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# Assessment of Heavy Metals Concentration in Soil Around Artisanal Gold Mining Site, Osun State, Southwestern Nigeria

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**ABSTRACT**

The concentration of heavy metals in soil samples from artisanal gold mining site at Ijana Osun State South West Nigeria and its effect on the immediate environment was investigated. Soil samples were randomly collected at the Ijana Wasare gold mine site and also a few kilometres from the gold mine site where there were no records of mining activities. The samples were analyzed for heavy metals such as, copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), chromium (Cr), nickel (Ni) and cobalt (Co) using a Flame Atomic Absorption Spectrophotometer (AAS). The results obtained showed the mean heavy metal concentrations in the mining area for As, Hg, Cu, Zn, Co, Cr, Cd, Pb and Ni as 10.32 mg/kg, 9.69 mg/kg, 72.46 mg/kg, 54.73 mg/kg, 7.54 mg/kg, 34.32 mg/kg, ND mg/kg, ND mg/kg and, 20.06 mg/kg, respectively while the concentrations in the control area were 3.18 mg/kg, 1.16 mg/kg, 16.25 mg/kg, 15.12 mg/kg, ND mg/kg, 18.72 mg/kg, ND mg/kg, ND mg/kg and 9.37 mg/kg, respectively. The mean value of soil pH was 5.28 in the mining areas and 6.61 in the control sites. The results revealed that the concentration of heavy metals in the mining area was higher compared to those in the control area, this showed that the artisanal mining activities have elevated the concentration of heavy metals in the soil within the mine environment, this calls for urgent attention and adequate environmental regulations.

## INTRODUCTION

The level of natural occurring heavy metals in soil due to pedogenic processes are usually nontoxic but elevated concentrations of heavy metals in the environment is usually due to human activities such as municipal waste landfilling, disposal of metallic wastes, sewage disposal, petrochemicals spillage and mine tailings from artisanal mining (Pierzynski et al, 2000; Kabata-Pendias & Pendias, 2001; Khan et al 2008; Zhang et al 2010). Soils can become contaminated by the accumulation of heavy metals from any of these anthropogenic activities. Artisanal mining is an informal small scale mining activity that uses crude and primitive methods for extraction and processing of minerals from the deposit of the earth subsurface unlike the semi-automated mining which makes use of earthmoving equipment such as excavators and bulldozers. These mining activities have a negative influence on the environment, some of the negative impacts of mining on the immediate environment includes: Air pollution from airborne particulate matter from mining site which pose a health risk to people, animals and vegetation (Ndinwa, 2014), Deforestation, (Ogunwale, 2015), Water Pollution, Soil erosion and Land degradation (Ako et al., 2014), Geological and radiation hazards (Aigbedion, 2005). Elevated concentration of heavy metals above pedogenic level in soils poses serious health concerns because they are toxic and non-degradable hence they exert long term negative effects on man and the environment (Nriagu, 1979 and 1988; Nriagu and Pacyna, 1988; Thornton, 1993).

Research has shown that exposure in small concentrations can result in extremely severe sickness in humans (Nnabo and Taiwo, 2001; WHO, 2007; Singh et.al. 2011; Nakazawa et. al., 2016). Previous studies have shown that dust from gold mining sites contains high levels of silica which aggravate asthma and arthritic symptoms, respiratory disorders, silicosis, and lung diseases (Akabzaa and Daimani, 2001, Nnabo and Taiwo, 2001). This study was aimed at determining the concentration of heavy metals such as copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), chromium (Cr), nickel (Ni) and cobalt (Co) in Ijana Wasare, Atakunmosa gold mine site and it effect on the immediate environment.

## MATERIALS AND METHODS

### Study Area

The research was carried out in an artisanal gold mining site located at Ijana Wasare, Atakunmosa West Local Government of Osun State in the South western geopolitical region of Nigeria. The study area is in the Southwestern Nigeria basement complex which consists of migmatite-gneiss complex, metaigneous rock such as pelitic schist, quartzite, amphibolites, charnokitic rocks, older granite and unmetamorphorsed dolerite dykes (Rahman, 1976). The mining site is located between latitude 7°33'38"N and 7°33'41"N and longitude 4°41'1"E and 4°41'14"E and the control site which is a few kilometres away from the mining area, between latitude 7°34'5"N and 7°34'58"N and longitude 4°40'43"E and 4°40'47"E. The map of the study area is shown in Figure 1 while the artisanal mining activity is shown in Figure 2.

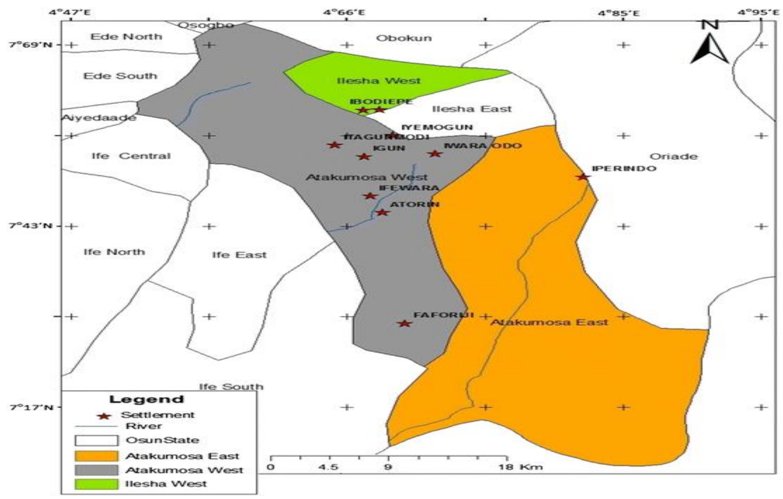


Figure 1: Map of the Study Area

Figure 2: Artisinal Mining at Ijana Wasare Gold Mine Site

### Soil Sampling

Soil samples were randomly collected within the Ijana Wasare gold mine site and also collected a few kilometres from the gold mine site where there are no records of mining activities and other human interference is minimal, this is to serve as the control sites. Soil samples were taken at both mining and control sites at a depth of 10-15 cm below the surface in order to avoid contamination or removal of the heavy metals from the surface by wind. The soil samples, each weighing at least 250g were collected and stored in plastic (polythene) bags, then labeled correctly before being transported to the laboratory for analysis.

### Soil Sample Preparation and Quality Control

The soil samples were air-dried at room temperature for 3 days (Figure 3) to constant weight and then grounded to a fine powder. The samples were then sieved through a 2 mm mesh to obtain fraction less than 2 mm. Afterward, 0.5g of each sample was weighed into a beaker, and 10mL of mixture of Nitric acid ($HNO_3$) and Perchloric acid ($HClO_4$) were added to make it a solution. The solution was covered with a coverslip and allowed to undergo heating or digestion on a hot plate at a regulated temperature for about 30 minutes under a fume cupboard. The digested samples were cooled to room temperature and then filtered through WhatmanNo.42 filter paper. The filtrates were then collected and made up to 10mL volume with distilled water in a volumetric flask for the determination of the concentration of heavy metals using flame Atomic Absorption Spectrophotometer (AAS) model 210/211 VGP (Figure 4), furthermore the pH of the soil was determined using Thermo Scientific Orion Star A211 pH Benchtop Meter.

Figure 3: Air drying of the Samples

Figure 4: The Prepared Sample and Atomic Absorption Spectrophotometer (AAS)

**Determination of Heavy Metal Concentration**

The heavy metals (Hg, Zn, As, Cu, Co, Ni, Cd, Cr, and Pb) concentrations in digested samples of the soils were determined using equation 1.

$$\text{Concentration (mg/kg)} = \frac{\text{Concentration (mg/L) x V}}{\text{W}} \quad (1)$$

Where V = Final Volume (10 ml) of the solution, and W= Initial weight (0.5g) of the sample measured.

**RESULTS AND DISCUSSION**

The results of the heavy metals Hg, Zn, As, Cu, Co, Ni, Cd, Cr, and Pb concentrations (mg/kg) and the soil pH levels from the samples from the mining site and three samples from control area are presented in Tables 1. Figures 5 to 11 show the variation of the concentration of each metal in the samples while Figure 12 showed the pH level variations in the samples and Figure 13 compared the mean concentration levels from the mining area with the concentrations in the control.

**Table 1: Concentration of Heavy Metals in Soil and pH Level of Soil in the Study Area**

| S/N | Sample | As | Hg | Cu | Zn | Co | Cr | Cd | Pb | Ni | Soil pH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sample1 | 4.86 | 9.31 | 49.00 | 55.40 | 8.70 | 22.40 | 0.00 | 0.00 | 13.20 | 5.82 |
| 2 | Sample2 | 5.27 | 8.74 | 26.50 | 30.15 | 10.70 | 43.20 | 0.00 | 0.00 | 15.45 | 5.28 |
| 3 | Sample3 | 6.83 | 11.05 | 37.75 | 63.80 | 7.30 | 43.80 | 0.00 | 0.00 | 24.95 | 5.05 |
| 4 | Sample4 | 5.62 | 8.50 | 22.50 | 33.65 | 8.10 | 46.70 | 0.00 | 0.00 | 18.30 | 5.35 |
| 5 | Sample5 | 6.39 | 7.30 | 51.90 | 135.00 | 5.25 | 34.45 | 0.00 | 0.00 | 16.85 | 4.96 |
| 6 | Sample6 | 21.80 | 8.56 | 262.00 | 73.70 | 9.80 | 25.10 | 0.00 | 0.00 | 24.65 | 5.61 |
| 7 | Sample7 | 30.50 | 11.27 | 123.50 | 34.25 | 6.75 | 26.85 | 0.00 | 0.00 | 23.95 | 4.95 |
| 8 | Sample8 | 6.15 | 12.10 | 37.50 | 29.40 | 4.55 | 29.60 | 0.00 | 0.00 | 22.50 | 5.28 |
| 9 | Sample9 | 5.50 | 10.36 | 41.45 | 37.20 | 6.70 | 36.80 | 0.00 | 0.00 | 20.65 | 5.21 |
| 10 | Control1 | 3.78 | 1.14 | 18.90 | 16.95 | 0.00 | 15.40 | 0.00 | 0.00 | 5.60 | 7.75 |
| 11 | Control2 | 2.56 | 0.96 | 11.40 | 13.55 | 0.00 | 20.30 | 0.00 | 0.00 | 10.55 | 6.87 |
| 12 | Control3 | 3.20 | 1.38 | 18.45 | 14.85 | 0.00 | 20.45 | 0.00 | 0.00 | 11.95 | 5.21 |

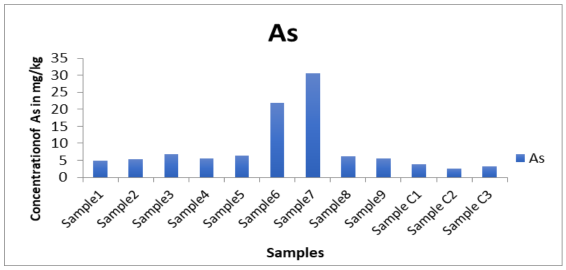

Figure 5: Concentration of Arsenics in Soil Samples

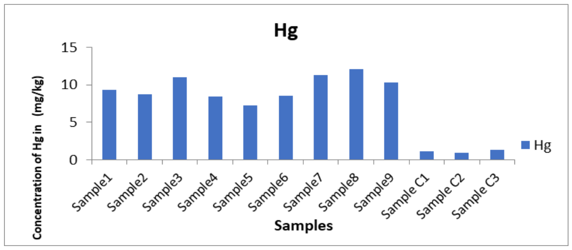

Figure 6: Concentration of Mercury in Soil Samples

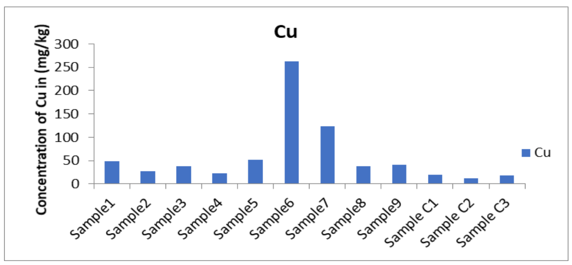

Figure 7: Concentration of Copper in Soil Samples

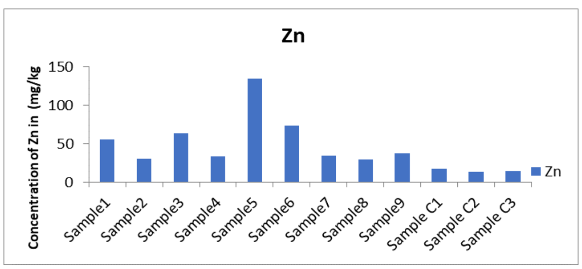

Figure 8: Concentration of Zinc in Soil Samples

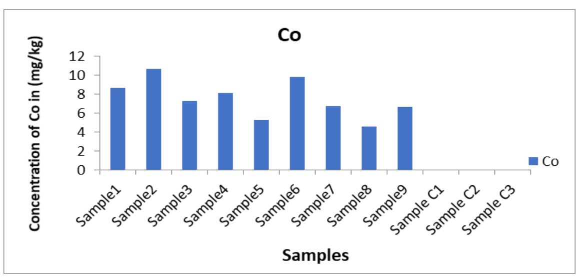

Figure 9: Concentration of Cobalt in Soil Samples

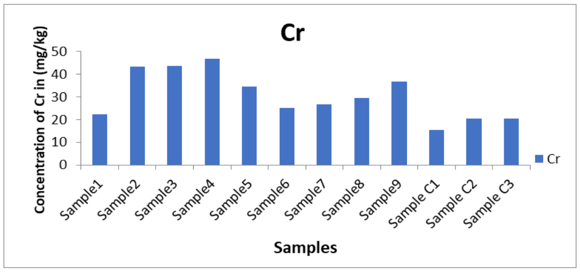


Figure 10: Concentration of Chromium in Soil Samples

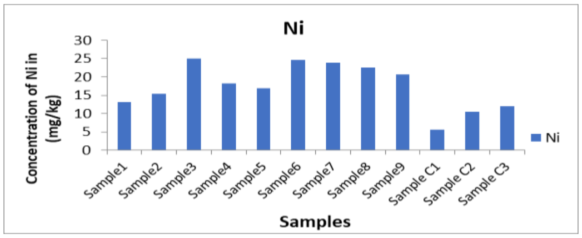


Figure 11: Concentration of Nickel in Soil Samples

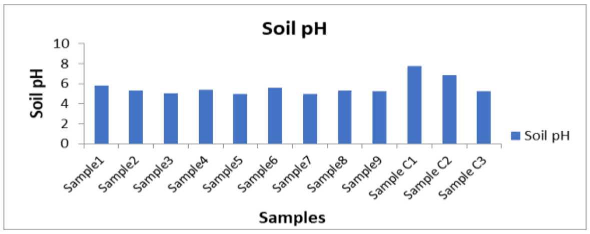


Figure 12: pH Level in Soil Samples

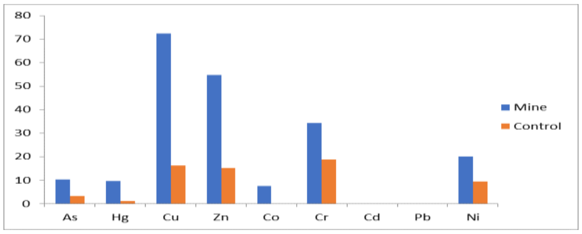


Figure 13: Heavy Metal Concentration in the Mining area vs Control Area

The concentration of Arsenic in the mining area varied between 4.86(sample 1) and 30.50 mg/kg(sample 7) Table 1, which is higher than the amount of As found in the unexploited control site which varied between 2.56 and 3.78 mg/kg. Hg concentration in the soil samples from the mining site varied between the range 7.30 (sample 5) and 12.10 mg/kg (sample 8), this is higher than the amount of Hg present in the unexploited area which varied between 0.96 and 1.38 mg/kg. The concentration of Cu varied between 22.50 (sample 4) and 262.00 mg/kg (sample 6) in the mining site, while it varied between 11.40 and 18.90 mg/kg in the unexploited area. Zn varied between 29.40 (sample 8) and 135.00 mg/kg (sample 5) in the mining site, and between 13.55 and 16.95 mg/kg in the unexploited site. Co varied between 4.55 (sample 8) and 10.70 mg/kg (sample 2) in the mining area, while it has zero concentration in the unexploited control site. Cr varied between 22.40 (sample 1) and 46.70 mg/kg (sample 4) in the mining site, while the amount of Cr present in the unexploited control varied between 15.40 and 20.45 mg/kg, and the concentration of Ni varied between 13.20 (sample 1) and 24.95 mg/kg (sample 3) in the mining area, while it varied between 5.60 and 11.95 mg/kg in the unexploited area. The results show that the heavy metals are highly concentrated in soils in the mining area than in the unexploited control sites (Figure 13). The average values in soils from mine were: As; 10.32 mg/kg, Hg; 9.69 mg/kg, Cu;72.46 mg/kg, Zn; 54.73 mg/kg, Co;7.54 mg/kg, Cr; 34.32 mg/kg, Cd; 0.00 mg/kg, Pb; 0.00 mg/kg, Ni; 20.06 mg/kg, while the average values in the unexploited control sites were: As; 3.18 mg/kg, Hg; 1.16

mg/kg, Cu;16.25 mg/kg, Zn;15.12 mg/kg, Co;0.00 mg/kg, Cr;18.72 mg/kg, Cd;0.00 mg/kg, Pb; 0.00 mg/kg, Ni; 9.37 mg/kg. This show that the mean values of the concentration of heavy metals in the mining site, is very high compare to the undisturbed or unexploited control site, this is also reflected in the Figures 5 to 11 and Table 1, with Copper (Cu) having the highest mean concentration (highest in samples 6 and 7, with concentrations of 262 mg/kg and 123.50 mg/kg respectively) and Concentrations of Cd and Pb were not detected in the soil samples. The metals follow a decreasing concentration order Cu > Zn > Cr > Ni >As > Hg > Co > Cd >Pb. Mining activities in artisanal mines involves digging and excavation which exposes sulphide minerals and metals bearing rocks to air thus releasing metallic ions to the soil and the environments leading to elevation concentration of heavy metals in the soil, the collective effects of the elevated concentration possess more risks to the ecosystem.

The result of the physiochemical properties of soil samples (Figure 12) revealed that the soil pH varied from 4.95 to 5.82 (mean 5.28) in the mining area, which shows the soil is acidic, and varied from 5.21 to 7.75 (mean 6.61) in the control sites, which imply that the pH of the soil in the mining area is more acidic. Soil acidity can be primarily attributed to oxidation of sulphide minerals, because oxidation of sulphides in organic matter in soils promotes mobility of the metals which decreases pH although local geology of an area would also play a significant role in soil acidity. The pH is regarded as an important chemical parameter that afffcet soil fertility, crop productivity and the bioavailability of heavy metals in soil. Soil acidity increases bioavailability of heavy metals which further increases soil toxicity because the acidic environment enhances further dissolution of metal ions and inhibit nutrient uptake hence fertile land can becomes nutrient-deficient due to soil acidity (Kochian et al. 2004; Alloway 2013; Brady and Weil, 2017).

## CONCLUSION

The artisanal gold mining site is characterized by higher concentrations of heavy metals with average values significantly higher than the concentrations of heavy metals in the samples from the control site. This shows that the mining activities have elevated the heavy metals concentration above pedogenic values and subsequently contaminated the immediate environment of the artisanal gold mining sites at Ijana Osun State South West Nigeria, this calls for urgent attention and adequate environmental regulations

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