

Geochemical composition of the Lomé Lagoon sediments, Togo: seasonal and spatial variations of major, trace and rare earth element concentrations.

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Supplementary Materials

Table S1- Major element contents in the fine fractions (<63 µm) of the Lomé lagoon sediments during the wet and the dry seasons. S4, S5 and S6 : Lake Bè sites ; S7, S8 and S9 : East Lake sites ; S10, S11 and S12 : West Lake sites. LOI: Loss-On-Ignition which corresponds to the organic matter and the carbonates.

Major elements (%)	Fine fractions of Lomé Lagoon sediments, n=9																	
	Dry season (DS)									Wet season (WS)								
	Lake Bè			East Lake			West Lake			Lake Bè			East Lake			West Lake		
	S4	S5	S6	S7	S8	S9	S10	S11	S12	S4	S5	S6	S7	S8	S9	S10	S11	S12
SiO ₂ (%)	39.07	41.53	44.47	47.43	47.84	45.42	37.99	36.47	38.90	43.91	36.15	41.09	35.22	36.00	38.05	46.74	39.48	41.72
Al ₂ O ₃ (%)	11.07	10.78	15.80	6.95	4.87	9.88	17.24	13.85	13.66	23.18	20.75	24.26	10.21	12.66	12.42	18.35	17.07	15.90
Fe ₂ O ₃ (%)	6.30	6.00	9.70	5.92	5.75	6.97	7.25	7.46	6.79	10.68	8.11	8.73	7.94	5.97	6.26	6.59	7.63	6.90
MnO (%)	0.09	0.12	0.13	0.12	0.12	0.17	0.15	0.15	0.11	0.10	0.10	0.08	0.37	0.20	0.20	0.10	0.14	0.10
MgO (%)	0.91	1.04	0.84	0.76	0.86	1.02	0.99	1.01	0.94	0.88	0.95	0.78	1.76	1.36	1.28	0.68	1.07	0.86
CaO (%)	14.52	13.33	6.06	9.21	11.46	7.60	4.74	6.81	5.81	2.57	8.16	2.64	14.19	12.46	11.38	4.12	4.75	5.21
Na ₂ O (%)	0.46	0.61	0.80	0.52	0.59	0.49	0.58	0.70	0.60	0.52	0.58	0.68	0.51	0.60	0.62	0.34	0.40	0.40
K ₂ O (%)	0.49	0.64	0.88	0.41	0.47	0.68	0.59	0.55	0.51	0.86	0.61	0.63	0.98	0.67	0.65	0.44	0.63	0.46
TiO ₂ (%)	0.95	0.94	0.94	1.01	1.45	1.05	1.11	0.98	1.01	0.79	0.67	0.77	0.69	0.83	0.87	1.33	1.12	1.16
P ₂ O ₅ (%)	0.34	0.32	0.21	0.77	2.50	0.66	0.60	0.79	0.81	0.15	0.22	0.25	0.57	0.63	0.62	0.58	0.71	0.75
LOI (%)	23.16	21.46	18.33	21.93	18.24	22.59	28.45	28.83	29.59	17.24	23.34	20.16	21.89	25.56	25.16	21.13	26.51	25.42

Table S2- Rare earth element concentrations in the fine fractions (<63 µm) of the Lomé lagoon sediments during the wet and the dry seasons. S4, S5 and S6 : Lake Bè sites ; S7, S8 and S9 : East Lake sites ; S10, S11 and S12 : West Lake sites.

REE µg.g ⁻¹	Fine fractions of Lomé Lagoon sediments, n=9																	
	Wet season (WS)									Dry season (DS)								
	Lake Bè			East Lake			West Lake			Lake Bè			East Lake			West Lake		
	S4	S5	S6	S7	S8	S9	S10	S11	S12	S4	S5	S6	S7	S8	S9	S10	S11	S12
La	35.3	31.7	43.9	23.6	21.7	31.9	49.0	39.1	39.8	57.1	52.9	61.8	29.8	36.9	37.1	52.6	47.1	47.3
Ce	78.8	71.1	96.7	55.0	48.6	74.0	105.4	85.8	89.5	117.0	108.9	127.8	65.5	83.0	82.2	114.6	100.9	103.6
Pr	8.1	7.3	10.2	5.6	5.0	7.3	10.8	8.7	9.0	12.0	11.0	13.0	6.9	8.3	8.3	11.6	10.3	10.3
Nd	29.7	27.6	37.3	21.3	19.0	28.2	39.3	32.5	33.6	41.9	37.9	45.1	26.8	31.5	31.6	43.3	38.0	38.5
Sm	5.9	5.5	7.3	4.4	3.8	5.6	7.8	6.3	6.5	7.8	6.9	8.3	5.2	6.2	6.1	8.5	7.4	7.3
Eu	1.1	1.2	1.6	0.9	0.7	1.1	1.6	1.3	1.3	1.8	1.6	1.9	1.1	1.3	1.3	1.7	1.5	1.5
Gd	4.5	4.4	5.8	3.6	3.2	4.3	5.9	4.9	5.0	6.1	5.4	6.4	4.1	4.7	4.7	6.6	5.7	5.8
Tb	0.7	0.7	0.9	0.5	0.5	0.6	0.8	0.8	0.7	0.9	0.8	0.9	0.6	0.7	0.7	1.0	0.9	0.9
Dy	4.0	4.0	5.2	3.3	3.3	3.7	4.9	4.6	4.3	5.1	4.3	5.1	3.6	4.2	4.1	5.8	5.0	5.1
Ho	0.8	0.9	1.1	0.7	0.8	0.8	1.0	0.9	0.9	1.0	0.8	1.0	0.7	0.8	0.8	1.2	1.0	1.0
Er	2.3	2.5	3.0	2.0	2.4	2.1	2.6	2.5	2.5	2.6	2.1	2.4	2.0	2.2	2.2	3.1	2.6	2.7
Tm	0.4	0.4	0.4	0.3	0.4	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.5	0.4	0.4
Yb	2.6	2.7	3.2	2.3	3.0	2.3	2.5	2.5	2.5	2.4	1.9	2.1	2.0	2.2	2.2	3.1	2.6	2.8
Lu	0.4	0.5	0.5	0.4	0.6	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.5	0.4	0.4

Table S3- Average trace element concentrations in the Lomé lagoon sediments (fraction <63µm) and TE concentrations of PAAS, UCC, two local materials (Sed_R and H3), and some Sediment Quality Guidelines (SQGs). See also TE concentrations for each site in Table S4.

TE µg.g ⁻¹	Fine fractions of Lomé Lagoon sediments, n=9										SQGs									
	Wet season (WS)			Dry season (DS)			PAAS	UCC	Sed_R	H3										
	Min	Max	Mean	Min	Max	Mean					TEL	ERL	LEL	MEL	PEL	ERM	SEL	TET	CB	PEC
As	3.9	24.7	9.1	8.0	23.0	13.3	-	1.5	1.6	1.8	5.9	33	6	7	17	85	33	17	33	
Ba	255	444	304	240	345	289	650	550	794	612										
Be	0.7	1.8	1.2	1.1	2.5	1.6	-	3	1.6	2.0										
Bi	0.1	0.1	0.1	0.2	0.7	0.4	-	0.1	0.1	0.1										
Cd	0.4	2.2	0.9	0.1	0.9	0.5	-	0.1	0.1	0.1	0.6	5	0.6	0.9	3.5	9	10	3	5.0	
Co	9.4	17.3	13.1	12.0	17.5	14.8	23	10	21	33.1										
Cr	67	153	102	77	178	130	110	35	75.3	280	37.3	80	26	55	90	145	110	100	111	
Cs	0.8	3.2	1.9	2.1	3.3	2.6	15	3.7	2.5	2.7										
Cu	46.3	334.6	112.6	35.9	94.1	63.6	50	25	35.8	40.3	35.7	70	16	28	197	390	110	86	149	
Ga	7.4	22.3	15.4	14.1	30.4	22.6	17.5	17	17.1	21.7										
Ge	0.8	1.7	1.2	1.0	1.8	1.5	-	1.6	1.5	1.7										
Hf	7.0	61.9	24.3	3.3	11.4	7.6	-	5.8	16.6	11.0										
Mo	4.2	7.1	5.2	2.8	8.7	4.6	1	1.5	0.9	0.8										
Nb	13.7	22.9	17.4	10.9	25.4	16.7	19	25	17.2	18.3										
Ni	20.1	36.8	27.4	30.8	42.7	37.7	55	20	34.4	151.3	18	30	16	35	36	50	75	61	48.6	
Pb	50.3	716.6	182.3	34.1	188.3	98.7	20	20	21.3	19.0	35	35	31	42	91.3	110	250	170	128	
Rb	13.6	34.9	23.7	26.6	42.7	33.7	160	112	86.6	70.4										
Sb	2.1	7.6	3.4	0.8	4.1	2.3	-	0.2	0.2	0.2										
Sc	4.9	15.2	10.4	9.5	19.9	15.3	16	11	14.4	20.0										
Sn	8	81.8	31.0	3.13	17.4	9.6	4	2.7	2.2	2.5										
Sr	214	497	342	151	863	361	200	350	184.4	142										
Ta	1.1	1.9	1.4	0.9	2.2	1.4	-	1	1.5	1.5										
Th	7.8	12.2	9.8	7.9	14.5	10.8	14.6	10.7	16.6	12.8										
U	2.4	5.0	3.7	2.6	3.2	2.8	3.1	2.8	3.5	2.7										
V	66.7	133.7	87.9	73.4	172.9	113.6	150	60	87.2	115.3										
W	-	1.9	1.8	1.0	2.1	1.5	-	2	1.2	1.2										
Y	19.2	29.2	23.0	20.0	29.0	23.7	27	22	44.4	39.1										
Zn	179	1696	704	114	950	438	85	71	59	73	123	120	120	150	315	270	820	540	459	
Zr	271	2446	956	119	451	302	210	190	651	427										

Sediment Quality Guidelines for sediments (SQGs): TEL-Threshold Effect Level [73], ERL- Effects Range Low [70], LEL-Lowest Effect Level [72], MEL- Minimum Effect Level [71], PEL- Probable Effect Level [73], ERM-Effect Range Median [70], SEL-Severe Effect Level [72], TET- Toxic Effect Threshold [71], CB PEC-Consensus-Based for Probable Effect Concentrations [74].

Table S4- Trace element concentrations in the fine fractions (<63 µm) of the Lomé lagoon sediments during the wet and the dry seasons. S4, S5 and S6 : Lake Bè sites ; S7, S8 and S9 : East Lake sites ; S10, S11 and S12 : West Lake sites.

TE (µg.g ⁻¹)	Fine fractions of Lomé Lagoon sediments, n=9																	
	Wet season (WS)									Dry season (DS)								
	Lake Bè			East Lake			West Lake			Lake Bè			East Lake			West Lake		
	S4	S5	S6	S7	S8	S9	S10	S11	S12	S4	S5	S6	S7	S8	S9	S10	S11	S12
As	9.4	9.9	24.7	8.5	9.2	6.0	4.7	3.9	5.6	23.1	16.2	17.9	13.0	10.1	11.2	8.0	10.0	9.9
Ba	296.7	338.9	443.8	254.9	302.2	281.9	266.4	274.1	275.4	328	251	240	345	304	317	246.7	262.1	309.8
Be	1.0	1.1	1.8	0.7	-	0.9	1.4	1.2	1.1	2.5	2.1	2.5	1.3	1.12	1.2	1.3	1.4	1.2
Bi	-	-	-	-	0.1	-	0.1	-	-	0.2	0.2	0.2	0.2	0.4	0.4	0.5	0.7	0.7
Cd	1.0	1.0	0.9	1.0	2.2	1.0	0.4	0.4	0.5	0.1	0.2	0.2	0.3	0.6	0.7	0.6	0.8	0.9
Co	10.8	10.2	13	13.1	9.4	12.1	17.3	16.1	16.2	14.1	12.1	12.8	14.9	15.0	14.7	15.2	17.5	16.8
Cr	103	103.8	153.3	67.3	73.3	80.7	114	116.9	108.2	177	155	178.2	77.1	93.8	99.7	129.6	126.9	130.7
Cs	1.6	1.5	1.9	1.1	0.8	1.9	3.2	2.5	2.5	2.6	2.3	2.6	2.1	2.3	2.2	3.2	3.3	3.0
Cu	80.2	83.4	46.3	145.1	334.6	85.8	72.2	87.4	78.2	35.9	40.9	47.3	40.1	73.8	88.5	67.5	84.3	94.1
Ga	14.8	13.8	19.7	10.0	7.4	13.9	22.3	18.5	18.4	28.5	25.8	30.4	14.1	17.1	17.0	24.9	23.1	22.2
Ge	1.0	1.2	1.4	0.8	0.9	1.3	1.7	1.1	1.2	1.7	1.5	1.8	1.1	1.2	1.3	1.8	1.6	1.6
Hf	26.5	25.6	29.1	26.1	61.9	23.3	7.0	9.0	10.0	5.5	3.3	3.6	11.0	7.7	9.2	11.4	7.6	9.5
Mo	4.2	4.2	5.7	6.8	4.2	4.7	4.8	4.9	7.1	3.1	4.0	3.9	8.7	5.1	5.8	2.8	4.0	4.3
Nb	15.1	13.7	13.9	16.3	18.4	18.5	22.9	18.3	19.3	12	10.9	12.5	12.0	16.8	16.1	25.4	21.9	23.1
Ni	21.6	22.2	31.1	22.6	20.1	27.8	36.8	32.0	32.2	42.6	35.7	38.9	30.8	34.2	35.9	38.5	42.8	40.0
Pb	88.9	100.4	50.3	101.4	716.6	217.8	140.3	141	83.6	34.1	42.4	54.1	58.9	138.7	188.3	96.3	141.2	134.4
Rb	19.7	23.5	34.9	14.3	13.6	27.6	31.2	24.3	24.6	42.7	32.7	35.2	41.5	31.1	29.9	27.5	36.5	26.6
Sb	3.7	3.0	2.3	3.8	7.7	2.7	2.1	3.1	2.6	0.8	1.3	1.2	1.2	2.9	3.7	2.5	3.0	4.0
Sc	9.6	9.6	13.6	6.7	4.9	9.1	15.2	12.7	12.4	19.6	17.1	19.9	9.5	11.7	11.5	17.4	15.9	14.9
Sn	14.3	12.2	8.0	59.3	81.8	49.0	15.5	22.2	16.9	3.1	3.6	4.3	4.8	11.3	15.2	10.7	17.4	15.9
Sr	497	480	299.6	301.2	419.4	335.1	213.7	275.1	258.7	164	286	151	863	579	567	177.5	222.5	234.8
Ta	1.2	1.1	1.3	1.3	1.4	1.5	1.9	1.5	1.6	1.0	0.9	1.0	1.0	1.3	1.4	2.2	1.9	1.9
Th	11.6	8.6	10.1	7.8	8.6	9.1	12.2	10.2	10.5	10.5	8.9	10.3	7.9	9.6	9.6	14.6	12.8	13.1
U	3.7	3.5	4.6	5.0	4.9	3.1	2.4	2.8	3.0	2.7	2.7	2.6	2.8	3.1	3.2	2.6	2.7	2.8
V	100.6	98.3	133.7	86.8	73.2	66.7	72.8	74.9	83.8	173	145	167	73.4	76.6	79.8	111.9	93.4	102.6
W	-	-	-	-	-	1.8	1.8	1.6	1.9	1.0	1.0	1.1	1.1	1.5	1.6	2.1	2.0	2.1
Y	21.7	23.8	29.2	19.2	21.2	19.7	24.8	24.2	23.4	24.6	20.9	24.3	20.0	21.6	21.4	29.0	25.0	26.5
Zn	362.1	266.5	179.3	854.4	1696	751.6	632.4	823.6	771.4	114	154	159.7	192.3	454.6	525.7	550.5	837.3	950
Zr	1012	1030	1162	1033	2446	909.8	270.9	346.1	398.7	207	119	134	451	309	365	450	294	385

Table S5- Ranking of priority sites with respect to sediment contamination according to ERM and PEL quotients (Q_{ERM} and Q_{PEL}) and to the probability (%) of toxicity for benthic organisms (after [99]). See Q_{ERM} and Q_{PEL} values calculated for Lomé lagoon sediments in Table S6.

Q _{ERM} and Q _{PEL} limit values			
Q _{ERM} > 1.5	0.51 < Q _{ERM} < 1.5	0.11 < Q _{ERM} < 0.5	Q _{ERM} < 0.1
Q _{PEL} > 2.3	1.51 < Q _{PEL} < 2.3	0.11 < Q _{PEL} < 1.5	Q _{PEL} < 0.1
Probability of toxicity in amphipod survival tests [100] Q _{ERM} - Q _{PEL}			
74% - 76%	46% - 50%	30% - 25%	12% - 10%
Priority sites			
Highest	Medium-high	Medium-low	Lowest

Table S6- PEL and ERM quotients, respectively Q_{PEL} and Q_{ERM} calculated for the all the sites (S4, S5 and S6 for Lake Bè, S7, S8 and S9 for East Lake and S10, S11 and S12 for West Lake) for the two seasons (WS, wet season and DS, dry season). **Bold figures**: highest priorities, ***bold italics*** : medium-high priorities, normal figures: medium-low priorities, *italics* : low priorities (see table S5 for the corresponding Q_{PEL} and Q_{ERM} limit values and for the toxicity probabilities).

TE		S4		S5		S6		S7		S8		S9		S10		S11		S12	
		WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS
As	Q _{PEL}	0.55	1.36	0.58	0.96	1.46	1.05	0.50	0.77	0.54	0.60	0.36	0.66	0.28	0.47	0.23	0.59	0.33	0.58
	Q _{ERM}	0.11	0.27	0.12	0.19	0.29	0.21	<i>0.10</i>	0.15	0.11	0.12	<i>0.07</i>	0.13	<i>0.06</i>	<i>0.09</i>	<i>0.05</i>	0.12	<i>0.07</i>	0.12
Cd	Q _{PEL}	0.29	0.03	0.28	0.05	0.27	0.05	0.29	0.07	0.63	0.16	0.28	0.19	0.11	0.18	0.11	0.23	0.14	0.26
	Q _{ERM}	0.11	<i>0.01</i>	0.11	<i>0.02</i>	0.11	<i>0.02</i>	0.11	<i>0.03</i>	0.25	<i>0.06</i>	0.11	<i>0.08</i>	<i>0.04</i>	<i>0.07</i>	<i>0.04</i>	<i>0.09</i>	<i>0.05</i>	<i>0.10</i>
Cr	Q _{PEL}	1.15	1.97	1.15	1.72	1.70	1.98	0.75	0.86	0.81	1.04	0.90	1.11	1.27	1.44	1.30	1.41	1.20	1.45
	Q _{ERM}	0.71	1.22	0.72	1.07	1.06	1.23	0.46	0.53	0.51	0.65	0.56	0.69	0.79	0.89	0.81	0.88	0.75	0.90
Cu	Q _{PEL}	0.41	0.18	0.42	0.21	0.24	0.24	0.74	0.20	1.70	0.37	0.44	0.45	0.37	0.34	0.44	0.43	0.40	0.48
	Q _{ERM}	0.21	<i>0.09</i>	0.21	<i>0.10</i>	0.12	0.12	0.37	<i>0.10</i>	0.86	0.19	0.22	0.23	0.19	0.17	0.22	0.22	0.20	0.24
Ni	Q _{PEL}	0.60	1.18	0.62	0.99	0.86	1.08	0.63	0.86	0.56	0.95	0.77	1.00	1.02	1.07	0.89	1.19	0.89	1.11
	Q _{ERM}	0.43	0.85	0.44	0.71	0.62	0.78	0.45	0.62	0.40	0.68	0.56	0.72	0.74	0.77	0.64	0.85	0.64	0.80
Pb	Q _{PEL}	0.97	0.37	1.10	0.46	0.55	0.59	1.11	0.65	7.85	1.52	2.39	2.06	1.54	1.05	1.55	1.55	0.92	1.47
	Q _{ERM}	0.81	0.31	0.91	0.39	0.46	0.49	0.92	0.54	6.51	1.26	1.98	1.71	1.28	0.88	1.28	1.28	0.76	1.22
Zn	Q _{PEL}	1.15	0.36	0.85	0.49	0.57	0.51	2.71	0.61	5.38	1.44	2.39	1.67	2.01	1.75	2.61	2.66	2.45	3.02
	Q _{ERM}	1.34	0.42	0.99	0.57	0.66	0.59	3.16	0.71	6.28	1.68	2.78	1.95	2.34	2.04	3.05	3.10	2.86	3.52