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Determination of Heavy Metal Pollution in Soil Samples from Angwan Kawo Gold Mining Sites, Niger State, Nigeria

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Abstract- This present study involves the determination of heavy metal composition and its pollution levels in Angwan Maigero gold mining sites, Niger State Nigeria using Contamination Factor (CF), Pollution load Index (PLI), and Degree of Contamination (DC) Index. Samples were analyzed using Atomic Absorption Spectroscopy (AAS) to obtain their concentrations and composition. The study area was observed to be contaminated with Pb, Fe, Mn, Cu, Zn, As, Cr, Co, Ni, and Cd. The mean concentrations (ppm) of the heavy metals in the mine site was found to be 429.765, 1707.631, 181.614, 90.945, 37.412, 17.992, 93.187, 47.940, 22.282 and 3.232 respectively, Also the mean concentrations (ppm) of heavy metals in the mill tailing site was found to be 846.867, 1914.993, 177.703, 739.333, 100.405, 43.519, 163.284, 53.476, 45.591, 5.828. The highest concentration corresponds to Fe and the lowest corresponds to Cd. The increasing trend was in the order: Cd <As <Ni <Zn <Co <Cu <Cr <Mn<Pb<Fe. The concentrations of all the elements in the mill tailing sites were found to be higher than that obtained in the mine site with greater variation in relative abundance of most of the metals. These variations can be attributed to the variable dumping of tailings.

Keywords: *heavy metals; pollution; PLI; DC; CF; FAAS.*

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Strictly as per the compliance and regulations of:

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Abstract- This present study involves the determination of heavy metal composition and its pollution levels in Angwan Maigero gold mining sites, Niger State Nigeria using Contamination Factor (CF), Pollution load Index (PLI), and Degree of Contamination (DC) Index. Samples were analyzed using Atomic Absorption Spectroscopy (AAS) to obtain their concentrations and composition. The study area was observed to be contaminated with Pb, Fe, Mn, Cu, Zn, As, Cr, Co, Ni, and Cd. The mean concentrations (ppm) of the heavy metals in the mine site was found to be 429.765, 1707.631, 181.614, 90.945, 37.412, 17.992, 93.187, 47.940, 22.282 and 3.232 respectively, Also the mean concentrations (ppm) of heavy metals in the mill tailing site was found to be 846.867, 1914.993, 177.703, 739.333, 100.405, 43.519, 163.284, 53.476, 45.591, 5.828. The highest concentration corresponds to Fe and the lowest corresponds to Cd. The increasing trend was in the order: Cd <As <Ni <Zn <Co <Cu <Cr <Mn<Pb<Fe. The concentrations of all the elements in the mill tailing sites were found to be higher than that obtained in the mine site with greater variation in relative abundance of most of the metals. These variations can be attributed to the variable dumping of tailings.

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I. Introduction

Mining activities has been observed to be one of the major contributors of heavy metals in the environment. The effect of heavy metals on gold mining areas is of serious concern, as such threatens life in all forms (Esiole, *et al.*, 2016). Following the recent illegal mining in the country, that reared its ugly head once again in rural Rafi Local Government Area in Niger state with reports of numerous deaths of children and women from lead poisoning. The outbreak is traced as a result of the new illegal mining sites from where high leaded ores were brought home for crushing and processing by illegal miners (The sun, 15th May, 2015). Mining activities in AngwanMaigero has generated a lot of survival related activities such as petty trading, hard and conventional drug peddling and prostitution. These developments expose people in these groups to radiation from exposed radioactive rock surface, milling processes, mine tailings, and raised indoor radon level. All of these cumulatively are of grave danger to their health (Esiole, 2016). The pathway of the seasonal stream, where panning and sedimentation takes place is a potential source of radiation hazards. All users of the stream for agricultural and domestic purposes have a possibility of exposure by contamination from radionuclides in tailings and toxic elements or in dissolved stream water as well as ones taken up by plants (Esiole, 2016).

The seemingly non-existence of government impact in terms of provision of social services to the area, education of communal people on risks to health of the mining operation as well as other related matters that require government participation has serious integrating effects on possibilities of radiation absorption and impacts of toxic elements on these communal people (Esiole, 2016).Several analytical techniques have been extensively employed for the assessment of heavy metal pollution such as; Instrumental Neutron activation analysis (INAA) (Coskun, et al., 2006). X-ray Fluorescence analysis (XRF) (Ene, et al., 2009), Particle-induced x-ray emission (PIXE) (Ene, et al., 2010), Atomic Absorption spectrometry (AAS) (Al-Khashiman, 2009) and inductively coupled plasma spectrometry-Atomic Emission Spectroscopy (ICP-AES) (Popescu, et al., 2009). For the purpose of this present study, the analytical technique chosen to be used will be the Atomic Absorption Spectrophotometry (AAS).

The Knowledge of metal composition present in soil in a particular region would enable one to assess any possible health hazard to man and his environment, hence the present study is therefore aimed at establishing a base line data on the composition and concentration of the studied heavy metals and the possible health risk associated with the gold mining and ore processing activities in the area. Results of this study are important for assessment of the risk for human health, planning process and policy making in Nigeria.

II. Materials and Methods

a) Study Area

The study area is located between latitude 1001‘29‘‘N and 1001‘30‘‘N and longitude 60 28’ 30‘‘E to 6028‘31‘‘Ein Niger State of Nigeria. Two sites were selected to carry out the present study. The field

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measurement and sampling were made at the artisan mines. For the purpose of accuracy the positions were marked with a portable hand held global positioning system (GPS). The horizontal profile soil sampling strategy was chosen for the present study, since the mine site is a virgin site. A total of 49 samples were collected all together. After removal of stones and vegetable matter, each soil sample were packed into its own secure water-tight polythene bag in order to prevent cross contamination and was taken to the laboratory for analysis.

b) Sample Preparation and Analysis

Samples were each dried at ambient laboratory temperature. For one week, ground, sieved 2.0mm with the aid of spatula and weighing bottle. 0.5g of each soil/mill tailing sample was obtained. The digestion was carried out using concentrated nitric (10ml) and concentrated perchloric acids in the ratio of 2:1 and the oven was maintained at 200oC. After one hour, the mixture was allowed to cool before leaching the residue with 5cm3 to 20% HNO3. Digested samples were then filtered and made up to 100ml with de-ionized water. A blank determination was treated in the atomic Absorption spectrometer, but without sample. Solution of samples were taken and aspirated into Unicom 969 Atomic Absorption spectrometer for analyzing metals. At least one reagent blank and one duplicate sample were run as described above for background correction and to verify the precision of the method.

A calibration graph was plotted for each element using measured absorbance and the corresponding concentration. The calibration curve was used to determine the concentration of the metal.

Accuracy was however assessed by analyzing two replicates of certified reference materials, Recoveries were satisfactory, average value being in excess of 90% for Pb, Cu, Zn, As, Mn, Fe, Cd, Cr, Co, Mn and Ni analyzed.

c) Assessment of Heavy Metal Contamination

i. *The contamination factor (CF)*

The level of contamination of soil in metal is expressed in term of a contamination factor calculated as follows (Harikumar, *et al.*, 2009):

$$CF = \frac{C_m\, sample}{C_m\, Background} \quad (1)$$

Where C_m represent the metal concentration in sample and $C_m\ Background$ represent metal concentration. If the contamination factor (CF) < 1 refers to low contamination; $1 \le CF < 3$ means moderate contamination; $3 \le CF \le 6$ indicates considerable contamination and $CF > 6$ indicates very high contamination.

ii. *The Pollution Load Index (PLI)*

The pollution Load Index (PLI) is obtained as contamination factors (CF), the CF is the quotient obtained by dividing the concentration of the metal related to the target area by reference area. The PLI also provide comprehensive information about the metal toxicity in the respective samples. This method was developed by Tomlison (Tomlison, *et al.,* 1980). The PLI of the site are calculated by obtaining the n-root from the n-CFs that was obtained for all the metals as follows (Tomlison, *et al.,* 1980):

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots . \times CF_n)^{1/n} \quad (2)$$

Where n represent number of metals studied, CF represent contamination factor and PLI represent pollution load index.

The PLI value of >1 is polluted, where as <1 indicates no pollution (Harikumar, *et al.,* 2009).

iii. *Degree of contamination (DC)*

The degree of concentration (DC) of one determined area is the sum of all contamination factors.

$$DC = \sum CF \quad (3)$$

If $DC < 1$: indicates low concentration

$1 \le DC < 3$: Indicates moderates contamination

$3 \le DC < 6$: Indicates considerable contamination

$DC \ge 6$: Indicates Very high contamination (Hakanson, 1980)

III. Results And Discussion

a) Heavy Metal Concentrations

The mean concentrations in (ppm) of the heavy metals (Pb, Fe, Mn, Cu, Zn, As, Cr, Co, Ni, Cd) were analyzed for the mine, mill tailing and control samples respectively. Heavy metals were detected at varying concentrations in the samples. Table 1 presents the mean concentrations of the heavy metals in the mine, mill tailing and control sites with the WHO limit and its toxic response factor. The mean concentrations (ppm) of the studied heavy metals in mine site were calculated to be 429.76±26.202 1707.63±237.78, 181.61±82.38, 90.95±59.42, 37.41±33.30, 17.99±4.53, 93.19±47.39, 47.94±5.71 22.28±6.17, and 3.23±2.07 respectively. For the mill tailing site, the mean concentrations (ppm) of the heavy metals were calculated to be 846.87±100.27, 1914.99±89.06, 177.70±50.51, 739.33 ±337.57, 100.41±41.37, 43.52±7.97, 163.28±39.48, 53.48±2.79, 45.59±18.54, 5.83±0.48 respectively and for the control area, the mean and standard deviations of the concentrations of heavy metals were calculated to be21.40±6.11, 1331.00±142.75, 68.10±23.99, 35.72 ±16.45, 11.91±8.91, 5.73±2.71, 47.85±4.78, 18.17 ±5.65, 14.26±3.26, and 0.23±0.29 respectively.

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Table 1: Mean concentrations of the heavy metals in the mine, mill tailing and control sites with WHO recommended limits and its toxic response factor

Element	Control site	Mine site	Mill tailing site	Toxic response factor	WHO recommended limits
Pb	21.40	429.76	846.87	5.00	100.00
Fe	1331.45	1707.63	1914.99	N/A	N/A
Mn	68.10	181.61	177.70	N/A	N/A
Cu	35.72	90.95	739.33	5.00	30.00
Zn	11.91	37.41	100.41	1.00	300.00
As	5.73	17.99	43.52	10.00	N/A
Cr	47.85	93.19	163.28	2.00	100.00
Co	18.17	47.94	53.48	N/A	N/A
Ni	14.26	22.28	45.59	5.00	80.00
Cd	0.23	3.23	5.83	30.00	3.00

It can be observed from the mean concentrations calculated that the mean concentrations in the mill tailing site were higher than that in the mine site and control area for all of the observed heavy metals in the study area. The Highest concentration corresponds to Fe and the lowest corresponds to Cd. The increasing trend was in the order: Cd <As <Ni <Zn <Co <Cu <Cr <Mn<Pb<Fe. The concentrations of all the observed heavy metals in the mill tailing site were found to be higher than that obtained in the mine site and control area with greater variation in relative abundance of most of the heavy metals. These variations can be attributed to the variable dumping of the mill tailing deposits.

Comparing the results obtained from this study with the World Health Organization guideline on the maximum limits of toxic metals in the soils. Most of the observed heavy metals in the mine site and mill tailing site were observed to have concentrations above the WHO limit, while in the control area the concentrations were below the WHO limit. In the mine site, Pb was observed to have concentration 4 times higher than the recommended WHO limit, Co, was observed to have concentration 2 times higher than the recommended WHO limit, and Cd, was observed to have concentration 1.1 times higher than the recommended WHO limit while in the mill tailing site, Pb was observed to have concentration 8 times higher than the recommended WHO limit, Co, Cd, Ni and Cr were found to have concentrations about 2 times higher than the recommended WHO limit.

b) Contamination Factor (CF)

The contamination factor was used to assess the level of contamination of each element in the studied soils, based on the categories discussed in section 2.3.1, the elemental concentrations could be categorized as follows: in the mine site (i) Pb (14.94) and Cd (13.96) in the very high contamination category (ii) As (3.14) and Zn (3.14) in the considerable contamination category (iii) Mn (2.67), Cu (2.55), Co (2.64), Ni (1.56), Fe (1.28) and Cr (1.95) in the moderate contamination category and for the mill tailing site (i) Pb (39.58), Cu (20.70), Zn (8.43), As (7.61), and Cd (25.17) in the very high contamination category (ii) Cr (3.41) and Ni (3.20) in the considerable contamination category (iii) Fe (1.44), Mn (2.61), and Co (2.94) in the moderate contamination category.

c) Degree of Contamination (DC) and Pollution Load Index (PLI)

The degree of contamination and pollution index was used to assess the overall pollution level of the site resulting from the observed heavy metals. The pollution load index results indicate that the mine site was contaminated with all the observed heavy metals (mean PLI=2.71) and also the pollution load index results indicate that the mill tailing site was contaminated with all the observed heavy metals (mean PLI=5.78). The results of the degree of contamination index indicated that the mine site is in a very high degree of contamination (Mean DC=47.84) and also (Mean DC=115.088) for the mill tailing site respectively as described in sections 2.3.2 and 2.3.3.

IV. Conclusion

Determination of heavy metal pollution of soil and mill tailing samples from the AngwanKawo has been carried out using contamination factor, pollution load index and degree of contamination index. Flame Atomic Absorption Spectrometry (FAAS) were used to obtain their concentrations. The study area was observed to be contaminated with Pb, Fe, Mn, Cu, Zn, As, Cr, Co, Ni, and Cd. These heavy metals have been proved to be toxic to human health. Owing to their possible bioaccumulation, it is advisable that these sites should be subject to mandatory monitoring. Based on the findings of this study, the obtained result showed that the mine and mill tailing sites are seriously accumulated with heavy toxic metals, some of which were found to have high concentration above the WHO worldwide threshold limit. These heavy metals are thus terribly alarming and can cause serious environmental problems in the ecosystem of the area. Hence, it is suggested that these sites should be monitored for health related problems so as to minimize the extent of the accumulated pollution level in the area.

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