Assessment of Potentially Toxic Elements in Egbetua Stream Sediments, South-Western Nigeria

S. O. Obaje

ABSTRACT

The study area is located in Egbetua area in Akoko Edo Local Government Area of Edo State, southwestern Nigeria. the aim of the study is to assess the concentrations of potentially toxic elements in sediments from the study area. Ten samples collected from various locations in Egbetua stream were subjected to standard geochemical analysis using energy dispersive x-ray fluorescence spectrometer model “Minipal 4”. The average concentrations of six elements are V (26.89 ppm), Cr (32.33 ppm), Co (6.13 ppm), Ni (16.10 ppm), Au (21.13 ppm), and Zr (1,285.20 ppm) and they were compared to those of upper continental crust baseline values. V, Cr, Co, and Ni have extremely low concentrations, while Au and Zr have very high concentrations. Moreover, V, Cr, Co, and Ni have average enrichment ratios of 0.28, 0.35, 0.35 and 0.34, respectively, which are < 1 implying their depletion in relation to their average crustal baseline concentrations. On the other hand, Au and Zr are highly enriched in the study area. Au has average geoaccumulation index (Igeo) values of 4.40 indicative of strongly to extremely polluted, while Cr, Co, Ni and Zr have average Igeo values of 10.95, 6.14, 9.98 and 17.34, respectively, indicative of sediments that are extremely polluted. The potentially toxic elements pose very serious environmental geochemical pollution threat in the study area. It is recommended that urgent action should be taken to mitigate and clean the study area of these potentially toxic elements.

Keywords: Geochemical analysis, Egbetua, Nigeria, potentially toxic elements.

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I. INTRODUCTION

The study area is located in Egbetua area in Akoko Edo Local Government Area of Edo State, Southwestern Nigeria. It is located on latitudes $07^{\circ}21'30''N$ and $07^{\circ}22'N$ longitudes $06^{\circ}15'30''E$ and $06^{\circ}17'E$ and average elevation of 182 metres (Fig. 1). The aim of the study is to assess potentially toxic elements in Egbetua stream sediments. Trace element geochemistry of stream sediments is useful in determining concentration of potentially toxic elements in the environment [1]-[4]. Egbetua has rugged topography, and the drainage pattern is dendritic (Fig. 1). The area is accessible via untarred road, footpaths, and stream channels. Egbetua is a rural agricultural settlement, though there is presence of small-scale artisanal mining of river sand, dimension stones and gold. Though much has been published on the basement geology of the study area, there is extreme scarcity of published works on the geochemistry of stream sediments of the study area.

A. Local Geology of the Study Area

The study area belongs to the Igarra Schist belt which is within the crystalline Basement Complex rocks of the Southwestern Nigeria. The predominant rocks in the area are migmatite-gneiss-quartzite complex, schist, marbles, and porphyritic granites [5], [6].

II. MATERIALS AND METHODS

The materials used in the field during the collection of samples includes GPS, hammer, sample bags, field notebook, sampler, pen, pencil, masking tape, metre rule, funnel and set of sieves. The laboratory materials used are Energy Dispersive X-Ray Fluorescence (EDXRF) spectrometer of model “Minipal 4”, oven, pulveriser, desiccators, pelletizer, and crucibles.

Samples of stream sediments were taken from ten locations in the study area. The geographic coordinates of sample locations were noted in the field notebook. The samples were wet sieved and conveyed in well labelled sample bags.

Fig. 1. Topographic map of the study area with sampling location (after FSN [7]).

The samples were pulverised (milled into fine powder) using target pulverising machine (Planetary Micro Mill Pulverisette 7). 5g of the pulverised sample was weighed into a beaker, 1g of binding aid (Starch soluble). Homogeneity was achieved through thorough mixing of the sample with the binder together pressed under high pressure (6 tonnes”) to make pellets for trace element analysis. Energy Dispersive X-Ray Fluorescence (EDXRF) spectrometer of model “Minipal 4” was used for the analysis. The well labelled compressed pellets achieved under pressure of 1,500Kgm⁻² were carefully placed in the various measuring positions on the machine.

III. RESULT AND DISCUSSION

The elemental composition in parts per million (ppm) for V, Cr, Co, Ni, Au and Zr are given in Table I, while Fig. 2 shows the elemental compositions given in Table I as a histogram plot. The result of the six potentially toxic elements in the sediments from the study area are as follows: V (14.82 ppm - 43.32 ppm, average 26.89 ppm), Cr (16.64 ppm - 63.32 ppm, average 32.33 ppm), Co (3.00 ppm - 12.34 ppm, average 6.13 ppm), Ni (4.51 ppm - 52.84 ppm, average 16.10 ppm), Au (11.47 ppm - 47.50 ppm, average of 21.13 ppm) and Zr (170.00 ppm - 3,180 ppm, average 1,285.20 ppm).

In Table II, the average concentrations of the six elements were compared to those of upper continental crust baseline values of Gao *et al.* [8], Taylor and McLennan [9]-[10], Wedepohl [11], Rudnick and Gao [12]. In comparison with the upper continental crust baseline concentration values of Rudnick and Gao [12], V, Cr, Co, and Ni have extremely low concentrations, while Au and Zr have very high concentrations.

Element enrichment ratios were calculated in order to assess the extent of enrichment and/or depletion of the trace elements in the study area. The enrichment ratios (ER) were calculated using the formula: $ER = C_n/B_n$ where C_n is an element's concentration in the sample, while B_n is the background/baseline concentration of an element in known standard or average upper continental crustal concentration [12]. The upper continental crust concentrations of elements were taken as baseline and background values. $ER > 1$ or < 1 means enrichment or depletion of an element relative to average crustal concentration.

In Table 3, V, Cr, Co, Ni have average enrichment ratios of 0.28, 0.35, 0.35, 0.34, respectively, which are < 1 implying their depletion in relation to their average crustal concentrations. On the other hand, Au and Zr have average ER of 14.09 and 6.66, respectively, indicative that Au and Zr are highly enriched in the study area. The abnormalous concentrations of Au and Zr are attributable to geogenic factors such as the Au mineralised schist and complete weathering of the source rocks of the study area.

Igeo is used to assess metal contamination in the sediments in line with Muller [13]. Igeo is computed using the formula:

$$I_{geo} = \log_2 (C_n/1.5B_n)$$

where C_n is the measured concentration of an element in the sediments and B_n is the background/baseline concentration of an element in known standard or average upper continental crustal concentration [12]. In Table IV, the Igeo values range and average for the elements are as follows: V (9.90 ppm - 11.45 ppm, average of 10.76 ppm), Cr (10.00 ppm - 11.92 ppm, average of 10.95 ppm), Co (5.11 ppm - 7.15 ppm, average of 6.14 ppm), Ni (7.14 ppm - 10.69 ppm, average of 8.98 ppm), Au (3.52 - 5.57 ppm, average of 4.40 ppm) and Zr (14.42 ppm - 18.64 ppm, average of 17.34). Au has Igeo values of 4.40 which fall within the Igeo class of 4-5 in Table V, indicative of strongly to extremely polluted, while Cr, Co, Ni and Zr have average Igeo values of 10.95, 6.14, 9.98 and 17.34, respectively, which are > 5 Igeo values of Table V, indicative that the sediments from the study area are extremely polluted with the elements. Consequently, V, Cr, Co, Ni, Au and Zr pose very serious environmental geochemical pollution threat in the study area.

Fig. 2. Trace elements concentration in sediments from study area.

TABLE I: TRACE ELEMENT GEOCHEMICAL ANALYSIS OF SAMPLES FROM STUDY AREA (IN PPM)

Element	SL1	SL2	SL3	SL4	SL5	SL6	SL7	SL8	SL9	SL10	Min	Max	Mean
V	31.92	27.16	14.82	22	17.71	32.82	43.32	24.18	28.42	26.54	14.82	43.32	26.89
Cr	16.64	48.12	63.32	28.41	22.92	27.48	19.2	21.51	40.82	34.91	16.64	63.32	32.33
Co	8.24	4.52	3.00	5.64	4.48	5.9	5.62	4.84	6.71	12.34	3.00	12.34	6.13
Ni	4.51	21.6	12.42	9.26	13.58	9.46	18.5	7.14	11.65	52.84	4.51	52.84	16.10
Au	12.31	18.63	23.4	25.38	11.93	24.65	47.5	11.47	23.4	12.63	11.47	47.50	21.13
Zr	800	840	1738	2850	170	1600	910	463	3180	301	170	3180	1285.20

TABLE II: RESULT OF GEOCHEMICAL ANALYSIS OF SAMPLES WITH TRACE ELEMENTS IN COMPARISON TO PUBLISHED UPPER CRUST CONCENTRATIONS IN PPM (N=10)

Element	This Study			Upper Continental Crust			
	Min	Max	Mean	A	B	C	D
V	14.82	43.32	26.89	98.00	107.00	53.00	97.00
Cr	16.64	63.32	32.33	80.00	85.00	35.00	92.00
Co	3.00	12.34	6.13	17.00	17.00	12.00	17.30
Ni	4.51	52.84	16.10	38.00	44.00	19.00	47.00
Au	11.47	47.5	21.13	1.24	1.80	-	1.50
Zr	170	3180	1285.20	188.00	190.00	237.00	193.00

^A[8]; ^B[9], [10]; ^C[11]; ^D[12] - (case study used).

TABLE III: ENRICHMENT RATIOS FOR EGBETUA STREAM SEDIMENT

SAMPLES (N=10)			
Element	Min	Max	Mean
V	0.15	0.45	0.28
Cr	0.18	0.69	0.35
Co	0.17	0.71	0.35
Ni	0.10	1.12	0.34
Au	7.65	31.67	14.09
Zr	0.88	16.48	6.66

TABLE IV: INDEX OF GEOACCUMULATION OF TRACE ELEMENTS IN EGBETUA STREAM SEDIMENTS (N=10)

Element	Min	Max	Mean
V	9.90	11.45	10.76
Cr	10.00	11.92	10.95
Co	5.11	7.15	6.14
Ni	7.14	10.69	8.98
Au	3.52	5.57	4.40
Zr	14.42	18.64	17.34

TABLE V: CLASS INTERPRETATION OF INDEX OF GEOACCUMULATION OF TRACE ELEMENTS (AFTER MULLER [13])

Igeo value	Igeo 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

IV. CONCLUSION AND RECOMMENDATION

Potentially toxic elements in the sediments from the study area have been analysed. Six of these elements analysed have the following concentrations in range and average values: V (14.82 ppm – 43.32 ppm, average 26.89 ppm), Cr (16.64 ppm – 63.32 ppm, average 32.33 ppm), Co (3.00 ppm – 12.34 ppm, average 6.13 ppm), Ni (4.51 ppm – 52.84 ppm, average 16.10 ppm), Au (11.47 ppm – 47.50 ppm, average of 21.13 ppm) and Zr (170.00 ppm – 3,180 ppm, average 1,285.20 ppm).

The average concentrations of the six elements were compared to those of upper continental crust baseline values. In comparison with the upper continental crust baseline concentration values of Rudnick and Gao [12], V, Cr, Co, and Ni have extremely low concentrations, while Au and Zr have very high concentrations.

V, Cr, Co, and Ni have average enrichment ratios of 0.28, 0.35, 0.35, 0.34, respectively, which are < 1 implying their depletion in relation to their average crustal concentrations. On the other hand, Au and Zr have average ER of 14.09 and 6.66, respectively, indicative that Au and Zr are highly enriched in the study area. The abnormal concentrations of Au and Zr are attributable to geogenic factors such as the Au mineralised schist and complete weathering of the source rocks of the study area.

According to Muller [13], Igeo values 4-5 indicate strongly to extremely polluted and Igeo values > 5 indicate extremely polluted. Au has average Igeo values of 4.40 indicative of strongly to extremely polluted, while Cr, Co, Ni and Zr have average Igeo values of 10.95, 6.14, 9.98 and 17.34, respectively, which are > 5 Igeo values of Table V, indicative that the sediments from the study area are extremely polluted with the elements and they pose very serious environmental geochemical pollution threat in the study area.

It is recommended that urgent action should be taken to mitigate and clean the study area of these potentially toxic elements.

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CONFLICT OF INTEREST

The Author declares that he does not have any conflict of interest.

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