 |
| Arsenic (mg/l) | 0.00 0.00 | 0.00 0.00 | 0.00 0.00 | 0.00 0.00 | 0.00 0.00 | 0.00 0.00 |
| Chromium (mg/l) | 3.77 0.00 | 3.80 0.00 | 2.2 0.00 | 3.20 0.00 | 16.10* 0.00 | 3.50 0.00 |
| Nickel (mg/l) | 10.53* 0.59 | 3.82 0.41 | 8.24* 0.62 | 3.18 0.74 | 4.26 0.68 | 10.32* 0.79 |
| Cobalt (mg/l) | 0.00 2.20 | 0.00 1.70 | 0.00 2.70 | 0.00 1.40 | 0.00 2.70 | 0.00 1.90 |
| Zinc (mg/l) | 2.26 2.35 | 1.84 1.64 | 0.00 2.60 | 2.67 1.63 | 2.56 1.40 | 3.25 1.00 |

Cf<1 low, 1≥Cf≤3 moderate, 3>Cf≤6 Moderately high, Cf> 6 very high contaminated. *indicates high contamination within the study area.

### Pollution Index

The result of pollution indices of heavy metals in water samples collected within the studied mining site (Table 5) showed a higher pollution index for samples collected within mining site in comparison with samples collected 500 m away from the mining site.

Moreover, all the samples collected recorded a high pollution level indicating the influence of anthropogenic activities within the study area. Enyigba mining site recorded a higher pollution index (112.05) around the mining site; while Akwatakwa recorded the highest pollution load index (7.21) 500 m away from the mining site.

Generally, the borehole water in the study area was polluted and this could result to adverse health effects on humans who consume the water [23, 29, 30].

**Table 5:** Pollution Index of heavy metals in water samples from the studied mining sites

| Study area | Mining sites | 500 m from mining sites |
|---|---|---|
| Enyigba | 112.05 | 6.31 |
| Izza South | 100.013 | 4.75 |
| Ikwo | 65.74 | 6.84 |
| Akwatakwa | 73.98 | 7.21 |
| Ameri ameka | 61.36 | 6.03 |
| Mpumeakwaokuku | 62.59 | 5.37 |

(PI ≤ 1), middle (1<PI≤3) or high (PI>3).

### Conclusion

This research has revealed that the water samples are acidic (low pH), with a moderate electrical conductivity, total dissolved solid, nitrate, chloride, fluoride and hardness. The ambient values reported are a clear indication of the influence of mining activities within the study area. The local populations who consume water from the boreholes are hereby advised to purify the water before usage. Generally, the heavy metal levels in the water samples from mining communities were higher within the mining sites than that of the samples collected 500 m away from the mining site. This could be associated with mining activities and the high level of air pollution that typically characterizes mining sites.

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