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Environmental Geochemical Assessment of River Gora Sediments in Minna, North-Central Nigeria

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Abstract
This paper is concerned with the assessment of pollution index level of trace elements in the sediments from River Gora using geochemical approach and also to investigate the environmental impact of artisanal mining activities in the area. The study area lies between latitude $9^0$33'N and $9^0$34'N and longitude $6^0$34'E and $6^0$35'E in Minna area of North-central Nigeria. Accessibility to the sampling locations is via Chanchaga-Tegina road, minor roads, footpaths and the river channel. Major oxide and trace elemental compositions of the samples were analyzed using X-Ray Fluorescence spectrometry Epsilon-5 Panalytical model. The results were subjected to statistical treatment and interpretation. The samples have calculated average chemical alteration index of 76.44 indicative of complete chemical weathering of feldspar and mica in the country rocks of the area. Sb, Au, Mo, Cu, Zr and V are enriched in the study area, while Nb, Co, Zn, Sr, Pb, As, Rb, Cr, Ni, and Ba are depleted in comparison to their upper continental crustal concentrations. The artisanal mining activities in the study area do not pose any environmental health concern because the concentrations of heavy metals such As, Pb, V, Rb, Sr, Cu, Zn, Cr, Co are within safe environmental health concentrations. However, the values for Sb and In are source of extreme pollution risk in the study area; thus a comprehensive study to mitigate their environmental health risks was recommended.
Keywords: Environmental Geochemistry, Pollution Index, Health Risk, River Gora, Minna

1. Introduction

Stream sediments are representative of upstream lithology that plays a large role in exploration and environmental geochemistry. Geochemical data of stream sediments trace possible source of anomalous concentrations to surrounding mineralogy and/or anthropogenic input into near surface soil and water bodies Kautsky and Bolviken (1998).

The environmental and health implications of mining have long been studied and scientific literature is full of documented cases of damage to the environment and human health directly linked to mining related pollution. Environmental problems related to artisanal gold mining are widely reported in the developing world, Ghana, Ecuador, and the Brazilian Amazon. Elevated levels of potential toxic elements (PTE) may be found in and around mines due to the dispersion of mine waste down slope by surface runoff, wind action and effluent drainage into nearby soil and open water system (Waziri, 2014).

In River Gora area of Minna the capital city of Niger State and many other part of Nigeria, artisanal mining of gold and associated sulfide minerals is commonly practiced and PTE may be introduced into the soil and stream sediments as result of such activities. The study area has a relatively long history of gold mining. Despite the recent national reforms on Nigerian's mining sector, probably due to inadequate funding and insufficient manpower, the artisanal mining activities are grossly under supervised. Besides, the environmental impact of these small scale artisanal miners, there have been reported cases of losses of human lives resulting from heavy metal poisoning, collapsed mine adits, pits and tunnels. According to Waziri (2014), sediment transport is an important means through which contaminants are moved not only in classic form but also hydromorphically from source to areas where their ecological and human health risks are felt. Erosion and contaminated soil ensure that contaminants are taken to areas far away from their source environment. Soil and sediments serve as both source and sinks of potentially toxic elements. Contaminant elements introduced into the soil and sediment environment may be immobilized by sorption and complexation with, for example, iron and manganese oxides and organic/humid substances. This is however depending on a number of the geochemical conditions such as pH and the prevailing Redox conditions (Waziri, 2014). Generally an understanding of the physiochemical properties of stream sediments and the geochemical concentrations of elements in the environment is imperative in determining the soil and water quality.

The aim of this paper is to present the result of the assessment of the pollution index level of trace elements in the sediments from River Gora using geochemical approach and the environmental impact of artisanal mining activities in the area. The study area lies between latitude $9^0$33'N and $9^0$34'N and longitude $6^0$34'E and $6^0$35'E in Minna area of North-central Nigeria. Accessibility to the sampling locations is via Chanchaga-Tegina road, minor roads, footpaths and the river channel (Fig. 1).

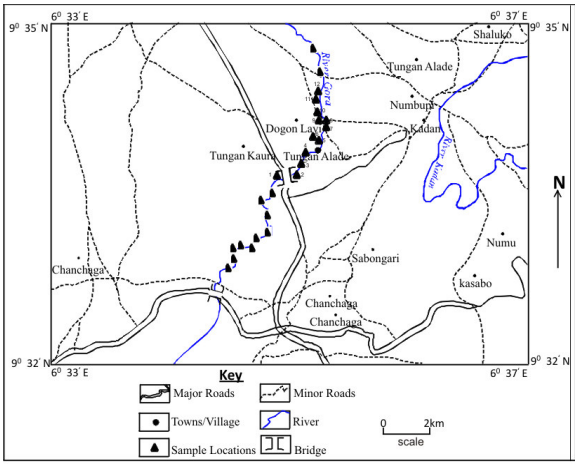

Figure 1. Road Map of Study Area showing Sampling Locations

The study area is covered by "guinea woodland savannah" vegetation. This vegetation comprises typical combinations of tall grasses, shrub and scattered trees with denser tree cover along drainage channels. Cotton and sugar plantations are found in the study area. The vegetation cover helps to prevent wind-scoring of unconsolidated soils during the wet season, but not during the dry season Iloeje (1991).

1.1. Geology of Study Area

The study area is underlain by the Precambrian Basement Complex of North-Central Nigeria. The Basement Complex is one of the three major litho-petrological components that make up the geology of Nigeria. The Nigerian Basement Complex forms a part of the Pan-African mobile belt and lies between the West African and Congo cratons and south of the Tuareg shield (Black, 1980; Grant et al., 1969). It is intruded by the Mesozoic Calc-alkaline ring complexes (Younger Granites) of the Jos Plateau and is unconformably overlain by Cretaceous and Recent sediments. The Nigerian Basement Complex was affected by the Pan-African (600 ± 150 Ma) orogeny and it occupies the reactivated region which resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin (Burke and Dewey, 1972). The Basement rocks are believed to be the results of at least four major orogenic cycles of deformation, metamorphism and remobilisation corresponding to the Liberian (2,800 ± 200 Ma), the Eburnean (2,000 ± 200 Ma), the Kibaran (1,100 ± 200 Ma), and the Pan-African cycles (600 ± 150 Ma). The first three cycles were characterized by intense deformation and isoclinals folding accompanied by regional metamorphism, which was further followed by extensive migmatization. The Pan-African deformation was accompanied by a regional meta-induced syntectonic granites and homogenous gneisses. Late tectonic emplacement of granites and granodiorites and associated contact metamorphism accompanied the end stages of this last deformation. The end of the orogeny was marked by faulting and fracturing (Gandu et al., 1986). The granitic emplacement was probably controlled by fractures within the Basement, and also showed outcrop pattern indicating that the Older Granite cut across all other structures with sharp and chilled contact. Within the Basement Complex of Nigeria, four major petro-lithological units are distinguishable, namely: Migmatite-Gneiss-Quartzite Complex, Schist belts, Pan-African Granitoids, and under-formed acid and basic dykes (Dada, 2006).

The dominant lithologic unit in River Gora area is schist. The area has undulating topography comprising high hills and valleys with covered vegetation. The highest elevation within the area is about 240 meters above mean sea level. The area is drained principally by River Gora. The drainage pattern of the area is dendritic. Most of the streams that drain the area are seasonal. Several quartz veins cross-cut the schist rocks in the area.

2. Materials and Methods

The method utilized for the research is fieldwork and laboratory techniques for sample preparation and analysis. In the field, the following materials were used, namely: location map, plastic samplers, plastic panning bowls, set of sieves, global positioning system (GPS), digital camera, kraft envelops, nylon bags, plastic hand gloves, field notebook and rubber boots. In the laboratory, the materials used are weighing balance (model: ScoutPro SPU601 S/N-7123270179), brush, set of sieves, sieves shaker (STSJ-4 digital high frequency sieves shaker: S/N-100064) and cardboard.

The fieldwork involved the collection of River Gora sediments and the recording of the geographical coordinates of the sediments sampling points using GPS. Twenty-four stream sediments taken at depths of 30-50 cm with the aid of plastic sampler were wet sieved and packed into labeled brown kraft envelopes, left to sun dry

and transported to field base camp for onward transportation to the laboratory. Sample preparation via dry sieving was carried out in the Department of Geology Laboratory of the Delta State University, Abraka, South-southern Nigeria. 10 g from 63 µm fractions of each sample were taken to the National Geochemical Laboratory of the Nigerian Geological Survey Agency in Kaduna, North-western Nigeria for X-Ray Fluorescence spectrometric analysis

The stream sediment samples were crushed to less than 63 microns with the aid of a Tema vibrating mill before sieving to 60 µm. Beads for major element analysis expressed in oxide weight percent were prepared by first drying the pulverized samples in an oven at 110 ^{0}C for 24 hours to remove moisture content. 5 grams of the dry sample was weighed in the silica crucible and then ignited in the furnace at 1,000 ^{0}C for 2 to 3 hours for the calcination of impurities in the sample powder. Thereafter, samples were removed from furnace and allowed to cool to room temperature in desiccators. Each ignited sample powder was weighed again to determine the weight of calcinated impurities which were H_2O^-, H_20^+ and CO_2. 1 gram of stored ignited sample powder and exactly 5 times of flux (x-ray flux-type) 66%:34% (66% lithium tetraborate: 34% lithium metaborate) was added to lower the vitrification temperature. The weighed mixture was properly mixed in a Platinum dish and ignited in the pre-set furnace (Eggon-2 Automatic Fuse Bead Maker) at 1,500 ^{0}C for 10 minutes to form glass bead. Each glass bead was labeled and slotted into the computerized XRF (Epsilon-5 Panalytical model) for major oxide analysis measured in weight percentages. The trace elemental analysis was carried out using compressed powder pellets. The pellets were prepared by weighing 3 grams of oven-dried samples and 3 grams flux (cellulose-powder) added as a binder and dispersive agent and shaken in small plastic containers for 12 minutes. The appropriately blended mixture was then compressed by applying pressure of 1,500 kgm^{-2} using both manual and electronic compressors. The pellets were placed in the computer programmed X-Ray Fluorescence spectrometer (XRF) and the conditions for trace elemental analysis were set to give the result in part per million (ppm).

3. Results and Discussion

3.1. Major Element Geochemistry

The statistics of the results for the major and trace elements and organic matter concentrations in the samples together with their background/baseline values in the upper continental crust (Gao et al., 1975; Taylor and McLennan, 1985, 1995; Wedepohl, 1995; Rudnick and Gao, 2003) are given in Table 1. On the other hand, the Enrichment Ratios and the Index of Geoaccumulation values of the samples are shown in Tables 2 and 4.

Table 1 shows that the dominant major oxide elements are SiO_2 (86.07 ± 9.50 wt. %), Al_2O_3 (14.50 ± 3.26 wt. %), Fe_2O_3 (13.48 ± 3.82 wt. %), CaO (4.18 ± 0.94 wt. %), and MgO (3.08 ± 1.01 wt. %). SiO_2 has the highest major elemental concentrations in the study area with 86.07 wt. % average, which is higher than its average concentrations in the upper continental crust. SiO_2 concentration is indicative of silica-rich source rock for the stream sediments. Next to SiO_2 is Al and its concentration indicated the presence of disintegrated aluminosilicate minerals such as feldspars and micas. The average concentration of Al_2O_3 in study area is slightly lower than its baseline concentration in the upper continental crust. In the study area, TiO_2, Fe_2O_3, MgO, and MnO have average concentrations of 1.76 wt. %, 13.48 wt. %, 3.08 wt. % and 0.25 wt. %, respectively, which are higher than their average crustal concentrations. On the other hand, CaO, K_2O and Na_2O have average concentrations of 4.18 wt. %, 0.19 wt. % and 0.10 wt. %, respectively, which are much lower than their average crustal concentrations. The low concentration range from 2.47-10.3 wt. % with mean 5.4 wt. % of the organic matter indicated by the values for the loss on ignition (LOI) is due to the sparse vegetation cover in the study area.

Chemical index of alteration, CIA (Price and Velbel, 2003; Nesbitt and Young, 1982) is used to measure the degree of weathering and computed using the equation, CIA = [((Al_2O_3/(Al_2O_3+ CaO+ Na_2O+ K_2O))) x 100]. The computed CIA values for River Gora sediments have range of 36.42 to 79.33 with average of 76.44. The CIA values for the study area are indicative of sediments in which complete chemical weathering has taken place with the subsequent decomposition of feldspar and mica from the country rocks leading to the enrichment of SiO_2 and depletion of Al_2O_3, CaO, K_2O and Na_2O. The CIA values support the major oxide wt. % for these elements.

3.2 Trace Element Geochemistry

Zr, Ba and V are considerately high in comparison to other trace elements. Zr ranges from 21-640 ppm with an average of 285 ppm, which is higher than its average crustal baseline concentrations, probably due to full weathering of source bedrocks in the Minna area (Key et al., 2012). Ba has average concentration of 131.17 ppm, which is very low in comparison to its average crustal concentration. V has concentration that range from 40-150 ppm with average concentration of 112.33 ppm that is higher than its average crustal concentration. On the other hand, Sr with concentration range from 12-319 ppm has average concentration of 181.50 ppm that is twice less than its average upper continental crustal concentration. Cr, Zn, Rb, Cu, Sb and Ni are the next group of trace elements with moderate concentrations: Cr (10-108 ppm), Zn (8-96 ppm), Rb (28-64 ppm), Cu (21-56 ppm), Sb

(9-26 ppm) and Ni (3-10 ppm) and their mean concentrations are given as 43.87 ppm, 39.58 ppm, 43.75 ppm, 42.42 ppm, 14.17 ppm and 12.75 ppm, respectively. The average concentrations of Cr, Zn, Rb and Ni are less than their average upper continental crustal baseline concentrations, while the average concentrations of Cu and Sb are higher than their average crustal concentrations.

Table 1. Results of Geochemical Analysis of Samples with Major Oxide in weight percentages and Trace Elements in ppm in comparison to published Upper Crust Concentrations in ppm. n=24

Oxide/Element	This Study						Upper Continental Crust			
	Min.	Max.	Mean	Std. Dev.	Skewness	Kurtosis	A	B	C	D
SiO_2	75.7	93.7	86.07	4.84	-0.58	0.70	67.97	65.89	66.80	66.62
TiO_2	1.01	2.13	1.76	0.40	-1.13	0.18	0.67	0.50	0.64	0.64
Al_2O_3	8.1	19	14.50	3.40	-0.81	-0.32	14.17	15.17	15.05	15.40
Fe_2O_3	7.44	20.8	13.48	4.00	-0.13	-0.19	5.33	4.49	4.09	5.04
Ca0	2.02	5.2	4.18	0.98	-1.20	0.87	3.44	4.19	4.24	3.59
MgO	0.12	4.13	3.08	1.06	-2.12	6.10	2.62	2.20	2.30	2.48
K_2O	0.06	0.34	0.19	0.10	0.10	-1.61	2.68	3.39	3.19	2.80
Na_2O	0.03	0.17	0.10	0.04	-0.10	-0.84	2.86	3.89	3.56	3.27
MnO	0.06	0.4	0.25	0.10	0.03	-0.24	0.10	0.07	0.07	0.10
SO_3	0.01	0.07	0.02	0.02	2.31	5.84				
LOI	2.47	10.3	5.83	2.64	0.19	-1.08				
Au	2.30	11.00	6.88	2.39	-0.31	0.07	1.24	1.80		1.50
V	40.00	150.00	112.33	29.22	-1.23	2.71	98.00	107.00	53.00	97.00
Cr	10.00	108.00	43.87	32.12	0.78	-0.44	80.00	85.00	35.00	92.00
Ni	3.00	30.00	12.75	9.35	0.41	-1.18	38.00	44.00	19.00	47.00
Cu	21.00	56.00	42.42	10.74	-0.58	-0.40	32.00	25.00	14.00	28.00
Ba	91.00	216.00	131.17	32.88	1.5	3.58	678.00	550.00	668.00	624.00
Zn	8.00	96.00	39.58	30.55	0.98	-0.27	70.00	71.00	52.00	67.00
As	1.00	5.00	2.50	1.17	0.82	0.61	4.40	1.50	2.00	4.80
Sr	12.00	319.00	181.5	86.60	-1.08	1.44	266.00	350.00	316.00	320.00
Zr	21.00	640.00	285.58	238.49	0.24	-1.74	188.00	190.00	237.00	193.00
Mo	0.50	21.00	4.75	2.13	4.21	0.5	0.78	1.50	1.40	1.10
Rb	28.00	64.00	43.75	12.37	0.55	-0.96	82.00	112.00	110.00	84.00
Pb	2.00	48.00	9.25	13.47	2.6	7.00	18.00	17.00	17.00	17.00
Sb	9.00	26.00	14.17	4.59	1.59	3.47	0.30	0.20	0.31	0.40
In	2.00	24.00	6.25	6.00	2.69	8.16		0.05	0.06	0.06
Co	7.00	18.00	10.92	3.97	0.58	-1.15	17.00	17.00	12.00	17.30
Nb	3.00	23.00	11.42	6.50	0.55	-0.71	12.00	12.00	26.00	12.00

[A]Gao et al. (1975); [B]Taylor and McLennan (1985, 1995); [C]Wedepohl (1995); [D]Rudnick and Gao (2003)

As, Pb and Au are the next group of trace elements in the samples with moderately low concentrations in comparison to the other trace elements. Their values range from As (1-5 ppm), Pb (2-48 ppm) and Au (2.3-11 ppm) and with mean concentration values of As (2.5 ppm), Pb (9.25 ppm) and Au (6.87 ppm). The average concentration of Au (6.86 ppm) is very much higher than its average crustal concentration (Table 1). On the other hand, the average concentrations of As (2.50 ppm) and Pb (9.25 ppm) are almost twice less than their average crustal concentrations.

3.2.1 Enrichment Ratios

The enrichment ratios (ER) are calculated from the formula $ER = C_n/B_n$ where C_n is the sample concentration, while B_n is the background/baseline concentration of an element in known standard or average upper continental crustal concentration (Rudnick and Gao, 2003). ER > 1 or < 1 means enrichment or depletion of an element. From Table 2, trace elements with ER > 1 are In (104.17 times higher than crustal concentration), Sb (35.43 times higher), Au (4.57), Mo (4.25), Cu (1.52), Zr (1.48), V (1.16). However, those with ER < 1 are Nb (0.95), Co (0.63), Zn (0.5), Sr (0.57), Pb (0.54), As (0.52), Rb (0.52), Cr (0.48), Ni (0.27) and Ba (0.21).

3.2.2 Index of Geoaccumulation

The index of geoaccumulation (I_{geo}) (Muller, 1969) is calculated using the formula, $I_{geo} = \log 2 (C_n/(1.5 \times B_n))$ where C_n is the sample concentration, while B_n is the background/baseline concentration of element in known standard or its average upper continental crustal concentration and 1.5 is a constant to account for the variation in the crustal concentrations (Rudnick and Gao, 2003) of the trace element. From Table 4, Sb has mean I_{geo}values of 7.11, while In has 20.91. In and Sb have extremely high pollution index and they are of environmental risk concern in the study area. The trace elements in the samples have values between 0 and 1. Ni and Ba have I_{geo}values of 0.05 and 0.04, respectively, and they fall below zero (0), meaning unpolluted. Au, Mo, Cu, V, Zn, As, Rb, Pb, Nb lie on class 1 (Table 3). Despite the artisanal mining activities in the study area, there is no heavy

metal environmental health risks from pollution from As, Pb, V, Rb, Sr, Cu, Zn, Cr, Co, etc. because their mean I_{geo}values are within safe environmental health concentrations in River Gora sediments.

4. Conclusion and Recommendations

4.1. Conclusion

The dominant major oxide elements are SiO_2 (86.07 ± 9.50 wt. %), Al_2O_3 (14.50 ± 3.26 wt. %), Fe_2O_3 (13.48 ± 3.82 wt. %), CaO (4.18 ± 0.94 wt. %), and MgO (3.08 ± 1.01 wt. %). Al_2O_3 has mean value of 14.50 wt. % and ranges 8.1 wt. % to 19 wt. %. The average concentration of Al_2O_3 in the samples is slightly lower or about the values for the upper continental crust. Al_2O_3 concentration came from complete decomposition of aluminosilicate minerals such as feldspars and micas via chemical weathering. The samples have TiO_2, Fe_2O_3, MgO, and MnO with average concentrations of 1.76 wt. %, 13.48 wt. %, 3.08 wt. % and 0.25 wt. %, respectively, which are higher than their average crustal concentrations. On the other hand, CaO, K_2O and Na_2O have average concentrations of 4.18 wt. %, 0.19 wt. % and 0.10 wt. %, respectively, much lower than their average crustal concentrations. The low concentrations of Al_2O_3, CaO, K_2O and Na_2O in study area are due to excessive leaching and losses resulting from poor vegetation cover of the soils. The computed CIA values for River Gora sediments have range of 36.42 to 79.33 with average of 76.44. The CIA values for the study area are indicative of sediments in which there had been complete chemical weathering that have led to the decomposition of feldspar and mica from the country rocks with subsequent enrichment of SiO_2 and depletion of Al_2O_3, CaO, K_2O and Na_2O. The organic matter content of the samples were calculated from the values of the loss on ignition (LOI) that range from 2.47-10.3 wt. % with mean 5.4 wt. %. The low content of organic matter is predicated by the sparseness of vegetation cover in the study area.

Table 2. Enrichment Ratios for River Gora Sediment Samples (n=24)

Element	Enrichment Ratios, ER		
	Min.	Max.	Mean
Au	1.53	7.33	4.57
V	0.41	1.55	1.16
Cr	0.11	1.17	0.48
Ni	0.06	0.64	0.27
Cu	0.75	2.00	1.52
Ba	0.15	0.35	0.21
Zn	0.12	1.43	0.59
As	0.21	1.04	0.52
Sr	0.04	1.00	0.57
Zr	0.11	3.32	1.48
Mo	0.46	19.09	4.32
Rb	0.33	0.76	0.52
Pb	0.12	2.82	0.54
Sb	22.50	65.00	35.43
In	33.33	400.00	104.17
Co	0.41	1.04	0.63
Nb	0.25	1.92	0.95

Table 3. Class Interpretation of Index of Geoaccumulation of Trace Elements (after Muller, 1969)

I_{geo} Value	I_{geo} Class	Pollution Intensity
> 5	6	Extremely polluted
4-5	5	Strongly to extremely polluted
3-4	4	Strongly polluted
2-3	3	Moderately to strongly polluted
1-2	2	Moderately polluted
0-1	1	Unpolluted to moderately polluted
0	0	Unpolluted

Table 4. Index of Geoaccumulation of Trace Elements in River Gora Sediments (n=24)

Element	Index of Geoaccumulation, I_{geo}		
	Min.	Max.	Mean
Au	0.31	1.47	0.92
V	0.08	0.31	0.23
Cr	0.02	0.24	0.10
Ni	0.01	0.13	0.05
Cu	0.15	0.40	0.30
Ba	0.03	0.70	0.04
Zn	0.02	0.29	0.12
As	0.04	0.21	0.11
Sr	0.01	0.20	0.11
Zr	0.02	0.67	0.30
Mo	-0.52	1.11	0.46
Rb	0.07	0.15	0.11
Pb	0.02	0.57	0.11
Sb	4.52	13.05	7.11
In	6.69	80.28	20.91
Co	0.08	0.21	0.13
Nb	0.05	0.38	0.19

Concentrations of Zr, Ba and V are considerately high in comparison to other trace elements in the samples. Zr ranges from 21-640 ppm with an average of 285 ppm, which is higher than its average crustal baseline concentration. Ba has average concentration of 131.17 ppm, which is very low in comparison to its average crustal concentration. V has average concentration of 112.33 ppm that is higher than its average crustal concentration. Sr has average concentration of 181.50 ppm that is twice less than its average upper continental crustal concentration. Cr, Zn, Rb, Cu, Sb and Ni are the next group of trace elements with moderate concentrations: Cr (10-108 ppm), Zn (8-96 ppm), Rb (28-64 ppm), Cu (21-56 ppm), Sb (9-26 ppm) and Ni (3-10 ppm) and their mean concentrations are given as 43.87 ppm, 39.58 ppm, 43.75 ppm, 42.42 ppm, 14.17 ppm and 12.75 ppm, respectively. The average concentrations of Cr, Zn, Rb and Ni are less than their average upper continental crustal concentrations, while the average concentrations of Cu and Sb in the samples are higher than their average crustal concentrations. The average concentration of Au (6.86 ppm) is very much higher than its average crustal concentration. On the other hand, the average concentrations of As (2.50 ppm) and Pb (9.25 ppm) are almost twice less than their average crustal concentrations.

Trace elements with ER > 1 are In (104.17 times higher than crustal concentration), Sb (35.43 times higher), Au (4.57), Mo (4.25), Cu (1.52), Zr (1.48), V (1.16), while those with ER < 1 are Nb (0.95), Co (0.63), Zn (0.5), Sr (0.57), Pb (0.54), As (0.52), Rb (0.52), Cr (0.48), Ni (0.27) and Ba (0.21). Sb has mean I_{geo}values of 7.11, while In has 20.91. In and Sb have extremely high pollution index and they are of environmental risk concern in the study area. The trace elements in the samples have values between 0 and 1. Ni and Ba have I_{geo}values of 0.05 and 0.04, respectively, and they fall below zero (0), meaning unpolluted. Au, Mo, Cu, V, Zn, As, Rb, Pb, Nb lie on class 1. Though there is active artisanal mining in the study area, there is no heavy metal environmental health risks from assessment of the pollution index of As, Pb, V, Rb, Sr, Cu, Zn, Cr, Co, etc. because their mean I_{geo}values are within safe environmental health concentrations in River Gora sediments.

4.2. Recommendation

The following recommendation is proffered:

That there is need for a comprehensive environmental impact assessment study of the area to design the best mitigation measures to effectively minimize the health risks from In and Sb environmental pollution.

References

Black, R. (1980). Precambrian of the West Africa, *Episodes* 4, 3-8.

Burke, K.C., Dewey, J.F. (1972). Orogeny in Africa, In: African Geology, T.F.J. Dessauvagie and A.J. Whiteman (eds.), Univ. Ibadan, 583-608.

Dada, S.S. (2006). Crust Forming Ages and Proterozoic Crustal Evolution in Nigeria: Re-appraisal of Current Interpretations, *Precambrian Research*, 65-74.

Gandu, A.H, Ojo, S.B., Ajakaye, D.E. (1986). A Gravity Study of the Precambrian in the Malufashi Area of Kaduna State, Nigeria. *Tectonophysics* 126, 181-191.

Grant, K., Rex, D.C, Burke, K.C., Freeth, S.J. (1969). The geological sequence and geochronology of old basement rocks from Ibadan, Nigeria, *Am. Fac. Sci. Clermom E-Fd 41, Geomineral, Fasc*. 19, 84.

Gao, S., Luo, T.C., Zhang, B.R., Zhang, H.F., Han, Y.W., Hu, Y.K., Zhao, Z.D. (1975). Chemical composition of the continental crust as revealed by studies in East China, *Geochim. Cosmochim. Acta* 62, 1959-1975.
Iloeje, N.P. (1991). A new geography of Nigeria, Academy Press Ltd., Lagos, 201.
Kautsky, G., Bolviken, N. (1998). Geochemical Atlas of Northern fennoscandia Nordkalott project, Geol. Surv. Sweden, 19.
Key, R.M., Johnson, C.C., Horstwood, M.S.A., Lapworth, D.J., Knights, K.V., Kemp, S.J., Watts, M., Gillespie, M., Adekanmi, M., Arisekola, T. (2012). Investigating high zircon concentrations in the fine fraction of stream sediments draining the Pan-African Dahomeyan Terrane in Nigeria. *Appl Geochem* 27(8), 1525-1539.
Muller, G. (1969). Index of geoaccumulation in sediments of the Rhine River, *GeoJournal* 2, 108-118.
Nesbitt, H.W., Young, G.M. (1982). Early Proterozoic climates and plate motions inferred from major element chemistry of lutites, *Nature* 299, 715-717.
Price, J.R., Velbel, M.A. (2003). Chemical weathering indices applied to weathering profiles developed on heterogeneous felsic metamorphic rocks, *Chem. Geo*l. 202, 397-416.
Rudnick, R.L., Gao, S. (2003). Composition of the continental crust, In: The Crust 3, R. L. Rudnick (ed.), In: Treatise on Geochemistry, Holland, H.D. and Turekian, K. K. (eds.), Elsevier-Pergamon, Oxford, 1-64.
Taylor, S.R., McLennan, S.M. (1985). The continental crust: Its composition and evolution. Blackwell, Oxford.
Taylor, S.R., McLennan, S.M. (1995). The geochemical evolution of the continental crust, *Rev. Geophys.* 33, 241-265.
Waziri, N.M. (2014). Environmental geochemistry of soils and stream sediments from Birnin-Gwari artisanal gold mining areas, North-western Nigeria, *Universal Journal of Geoscience* 2(1), 18-27.
Wedepohl, H. (1995).The composition of the continental crust. Geochim. Cosmochim. Acta 59, 1217-1239.

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