TRACE ELEMENT ASSESSMENT IN WATER OF RIVER KASSA SYSTEM, JOS-PLATEAU NIGERIA

A. MOMOH AND E.G. AMEH

ABSTRACT

Detailed geochemical investigation of water from River Kassa was carried out to assess trace element distribution in the river system. The results showed significant enrichment of these elements Pb, As, Co, Cr, V, Ni and Fe. The value of index of geoaccumulation (Igeo) is approximately 2; for Zn and Pb which indicates, moderate contamination. Areas of the river system with anomalous value of trace element concentrations are those where mine tailings have been deposited close to the river channel or places where run off from adjoining farmlands and settlements enter the river. The major sources of contamination are mining and agricultural activities on the flood plain of this river. The anomalous concentration of As, V, Cr, Co and Pb need further investigation in view of their health implications on man and aquatic lives.

KEYWORDS: Trace element, Index of Geoaccumulation, Contamination, Mine tailings, Aquatic.

INTRODUCTION

River Kassa is a major river which flows through several mining settlements and inhabitants of these areas depend on it for their domestic, agricultural and mining activities. The river drains an area of more than 1000km^2 during periods of high flow with a water shed of about 100km^2.

Trace elements may enter soil and aquatic environments via mine waste, industrial waste disposal, atmospheric deposition, application of fertilizers and pesticides (Forstner, 1983). The introduction of waste products into rivers and estuaries, especially those in industrial and highly populated cities has led to a significant increase in metal contamination (Fanfani, 1997, Cravotta and Bilger 2001, Horowitz et al 1995, Wood, 1996, Rabe and Bauer 1997).

Mine tailings from mining firms in these localities are discharged directly into the river system and flood plain of this river. Tributaries of Kassa River are channeled into their concessional area for processing of tin ore. The Kassa river system which is the south-eastern part of Jos-Plateau begins at the point of major hub of tin mineralized communities. It empties into the Gongola River. Land use on the path of flow is mainly agricultural and washing of tin ores.

The flood plains are cultivated yearly for dry season farming and the farmers use several pesticides, herbicides and fertilizers to control weeds and nourishment of their farmlands which on being washed by rainfall are equally discharged into this river.

This could make the water body unfit for human consumption and thus constitute health hazards for inhabitants of these communities that depend on this river for their water needs because of complete absence of potable water supply in most rural areas of Nigeria.

The objective of this paper is to assess the distribution and levels of trace elements in the water Kassa with a view to highlight some hazards that local communities will have to face in the near future. The focus is to identify important contamination sources: a dump on the flood plains made up of mine tailings and the leachates from abandoned tailings on the Jos-Plateau that drains into this river during rainy season.

STUDY AREA

Kassa river is located on Jos-Plateau with an areal coverage of about 1,200km2 (Fig. 2).The climate is typically tropical with a mean annual rainfall of about 1400mm.The annual water flow rate of the river is 5200m^3 (Hossain et al 1986).The main direction of flow is from south-west towards the northern part of the area due to structural trend

The geology is dominated by rocks of the Younger Granite Complex. Four main types of granites are recognized in the area (Ekwueme, 1993). The first type is hornblende pyroxene fayalite (Hpf) granite that usually forms ring dyke while the second group is hornblende biotite granite (Hbg). The third type is biotite granite (Bg) which forms the most abundant and widespread rock type in entire area. The fourth group of granites is the riebekites granites (Rg) which are mainly found in the northern part of the area as small sheet like intrusions.

MATERIALS AND METHODS

Twenty sampling sites in the Kassa River system were selected along the path of flow with the aid of a grab samples (Fig. 2). The sampling was carried out in February 2008 during dry season when dilution effect of storm runoff can be eliminated. Water samples were collected in acid-rinsed polyethylene bottles and acidified with nitric acid (HN0$_3$) to a pH of 2 and stored in ice-chested coolers. Samples were analysed for Pb, Zn, Cu, Cd, Fe, As and Hg by inductively coupled plasma atomic emission spectrometry (ICP-AES) at Activation laboratory in Canada.

A. Momoh, Department of Geology and Mining, University of Jos, Nigeria
E.G. Ameh, Department of Earth Sciences, Kogi state University, Anyigba Nigeria.

Data Evaluation

Quantitative index was used to describe the distribution pattern of trace elements and to allow easy comparison of the analysed parameters. The index is index of geo-accumulation as proposed by Mueller (1979). Index of geoaccumulation (Igeo) has been used to evaluate the degree of metal contamination in terrestrial and aquatic environments (Tijani, 2004, Sutherland 2000 and Manjunatha et al 2001). It is expressed as:

$$Igeo \ \hat{T} \log_2 \left| \frac{Cm}{1.5 * Bm} \right|$$

Where Cm is the measured concentration of metal in water and Bm is the background concentration value of metal (m) (Taylor and Mclennan,1985). 1.5 is a factor for possible variation in the background concentration due to lithologenic differences.

Igeo is classified into seven classes as follows:
0 = practically uncontaminated; 0 – 1 = slightly contaminated, 1 – 2 moderately contaminated, 2 -3 moderately – highly contaminated, 3 -4 highly contaminated, 4-5 highly to very highly contaminated. >5 very highly contaminated and Igeo of 6 and above is said to be very highly contaminated.

RESULTS

The concentrations of trace element analyses results for water samples and WHO Standard (1999) alongside with mean composition of World Rivers (MCWR, Hem, 1985) are presented in table 1. The mean concentration values in the samples are generally less than 1mg/l except Fe whose mean value is 1.43 mg/l. The higher concentrations of iron could be as a result of weathering processes of parent rocks resulting in the production of iron oxides along side with the clay minerals (Davis and Eary, 1997; Ramstedt et al 2003 and Levy et al 1997). The concentration of Co and Fe increases from Hpf to Rbg/Bg while other trace elements shows no defined trend in concentration from one rock type to the other.

Average concentrations of V, Cr, Ni, As and Pb are about five times that of WHO Standards while average Co concentration is about twice that of WHO Standards of 1999. The order of concentration is Fe > V ≥ Cu > Cr > Ni > Co > Zn > Pb > As. (Fig. 3).

On comparing the analysed trace elements with the WHO standards, the observed range of concentrations of the following trace Elements Fe, V, Cr, Ni, Co, Pb, As are above the permissible levels of drinking water. While Zn and Cu are below the permissible levels. These do not imply absence of contamination as the observed lower concentrations could be attributed to partitioning and accumulation within the sediment phase of Kassa River System. Possible changes in chemo-thermodynamic conditions can lead to remobilization into liquid phase (Tijani 2004).

Evaluation of trace element distribution pattern was determined by using index of geoaccumulation (Igeo) as the quantitative index.

The respective values of mean composition of world rivers (MCWR) were used as baseline values to give an idea about the levels of trace elements in the river system.

DISCUSSION

The results of the trace element analysis on Kassa River show that metals such as Vr, Cr, Ni, As, Pb, Co, and Fe have different concentrations on the entire flow part (Table 1). The upstream of the river and close to the historical mining and smelting sites, showed enrichment of analysed elements which decreases from upstream to downstream of the river. With the exception of Cu and Zn that fell below WHO (1999) standard, other trace elements were above WHO (1999) standard.

The index of geoaccumulation (Igeo) as presented in table 2 indicates Igeo value of 2 for Zn and Pb indicating moderate contamination. V, Cu, Cr, Ni have Igeo of above 6 which is indicative of 100 fold-enrichment of the metal (Mueller, 1979). It should be noted that the order of contamination defined by the Igeo is different from that of the absolute concentration outlined earlier. This is as a result of normalization with respect to mean composition of World Rivers which gives more reliable estimates of the degree of contamination of the metals with respect to the natural geogenic inputs (Tijani et al 2004).

CONCLUSION

The chemistry of river water is controlled by weathering of different lithologies and by anthropogenic inputs. The concentration of Co and Fe increases from Hpf to Rbg/Bg while other trace elements shows no defined trend in concentration from one rock type to the other Trace element concentrations in the upper Kassa River are generally higher than the lower portion.

Heaps of several mining wastes are dumped in this portion of the river and south-shore tributaries. Elements concentrations in this part are highly governed by dilution effects due to inputs of inorganic particles from mining wastes and run-off from the tailing dump on the flood plain.

In conclusion, long term and detailed research is necessary to resolve the extent of mining contamination, such research requires considerable financing and the combined efforts of Federal and State agencies of environmental protection are necessary. Consequently, the following are some recommendations:

Rain-proofing of the mine tailings that were dumped on the flood plain of this river should be embarked upon by relevant government agency and a limitation of the use of this river by mining companies on Jos-Plateau may also be suggested.

Fig 1: Discarded mine tailings on the flood plain of River Kassa and use of water for domestic activities
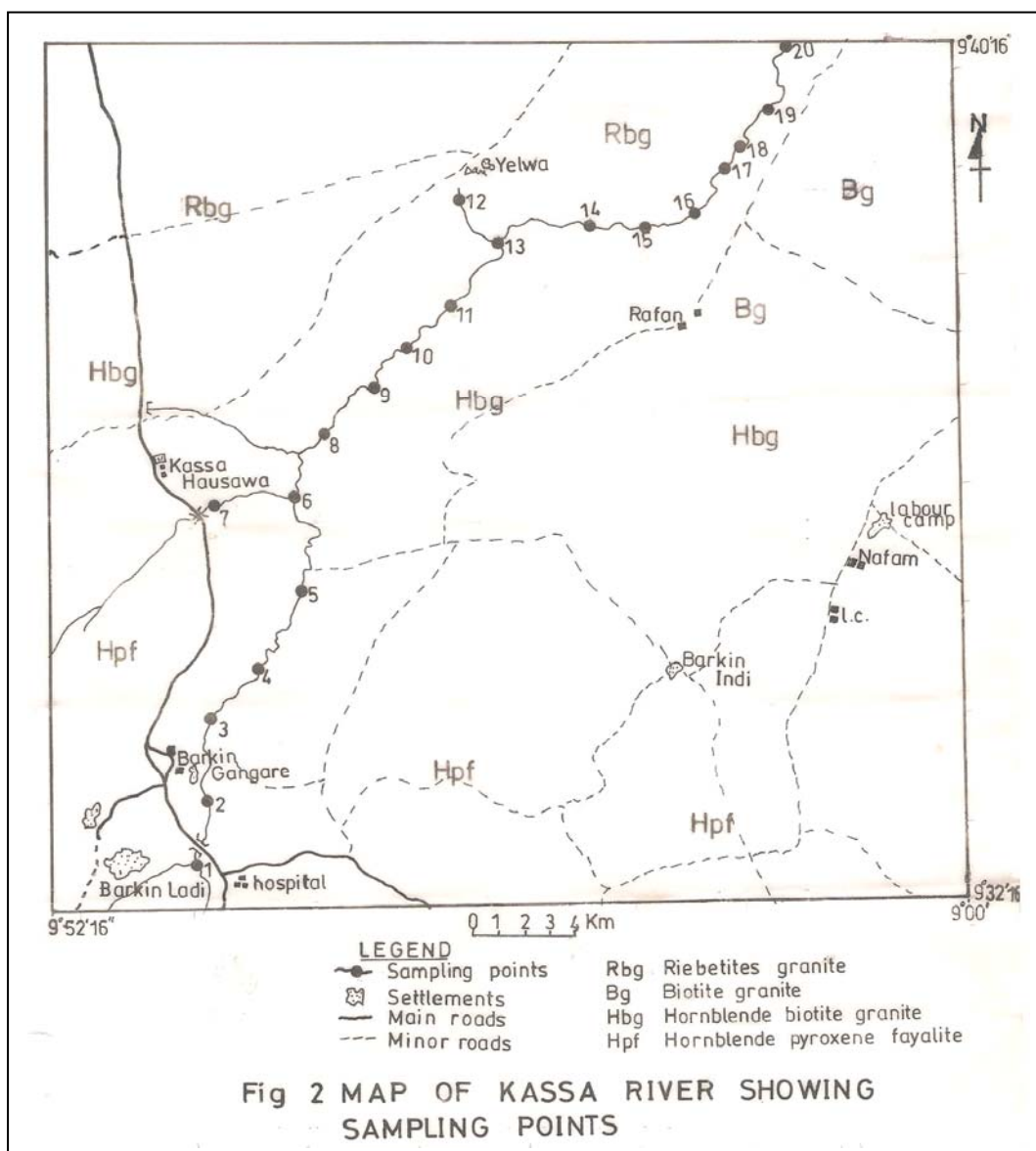

LEGEND
- Sampling points
- Settlements
- Main roads
- Minor roads

Rbg Riebetites granite
Bg   Biotite granite
Hbg Hornblende biotite granite
Hpf Hornblende pyroxene fayalite

Fig 2 MAP OF KASSA RIVER SHOWING SAMPLING POINTS

Table 1: Trace element data for Kassa River, February 2008.

Rock Types	Sampling Location	Latitude	Longitude	V (mg/l)	Cr (mg/l)	Ni (mg/l)	Cu (mg/l)	Zn (mg/l)	As (mg/l)	Pb (mg/l)	Co (mg/l)	Fe (mg/l)
Hpf	1.	9^0 32' 30"	8^0 54' 98"	0.41	0.30	0.14	0.11	0.12	0.05	0.07	0.11	1.14
	2.	9^0 32' 35"	8^0 54' 94"	0.31	0.19	0.10	0.56	0.10	0.06	0.06	0.13	1.52
	3.	9^0 32' 78"	8^0 54' 79"	0.25	0.17	0.13	0.06	0.09	0.04	0.07	0.14	1.28
	4.	9^0 32' 19"	8^0 55' 02"	0.36	0.24	0.08	0.13	0.09	0.07	0.08	0.12	1.29
	5.	9^0 31' 88"	8^0 55' 06"	0.30	0.18	0.09	0.10	0.16	0.06	0.05	0.16	1.38
	6.	9^0 31' 78"	8^0 54' 97"	0.35	0.10	0.10	0.09	0.18	0.07	0.06	0.10	1.32
	7.	9^0 31' 72"	8^0 54' 93"	0.24	0.22	0.09	0.09	0.14	0.16	0.08	0.09	1.52
	8.	9^0 31' 61"	8^0 54' 87"	0.32	0.26	0.78	0.12	0.15	0.06	0.08	0.09	1.49
	9.	9^0 31' 48"	8^0 54' 85"	0.28	0.18	0.09	0.19	0.10	0.04	0.07	0.07	1.86
Hbg	10.	9^0 31' 39"	8^0 54' 81"	0.34	0.23	0.12	1.14	0.11	0.05	0.08	0.18	1.69
	11.	9^0 32' 35"	8^0 54' 14"	0.29	0.19	0.08	1.53	0.06	0.06	0.06	0.13	1.48
	12.	9^0 32' 63"	8^0 54' 38"	0.37	0.28	0.10	1.26	0.05	0.05	0.06	0.15	1.42
	13.	9^0 33' 55"	8^0 54' 44"	0.36	0.20	0.81	0.07	0.06	0.03	0.07	0.14	1.11
	14.	9^0 33' 71"	8^0 54' 51"	0.24	0.17	0.93	0.09	0.09	0.05	0.07	0.12	1.15
	15.	9^0 34' 52"	8^0 54' 96"	0.29	0.26	0.15	0.08	0.15	0.05	0.08	0.11	1.29
	16.	9^0 34' 65"	8^0 54' 97"	0.38	0.26	0.06	0.10	0.11	0.07	0.06	0.19	1.45
	17.	9^0 34' 74"	8^0 55' 05"	0.31	0.23	0.07	0.11	0.16	0.05	0.06	0.17	1.27
	18.	9^0 34' 97"	8^0 54' 96"	0.33	0.20	0.08	0.09	0.17	0.05	0.06	0.17	1.70
	19.	9^0 34' 99"	8^0 54' 97"	0.37	0.24	0.09	0.14	0.15	0.06	0.07	0.16	1.95
Rbg/Bg	20.	9^0 34' 04"	8^0 54' 99"	0.32	0.20	0.13	0.53	0.17	0.05	0.08	0.14	1.93
	Mean WHO Standard (1999) World River (Mean) Hem (1985)			0.31 0.05 0.001	0.22 0.05 0.001	0.21 0.05 0.002	0.31 1.00 0.003	0.11 5.00 0.015	0.05 0.01 0.001	0.07 0.01 0.003	0.13 0.05 0.003	1.43 0.30 0.50

Hpf: Hornblende pyroxene fayalite
Hbg: Hornblende biotite granite
Rbg: Riebekite granite
Bg: Biotite granite

Table 2: Average trace element concentrations in the rock types.

Rock Types	V	Cr	Ni	Cu	Zn	As	Pb	Co	Fe	
Hpf (sample nos. 1-7)	0.32	0.20	0.10	0.16	0.13	0.07	0.07	0.12	1.35	
Hbg (sample nos. 8-13)	0.33	0.22	0.33	0.72	0.09	0.05	0.07	0.13	1.51	
Rbg/Bg (sample nos.13-20)	0.32	0.22	0.22	0.16	0.14	0.05	0.07	0.15	1.53	

Hpf: Hornblende pyroxene fayalite
Hbg: Hornblende biotite granite
Rbg: Riebekite granite
Bg: Biotite granite

Table 3: Trace elements, mean concentrations and 1999 WHO Standards

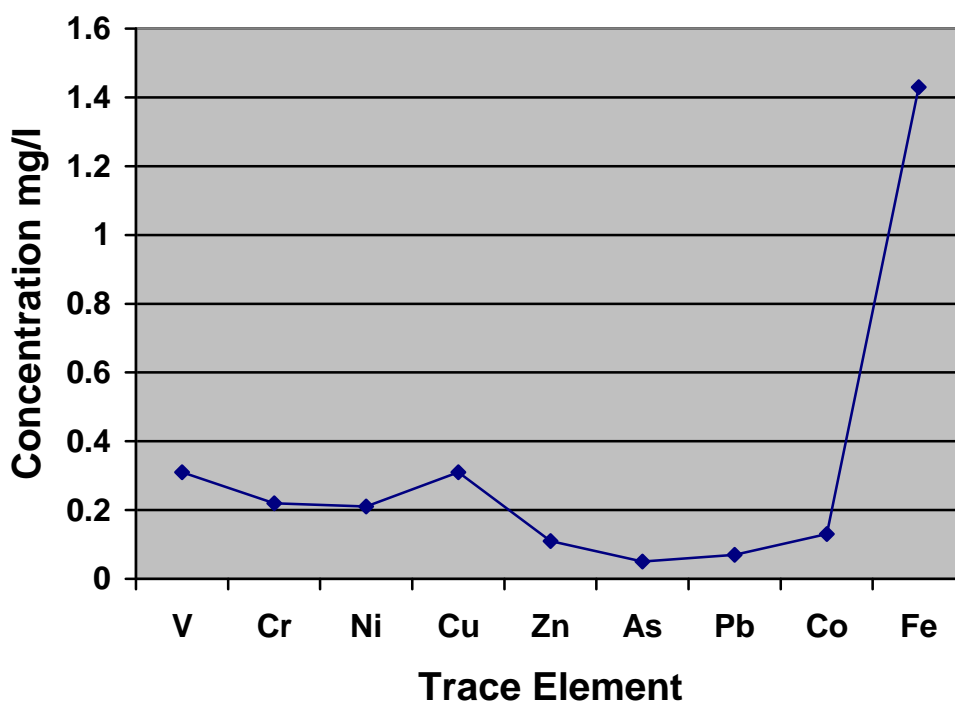| Parameters	Mean Concentration(mg/l)	WHO (1999) Standards
V	0.31	0.05
Cr	0.22	0.05
Ni	0.21	0.05
Cu	0.31	1.00
Zn	0.11	5.00
As	0.05	0.01
Pb	0.07	0.01
Co	0.13	0.05
Fe	1.43	0.03

Fig. 3: Mean concentration levels of trace elements in the water samples

Table 4: Summary of Quantitative Index with Respect to Trace Element Levels in   Water of Kassa River

Metals	Range	Mean	Igeo	Summary of Trace Element Level
V	0.24 – 0.41	0.31	7	Very highly contaminated
Cu	0.06 – 0.56	0.31	6	Very highly contaminated
Cr	0.17 – 0.30	0.22	7	Very highly contaminated
Ni	0.06 – 0.78	0.21	6	Very highly contaminated
Co	0.07 – 0.19	0.13	5	Highly contaminated
Zn	0.05 – 0.18	0.11	2	Moderately contaminated
Pb	0.05 – 0.08	0.07	2	Moderately contaminated
As	0.03 - 0.07	0.05	5	Highly contaminated

REFERENCES

Cravotta, C. A. and Bilger, M. D., 2001. Water quality trends for a stream draining the southern Anthracite field, Pennsylvania. Geochemistry: Exploration, Environment, Analysis,Vol. 1 2001 pp. 33-50.

Davis, A, and Eary, L. E., 1997. Pit lake water quality in the western United States: An analysis of chemogenetic trends. Mining Eng. June 98-182.

Ekwueme, B. N. 1993. An easy approach to Igneous Petrology. University of Calabar Publication 147-158.

Forstner, U. and Wittmann G. T. W., 1981. Metal Pollution in the Aquatic Environment Springer-Verlag, New York.

Fanfani, I., Zuddas, P. and Chessa, A., 1997. Heavy metal speciation analysis as a tool for studying mine tailings weathering. Journal of Geochemical exploration 58, 241-248.

Hem, J. D., 1985. Study and Interpretation of the Chemical Characteristics of Natural Water USGS Water Supply Paper 2254, 3rd Edition; 263p.

Hossain, M. T., Schoeneich, K. and Okechukwu., 1986. The Geology of Jos Plateau Excursion Guide. University Press, Jos.

Horowitz, A. J., Meybeck, M., Idlafkih, Z. and Biger, E., 1999. Variations in trace element geochemistry in the Seine River Basin based on flood plain deposits and bed sediments. Hydrological processes 13:1329-1340.

Levy, D. B. Custis, K. H., Casey, W. H. and Rock, P. A., 1997. The aqueous geochemistry of the abandoned Spenceville copper pit, Nevada County, California. J. Environ Qual. 26 233-243.

Manjunatha, B. R., Balakrishna, K., Shankar, R. and Mahalingam,T. R., 2001. Geochemistry and assessment of metal pollution in soils and river components of a monsoon dominated environment near karwar, Southwest Coast of India. Environmental Geology, 40:1462-1470.

Mueller, G., 1979. Schwermettale in den Sedimenten des Rheins-veraenderungenseit 1971. Umschau 79:778-783.

Ramstedt, M, Carlsson, E. and Lovgren, L., 2003. Aqueous geochemistry in the Udden Pit Lake northern Sweden. Applied Geochemistry 18:97-108.

Sutherland, R. A., 2000. Bed sediment associated trace metals in an urban stream Oahu Hawaii. Environmental Geology 39:611-627.

Taylor, S. R and MClennan, S. M., 1985. The continental crust: It's composition and Evolution. Blackwell, Oxford 312 pp.

Tijani, M. N., Jinno, K. and Hiroshiro, Y., 2004. Environmental impact of heavy metals distribution in water and sediments of Ogunpa River, Ibadan area, Southwestern Nigeria. Journal of Mining and Geology Vol. 40(1) 2004 pp. 73-83.

Rabe, F. and Bauer, S., 1977. Heavy metals in Lakes of the Coeurd Alene River Valley. Northwest Science 51, 183-197.

Wood, C. R., 1996. Water quality of large discharges from mines in the anthracite region of eastern Pennsylvania U.S. Geological Survey Water-Resources Investigations Report 95-4243.

World Health Organisation (1999) Guidelines for drinking water quality 2nd Edition