Environmental Impact of Artisanal Gold Mining on Soils in Saigbe and Environs, Part of Minna Sheet 164, North-Central Nigeria

Omanayin, Y. A.*, Abdurrahman, R., Akande, W. G., Mamodu, A., Alkali, Y. B., and Alabi, A. A.

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

*Corresponding author: o.adinoyi@futminna.edu.ng

Abstract

The environmental geochemistry of soils from Saigbe and environs, Minna, North-central Nigeria was studied with the aim of assessing the impacts of artisanal gold mining activity in Saigbe and environs. Geological fieldwork carried out in the area revealed that the underlying lithologies include schist, granite and amphibolite. A geochemical soil survey was also carried out and a total number of twenty (20) soil samples were systematically collected from both mined and unmined sites within the study area, of which eight (8) representative samples were geochemically analysed. Elemental concentrations (major and trace elements) in the soil samples were determined using X-Ray Fluorescence (XRF) technique. The physical impacts observed during fieldwork include loss of vegetation, land degradation, water pollution and abandoned pits. The average concentrations of the elements determined were compared with the published upper crustal abundance of the individual elements and subsequently their enrichment ratios were computed. Elements such as Ag, Au and Hg show high enrichment with 1.81 ppm, 0.03 ppm and 0.11 ppm concentrations respectively. The result from accumulation index (*Igeo*) also shows possible Hg contamination. This potentially toxic element can cause serious damage to the skin, nervous and digestive systems in man through direct or indirect consumption.

Keywords: Contamination, Geochemistry, Human Health, Land Degradation, Saigbe

1. Introduction

Mining is the extraction of mineral resources that occur naturally in the Earth such as gold, coal, cassiterite, gemstones and so on for the production and supply of raw materials needed for construction of social amenities in urban communities in developing nations (Ahmed *et al.,* 2016). Artisanal and Small Scale Mining (ASMs) refers to the mining activities carried out by individuals, groups or communities using simple and menial tools in developing nations to exploit minerals. Gold has always been depicted as a symbol of success among other characteristics it has (Smith, 2016). In order to win gold, the activities of panning in rivers and streams, development of underground workings, small scale processing plants as well as industrial mines have evolved. Artisanal gold mining as a process of exploiting for gold using rudimentary tools have been part of the socio-economic sector for the rural poor in many developing nations (Omanayin *et al.,* 2016).

Globally, the consequences of artisanal and small-scale mining are as important as large-scale mining activities. Some of these are large influx of population, change in level of natural and cummunity resources, potential effect on health, conflict generation, creation of employment, child and human labour (Roland, 2011). There are about 80 to 100 million people that globally depend directly or indirectly on this form of informal mineral resource exploitation as a means of survival (Gunson *et al.,* 2004). In some developing countries, the production of ASMs may even equal or exceed the production of large-scale mines (Hentschel *et al.,* 2002). It employs

about ten times as many people that work in industry mines, generally constituting workers who are not eligible for employment in industrial mining due to lack of formal education and experience (Bender, 2017). However, the repercussions of this method of exploitation can be devastating on the health of the artisans and the inhabitants of the mining area as well as surrounding communities leading to loss of vegetation, soil degradation and erosion as a result of engrained digging of the soils. In an attempt to assess some of these effects often associated with artisanal gold mining, this work focuses on the geochemical investigation of soils from the Saigbe artisanal gold mining in part of North-central Nigeria.

2. Location and Geological Setting

Saigbe is situated in Bosso Local Government Area of Niger State and it falls within South-western part of Minna Sheet 164 (Figure 1). It is bounded between the coordinates of Latitudes 6º33'30"N and 6º36'30"N; and Longitudes 9º45'00"E and 9º42'00"E, covering a total area of approximately 32 km^2. The study area is linked by several minor roads and a secondary road, and footpaths which made accessibility to the study area easy. Other neighbouring villages around the study area include Pawo, Shipada, Shipana and Dangwani.

Saigbe and its environ lies within the Precambrian basement rocks of central Nigeria. These basement rocks form part of the extensive Pan-African Province of West Africa and are bordered in the east by the Congo Craton and in the west by the West African Craton (Turner, 1983). On the basis of geochronology and lithological associations, the Nigerian basement rocks consist of Migmatite-Gneiss-Quartzite complex, Schist belts, Older Granite suites. The Migmatite-gneissic–quartzite complex is dated Archean to Early Proterozoic (2700 – 2000 Ma). The low grade schist consists of the NE-SW trending belts mainly advanced within the western half of the country and the granitoid plutons of the Older Granite suite dated Late Proterozoic to Early Phanerozoic (750 – 450 Ma). These schist belts, especially the western half have been studied extensively and established to serve as hosts to gold mineralization amongst others (Turner, 1983; Ajibade *et al*., 1987; Garba, 2000; 2003 and Obaje, 2009).
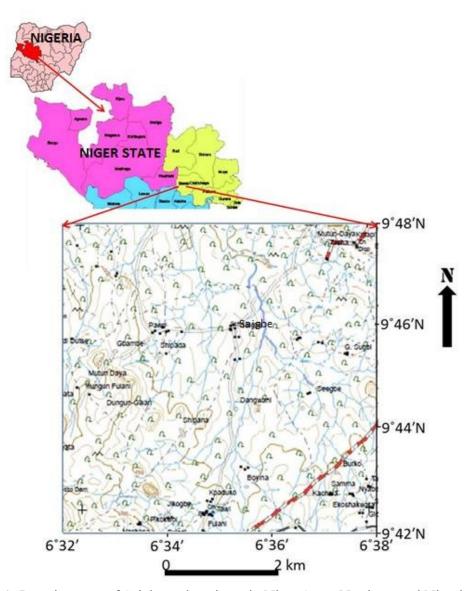
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Figure 1: Location map of Saigbe and environs in Niger State, North-central Nigeria.

3. Materials and Methods

The methods employed in this study include fieldwork during which soil samples were collected, physical impacts were observed, and laboratory work in which representative soil samples collected from the study area were analysed for their elemental contents.

3.1 Fieldwork

Systematic geologic mapping was done on a scale of 1: 25000. The soil samples were collected within the boundaries of the study area. The various rock types were mapped using traverse method while the soil samples were collected using grid-controlled method. The locations where the rock outcropped and soil samples collected were established on the map using Global Positioning System (GPS). Different lithologic units within the perimeter of the study area were closely observed and described in hand specimen with regards to their colour, texture and mineralogy. Soil samples were collected from both mined and un-mined areas, within the

mining site with the aid of hand trowel between 0 cm to 15 cm depth and their characteristics recorded *in situ* on the field notebook. A total of twenty soil samples were collected; four from mined site and sixteen from un-mined area. Eight representative soil samples were geochemically analysed using X-ray fluorescence analytical technique.

In the course of fieldwork, the whole mining site was evaluated in order to assess the level of physical damages the gold mining activity has incurred on the environment. This was made particularly on the agricultural land use since that is the major occupation of the inhabitants of the area.

3.2 Laboratory Work

3.2.1 Sample Preparation

Sample preparation for chemical analysis was carried out on eight representative soil samples out of the twenty samples collected from the field. It was partly done in the Engineering Laboratory of the Department of Geology, Federal University of Technology, Minna where the samples were first sun-dried under dust-free condition for about 24 hours in order to remove the moisture. 1000 grams of each of the selected samples was disaggregated or crushed using porcelain mortar and pestle and sieved using a stack of sieves of different mesh sizes to obtain minus 2 mm fraction. About 500 g of the minus 2 mm fraction each of the samples was sent to the National Geosciences Research Laboratories, Kaduna, Nigeria where further preparation was carried out on them. At the Laboratory, glass beads and powdered pellets were prepared for major oxides and trace elements geochemical analyses. For the glass beads, 75 μm fraction of each of the representative soil samples was mixed with a flux in a flux/sample ratio of 5:1 to 10:1 and heated to $90^{\circ}C - 100^{\circ}C$ in a platinum crucible. The sample was then dissolved in the flux using lithium tetraborate caste in a mould with a flat bottom and resultant glass/fused beads of each representative soil sample were produced. Powdered pellets were produced for each of the soil samples by weighing 5 g of the pulverised sample into a beaker and addition of 1 g of binding agent (starch and soluble). The mixture was thoroughly mixed to ensure homogeneity which was later pressed under high pressure (6 'tonnes') to produce pellets; labelled and packaged for analysis.

3.2.2 X-Ray Fluorescence Spectrometry Analysis of Soils

The prepared glass beads and powdered pellets of the soil samples were analysed for their major oxides and trace elements respectively using Energy Dispersive X-ray Fluorescence (EDXRF) spectrometer of model "Minipal-4" software machine. The current used were 14 kV and 20 kV, and selected filters were Kapton and Ag/Al thin, for major and trace elements respectively. The filters were selected based on a guided periodic table for elemental determination. The prepared glass beads and pellets from each of the samples were placed in each position on a sample changer of the machine and the spinner with the sample changer enables batches of samples to be processed fully and automatically. The mean concentration of each element in the samples was compared to Wedepohl (1995) and Rudnick and Goa (2003) average concentrations of elements in upper continental crust. Values that correspond or fall below the expected limit were accepted as safe while values above the limits indicate very high

concentrations of such elements in the soil which can cause serious environmental problems to plants and animals.

4. Results and Discussion
4.1 Lithology and Field Relations

Saigbe and environs is mainly underlain by three Precambrian rocks. These include the schist, granite and amphibolite (Plate 1). The schist occurred as a low-lying outcrop and it is light coloured, medium to coarse-grained in texture and fairly weathered, and occupied 60% of the study area. Mineralogical compositions in hand specimen include quartz, feldspar and mica. The rock generally trend in NE - SW direction with a dip angle ranging between 25º - 35º E. There are presence of joints which are filled with quartz and quartzo-feldspathic veins. The granites, second in term of areal extent (32%) intruded the schist. Granite is prominent towards the north-western part of the area. They are leucocratic to melanocratic in colour, fine to coarse-grained in texture, consist of quartz, feldspar, muscovite and other dark minerals in trace amount. They are highly jointed and faulted, and this serves as an evidence of deformational processes in the area. The Amphibolite occurs mainly in the north-eastern part of the area, clearly along the main River Saigbe which is believed to have been structurally controlled. The amphibolite are medium to coarse-grained in texture, weakly foliated and dark in colour which may be due to the presence of hornblende and plagioclase minerals. It occupied the remaining 8% of the whole area studied. Summary of the soil samples and their characteristics as obtained from Saigbe area is presented in Table 1.

Plate 1: (a) A slightly weathered schist showing schistosity (b) Granite outcrop with fault (c) Weakly foliated amphibolite.

Table 1: Summary of the physical features of the soil samples collected from the study area.

Sample No.	Latitude (N)	Longitude (E)	Moisture Content	Colour	Texture	Elevation (m) Above sea level	Lithology	Location Name
1	9º 44′ 17.4″	6º 35′ 44.8″	Damp	Dark	Fine	258	Amphibolite	Saigbe
2	9º 44′ 29.8″	6º 35′ 30.0″	Damp	Light Brown	Not Sorted	256	Granite	Saigbe
3	9º 44′ 32.7″	6º 35′ 29.4″	Damp	Light	Not Sorted	256	Schist	Saigbe
4	9º 44′ 39.0″	6º 35′ 32.4″	Damp	Light	Not Sorted	263	Schist	Saigbe
5	9º 44′ 37.5″	6º 36′ 07.5″	Dry	Light Brown Reddish	Not Sorted	270	Schist	Saigbe
6	9º 44′ 37.5″	6º 35′ 22.5″	Dry	Brown	Not Sorted	263	Granite	Saigbe
7	9º 44′ 37.5″	6º 34′ 37.5″	Wet	Brown	Medium Grained	266	Granite	Saigbe
8	9º 44′ 37.5″	6º 33′ 52.5″	Dry	Light	Not Sorted	292	Granite	Pawo
9	9º 43′ 52.5″	6º 33′ 52.5″	Dry	Dark	Not Sorted	293	Granite	Pawo
10	9º 43′ 52.5″	6º 34′ 37.5″	Dry	Light	Fine Grained	271	Granite	Saigbe
11	9º 43′ 52.5″	6º 35′ 22.5″	Dry	Light	Not Sorted	284	Granite	Saigbe
12	9º 43′ 52.5″	6º 36′ 07.5″	Dry	Dark	Not Sorted	286	Schist	Saigbe
13	9º 43′ 07.5″	6º 36′ 07.5″	Dry	Dark	Not Sorted	281	Schist	Saigbe
14	9º 43′ 07.5″	6º 35′ 22.5″	Dry	Light	Not Sorted	298	Schist	Saigbe
15	9º 43′ 07.5″	6º 34′ 37.5″	Wet	Light	Not Sorted	278	Schist	Shipada
16	9º 43′ 07.5″	6º 33′ 52.5″	Dry	Dark	Not Sorted	296	Granite	Shipada
17	9º 42′ 22.5″	6º 33′ 52.5″	Dry	Dark Reddish	Not Sorted	280	Pegmatite	Dungun-Gwari
18	9º 42′ 22.5″	6º 34′ 37.5″	Dry	Brown	Not Sorted	301	Schist	Shipada
19	9º 42′ 22.5″	6º 35′ 22.5″	Dry	Light	Not Sorted	290	Schist	Dangwani
20	9º 42′ 22.5″	6º 36′ 07.5″	Dry	Dark	Not Sorted	296	Schist	Dangwani

Artisanal mining activities are difficult to be monitored and therefore are detrimental to the environment, health of the operators and the inhabitants in the community. Field observations indicated that artisanal gold mining has resulted in lots of physical environmental degradation on the area of study. One of the numerous effects of artisanal gold mining in the study area is the destruction of the original landscape as a result of excavation. The heaps of rock and tailings generated during gold mining activity cannot easily be disposed of and hence constitute source of environmental impact (Plate 2a).

Plate 2: (a) Land degradation due to excavation during mining (b) Loss of vegetation and development of erosion features due to mining in Saigbe.

Also, mining activity has instigated the clearing of site which has been responsible for the removal of vast quantity of surface vegetation. The gold mining activity in the area has led to the destruction of vegetation, expose the soil to erosion and makes it unfertile for crop cultivation (Plate 2b). Tolulope (2004) reported a similar case of vegetation loss particularly in the Niger Delta areas where oil spillage has equally affected the growth of vegetation. Abandoned pits that have been left un-reclaimed now serve as death-traps for livestock and human beings especially when filled with water (Plate 3a). Reptiles are also forced to finding shelter in these pits because their habitats were destroyed during the gold exploitation. Artisanal mining of barytes in Azara area of Nasarawa State was reported to have destroyed more than 1000 hectares of arable farmlands and flooding of abandoned pits that have become dangerous traps (Salati *et al*., 2011). Potable water must be tasteless, odourless and colourless. Water along the river channels used for gold processing is observed to have been contaminated due to increase in heavy load from mine waste and rock dumps from the mine pits within the study area. This is evident in the discolouration of the water from processing areas (Plate 3b). The panning along the rivers or streams during gold processing generally pose risk on human health and environment because the river is the major source of water for the villagers that surround it.

Plate 3: (a) An abandoned open pit (b) Contamination of water along the stream due to gold processing.

4.2 Geochemistry of the Soil Samples

Table 2 presents the results of the concentrations of major and trace elements and organic matter composition for the analysed soil samples from Saigbe area of North-central Nigeria. The table shows the results of this work along with the crustal averages by Wedepohl (1995) and Rudnick and Goa (2003).

In Table 2a, alumina (Al_2O_3) has a mean concentration value of 10.89 wt.% which is low when compared with the published crustal abundances of 15.04 ppm and 15.40 ppm by Wedepohl (1995) and Rudnick and Goa (2003) respectively. The presence of alumina in the soil samples is as a result of chemical weathering of aluminosilicate mineral (residual clay minerals) compositions in the surrounding basement rocks such as feldspars ($XAlSi_3O_8$, X= K, Ca or Na) and micas. Silica (SiO_2) has an average concentration value 65.94 wt.% which is high compared to Wedepohl (1995) and low compared to Rudnick and Goa (2003). The SiO_2 concentrations in the samples indicate granitic composition of the surrounding rocks. Potassium oxide (K_2O) in the soil samples has a mean value of 1.93 wt.%, this value is low when compared to Wedepohl (1995) and Rudnick and Goa (2003). The presence of K_2O in the soil samples showed that clay minerals are present due to the weathering of feldspar in the country rock.

The values of CaO, MgO and Na_2O are considerably low in all the samples compared with Wedepohl (1995), and Rudnick and Goa (2003). Titanium oxide (TiO_2) has very high average concentration (3.05 wt.%) when compared with both Wedepohl (1995) and Rudnick and Goa (2003). TiO_2 might indicate an unusual amount of rutile, ilmenite or sphene since they are usually found in igneous rocks and sediments that formed from them. This high TiO_2 concentration was recorded in area underlain by granite with pegmatite intrusion. The mean concentration of manganese oxide (MnO) in the soils is 0.33 wt.%, which is high when compared with both standards. Concentration of manganese in the soils can occur naturally by geochemical processes which are small changes in pH of soils in the absence of oxygen (Dorn, 1998). The mean concentration of iron oxide (Fe_2O_3) is also high compared with Wedepohl (1995) and Rudnick and Goa (2003).

Table 2a: Summary of XRF data for major (wt. %) in soils from Saigbe area compared with published crustal abundances.

Oxides/ Element	Minimum concentration	Maximum concentration	Average concentration (N = 8)	Crustal Abundance of Chemical Elements			
				Wedepohl (1995)	Status	Rudnick and Goa (2003)	Status
Al_2O_3	2.29	16.50	10.89	15.05	Low	15.40	Low
SiO_2	41.2	82.50	65.94	61.50	High	66.60	Low
K_2O	0.64	4.21	1.93	2.40	Low	2.80	Low
Na_2O	0.31	1.78	0.81	3.20	Low	3.27	Low
CaO	0.506	4.81	2.47	5.50	Low	3.59	Low
MgO	0.36	2.58	1.19	3.70	Low	2.48	Low
TiO_2	0.85	5.88	3.05	0.68	High	0.64	High
MnO	0.14	0.74	0.33	0.10	High	0.10	High

Fe_2O_3	2.82	18.50	8.22	6.28	High	5.04	High

Table 2b: Summary of XRF data trace elements (ppm) in soils from Saigbe area compared with published crustal abundances.

Oxides/ Element	Minimum concentration	Maximum concentration	Average concentration (N = 8)	Crustal Abundance of Chemical Elements			
				Wedepohl (1995)	Status	Rudnick and Goa (2003)	Status
V	0.19	0.03	0.09	98.00	Low	97.00	Low
Cr	0.32	0.02	0.10	126.00	Low	92.00	Low
Cu	0.23	0.044	0.12	25.00	Low	28.00	Low
Zn	0.09	0.006	0.05	65.00	Low	67.00	Low
Sr	0.34	0.049	0.16	333.00	Low	320.00	Low
Zr	0.93	0.19	0.54	207.00	Low	193.00	Low
Ce	0.15	0.06	0.09	60.00	Low	63.00	Low
Ba	0.50	0.19	0.32	584.00	Low	628.00	Low
Pb	0.55	0.06	0.29	15.00	Low	17.00	Low
Co	0.002	0.004	0.002	24.00	Low	24.00	Low
Ag	3.30	0.08	1.81	0.07	High	0.05	High
Mo	0.03	0.09	0.06	1.10	Low	1.10	Low
Hg	0.009	0.17	0.11	0.04	High	0.05	High
Au	0.001	0.09	0.03	0.025	High	0.004	High

The results of trace element analysis are summarized in Table 2b along with their comparison with published concentrations by Wedepohl (1995) and Rudnick and Goa (2003). Trace elements such as V, Cr, Cu, Zn, Sr, Zr, Ce, Ba, Pb, Co and Mo have lower concentrations when compared with Wedepohl (1995) and Rudnick and Goa (2003). Ag, Hg and Au concentrations range from 0.08 ppm – 3.3 ppm, 0.009 ppm – 0.18 ppm and 0.001 ppm – 0.09 ppm with mean concentrations of 1.81 ppm, 0.11 ppm and 0.03 ppm respectively. The results show that mean concentrations of Ag, Hg and Au are higher when compared to Wedepohl (1995) and Rudnick and Goa (2003). Ag can get into human through ingestion and inhalation. Exposure to high level of Ag leads to discolouration of skin and breathing problem. The high concentration of Ag in the study area is possibly due to the local geology and mining activities. Hg occurs naturally in trace quantity in the earth crust (Cava *et al.,* 2004). Berzas *et al*. (2003) reported that mining of ore expose human to mercury. Hg may be released into water bodies, deposited in sediment or emitted into the atmosphere. Mercury contamination is passed through food chain to human. It is toxic to the reproductive and nervous system (Frumkin *et al.,* 2001). High Hg content interrupt metabolism in plants (Messer *et al.,* 2005). The high Hg concentration in the study area is probably related to mining activity.

4.3 Enrichment Ratios

In an attempt to deduce the enrichment and/or depletion of some trace elements in relation to their average crustal abundances in soil samples from the study area, enrichment ratios were calculated. The enrichment ratio (ER) was computed using the following equation:

$$ER = \frac{Cn}{Bn}$$

Where: Cn = Average concentration of an element measured in the soil sample

Bn = Relative concentration of the element in the background according to Rudnick and Goa (2003).

The enrichment ratios of the trace elements are summarized in Table 3. The assessment of these elements was done in accordance to the work of Sutherland (2000), who interpret enrichment ratios (ER) as follows:

ER< 2 – Depletion to minimal enrichment

ER 2 < 5 – Moderate enrichment

ER 5 < 20 – Significant enrichment

ER 20 < 40 - Very high enrichment

ER> 40 - Extremely high enrichment

Table 3: Enrichment ratio (ER) of trace elements in the soil samples from Saigbe area.

Elements	Average conc. (Cn)	Bn (Rudnick & Goa, 2003)	ER= (Cn/Bn)	Status
V	0.09	97.00	0.001	Depleted
Cr	0.10	92.00	0.001	Depleted
Cu	0.12	28.00	0.004	Depleted
Zn	0.05	67.00	0.001	Depleted
Sr	0.16	320.00	0.001	Depleted
Zr	0.53	193.00	0.003	Depleted
Ce	0.09	63.00	0.001	Depleted
Ba	0.32	628.00	0.001	Depleted
Pb	0.29	17.00	0.010	Depleted
Co	0.002	24.00	0.000	Depleted
Ag	1.81	0.05	36.200	Very high enrichment
Mo	0.06	1.10	0.100	Depleted
Hg	0.11	0.05	2.200	Moderately enriched
Au	0.03	0.004	7.500	Significantly enriched

ER = Enrichment Ratio, Cn = Concentration of the element measured in a sediment sample Bn = Relative concentration of the elements in crustal value given by Rudnick & Goa (2003).

It can be deduced from Table 3 that the soils in the study area are depleted in V, Cr, Cu, Zn, Sr, Zr, Ce, Ba, Pb, Co and Mo. The soils, however, are moderately enriched with Hg, significantly enriched with Au and very highly enriched with Ag.

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4.4 Index of Geoaccumulation (Igeo)

Index of geoaccumulation (*Igeo*) proposed by Muller (1969) is a method used to assess the extent of pollution using seven enrichment classes based on an increase on the numerical value in Table 4. Hence, the indices of geo-accumulation for these trace elements from Saigbe are presented in Table 5.

Table 4: Classes of the index of geo-accumulation, *Igeo* (Muller, 1969).

Igeo value	Igeo class	Pollution intensity
>5	6	Extremely polluted
4 – 5	5	Strong to extremely polluted
3 – 4	4	Strongly polluted
2 – 3	3	Moderate to strongly polluted
1 – 2	2	Moderately polluted
0 – 1	1	Unpolluted to moderatly polluted
0	0	Unpolluted

Table 5: Summary of index of geo-accumulation (*Igeo*) for trace elements in soils from the Saigbe area.

Elements (ppm)	Average conc. (Cn)	Average Crustal Abundance (Bn)	Average index of geoaccumulation (Igeo)	Status
V	0.09	97.00	-10.70	Unpolluted
Cr	0.10	92.00	-10.40	Unpolluted
Cu	0.12	28.00	-8.50	Unpolluted
Zn	0.05	67.00	-10.90	Unpolluted
Sr	0.16	320.00	-11.60	Unpolluted
Zr	0.53	193.00	-9.10	Unpolluted
Ce	0.09	63.00	-10.00	Unpolluted
Ba	0.32	628.00	-11.50	Unpolluted
Pb	0.29	17.00	-6.50	Unpolluted
Mo	0.06	1.10	-4.80	Unpolluted
Hg	0.11	0.05	0.60	Unpolluted to moderately polluted

Note: Average Crustal Abundance (Bn) as given by Rudnick and Gao (2003).

The index of geoaccumulation, *Igeo* was calculated for in all the samples according to the equation:

$$Igeo = Log2\left(\frac{Cn}{1.5Bn}\right)$$

The results show that the soils from this area are unpolluted to moderately polluted with Hg because the mean *Igeo* value for Hg is 0.6 which falls in class 1 of the Muller scale. Indices of geo-accumulation, *Igeo* for V, Cr, Cu, Zn, Sr, Zr, Ce, Ba, Pb, and Mo all fall below class 0 of

the Muller scale indicating the soils is not contaminated with any of these elements (Tables 4 and 5).

5. Conclusions and Recommendation

Artisanal and Small Scale Mining operation has generally created significant impacts on the socio-cultural environments and some of these include large influx of population, change in level of natural and cummunity resources, potential effect on health, conflict generation, creation of employment, child and human labour. These potential impacts informed the study of environmental impacts of artisanal gold mining in Saigbe and environs, North-central Nigeria. The mining activity in the study area has resulted into environmental problems such as land degradation, loss of vegetation, erosion and poor water quality.

The results of chemical analyses of the soil samples show that the area is highly enriched with Ag and Au and moderately enriched with Hg. This was confirmed with the presence of artisanal gold mining activity in the area. Trace elements such as Pb, Cu and Zn were depleted in the analysed soil samples indicating no mineralization of these elements in the area. The activity of artisanal mining in the area has slightly impacted on the environment with Hg. This toxic element when consumed through food chain can be detrimental causing cancer, skin colouration and kidney and lung diseases. To plants, it can result to stunted growth and low yields which are evident in the area with sparse vegetation and some yellow colouration.

It is recommended that other chemicals that are more environmentally friendly should be employed to recover gold in order to save the inhabitants and the ecosystem in the area from mercury poisoning.

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