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ASSESSMENT OF LEAD, MERCURY AND ARSENIC IN SOILS OF ANKA AREA, NORTH WESTERN NIGERIA

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Abstract: The study area lies precisely between longitude $5^0$48'E and $6^0$00'E and latitude $11^0$58'N and $12^0$15'N and the concentration of Pb, Hg and As were studied in soils of the area. The aim of this study was to determine the extent to which gold mining and the use of mercury for its processing has led to the contamination of the soils with Pb Hg and As. The assessment of the contamination of the soils was based on the geoaccumulation index (Igeo) and Enrichment Factor (EF); the Igeo gives a quantitative extent of accumulation of the metal with respect to the quality of medium analyzed while the Enrichment Factor is used to differentiate between metals originating from anthropogenic activities and those from natural processes. A total of twenty four (24) soil samples were collected and analyzed using the Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). The data revealed that the soils in the study area are significantly contaminated, showing high level of toxic elements than normal distribution. The ranges of concentration are: Pb (6.91-4157ppm), As (7.43-173.2ppm) and Hg (2.15-12.92ppm), This research therefore underscores the continued and urgent need of high-quality investigation of lead exposure in regions where health is poor and where no data currently exist.

Keywords: Geoaccumolation index, Enrichment Factor, Anka, North-Western Nigeria.

ITRODUCTION

The study area fall within Anka sheet 52SE and part of Maru sheet 53SW, precisely between longitude 5°48'E and 6°00'E and latitude 11°58'N and 12°15'N (Fig. 1). It is made up of five localities namely, Dareta, Bagega, Sunke, Abare and Yargalma.

The Anka Schist belt known for its good mineralization (Ogezi, 1977) has attracted artisanal and small scale miners. The Gold ore dumps (tailings) are the source of many heavy elements such as Cd, Pb, Zn, Cu, As, Se and Hg. Many artisans employed the services of their children and their wives, so the ore is brought home from the mines, crushed, ground, washed and finally mercury amalgamation process is used to separate the gold from sand and other materials. These miners work in difficult and often very hazardous conditions, ignorant of any safe mining knowledge or any regulations, (Appendix Plate 1&2).

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This study is essential in view of the impact of these mining activities which has lead to the contamination of the soil, surface and underground water and subsequently the death of many children under the age of five. The poisonous substance was mostly ingested through inhalation of dust coming from grinding or ingested through contamination of the soil, drinking water, eating compromised food or from touching mining equipment.

Soil contamination has become a serious problem in many industrialized and developing countries. Soil is considered as contaminated when chemicals are present or other alterations have been made to its natural environment (Marchender, 2010). These chemicals in the terrestrial environment clearly pose a significant risk to the quality of soil, plant, natural waters and human health (Adriano, 2001; USEPA 2003; WHO, 2004). Mining, smelting and other associated activities are one of the important sources by which soil, plants and surface waters are contaminated (Jung, 2008).

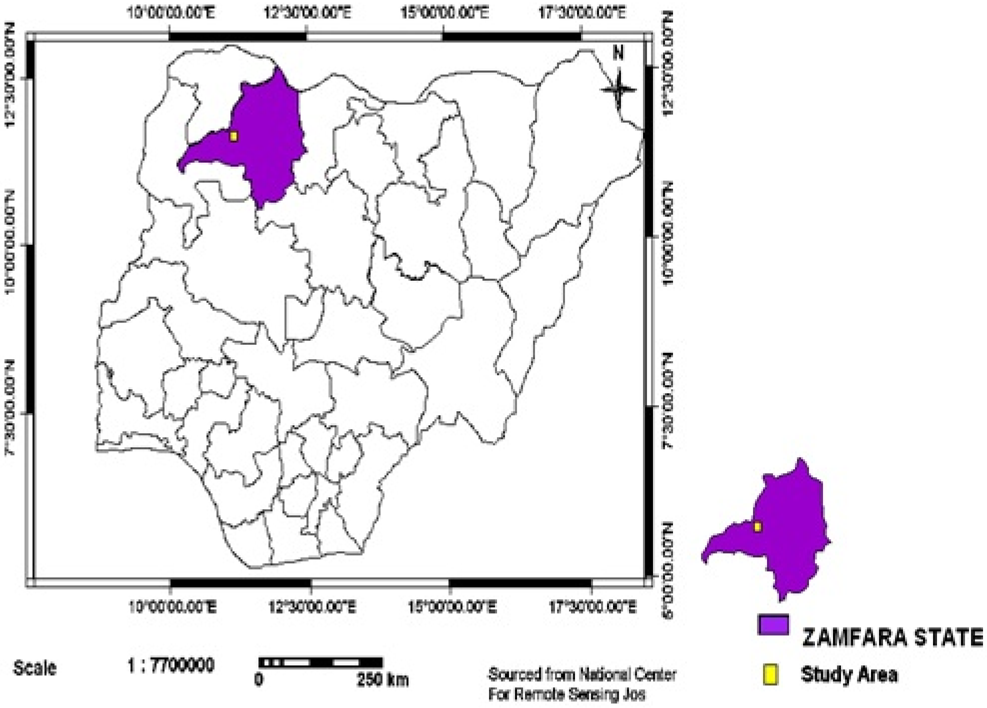

Figure 1: Map of Nigeria showing the study area in Zamfara State. (Source: NCRS, 2011).

MATERIALS AND METHODS

A total of twenty four (24) soil samples were collected from the area in a clean polythene bags to avoid contamination. Gamin Trex GPS was used to locate each sample point by recording the coordinates, (Fig.2). At each sampling point, the surface of the soil was cleared of vegetation and each sample was taken at a depth of 0-20cm with a hand auger, from five villages namely Bagega, Dareta, Yalgama, Sunke and Abare. Soils collected were from the mining site, processing area, farmland and village square. The samples were well labeled and dried to avoid moisture content. Soil samples were analyzed using the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) at the Geochemistry laboratory of Geology and Mining Department, University of Jos, Nigeria, in other to assess the level of soil contamination with respect to average concentration of toxic elements in the area. The Index of geo-accumulation (Igeo), and anthropogenic (enrichment) factor (AF), were determined, (Table4).

Igeo = $\log_2[C_m/(1.5xB_m)]$; AF = C_m/B_m

Where C_m is the measured concentration and B_m is the background concentration; the background values for Pb, Hg and As are 1-200, 0.056 and 7.5 ppm respectively, (Levinson, 1974).

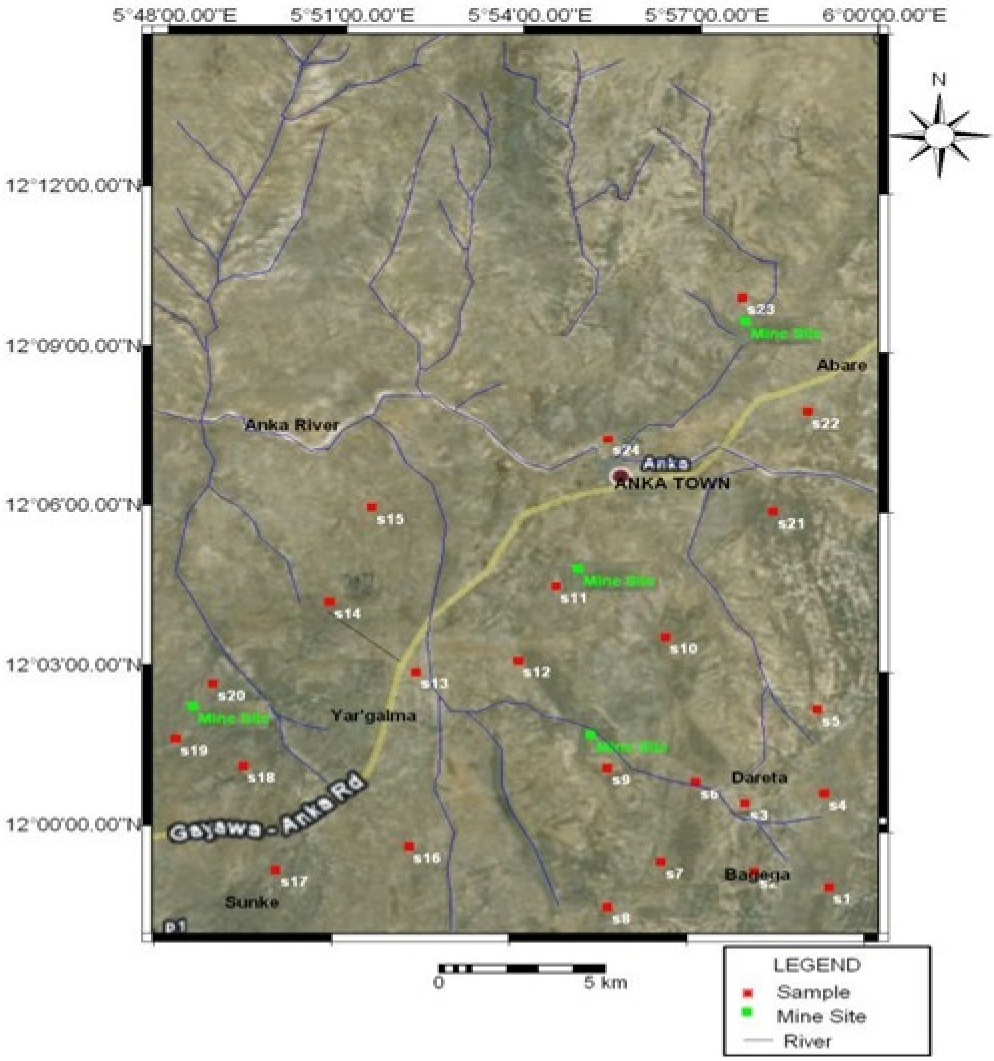

Fig. 2: Sample Location map of the study area

RESULTS AND DISCUSSION

The interpretation of the geochemical data was based on the geoaccumulation index Igeo and the Enrichment Factor (EF). The geoaccumulation index gives a quantitative contamination class with respect to the quality of medium analyzed while the Enrichment Factor is used to differentiate between metals originating from anthropogenic activities and those from natural processes, (Tables 2&3).

Summary of results of the soils from mining sites, processing sites, village squares, farmlands and uncultivated land are presented in Table 1 and figures 3&4.

Table 1: Concentration of Pb, Hg and As (ppm) in Soil Samples.

Samples	As	Hg	Pb	Samples	As	Hg	Pb
S9	98.03	2.84	1946	S13	27.14	2.985	289.7
S11	99.17	4.448	1218	S17	110.4	12.325	3326
S20	97.9	7.931	2637	S22	16.5	4.149	19.57
S23	63.78	6.288	1146	S4	38.2	3.892	30.26
S6	82.41	7.38	1740	S5	59.56	5.887	463.2
S10	127.2	9.011	3193	S7	24.05	2.153	25.73
S12	100.6	10.277	3920	S14	24.7	3.938	19.8
S18	85.37	7.399	1694	S15	96.91	10.231	2892
S19	84.31	8.388	1960	S1	7.434	3.449	6.909
S24	173.2	12.924	4152	S8	23.44	2.188	20.6
S2	124.2	5.481	1432	S16	98.57	6.367	770.3
S3	12.49	4.577	17.36	S21	55.97	5.733	447.4

Table 2: Contamination categories recognized on the basis of the enrichment factor, (after Sutherland, 2000).

Enrichment factor	Category
AF<2	Deficiency to mineral enrichment
AF>2-5	Moderate enrichment
AF>5-20	Significant enrichment
AF>20-40	Very high enrichment
AF>40	Extremely high enrichment

Table 3: Six classes of the Geoaccumulation Index, (after Muller, 1981)

Class	Value	Soil Quality
0	Igeo<0	Practically uncontaminated
1	0<Igeo<1	Uncontaminated to moderately contaminated
2	1<Igeo<2	moderately contaminated
3	2<Igeo<3	moderately to heavily contaminated
4	3<Igeo<4	heavily contaminated
5	4<Igeo<5	heavily to extremely contaminated
6	5<Igeo	Extremely contaminated

Table 4: Indices of Geoaccumulation and Enrichment factor for soil samples in Anka area

Samples	As	Hg	Pb	As	Hg	Pb
	Index of Geoaccumulation (Igeo)			Enrichment (Anthropogenic) Factor		
S1	-0.60	5.36	-1.88	1.22	77.05	0.50
S2	3.46	6.03	5.81	3.52	20.80	17.90
S3	0.15	5.77	-0.55	5.82	285.82	3.57
S4	1.76	5.53	0.25	4.59	101.92	1.60
S5	2.40	6.13	4.18	4.22	95.39	14.48
S6	2.87	6.46	6.09	5.09	93.03	47.40
S7	1.10	4.68	0.01	8.45	101.37	3.99
S8	1.06	4.70	-0.31	7.66	93.80	2.97
S9	3.12	5.08	6.97	3.67	14.24	52.72
S10	3.50	6.75	-0.39	23.59	498.18	1.59
S11	3.14	5.73	5.58	2.89	17.36	15.66
S12	3.16	6.93	7.26	9.05	269.05	155.65
S13	1.27	5.15	3.51	4.23	61.97	19.93
S14	1.13	5.55	-0.36	4.31	89.78	1.53
S15	3.11	6.93	6.83	3.25	86.78	42.72
S16	3.13	6.24	4.92	9.69	83.57	33.42
S17	3.29	7.20	7.03	12.75	335.55	169.50

S18	2.92	6.46	6.05	2.47	59.47	21.62
S19	2.91	6.64	6.26	3.38	92.60	34.62
S20	3.12	6.56	6.69	7.11	159.23	84.54
S21	2.31	6.09	4.13	2.07	43.22	7.31
S22	0.55	5.63	-0.38	2.24	75.53	1.17
S23	2.50	6.23	5.49	5.28	76.88	41.83
S24	3.94	7.27	7.35	16.90	376.18	178.77

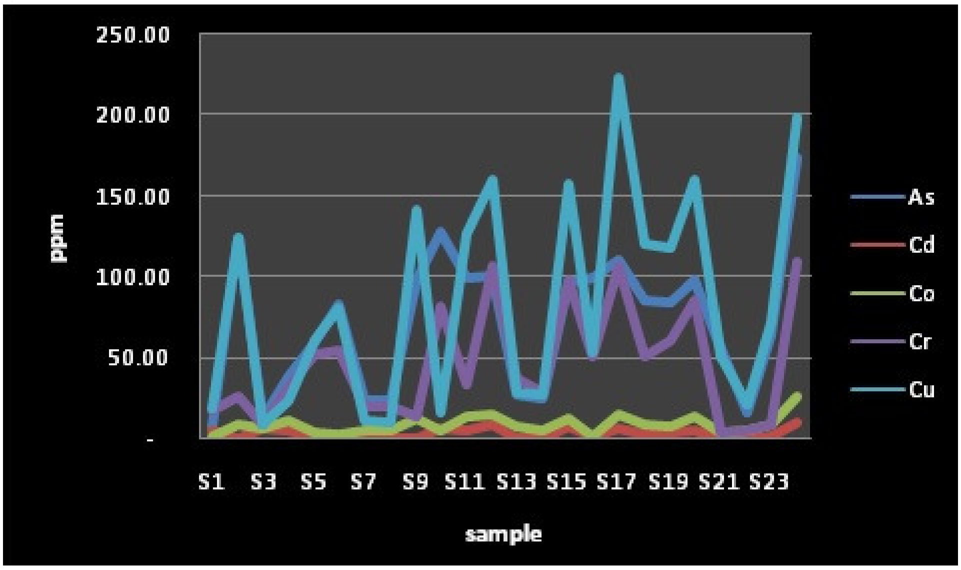

Fig.3: Concentration of As,Cd,Co,Cr,and Cu (ppm) in soil samples.

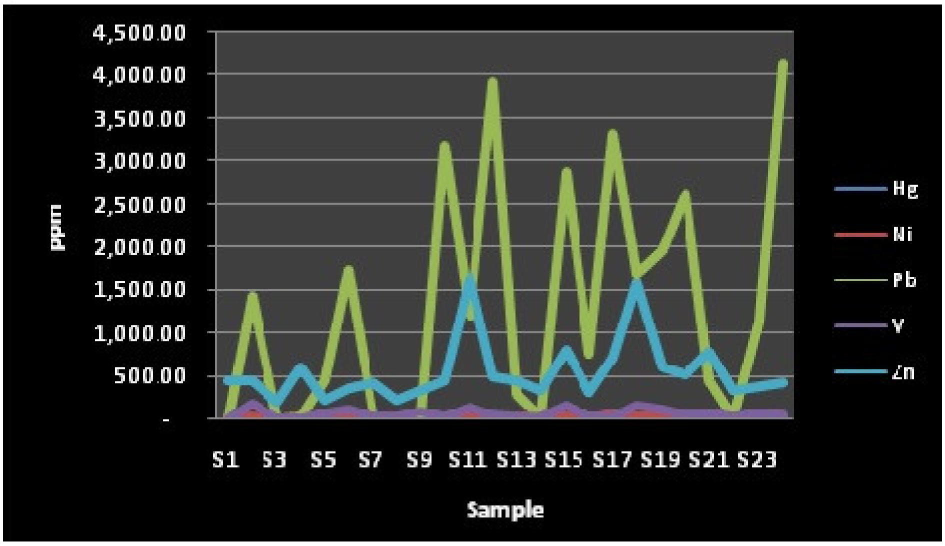

Fig.4: Concentration of Hg,Ni,Pb,V and Zn (ppm) in soil samples.

The result of analyses for Pb, As and Hg in soils from the study area is shown in Table 1. The range of concentration of Pb in the samples is from 6.91 to 4152.00 ppm, with a mean of 1171.43ppm. The maximum concentration is 4152.00.00 ppm, and is recorded at processing site around Anka town. As concentration in soils ranges from 7.43 to 173.20ppm with mean of 72.14ppm. The maximum and minimum concentrations are Anka processing site and uncultivated land around Bagega village respectively. The concentration of Hg varies from 2.15ppm in Bagega to 12.92ppm in Anka processing site with a mean of 6.25ppm.

With respect to the index of geoaccummulation (Igeo), Arsenic from the analyzed samples fall into three category of contamination which are: moderate (20%), moderate-heavy (25%) and heavy (41.7%) contamination respectively. Mercury shows two category of heavy-extreme (8.3%) and extreme (91.7) contamination respectively. Lead on the other hand shows three category of heavy (4%), heavy-extreme (12.5%) and extreme (50%) contamination respectively.

On the index of enrichment factor, Arsenic fall into three category of moderate (50%), significant (41.7%), and very high (4%) enrichment respectively. Mercury also fall into three category of significant (4%), very high (4%) and extremely high (87.5%) enrichment respectively. Lead on the other hand fall into four category of moderate (25%), significant (20%), very high (12.5%) and extremely high (50%) enrichment respectively.

Heavy metal content of soil is of major significance in relation to their fertility and nutrient status. Many metals such as Zn, Cu, Fe and Sr are essential for normal growth of plants and living organism. However, high concentrations of these metals become toxic. Other metals which are not included in the group of essential elements such as Pb and Cr etc. may be tolerated by the ecosystem in low concentration but become harmful in higher concentration (Alloway and Ayres, (1997), Nriagu, (1988)).

Soil serves as bridge between the environment and life (Mason, 1976). It supports agricultural activities and plants take their nutrients from soil and have a way of accumulating even elements they do not need if the element is highly concentrated where they grow. Excess toxic elements in the soil through a process of bioaccumulation and the food chain can produce adverse effects in man leading to sickness or organ malfunction (West et al., 1966). The high concentrations observed in soil samples probably stemmed from several sources which include geological weathering, artisanal mining and processing activities, leaching of metals from garbage and solid waste dumps as well as animal and human excretions which contain heavy metals.

SUMMARY AND CONCLUSION

Anka area is extremely contaminated with Pb, Hg, As and other potentially harmful elements due to many years of unprofessional and illegal gold mining activities and the use of mercury for gold recovery. The united Nation Industrial Development Organization (UNIDO) estimates that as much as 95-100% of mercury used in artisanal mining is released into the environment constituting a danger in all fronts: economic, environmental and most tragically human health. Data from household survey (UNICEF, 2011) from two villages (Dareta and Yargalma) in Anka area indicated that about 66% of household in the villages undertook at least one mining activity within their compound. These mining activities includes, breaking of the ore, grinding ,washing, drying, extracting gold with mercury and/or melting gold.

The results of the study show the impact of anthropogenic activities on abundance of potentially harmful elements in soils of the area. The Igeo for Pb ,Hg, and As indicates extreme contamination in places. The Enrichment factor (EF) also indicates that there is extremely high enrichment of the soil by Pb, Hg and As.

It could be stated that generally, artesanal mining activities cause a more accelerated release of trace element into an environment. The enhanced toxic element concentrations in the soil in the Anka area could be linked to base metal mineralization and mining, as well as agricultural practices through the use of fertilizer and insecticides. Pb, Hg and As can, through the food chain interfere with normal metabolic functions in man causing catastrophic human experiences. Direct or indirect exposure of human and/or animals to these potentially harmful elements overtime predisposes them to various health complications, severe damage of biological tissues, epidemics, disease such as cancer, skin disease, neurological problems, malfunction of several vital organs and probable death.

Appendix

Plate 1: A gold mining pit in Anka area

Plate 2: Processing and extraction of gold by artesanal miners

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