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Chemical Composition of Toxic Heavy Metals from Four Different Mine Water Samples Collected from Four States in Nigeria

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Abstract
Mine water contains toxic heavy metals in high concentrations causing the pollution of nearby water bodies, related ground waters and soils degradation. The aim of the study is to determine the toxic heavy metal pollutants present in four different mine water samples and their level of toxicity. Digestion technique was employed to treat the samples as received mine water samples. Physicochemical parameters were determined for pH, electrical conductivity (EC), and total dissolved solids (TDS). The samples collected from different mine locations are Sample A Gold, Sample B Copper, Sample C Iron,, and Sample D Tin. The untreated water samples were analyzed using inductively coupled plasma optical emission spectroscopy (ICP-OES). The results showed that the toxic heavy metals present in the mine water samples are U, Ba, Mn, Cd, and Pb were identified. U and Mn metals have higher concentrations in all the mines which are higher than WHO water permissible limit. The concentrations of Ba in all the mines are within the WHO drinking water permissible limits except for gold. The concentrations of Cd and Pb metals are above the WHO drinking water permissible limit for two of the mines, but they are not detected.The water sample collected from theiron mine indicated toxic heavy metals present in the sample are very high and could be harmful to all beings in the environment. In conclusion, most of the toxic heavy metals concentrations wereabove the World Health Organization (WHO) standard drinking water permissible limit.

Keywords: *Mine water, toxic heavy metals, physicochemical parameters, digestion, inductively coupling plasma (ICP)*

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I. Introduction

Mining is considered the prime source of heavy metal contamination in the surrounding environment. Heavy metals are described as metals that have high atomic weight and density, and in the field of biology[1-3], heavy metals are referred to the metals that are toxic for organisms even in a small amount. Metalloids are also sometimes considered in heavy metals; they are the chemical elements that have the characteristics of both metals and non-metals [4-6]. Some of the heavy metals that are of serious concern include Nickel, Zinc, Copper, Lead, Arsenic, Selenium, Cadmium, Chromium, Manganese, Cobalt and Mercury. Environmentalists are majorly focusing on heavy metal contaminated soil and water bodies. The past decade has seen a renewed importance in the elimination of heavy metal pollution as they are covert, persistent, and irreversible and degrade water quality, atmosphere, and agriculture and also raises a huge concern over the health of humans, plants, animals and microorganisms through contamination and accumulation in their food chain [7-10]. Due to these properties of heavy metals, they are non-biodegradable and remain in the environment for a very long time [11]. Studies have shown that magnetic pollution was related to heavy metal pollution concerning the anthropogenic origin and transportation mechanism [12, 13]. The degradation of toxic heavy metals from the ecosystem isentirelyvery difficult.The aim of this study is to determine the toxic heavy metal pollutants present in four different mine wastewater samples.

II. Materials and Methods

2.1 Sampling and Sample Collection

Samples of gold, copper, tin, and iron mine waste water were collected from differentlocations using high density polyethylene or plastic bottle containers from the mining sites. The samples were collected in triplicate, in which one sample from each mine was spiked with concentrated acid labeled as spiked and the other containers were labeled un-spiked that is without spiking with acid and water samples were transported in ice cooler or ice to the laboratory and preserved in a refrigerator regulated at 4 ^{0}C prior to analyses. Hand trowel was used to collect the sample (sand) into a plastic bottle and the plastic bottle was dipped into mine wastewater in the site for sample collection. 5 ml of concentrated nitric acid was added to the each waste mine water to prevent it from undergoing metal oxidation. Then the samples were taken to the laboratory for physicochemical analysis. The sample was subjected to filtration and the filtrate was collected and sent for analysis using inductively coupled plasma optical emission spectroscopy (ICP-OES).

2.2 Description of Sample Location

Samples of mine wastewater were collected from four different mines which are gold mine, copper mine, tin mine and iron mine.The gold mine is located in Sabo town, Ilesha in South West Local Government Area (LGA), Osun State, South WestNigeria. Gold mining has GPS coordinates of latitude 7.623914^{o}N and longitude 4.715163^{o}E.Coppermineis locatedatDawa Town, located in Toro LGA of Bauchi State, Northern Nigeria with GPS coordinates of latitude 10.431790^{o}N and longitude 8.986784^{o}E.Tin mineis located at in BisichiTown, SabonGidaDanyaya, BarikinLadiLGA of Plateau State, Northern Nigeria with GPS coordinates of latitude 9.71445^{o}N and longitude 8.91072^{o} E.Iron mine wastewater sample is located at in Ijero Town, Ekiti State, South West, Nigeria with GPS coordinates of latitude 7^{o} 48’54.50" N and longtitude 504’1.78 E"4^{o}.

2.3 Chemicals Used

Chemicals used are nitric acid, and hydrochloric acid was purchased from Merck chemicals. All the chemicals were used without any other further treatment.

2.4 Sample Digestion

50 mL wastewater sample was digested at 85° C in 12 ml of aqua regia (HCl/HNO_3 v/v) in ratio 3:1 on a hot plate in a fume cupboard until white fumes was observed. The sample was allowed to cool to room temperature and then diluted with 20 ml of 2 % Nitric Acid (v/v). The mixture was then transferred into a sample bottle after filtering using Whatman No.42 filter paper and made to the mark with distilled water. The sample was analyzed using Inductively Coupled Plasma Optical Emission Spectrophotometer (ICP – OES).

2.5Analytical Techniques

Physicochemical parameters such as pH, EC, and TDS of the mine water as received were determined using Hach water quality multifunction pH meter, model EZ- 9909. The multifunction pH meter was calibrated with buffers pH 4.0, 7.0, 12 and the electrical conductivity meter was calibrated using 10 µScm^{-1}, 500 µScm^{-1} and 1288 µScm^{-1} standard KCl solutions before testing the wastewater solution. The toxic and trace heavy metals were determined using Variance Liberty II inductively coupled plasma optical emission spectroscopy (ICP-OES) analytical technique.

III. Results

3.1 Physicochemical Analysis

Physicochemical analysis was conducted for the four different mine water samples and the results is presented in Table 1. The pH of all the mine water was acidic because they are less than 7 but gold mine water was more acidic than the others and does not fall within the WHO standard drinking water permissible limit (WHO, 2011). The electrical conductivity (EC) revealed iron mine water has a very high conductivity, followed by copper mine water and the remaining two have equal conductivity of 154 µS/cm. Copper and iron have the same TDS higher than gold and tin. The salinity of the mine samples showed that gold and iron mine water have same concentration (160 mg/L) higher than copper and tin with the same concentration (78 mg/L). The other physicochemical parameters of all the mines fall within the WHO standard drinking water permissible limit except EC of iron mine which exceed the limit (WHO, 2011).

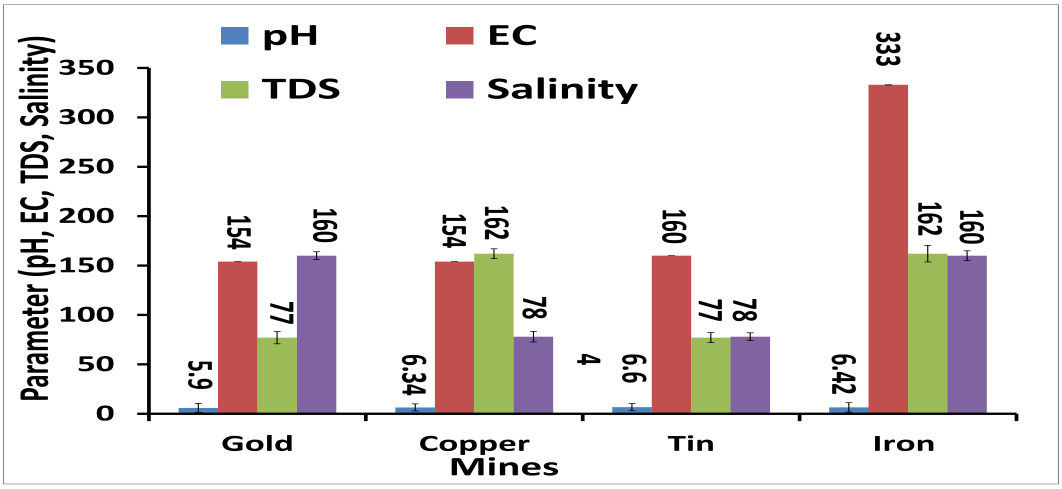

Figure 1: physicochemical parameters of water samples collected from four mines (n = 3)

3.2 Toxic Heavy Metals

Five toxic heavy metals (U, Ba, Mn, Cd, and Pb) were analyzed in the four different mine wastewater samplescollected from four different mines: gold, copper, tin and iron were subjected to ICP-OES analysis andthe results are presented in Figures 2, 3, 4 and 5. The results fromgold and copper mine wastewater samples contained all the five toxic heavy metals (U, Ba, Cd, Cr, and Pb) but tin and iron mine wastewater contained only three toxic heavy metals (U, Ba, and Mn).The result of the gold mine wastewater determined consist of five toxic heavy metals (U, Ba, Cd, Cr and Pb) in Figure 2 revealed concentrations as Ba >Mn> U >Pb> Cd to be 1.159, 0.571, 0.033, 0.01 and 0.001 respectively. Copper mine wastewater consist of five toxic heavy metals (U, Ba, Cd, Cr and Pb) in Figure 3 revealed the concentrations as Mn> Ba >Pb> U > Cd to be 0.2927, 0.0123, 0.0010, 0.0013, and 0.0005 respectively. Tin mine wastewater consist of three toxic heavy metals (U, Ba, and Mn) in Figure 5 revealed concentrations as Mn> Ba > U to be 0.587, 0.507, and 0.021 respectively. Iron mine wastewater consist of three toxic heavy metals (U, Ba, Cd) in Figure 4 revealed concentrations as Ba >Mn> U >Pb to be 0.171, 0.041, 0.004 respectively.

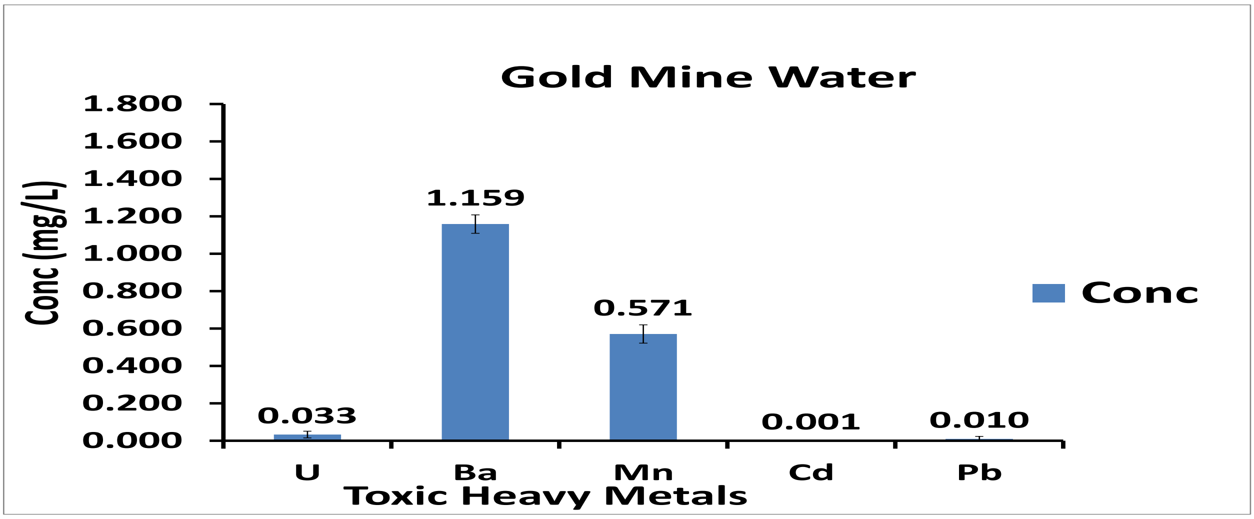

Fig 2: Toxic heavy metals present in Gold mine wastewater: (n = 3)

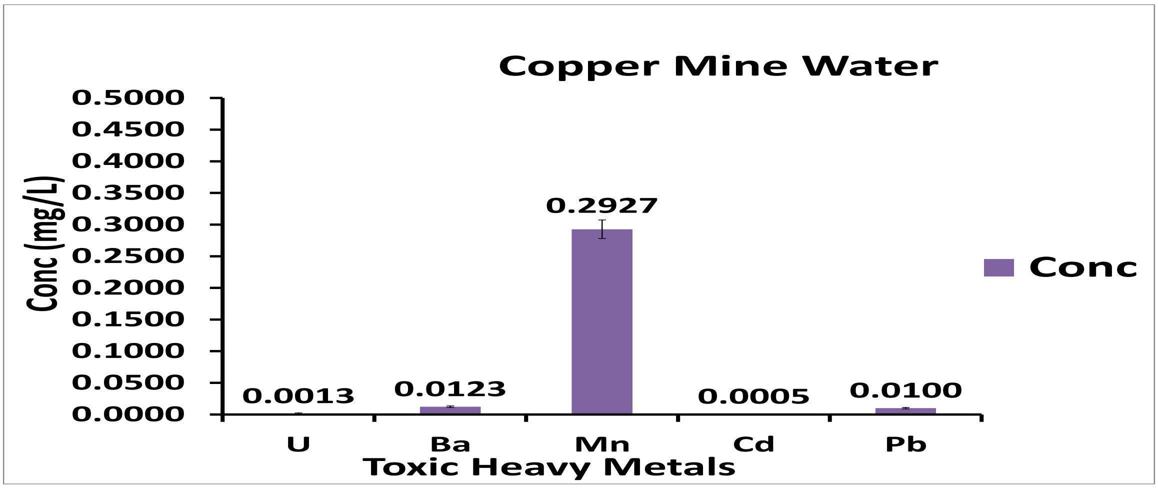

Fig 3: Toxic heavy metals present in Copper mine wastewater: (n = 3)

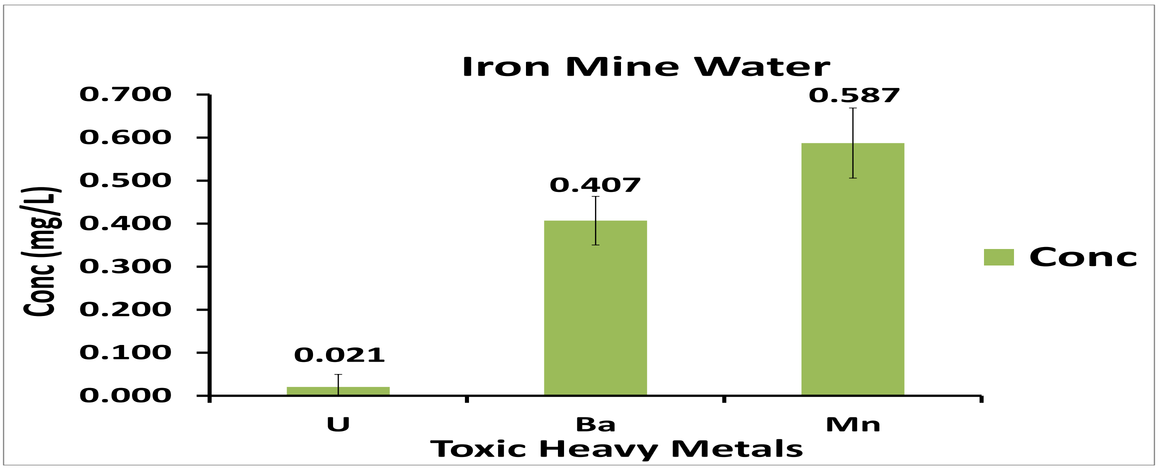

Fig 4: Toxic heavy metals present in Iron mine wastewater: (n = 3)

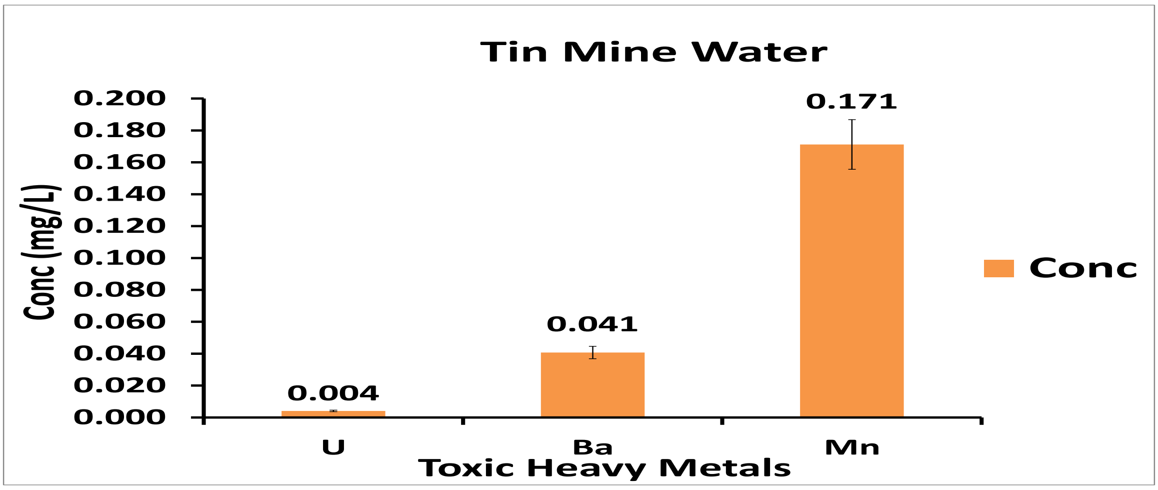

Fig 5: Toxic heavy metals present in Tin mine wastewater: (n = 3)

Figure 6 presents the results of all the toxic metals present in all the mine water samples for easy comparative study of all the four mines.The toxic heavy metals present in each mine showed the presence of U, Ba, Mn, Cd and Pb. The concentrations of uranium (U) present inthe minesare tin>gold>iron>copper.The concentrations of Ba present in the mines are gold>iron>tin>copper mines. Theconcentrations of Mnpresent in the mines are iron>gold>copper>tin mines.The concentrations of Cdpresent in the mines are only detected in copper>gold mines but was not detected in iron and tin mines, and the concentrations of Pbpresent in the mines are only present in copper>goldmines butwas not detected in iron and tin mines. The concentrations of U from all the mines are higher than the WHO permissible limit. The concentrations of Ba from all the mines are within the WHO permissible limits except for that of gold mine. The concentrations of Mn from all the mines are higher than the WHO permissible limit. The concentrations of Cd and Pb from all the mines are higher than the WHO permissible limit except for the iron and tin mines that were not detected.

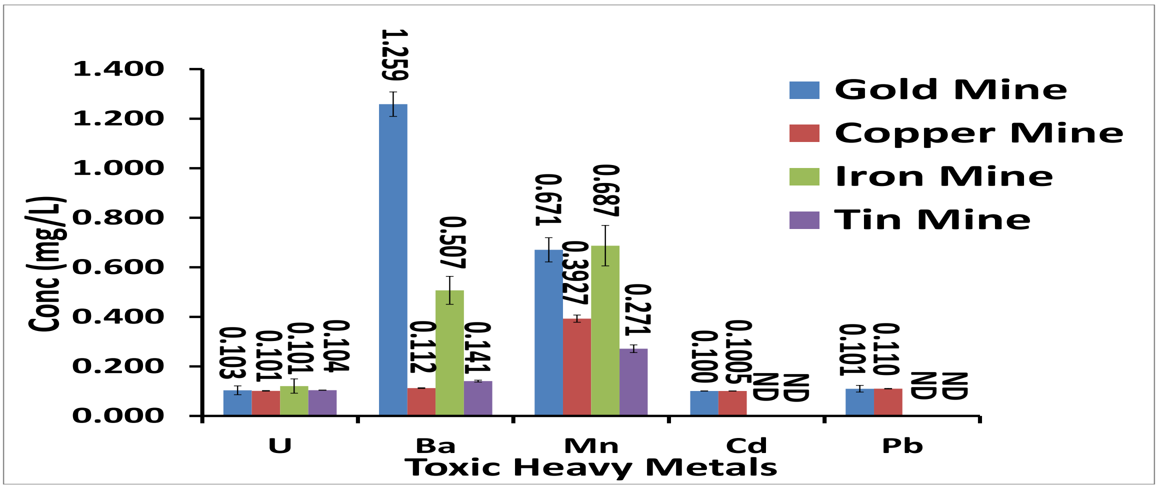

Fig 6: Toxic heavy metals present in four different mine wastewater: (n = 3)

IV. Conclusion

- This study has shown that the water samples collected from the four mines contained toxic heavy metalssuch as U, Ba,Mn, Cd and Pb.
- The people living around these mines are exposed to serious health danger, since most of heavy metals have severe consequences on human health.
- The concentrations of some of the toxic heavy metals in some of the mines are above the WHO standard permissible limits.
- These mine wastewater samples could be of a high risk to humans if it runs into the natural water bodies being used by the inhabitants of the community

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