

<http://www.pjbs.org>

PJBS

ISSN 1028-8880

**Pakistan
Journal of Biological Sciences**

ANSI*net*

Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Contribution to the Geochemistry of Trace Elements in the Sediments of the Noun River and Tributaries, Western Cameroon

^{1,2}C. Njofang, ¹J. Matschullat, ²J.P. Tchouankoué and ²A. Amougou

¹Interdisciplinary Ecological Research Center, Brennhausgasse 14,

Technische Universität Bergakademie Freiberg, Freiberg, D-09599, Germany

²Faculty of Science, P.O. Box 812, Université de Yaoundé 1, Yaoundé, Cameroon

Abstract: This study reports on the distribution of trace elements in the sediments of the Noun River valley. Two groups of trace elements have emerged based on their distribution and geochemical behaviour. The first group shows lower values whereas the second group aligns higher values. Elements like Al and Sr in one side and Zn, Zr in the other present concentrations statistically different from those of the rocks compared to other elements in trace analyzed (Cr, Ni, Ba, Co, Cu, Fe, Mn, V, As and Pb). The trace elements Al, Sr, Zr, Zn and Pb in the sediments of the Noun River show concentrations rather lower than those of the world. The average concentrations in elements C (3.72%), N (0.27%), S (0.05%) and of the ratios C/N (13.77) and N/S (5.29) reflect those resulting from the decomposition of the organic matter which derives from soils with very small concentrations in S. The Noun valley sediments are mostly of primary (quartz, microcline, plagioclase, orthoclase, ilmenite, anatase) and newly formed or secondary (kaolinite, gibbsite, hematite, goethite) minerals. This mineralogy and the overall low concentration of the studied trace elements, with Al, Fe, Ti and Mn as most abundant elements, is consistent with the local geology made up of the basic rocks (basalts, volcanic ash) and of the acid rocks (granites, gneiss). Overall the trace elements concentration and distribution suggest their geogene origin. Yet, this study is a first contribution of its kind towards the development of a baseline geochemical database essential for a sustainable and healthier Noun valley ecosystem.

Key words: Trace elements, sediments, geochemical base, noun valley, Cameroon

INTRODUCTION

Over the last decades, regional studies on the distribution of trace elements have been gaining much interest due to the established link between their deficit or excess in the environment and human related health. In this context, a geochemical study of river basin sediments can help understand and identify the sources of trace elements. Their total load in sediments depends on a myriad of factors including the local geology, human activities along river beds and the ecological health of the system. As it can be inferred from Gailardet *et al.* (2003), trace elements distribution in the sediments can be regarded as the signature of all physical, chemical and biological processes affecting an aquatic ecosystem. It is within this framework that regional management of sediments to provide the much needed baseline geochemical information has been getting interest world wide (Muller *et al.*, 1996). This study was motivated by a probable environmental threat to the Noun valley from its active and growing population, economy and quasi intensive agriculture.

Furthermore, despite its relatively cardinal importance, the Noun River basin has not been the focus of a study on the distribution of trace elements in its sediments. Thus, the major objective of this study was to assess the distribution and fate controlling mechanisms of selected trace elements in the sediments of the Noun River and in some of its tributaries. It lays ground towards the development of a comprehensive geochemical database. Such a database is needed as guidelines and for monitoring trace elements cycle from the sediments to the food web.

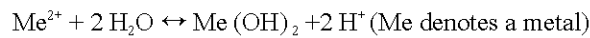
MATERIALS AND METHODS

Study area: The studied area is part of the high plateaus of the Western Cameroon (HPWC) (10° and 11° of longitude East, 5° and 7° of latitude North) in the central part of the Volcanic Line of Cameroon (VLC). The average altitude of the HPWC is 1400 m. The Noun River drains much of the studied area. Its principal tributaries include the eastern rivers Mafoumba, Maouat, Temudjin, Panké and Nkoup whereas in the West flow the Mifi (Southern

between trace elements. The correlation of the products of Pearson moments are also studied for the affinities and the tests W of Mann Whitney (Wilcoxon) were used to compare medians between sediments.

RESULTS AND DISCUSSION

Relationships between the physico-chemical characteristics of water of the Noun River and its tributaries and the behaviour of trace elements: The quasi-neutrals pH from 6 to 7.5 (Table 1) of water of the Noun River and of its tributaries are in the range (6.5-8.5) of unpolluted natural surface water (Radojeviæ and Bashkin, 1999; Weiner, 2000). This observation suggests water with low mobility of metallic trace elements as opposed to acid mine water generally rich in trace elements and very dependent on protonation/deprotonation reactions of the type:



The electric conductivity observed in water of the Noun River and its tributaries (22.5-95 $\mu\text{S cm}^{-1}$) is far below Bifano and Mogollón (1995) clean water of rivers (430 $\mu\text{S cm}^{-1}$) and contaminated (950 $\mu\text{S cm}^{-1}$). The observed values are rather contained in the range from 10

to 100 $\mu\text{S cm}^{-1}$ given by Radojeviæ and Bashkin (1999) for surface water. These low values of electric conductivity are consistent with the quasi neutral pH values and the low contents in trace elements. These conditions of pH and electric conductivity contribute more towards the precipitation of elements like Fe^{2+} , Fe^{3+} , Mn^{2+} , Al^{3+} with possibly the formation of complexes with ligands NO_3^- , HPO_4^{2-} , H_2PO_4^- which can precipitate. The electric conductivity which appears high with 95 $\mu\text{S cm}^{-1}$ in the tributary sample S8I7 (Nkoup) may be explained by fact that this tributary drains the volcanic ash rich in Ca_2^+ , Na^+ , Mg_2^+ , SO_4^- . Besides, the temperatures recorded in water (20.4-24.7°C) reflect only the natural and normal process which characterizes the climate of the area.

Table 1: Physico-chemical parameters of water

Codes	Sampling sites	pH	EC ($\mu\text{S cm}^{-1}$)	T of water (°C)
S1D5**	Noun-Bamendjing	7.0	42.0	24.7
S2E3	Mifi-Nord	7.5	26.5	20.5
S3G5**	Noun-Nkoukpa Palmeraie	7.0	56.0	22.0
S4H5**	Noun-Terjounoun Palmeraie	7.0	56.5	22.1
S5J6	Nkong	6.5	22.5	24.5
S6J7	Ngam	6.0	33.0	23.4
S7J7**	Noun-Projet route du Noun	6.5	60.0	23.4
S8I7	Nkoup	6.5	95.0	22.8
S9G5**	Noun-Mangoun	6.5	63.5	21.7
S10F2	Mifi-Sud	6.5	49.0	20.4

**Samples from Noun River

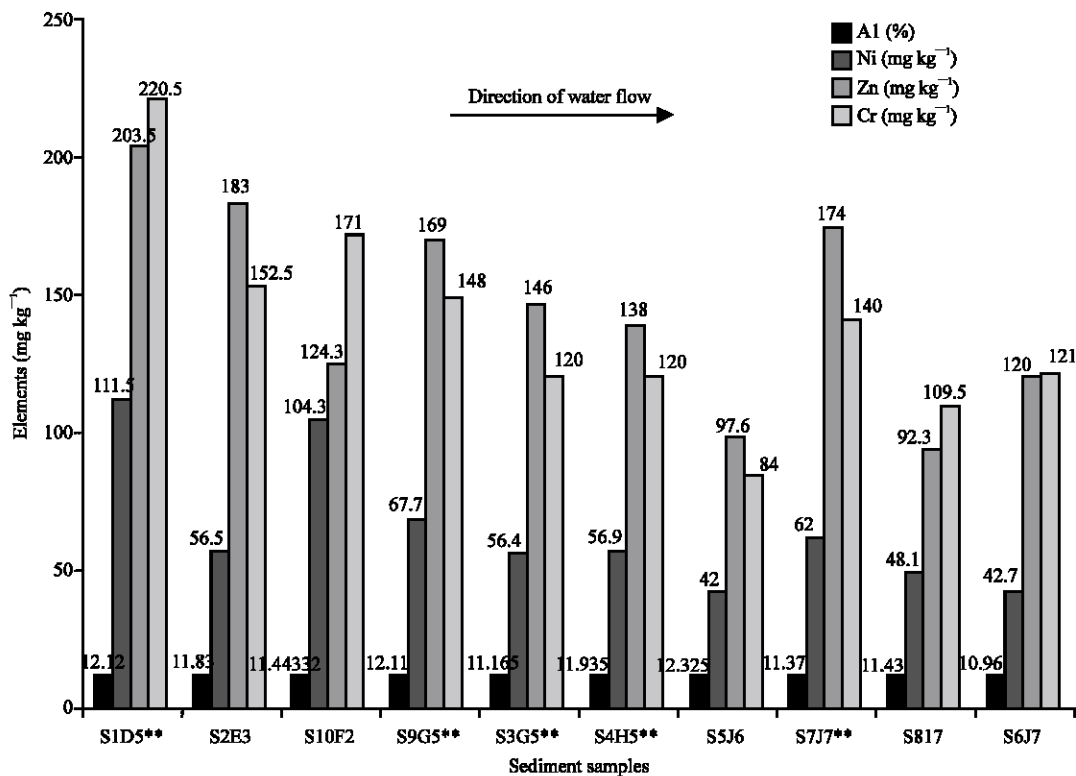


Fig. 2: Comparison of Al, Ni, Zn and Cr concentrations in sediments along a flow path

Influence of water flow on the distribution of the trace elements along the Noun River and its tributaries: Some trace elements such as Al, Ni, Zn and Cr were selected to assess the dilution phenomenon in the sediments. Their concentrations along the sampling flow path are compared (Fig. 2) and also a basis for discussing their behaviours taking into consideration their physicochemical properties (for example geogene and anthropogene and the difference in their mobility).

Aluminium: The Al concentrations along the Noun and in the tributaries are quasi-constants. This constancy is probably related to Al tendency to immobility (Reimann and De Caritat, 1998), which is consistent with the near neutral pH of the Noun water of 6-7.5 less favourable to the solubility of the majority of natural Al compounds (Weiner, 2000). Thus, the low concentrations of Al reflect those originating naturally by the degradation of the acid rocks (granites and gneiss) or basic (basalt) rocks of the area. These types of rocks present the lowest Al variations as they contain respectively 73,000 mg kg⁻¹ in the granites and 83,000 mg kg⁻¹ in basalts (Reimann and De Caritat, 1998).

Nickel: The variations of Ni along the Noun agree with its mobile character. Weiner (2000) argues that Ni is one of the most mobile metals of the aquatic environment. The increase in its concentration in the Noun sample S7J7 (road Noun-project of Noun) may be most likely related to the pH. It can also be linked to the decrease of the hydraulic gradient and the resulting prevalence of precipitation/co-precipitation process at this sampling location (altitude of 945 m). This explanation also applies for the high Ni concentration observed in the sample S1D5 (Bamendjing). The neutral water pH 7 combined with this sampling point located just downstream from the dam where the local hydraulic conditions might be prone to metal accumulation. Ni lowest concentrations which appear in the samples from the tributaries S5J6 (Nkong), S8I7 (Nkoup), S6J7 (Ngam) are undoubtedly related to the drainage by these tributaries of the granitic and gneissic areas where the rocks have lower Ni concentrations.

Zinc: Zn and Ni have similar behaviour. They are observed in higher concentrations in samples S1D5 and S7J7. The slight variation of the concentrations in the other samples along the Noun can be explained by Zn mobility as Zn²⁺ species under oxidizing conditions of running and slightly acidic water (Reimann and De Caritat, 1998). These concentrations along the Noun River seem mainly influenced by the location of the sample S2 E3 (Mifi-North) because of its almost similar altitude to that

of S1D5 (Bamendjing). The low concentrations observed in the tributaries are also probably related to the drainage of the local geology materials of low Zn concentrations.

Chrome: The low mobility character of Cr would explain the slight variation of its concentrations observed in the samples taken along the Noun River, except the sample S1D5 which exceptionally presents a high concentration. Similarly lower concentrations of Cr and Ni found in the samples of the tributaries such as S5J6 (Nkong), S8I7 (Nkoup), S6J7 (Ngam) can be due to their natural association and common origin. In general, the behaviours of Al and Ni, Zn, Cr are almost divergent. Aluminium seems not to be influenced by the contributions of water of the tributaries because its concentrations remain almost identical in the various samples contrary to three other elements Ni, Cr, Zn which present a slight variation along the Noun. Dilution does not seem to be an important factor for the three elements, because the sample S7J7 (Noun-road project of Noun) from a lower relief location presents even higher concentrations in these elements. The statistical analyses carried out for these samples as shown in the dendrogramme (Fig. 3a) and the principal component analyses (Fig. 3b) confirm these similarities in the composition of the samples in trace elements along the Noun and the divergences between these samples. Also, the samples along the Noun present a very great affinity between them suggesting that they are not affected by the dilution phenomenon. The only sample which presents a very great variation in its composition is S1D5 ** (Noun-Bamendjing). The difference which exists between this sample and the others is probably related to the fact that it comes from a sampling point located just downstream of the Bamendjing dam. This sampling point acts as a sink for heavy metals due to the near neutral pH and quasi stagnant water that favours precipitation and co-precipitations of dissolved heavy metals.

Appreciation of the natural background of trace elements in the sediments: The term background means here the absence of geochemical anomaly. The evaluation of the sediments background can be achieved through comparison with local geology and to the sediments of the world.

Total contents of trace elements in sediments and rocks: The total concentrations of trace elements in the sediments of the study area are compared to those of the rocks of the HPWC (Table 2) as reported by Fosso (1999), Kamgang (2003), Talla (1995), Tchouankoue (1992) and Wandji (1995). Statistically significant differences of

Table 2: Geochemical composition of sediments of the Noun River and its tributaries compared to estimated mean values in the rocks of HPWC. All reported values are in mg kg⁻¹ dry weight of sediments and rocks

Elements	Arithmetic mean values	Standard deviation	Geometric mean values	Minimum	Maximum	Median	25% quartile	75% quartile	Mean values of rocks from HPWC
Al*	116.688	4.569	116.608	109.600	123.250	116.367	113.700	121.100	143.280
Ni	65	24	61	42	112	57	48	68	62
Zn*	145	37	141	93	204	142	120	174	82.4
Zr*	400	153	373	153	744	398	340	453	178
Ba	683	211	660	450	1.230	635	570	720	734
Co	46	9	45	38	63	43	40	46	33
Cr	139	38	134	84	221	131	120	153	130
Cu	31	5	30	24	41	29	27	32	32
Fe	88.785	11.236	88.175	72.750	113.100	87.350	83.050	95.700	91.130
Mn	1.983	1.739	1.628	799	6.795	1.513	1.270	1.667	1.310
Sr*	154	52	146	72	244	147	116	182	628
Ti	18.920	3.575	18.550	10.695	22.800	19.550	17.300	21.900	/
V	168	24	167	130	220	164	156	179	158
As	2	2	1.2	0.5	6	1	0.9	1.6	0.8
Pb	31	16	29	17	74	28	24	29	21

*Elements showing a statistically significant difference. Mean values of rocks (Fosso, 1999; Kamgang, 2003; Talla, 1995; Tchouankoue, 1992; Wandji, 1995)

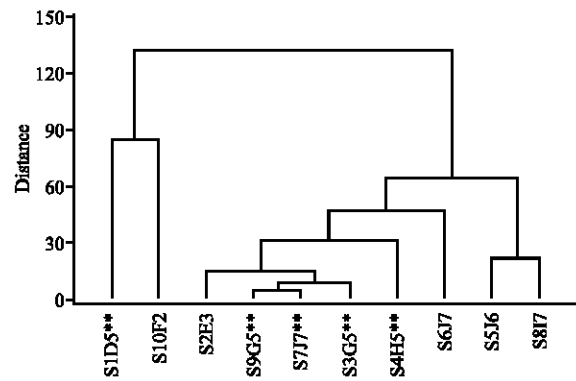


Fig. 3a: Grouping of samples as function of their composition

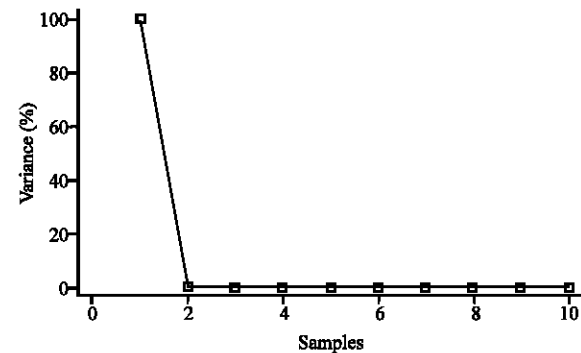


Fig. 3b: Discrepancies in sample composition

certain elements (Al, Zn, Zr, Sr) with 95 and 99% of confidence limits indicate values of Al and Sr lower than those of the rocks whereas Zn and Zr higher than those of the rocks. The remaining elements (Cr, Ni, Ba, Co, Cu, Fe, Mn, V, As, Pb) have similar concentrations with those

of the rocks. The observed differences can be related to the elements intrinsic properties, the mechanisms governing their accumulation or even the mechanical sedimentary differentiation, which can increase their concentration.

Aluminium and strontium: These elements have rather higher concentrations in rocks than in the sediments. The median values presented for Al are respectively 141.600 and 116.367 mg kg⁻¹ for the rocks and the sediments. These differences for the two types of samples can be due to the immobility prone character of aluminium coupled with the near neutral pH (6-7.5) of the draining water and hence its low solubility. The amount of aluminium which is found in the sediments can be related to normal sedimentation because it does not show any positive correlation (Table 3) with elements likely to support its accumulation.

Sr presents the respective median values of 569.500 mg kg⁻¹ for the rocks and 147 mg kg⁻¹ for the sediments. It does not present any correlation with pH, C and minerals in the sediments. Its low concentration in the sediments can be related to its similar geochemical characteristics to those of calcium and magnesium. These elements can through competition take over the adsorbing sites in the sediments and consequently Sr remains much mobilized by water.

Zinc and zirconium: Zn and Zr have median concentrations higher in the sediments than in the rocks. Zn respectively presents median concentrations values of 81 mg kg⁻¹ in rocks and of 142 mg kg⁻¹ in sediments. Zn accumulation may be through the mechanism of precipitation/coprecipitation from water draining the studied area. It presents positive correlations with the pH

Table 3: Pearson correlation of some trace elements in the sediments

	Al	Ni	Zn	Zr	Ba	Co	Cr	Cu	Fe	Mn	Sr	Ti	V	As	Pb	C	Kaolinite	pH	Hématite	Gibbsite	
Al	1.00																				
Ni	0.199	1.000																			
Zn	0.235	0.514*	1.000																		
Zr	0.139	-0.180	0.468	1.000																	
Ba	-0.344	-0.370	-0.180	-0.270	1.000																
Co	0.007	0.923*	0.286	-0.400	-0.080	1.000															
Cr	0.152	0.905*	0.760*	0.010	-0.180	0.813*	1.000														
Cu	0.092	0.883*	0.211	-0.250	-0.530	0.794*	0.643*	1.000													
Fe	0.099	0.842*	0.417	0.111	-0.350	0.812*	0.733*	0.768*	1.000												
Mn	0.293	0.710*	0.520*	-0.360	-0.030	0.626*	0.774*	0.513*	0.263	1.000											
Sr	-0.517	-0.500	-0.150	0.096	0.539*	-0.331	-0.426	-0.497	-0.170	-0.628	1.000										
Ti	-0.113	0.141	0.301	0.434	0.193	0.204	0.173	-0.011	0.517	-0.324	0.534*	1.000									
V	-0.086	0.725	0.280	0.016	-0.070	0.805	0.618*	0.646*	0.943*	0.146	0.069	0.670*	1.000								
As	0.250	-0.110	-0.000	0.224	-0.260	-0.281	-0.127	0.120	-0.130	0.015	-0.135	-0.680	-0.310	1.000							
Pb	0.361	0.479	0.481	-0.300	0.236	0.431	0.605*	0.213	0.042	0.915*	-0.503	-0.210	-0.000	-0.092	1.000						
C	-0.082	0.302	-0.240	-0.050	-0.810	0.176	0.017	0.636*	0.319	-0.090	-0.410	-0.310	0.145	0.301	-0.420	1.000					
Kaolinite	0.404	0.400	-0.130	-0.470	-0.640	0.260	0.130	0.599*	0.143	0.364	-0.555	-0.600	-0.070	0.442	0.107	0.650*	1.000				
pH	0.359	0.196	0.549*	0.611*	-0.590	-0.149	0.313	0.201	0.062	0.299	-0.593	-0.250	-0.210	0.491	0.217	0.293	0.175	1.000			
Hematite	-0.277	0.399	0.645*	0.013	0.326	0.456	0.692*	0.201	0.273	0.493	-0.056	0.342	0.324	-0.403	0.508	-0.408	-0.435	0.041	1.000		
Gibbsite	0.101	0.024	0.521*	0.863	-0.460	-0.213	0.141	-0.070	0.208	-0.245	-0.055	0.466	0.092	-0.173	-0.211	0.098	-0.346	0.583*	0.15	1.000	

* Correlations not less or equal to 0 statistically significant at confidence level of 95%

of water (0.55), Hematite-Zn (0.65) and Gibbsite-Zn (0.52) (Table 3). The coprecipitation of Zn might have occurred through minerals like gibbsite. It is favoured by the near neutral pH of water as supported by the positive correlation between the gibbsite and the pH (0.58). Zn is also probably retained through adsorption on iron oxide surfaces such as hematite.

Zr shows concentrations of 222 mg kg⁻¹ in rocks and of 398 mg kg⁻¹ in sediments. The observed higher concentrations in the sediments is probably due to the mechanism of coprecipitation taking considering its very low solubility under the pH range of 6-7.5. As for Zn, coprecipitation with gibbsite under the influence of the pH may have taken place as supported by the positive correlations of Zr-pH (0.61) and gibbsite-Zr (0.86). Besides, the dendrogrammes (Fig. 4a) and the correlations of Pearson (Table 3) suggest the following natural associations: Al and As; Mn and Pb; the majority of transition metals Ni, Co, Cr, Cu, Fe, V; Zn, Ti, Zr and that of Ba, Sr.

These regroupings can thus have been favoured by the natural origin of these elements but also by their intrinsic properties because of their similar behaviours under certain conditions. Besides, the concentrations of the analyzed trace elements confirm their order of abundance in the earth's crust and in the parent materials (rocks of the area). This relative abundance is consistent with the principal component analysis showing the percentage of variance of trace elements in the sediments (Fig. 4b). These elements appear in high concentration according to the order: Al > Fe > Ti > Mn.

Trace elements in the non sediments versus the sediments of the world: The comparisons between trace elements in the sediments of the studied area and those of the world are presented (Table 4). The elements Al, Sr, Zr, Zn which previously were found with variations compared

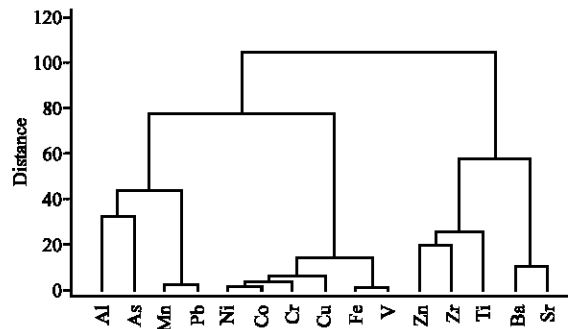


Fig. 4a: Grouping of trace elements

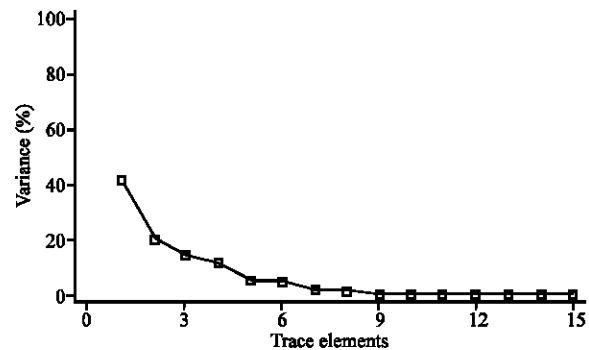


Fig. 4b: Divergence of trace elements in samples

to the concentrations of the rocks are reported in the range of the sediments of the world presented by Deschamps *et al.* (2002) and Reimann and De Caritat (1998). It is the same for Pb. However, certain elements like Ni, Ba, Co, Cu, Fe, Ti, V present concentrations higher than the range found in the world. This variation can be due to many factors in particular those related to the inherent differences on the rocks, minerals and soils which were drained in the sediments analyzed in the world. The list of factors may also include the size of the grains used for the analyses and the type of analyses

Table 4: Comparison between the geochemical composition of the sediments of the Noun River and its tributaries with estimated mean values of the world. All reported values are in mg kg⁻¹ dry weight of sediments

Elements	Arithmetic mean values	Standard deviation	Geometric mean values	Minimum	Maximum	Median	25% quartile	75% quartile	World sediments
Al	116.688	4.569	116.608	109.600	123.250	116.367	113.700	121.100	12000-166000a
Ni	65	24	61	42	112	57	48	68	14-59a
Zn	145	37	141	93	204	142	120	174	44-209a
Zr	400	153	373	153	744	398	340	453	256-818b
Ba	683	211	660	450	1.230	635	570	720	64-607b
Co	46	9	45	38	63	43	40	46	7.0-32a
Cr	139	38	134	84	221	131	120	153	24-161a
Cu	31	5	30	24	41	29	27	32	12.0-24a
Fe	88.785	11.236	88.175	72.750	113.100	87.350	83.050	95.700	14000-78000a
Mn	1.983	1.739	1.628	799	6.795	1.513	1.270	1.667	700-2500a
Sr	154	52	146	72	244	147	116	182	26-250b
Ti	18.920	3.575	18.550	10.695	22.800	19.550	17.300	21.900	2100-9700a
V	168	24	167	130	220	164	156	179	21-118b
As	2	2	1.2	0.5	6	1	0.9	1.6	2.0-22a
Pb	31	16	29	17	74	28	24	29	8-195a

a: data compiled in Deschamps *et al.* (2002); b: data compiled in Reimann and De Caritat (1998)

carried out. For example, Ti concentration in the sediments of the studied area (18.920 mg kg⁻¹), twice larger than the maximum of concentration met in the world, can be due to the fact that the studied area presents minerals rich in titanium.

Carbon, Nitrogen and Sulphur (CNS) contents and the sediments mineralogy: The CNS content has been shown by Matschullat *et al.* (2000) as important for assessing a geochemical background. The sediments mineralogy is the signature not only of the recent geological history but can also indicate the potential anomaly of trace elements distribution.

CNS: The sediments ratios C/N (13.77) and N/S (5.29) and the slightly low values in particular for C (1.84-5.74%) with average of 3.72%; N (0.13-0.42%) with average 0.27% and for the S (0.03-0.06%) with average 0.05% suggest that the elements CNS in the sediments originate only from the weathering of the soils. These results are almost similar to those of Evans *et al.* (1995) in the study of the sediments of Ensenada de San Simón in Spain with values of C (0.4-6.5) with average 4.8% and N (0.1-1.8) with average of 0.4%. These values and their corresponding C/N ratio of 2.4-13.2 with average 10.7 were explained as signature of the predominance of the organic matter from soils. In general as noted by Meybeck (1993), the concentrations in CNS in the sediments reflect the conditions of degradation, thickness of the soil transported by water, climate and even also of the type of vegetation of the area (savanna). The N content of approximately the 1/14 of C and the S content the 1/6 of N suggest that these CNS elements could be a continuity of the biogeochemical cycle in the sediments, with however moderate concentrations. Lastly, the very low content of S can

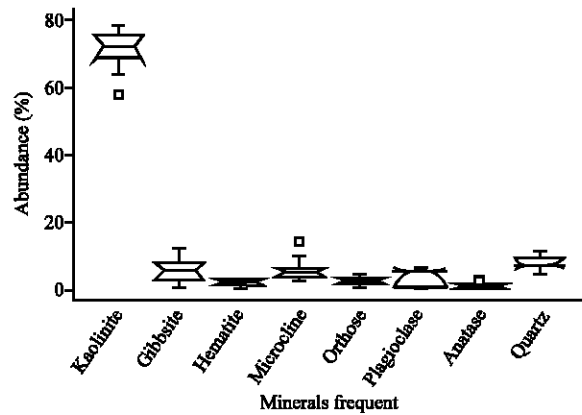


Fig. 5: Abundance of minerals in the sediments

characterize the sediments which do not result from the acid sulphate soils. Values of S less or equal to 0.10% and of C superior to 4% in the sediments are interpreted by Österholm and Åström (2002) as not resulting from the acid sulphate soils.

Mineralogy: The minerals observed in the sediments of the studied area (Fig. 5) are mostly primary quartz, microcline, plagioclase, orthoclase, ilmenite, anatase and of newly formed kaolinite, gibbsite, hematite and goethite.

This mineralogy corresponds with the regional geology characterized by the prevalence of the pluto-volcanic and metamorphic acids (granite and gneiss) and basic (basalts, ashes and lapilli) rocks, as well as the overlying soils. In general, the observed minerals do not indicate some geochemical anomalies that could be related to trace elements. They are rather common products of intense chemical weathering of tropical regions with ultimate degradation products such as kaolinite and gibbsite (Johnsson, 2000). Mention should however be made on the presence of titanium minerals ilmenite

(FeTiO₃) and anatase (TiO₂), which probably contributed to the relatively high concentration of Ti in the sediments. Similarly, the abundant presence of silicates and iron oxides such as ilmenite may explain the relative high concentrations of Al and Fe in the sediments.

CONCLUSIONS

The concentrations of trace elements in the sediments of the Noun River and its tributaries reflect those of the acidic and basic rocks of the region with Al, Fe, Ti and Mn as the most abundant elements. The mechanisms governing their distribution include their intrinsic geochemical properties; precipitation and coprecipitation, as well as adsorption on Fe (hematite), Mn (mainly for Zr, Zn, Pb, Cr) oxides and Al hydroxides (gibbsite), kaolinite and the organic matter surfaces (likely for Cu). The influence of the dilution which would have resulted from the rainy season related leaching seems negligible. The sediments downstream in the vicinity of the Bamendjing dam is the only sampling location with divergent concentrations of trace elements. The variations observed with ranges found in the world are due to several reasons that may include slight differences in soil and minerals types, the size of the grains used for the analyses or also the types of analytical procedures carried out. The observed minerals reflect those generally found in the tropical areas. However, the presence of Ti bearing minerals mainly ilmenite and anatase are probably the main source of its relatively higher concentration. The composition in biogenes elements C, N and S can only be the continuation of the biogeochemical cycle in the sediments. Overall this study is a first approach and a contribution for the establishment of the environmental levels of trace elements in the sediments of the Noun River and its tributaries. It lays grounds towards the development of a geochemical baseline of data essential for the sustainable development of the important ecosystem of the Noun valley.

ACKNOWLEDGMENTS

The first author acknowledges the financial support from the German Academic Exchange Service (DAAD) for the fieldwork in Cameroon and the living expenses at the Technische Universität Bergakademie Freiberg in Germany.

REFERENCES

Bifano, C. and J.L. Mogóllon, 1995. Metallic contaminant profiles in sediment cores from lake Valencia Venezuela. *Environ. Geochem. Health*, 17: 113-118.

Blasig, A., 2004. Mineralogy of Soils and Sediments of the Noun Valley in W-Cameroon, Bafoussam Distrikt. (In German). Unpublished BSc. Thesis. Institut für Mineralogie, Technische Universität Bergakademie Freiberg, Freiberg.

Borba, R.P., B.R. Figueiredo, B. Rawlins and J. Matschullat, 2000. Arsenic in water and sediment in the Iron Quadrangle, State of Minas Gerais, Brazil. *Revista Brasileira de Geociências*, 30: 554-557.

Deschamps, E., V.S.T. Ciminelli, F.T. Lange, J. Matschullat, B. Raue and H. Schmidt, 2002. Soil and sediment geochemistry of the iron quadrangle, Brazil: The case of arsenic. *J. Soil Sediments*, 2: 216-222.

Dumort, J.C., 1968. Manual on the sheet Douala-West. Geologic map of recognition on the scale of 1/500 000. (In French). DMG, Yaoundé, Cameroun, index, 12 carte h.t., pp: 69.

Evans, L.J., G.A. Spiers and G. Zhao, 1995. Chemical aspects of heavy metal solubility with reference to sewage sludge amended soils. *Int. J. Environ. Anal. Chem.*, 59: 291-302.

Fosso, J., 1999. Vulcanology, petrology and geochemistry of a stratovolcan of the high plateaus of the Western Cameroon. The Bangoun Mount. (In French). Thesis (doctorat 3ème cycle). Yaoundé 1 University, Yaoundé.

Gailardet, J., J. Viers and B. Dupré, 2003. Trace Elements in River Waters. In: Drever, J.I. (Ed.), *Surface and Groundwaters, Weathering and Soils*. In: *Treatise on Geochemistry*. Holland, H.D. and K.K. Turekian (Eds.), Elsevier, Oxford, 5: 225-272.

Johnsson, M.J., 2000. Chemical Weathering and Soils: Interface Between the Geosphere, Hydrosphere, Atmosphere and Biosphere. In: Ernst, W.G. (Ed.), *Earth Systems: Processes and Issues*. University Press, Cambridge, pp: 119-132.

Kamgang, P., 2003. Petrology and Geochemistry of a sector of the Cameroon Line, The Bamenda Mounts: Implications on the genesis and the evolution of magmas. (In French). Thesis (doctorat d'état). Yaoundé 1 University, Yaoundé.

Matschullat, J., 2000. Arsenic in the geosphere-A review. *Sci. Total Environ.*, 249: 297-312.

Matschullat, J., B.R. Perobelli, E. Deschamps, B.R. Figueiredo, T. Gabrio and M. Schwenk, 2000. Human and environmental contamination in the iron quadrangle, Brazil. *Applied Geochem.*, 15: 181-190.

Meybeck, M., 1993. C, N, P and S in Rivers: From Sources to Global Inputs. In: *Interactions of C, N, P, S: Biochemical Cycles and Global Change*. Wollast, R., F.T. Mackenzie and L. Chou (Eds.), Springer-Verlag, Berlin Heidelberg, pp: 163-193.

- Muller, H.W., B. Schwaighofer and W. Kalman, 1996. Heavy metal contents in river sediments. *Water Air Soil Pollut.*, 72: 191-203.
- Österholm, P. and M. Åström, 2002. Spatial trends and losses of major and trace elements in agricultural acid sulphate soils distributed in the artificially drained Rintala area, W. Finland. *Applied Geochem.*, 17: 1209-1218.
- Pansu, M., J. Gautheyrou and J.Y. Loyer, 1998. *Soils Analysis: Sampling, Instruments and Control.* (In French). Masson, Paris.
- Radojević, M. and V.N. Bashkin, 1999. *Practical Environmental Analysis.* The Royal Society of Chemistry, Cambridge.
- Reimann, C. and P. De Caritat, 1998. *Chemical Elements in the Environment: Factsheets for the Geochemist and Environmental Scientist.* Springer Verlag, Berlin Heidelberg New York.
- Segalen, P., 1967. The Soils of the Noun Valley. (In French). *Cah. ORSTOM série Pédologie*, 5: 287-349.
- Talla V., 1995. The Pan-African granitic massif of Batié (West-Cameroon): Petrology, petrostructural, geochemistry. (In French). Thesis (doctorat 3ème cycle). Yaoundé 1 University, Yaoundé.
- Tchouankoue, J.P., 1992. The syenite of Bangangté: A Pan-African complex with intermediate characters: petrology geochemistry. (In French) Thesis (doctorat 3ème cycle). Yaoundé 1 University, Yaoundé.
- Wandji, P., 1995. The recent volcanism of the plain of Noun (West-Cameroon). *Vulcanology, petrology, geochemistry and pouzzolanicite.* (In French). Thesis (doctorat d'état). Yaoundé 1 University, Yaoundé.
- Weiner, E.R., 2000. *Applications of Environmental Chemistry: A Practical Guide for Environmental Professionals.* CRC Press LLC, Boca Raton London New York, Washington DC.