Determination of Selected Heavy Metals in Soil and Water from Jatau–GarinGabas Gold Mining Site in Niger State

Alexander Ikechukwu Ajai,[1*]Abdulrahman Ali Yusuf,[2]JimohOladejoTijani[2]

Department of Chemistry, Federal University of Technology, Minna, Nigeria

ajiyusuf20@gmail.com

*Corresponding author

Abstract

Concentrations of Cd, Fe, Ni, Pb and Zn in soil and water collected within and around local artisanal gold mining sites in Jatau – GarinGabas village of Rafi Local Government Area of Niger State were determined using Atomic Absorption Spectrophotometry (AAS) technique. The mean concentration for Ni was 103.38 and 186.11 mg/kg for the soil samples and between 0.01 and 0.23 mg/l for the water samples; Fe, between 273.35 and 476.71 mg/kg for the soil samples, and 0.28 and 2.87 mg/l for the water samples; Zn between 49.90 and 117.47 mg/kg for the soil samples, and 1.05 and 2.08 mg/l for the water samples; Pb varied widely from 19.0 and 28.39 mg/kg for the soil samples, while for the water samples it ranged between 0.17 and 0.58 mg/l; Concentration of Cd in soil samples ranged between 0.22and 0.85mg/kg and 0.001 and 0.003 mg/l for the water samples. The order of occurrence in the soil samples were Fe > Ni > Zn >Pb> Cd for the soil samples, and Fe > Zn >Pb> Ni > Cd for the water samples. All heavy metals tested in the soil samples except Pb were found to have exceeded the permissible limits set by the World Health Organisation. Similarly, Pb and Fe in the water samples tested exceeded the permissible limits. The study revealed that the water bodies and the soil around the mining site were polluted with tailings from the mines during the process of washing the minerals,and therefore not fit for drinking and agricultural activities respectively. Regular monitoring of mining activities should be carried out from time to time to ensure a safe environment for man and other living organisms in the area.

Introduction

Mineralexploration and exploitation have been identified as one of the anthropogenic activities contributing significantly to environmental degradation and deterioration due to the release of potentially toxic elements into soil, water and air (Udosen*et al*, 2018).

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Literature Review

According to report by expert committee on metals, all essential elements become toxic at high intake and the margin between levels that are beneficial and those that are harmful may be small (Abdallah, 2014). Copper, zinc, cobalt, nickel, chromium, manganese, iron, selenium, silicon, tin, fluorine, iodine, molybdenum and vanadium are essential trace elements, while lead, cadmium, mercury are non-essential. Heavy metals are natural component of the earth crust; they enter our bodies via food, drinking water and air (Uzairu*et al.*, 2015). Some heavy metals (such as copper, selenium and zinc) are essential to maintain the metabolism of the human body. However, at higher concentration, they can lead to poisoning (Tijjani*et al.*, 2014).

Soil is a very important natural resource to man as it is a source of his life on this planet. Without soil the earth would be lifeless (Ujoh*et al.*, 2014). Water plays an important role in the world economy, as it functions as a solvent for many chemical substances and facilitates industrial cooling and transportation. Approximately 70% of the freshwater used by man goes to agriculture. However, pollution of water by natural and anthropogenic means is a source of worry globally, and as such, requires adequate attention (Tijjani*et al.*, 2014).

The aim of this research is to determine the effects of mining activities on the levels of heavy metals in soil and water around Jatau-GarinGabas local mining site.

Methodology

Sample Location

Jatau – GarinGabas, is located between latitudes $10^0 11^1 04''$N and longitudes $6^0 15^1 12''$E. It is an agrarian community in Rafi Local Government Area of Niger State, Nigeria (NIGIS, 2013). It is 104 km from Minna the state capital. The area enjoys both wet and dry seasons with a total annual rainfall of between 804.5-1767.1 mm (NIGIS, 2013). Mean annual temperature is about 27.7^0C with a relative humidity of 30% in dry season and 70% in wet season. Average daily wind speed is 89.9km/hr. Average daily vapour pressure is 26Hpa (Niger State Ministry of Information, 2009). The land rises from about 300 m along the Niger valley to between 300-900 m above sea level in the uplands (Niger State Ministry of Information, 2009).

Sample Collection

Soil and water samples were collected at various points from the mining site. Water samples were collected from 3 different points along the river around the mining sites. The first water sample labelled A was collected approximately 100 m before the mining site, and B from the

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actual mining site, and C, 100 m after the mining site. Each water sample was acidified with dilute HNO_3 to avoid oxidation and stored for laboratory analysis (Amadi*et al.*, 2015).

Soil samples were collected at a depth of 0-15 cm and 15-30 cm according to the method reported by Agbalaje (2015), making 2 different samples from each point. The soil samples were collected from three different points; the actual mining site, approximately 100 m before it and 100 m after it. The 2 samples from the same point were pulled together to form a composite for each of the sampling points. They were stored in a black polythene bag, labelled and transferred to the laboratory for further analysis (Musa *et al.*, 2016).

Sample Digestion

The procedure reported by Chiroma*et al.* (2014) with some modifications was used for the digestion of the water samples. 50 cm^3 of the water sample was accurately measured into a 100 cm^3beaker.10 cm^3 of concentrated HNO_3 was added to it. The solution was heated on a hot plate at 95°C. The solution was then reduced to 30 cm^3. It was allowed to cool before being filtered using Whatman No. 1 filter paper and then transferred into a 100 cm^3 standard flask. The solution was then diluted to the mark with distilled water and stored for analysis. The digested samples were analysed for 5 heavy metals, namely: Ni, Pb, Fe, Zn and Cd using Atomic Absorption Spectrophotometry (Buck Scientific 210VGB). Same procedure was applied to all the water samples collected.

The procedureby Rao*et al.* (2017) with some modifications was used for digestion of the soil samples. 2.0 g of the soil sample was weighed into a 100 cm^3 beaker and 8.0 cm^3 of aqua-regia (1:3 HNO_3 and HCl) was added. The mixture was heated on a hot plate for 30 minutes at 90°C. The sample was dissolved after evaporation to near dryness with 10 cm^3 of 2% nitric acid and then filtered through Whatman No. 1 filter paper into a sample bottle before itwas then diluted to the mark with distilled water. It was stored and later analysed for selected heavy metals (Ni, Pb, Fe, Zn and Cd) using Atomic Absorption Spectrophotometry (Buck Scientific 210VGB).

Results and Discussion

From the results on the physicochemical properties of the water sample (Table 1), it can be observed that the pH of the water samples ranged from 5.33 to 6.34, which indicates that the samples were fairly acidic; this could be attributable to the mining activities going on at the locations. The value of COD ranged between 115.15 and 135.80. According to Odukoya (2015),the concentrations of COD observed in surface waters range from 20 mg/L or less in unpolluted water to greater than 200 mg/L in waters receiving effluents. According toTsafe*et al.* (2016), industrial wastewaters may have COD values ranging from 100 mg/Lto 60,000

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mg/L. The concentrations of COD observed in this study showed that the water may be polluted with discharge from the mining site. The BOD levels obtained ranged from 51.29 to 60.89 mg/L. The BOD levels of the samples are also high. However, COD levels are generally higher than the BOD (Musa and Jiya, 2014).

Table 1: Physicochemical Properties of Water Samples

Location	pH	COD (mg/L)	BOD (mg/L)	TOC (mg/L)	Turbidity (NTU)
A	6.01 ± 0.01	135.80 ± 2.2	57.43 ± 1.2	2.61 ± 0.3	0.56 ± 0.8
B	5.33 ± 0.04	126.21 ± 2.4	60.89 ± 1.7	2.99 ± 0.6	0.85 ± 0.7
C	6.34 ± 0.03	115.53 ± 1.5	51.29 ± 1.4	2.21 ± 0.2	0.46 ± 0.5

Where A, B and C are 100 m before, at and 100 m after the local mining site located at Jatau village respectively.

Organic carbon in freshwaters arises from living material (directly from plant photosynthesis or indirectly from terrestrial organic matter) and also as a constituent of many waste materials and effluents (Alhassan*et al*, 2016). Consequently, the total organic matter in the water can be a useful indication of the degree of pollution, particularly when concentrations can be compared upstream and downstream of potential sources of pollution, such as sewage or industrial discharges or urban areas. The TOC in the analysed water samples from the mining site ranged from 2.21 to 2.99 mg/L. This high concentration of TOC may be due to the presence of tailings in the water. TOC concentrations in municipal wastewaters range from 10 to > 100 mg/L (Adelekan and Abegunde, 2015). The type and concentration of suspended matter controls the turbidity and transparencyof the water. Turbidity values from the study were between 0.46 and 0.85 NTU. Turbidity results from the scattering and absorption of incident light by the particles, and the transparency is the limit of visibility in the water.

Concentration of nickel in the water samples ranged between 0.01 and 0.23 mg/L, which wereabove the permissible limit of 0.02 mg/L set by WHO (1993). The values of Ni in this present study were similar to those obtained by Wong *et al.*(2016) which ranged from 0.15 – 0.21 mg/L for water samples. The values of Fe in the water samples ranged from 0.28 to 2.87 mg/L (Table 2). They were slightly higher than the limit of 0.2 mg/L set by WHO in 1993.

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Concentration of Zn in water samples ranged between 1.05 to 2.08 mg/L as shown in Table 2. The permissible limit of Zn in water according to WHO (1993) standards is 2.6 mg/L (Adelifa*et al.*, 2016). In all the collected water samples, concentration of Zn was obtained below the permissible limit. In all the collected water samples, concentration of Pb ranged between 0.17 and 0.58 mg/L as presented in Table 2. According to WHO (1993) standards, permissible limit forPb in water is 0.01mg/L (Mutune*et al.* 2014). Concentration of Pbin the water was above the permissible limit. Pb as a water contaminant accumulates with age in bones, kidney and liver. It can enter the human body through uptake of food (65%), water (20%) and air (15%) (Nkwocha*et al.*, 2014).

Table 2: Heavy Metal Concentrations in the Water Samples (mg/L)

Sample location	Ni	Fe	Zn	Pb	Cd
A	0.10 ± 0.01^{b}	0.55 ± 0.20^{b}	1.47 ± 0.32^{b}	0.28 ± 0.44^{b}	0.001 ± 0.00^{a}
B	0.23 ± 0.00^{c}	2.87 ± 0.75^{c}	2.08 ± 0.59^{c}	0.58 ± 0.15^{c}	0.003 ± 0.01^{c}
C	0.01 ± 0.00^{a}	0.28 ± 0.23^{a}	1.05 ± 0.25^{a}	0.17 ± 0.12^{a}	0.002 ± 0.02^{b}
WHO Standard (1993)	0.02	0.2	2.6	0.01	0.005

Values with different superscripts on each column are statistically significant at ($p < 0.05$).
A is a well before the mining site, B is a water body at the actual mining site in Jatau village and C is a well located after the mining site.

Concentration of Cd in all the collected water samples ranged between 0.001 and 0.003 mg/L as shown on table 2. In all the collected water samples, concentration of Cd was recorded below the maximum permissible limit of 0.005 mg/L set by WHO (1993).

For the physicochemical properties of the soil samples presented on Table 3, the pH of all the samples were found to be acidic (between 6.00 and 6.40); this may be as a result of the sorption of metals in the soil (Mordi*et al.*, 2013). The electrical conductivity values were found to vary significantly across the sites; 2.94 μScm^{-1} (for point A), 3.46 μScm^{-1} (for point B) and 2.48

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μScm^{-1} (for point C). The variation observed in electrical conductivity between sites could be attributed to soluble salts in the soil samples. The organic matter content ranged from 1.74 to 2.89. This relatively high value could be due to the lower soil moisture contents during the dry season which retards the activities of the micro-organisms involved in the organic matter decomposition, thereby accumulating more organic matter (Gyang and Ashano, 2014).

Table 3: Physicochemical Properties of Analysed Soil Samples

Location	pH	Organic matter (g/kg)	CEC (cmol/kg)	Electrical conductivity (dsm^{-1})
A	6.20 ± 0.04	2.87 ± 1.24	4.12 ± 1.25	2.94 ± 1.71
B	6.00 ± 0.02	1.74 ± 0.90	2.18 ± 1.11	3.46 ± 1.82
C	6.40 ± 0.03	2.89 ± 1.08	5.28 ± 1.36	2.48 ± 1.63

Where A, B and C are 100 m before, at and 100 m after the local mining site located at Jatau village respectively.

The levels of Cation Exchange Capacity (CEC) ranged from 2.18 to 5.28 cmol/kg. This high CEC value could influence the ability of the soil to hold onto essential nutrients (Amadi and Nwankwoala, 2015).

The concentration of Ni in soil samples collected within the mining site varied between 103.38and186.11 mg/kg. The permissible limit set by WHO (1993) is 35 mg/kg, the concentration values were all above the permissible limit especially at point B with a value of 186.11 mg/kg which was highest. The values of Ni in this present study were similar to those obtained by Wong *et al.*(2016) in a study carried out around Pearl River Delta in China, which ranged from 98.50 – 165.00 mg/kg for the soil samples studied. Although Ni has been considered to be an essential trace element for human and animal health,it is absorbed easily and rapidly to harmful levels by plants (Wong *et al.*, 2016).

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Concentration of Fe in all the collected soil samples ranged between 273.35 and 476.71 mg/kg (Table 4). In all the soil samples, concentration of Fe was above the permissible limit of 200 mg/kg set by WHO (1993).This could pose perilous threats to residents in the locality. Excess amount of Fe causes rapid increase in pulse rate and coagulation of blood in the blood vessels, hypertension and drowsiness(Gyang*et al.*, 2014).

In this study, the concentration of Zn in the soil (Tables 4) at the actual mining site and at locations approximately 100 m before and after it varied between 49.90and117.47 mg/kg. It showed the highest concentration of 117.47 at point B which is the actual mining site. This is higher than the results obtained by Sourav*et al.* (2014) which stood at between 25.95 and 72.22 mg/kg. The WHO (1993) standard for Zn is 50 mg/kg. This high concentration could be attributed to the anthropogenic activities like breaking up ores around the gold mine that also contain Zn, which are subsequently translocated to areas close to the mine by erosion or human activities. The values in this study were however lower than the results obtained by Tsafe*et al.* (2016) who got values ranging from 185- 373 mg/kg for evaluation of heavy metals uptake and risk assessment of vegetables grown in Yargalma in Northern Nigeria.

Zn is one of the important trace elements that play a vital role in the physiological and metabolic process of many organisms. Nevertheless, higher concentrations of Zn can be toxic to living organisms (Nkwocha*et al.*, 2014).

The concentration of Pbin the soil samples from the study area also varied widely from 19.00–28.39 mg/kg (Table 4). The WHO (1993) recommended limit forPb is 85 mg/kg.The values were fairly low and below the recommended limits. The low concentration indicates that the environment is relatively safefrom the adverse effects of Pb which may result from the mining activitiestaking place around the area, which is usually accompanied by other harmful by-products (Odukoya 2015).

Table 4: Heavy Metal Concentration in the Soil Samples (mg/kg)

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Sample location	Ni	Fe	Zn	Pb	Cd
A	120.15 ±1.05^{b}	378.25 ±1.3^{b}	49.90 ±0.2^{a}	24.55 ±0.9^{b}	0.22±0.17^{a}
B	186.11 ±2.5^{c}	476.71 ±2.1^{c}	117.47 ±1.6^{c}	28.39 ±0.5^{c}	0.85±0.51^{c}
C	103.38 ±2.0^{a}	273.35 ±2.2^{a}	61.20 ±0.1^{b}	19.00 ±0.1^{a}	0.31±0.28^{b}
WHO Standard (1993)	35.00	200.00	50.00	85.00	0.80

Values with different superscripts on each column are statistically significant at ($p < 0.05$). Where A, B and C are 100 m before, at and 100 m after the local mining site located at Jatau village respectively.

Concentration of Cd in soil samples ranged between 0.22and 0.85 mg/kg (Table 4).The maximum permissible limit for Cd in soil is 0.8 mg/kg according to WHO (1993). From the results of the soil samples collected, concentration of Cdobtainedfrom all locations were below the WHO permissible limit, except for point B, which is the actual mining site. Consequently, the mining activity at point B had given rise to pollution of the soil within the environment, which could expose the inhabitants to various environmental hazards caused by Cd.

Conclusion

The study shows that heavy metal pollution of water and soil is of environmental concern within the perimeter of the gold mining site in Jatau village. The heavy metal concentrations in the soils varied significantly by sampling sites and metal type. The soil samples from the mining site are more contaminated with heavy metals with maximum concentrations of 186.11 mg/kg Ni; 476.71 mg/kg Fe; 117.47 mg/kg Zn; 28.39 mg/kg Pb and 0.85 mg/kg Cd. The surface water around the mining site had concentrations of 0.23 mg/L Ni; 2.87 mg/L Fe; 2.08 mg/L Zn; 0.58 mg/L Pb and 0.003 mg/L Cd. This research also revealed that heavy metals at location B (Table 4) had the highest concentration of iron (476.71 mg/kg).

From this study, it was observed that the most polluted soil is that of the actual mining site, as it had the highest concentration of all the heavy metals analysed. The results imply that

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pollution of such environment by heavy metals could have adverse effect on human health and the environment, and cultivation of crops around the area may result to significant bioaccumulation of the heavy metals into the food chain.

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