Solid Waste Landfill and Soil/Sediment Contamination: Case Studies in Tunisia, p.19-29.
© 2002, INRST-JICA

Subsurface sediment contamination observed in SC5 borehole cores, Henchir El Yahoudia landfill: Interpretation using Scandium normalization

Mitsuo Yoshida, Ahmed Ghrabi* and Mounir Ferchichi***
** Laboratoire Eau & Environnement, INRST*
**** Agence National de Protection de l'Environnement, Tunisie*

Abstract

Chemical composition of subsurface sediments distributed near a MSW landfill were analyzed. The most contaminated part is the uppermost horizons above 0.60 m in depth, which is caused by the migration from ground surface. Three permeable layers, that is potentially aquifers, contains relatively smaller amount of metal pollutants possibly due to a grain-size effect. However non-metal pollutants, As and Se, were significantly contained based on Sc normalization. It is probably derived from the contaminants transport by groundwater.

Keywords

MSW landfill, lake sediments, Aqua regia extraction, Sc normalization, Evaporite

I. Introduction

After the closure of municipal solid waste (MSW) landfill at Henchir El Yahoudia in 1999, four perimeter wells were penetrated for monitoring environmental pollution in 2000. The SC5 hole is one such perimeter wells, which is located a lakeside of Sebkhat Sejoumi, the south of the Henchir El Yahoudia landfill. The subsurface sediments were previously partly analyzed by Sothom (2000) and Yoshida et al. (2001), while full of the environmental information of SC5 sequence has not been investigated. In this paper we report the results of potentially toxic elements (PTEs) analysis and environmental geological observation of the SC5 sequence.

II. SC5 Borehole

The location of the SC5 borehole is shown in Figure 1. The site is located at a lakeside barren field to the south of the Henchir El Yahoudia landfill, where various types of solid waste are scattered due to illegal disposals. Landfill contaminated water may migrate into the area. The geologic columnar section of the borehole SC5 is illustrated in Figure 2. A total of 21 samples were collected from the sequence based on the lithostratigraphy. According to the lithostratigraphic observation of the SC5 borehole cores, we could recognize two geologica units in the sequence, the upper unit and lower unit. The upper unit from surface to –13.1 m in depth is mainly composed of lake sediments such as unconsolidated clay, silt, and sand layers, where three permeable layers could be recognized. They are potentially groundwater aquifers. The basal part of the upper unit, from –12.6m to

–13.1m in depth, is well-consolidated calcareous granule sand that is possibly evaporite origin. The lower unit consists of massive limestone appear below 13.1 meters in depth that is a hydrogeological basement in the area. It is probably correlated with Paleogene limestone.

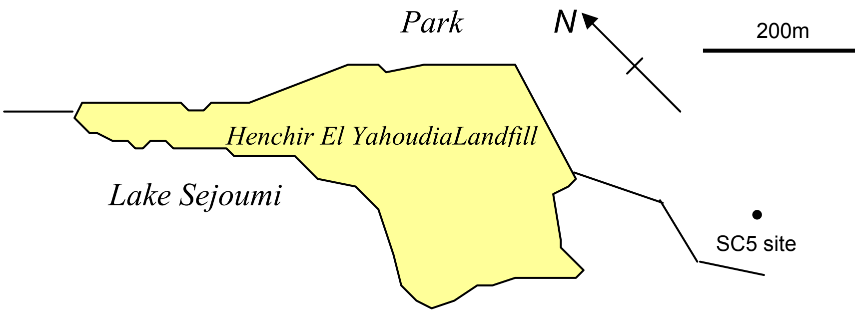


Figure 1: Location map

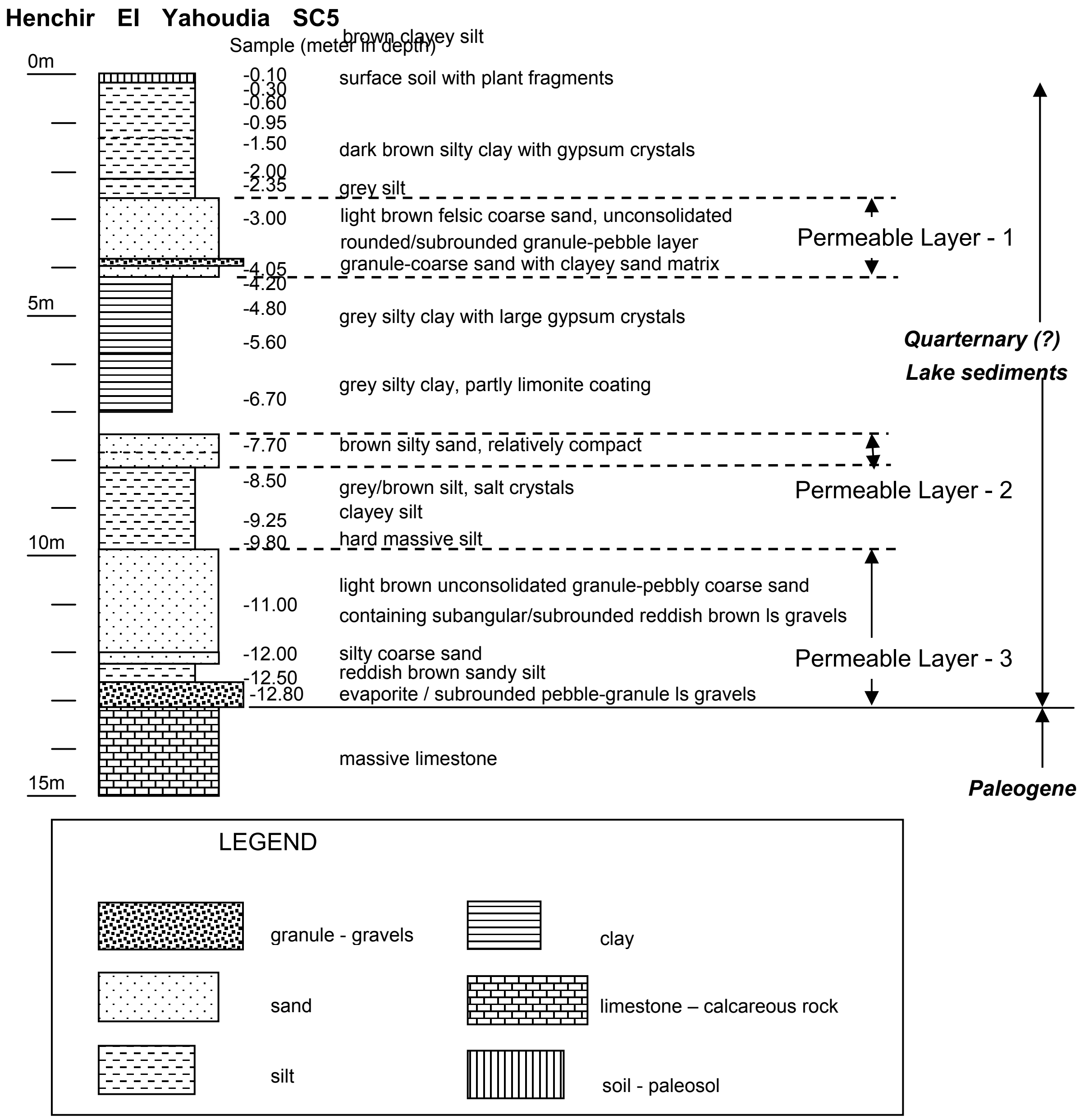


Figure 2: Geologic columnar section of the borehole SC5, Henchir El Yahoudia, and sampled horizons.

III. Analytical Method

III-1. Mineralogy

In order to identify the rock type and mineralogical composition, the powder sample of SC5-12.80m was used for X-ray diffraction analysis using a Shimadzu XRD-6000 (Target Cu). A solid sample collected from the same layer was also used for the petrographic observation of a thin section using a polarized microscope.

III-2. Environmental Chemistry

The borehole core samples collected were disintegrated and dried under room temperature, and powdered by a ceramic mill. Then the powder samples were sieved by a 1.0 mm, and the finer fraction was used for the analysis.

A 15.0 gm sample split was digested in 90 mL aqua regia (HCl-HNO_3-H_2O) at 95°C for one hour. The solution is diluted to 300 mL with distilled water. Analysis was made by an Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) and Mass Spectrometry (ICP-MS). Total 37 elements were measured: B, Na, Mg, Al, P, S, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Sr, Mo, Ag, Cd, Sb, Te, Ba, La, W, Au, Hg, Tl, Pb, Bi, Th, and U. The upper detection limit for Ag, Au, Hg, W, Se, Te, Tl, and Ga is 100 ppm, that for Mo, Co, Cd, Sb, Bi, Th, U, and B is 2 %, and that for Cu, Pb, Zn, Ni, Mn, As, V, La, and Cr is 10 %. The aqua regia digestion of sediment extracts only a fraction of the major elements (pseudo-total analysis) because silicates are not completely dissolved with this method. Owing to this limitation, results are total to near total for trace and base metals and possibly partial for rock-forming elements such as Na, Mg, Al, K, Ca, Mn, and Fe. However, environmentally concerned components like heavy metals or potentially toxic elements (PTEs; Alloway, 1995) not bound to silicates are efficiently dissolved (Ure, 1995), which is indicative for the assessment of toxicity.

IV. Results and Discussion

IV-1. Results of Mineralogical Observation

The lowest part of the permeable layer-3 is well-consolidated calcareous bed. In order to identify its mineralogical composition, X-ray diffraction analysis has been done, and following three minerals could be detected (Figure 3):

Calcite >> Halite, Quartz

According to the petrographic observation of a thin section using polarized microscope, following particles/minerals are identified:

Fragmented carbonate rock, Densely-weathered quartz > Fragmented mudstone > Plagioclase

A lot of calcite growth is observed in the matrix, and trace amounts of anhydrite, halite, and halloysite (?) are also recognized (Plate 1). The rock type is classified as an evaporite mainly composed of recrystallized calcite. The texture and abundant subangular particles suggests us the sediment was deposited under a terrestrial arid conditions.

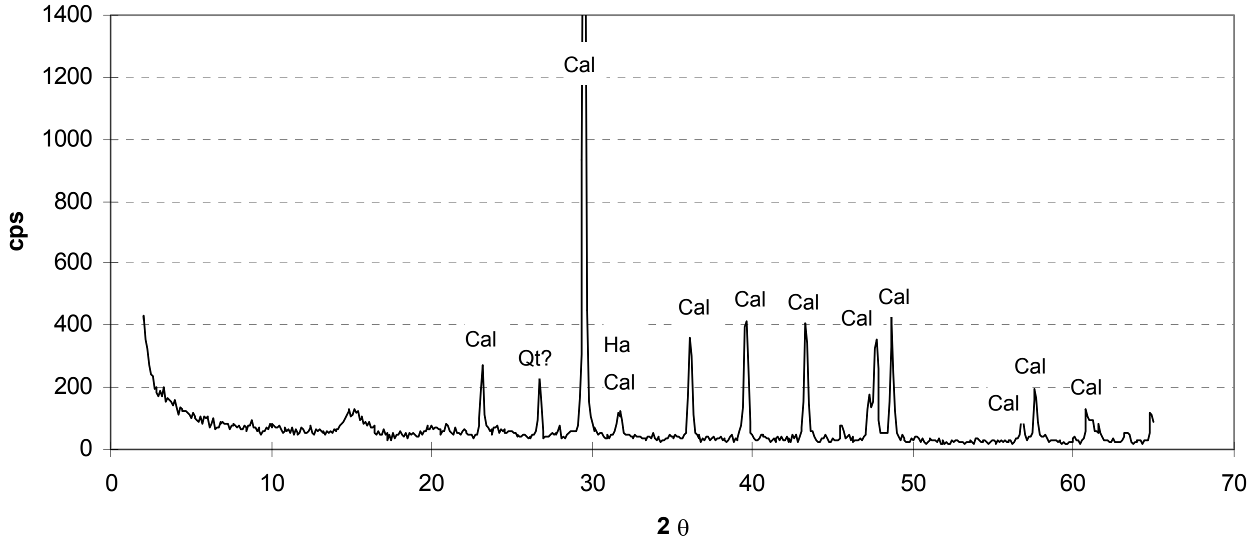


Figure 3: X-ray diffraction pattern of the sample SC5-12.80.
Cal: calcite ($CaCO_3$), Qt; quartz (SiO_2), Ha: halite (NaCl)

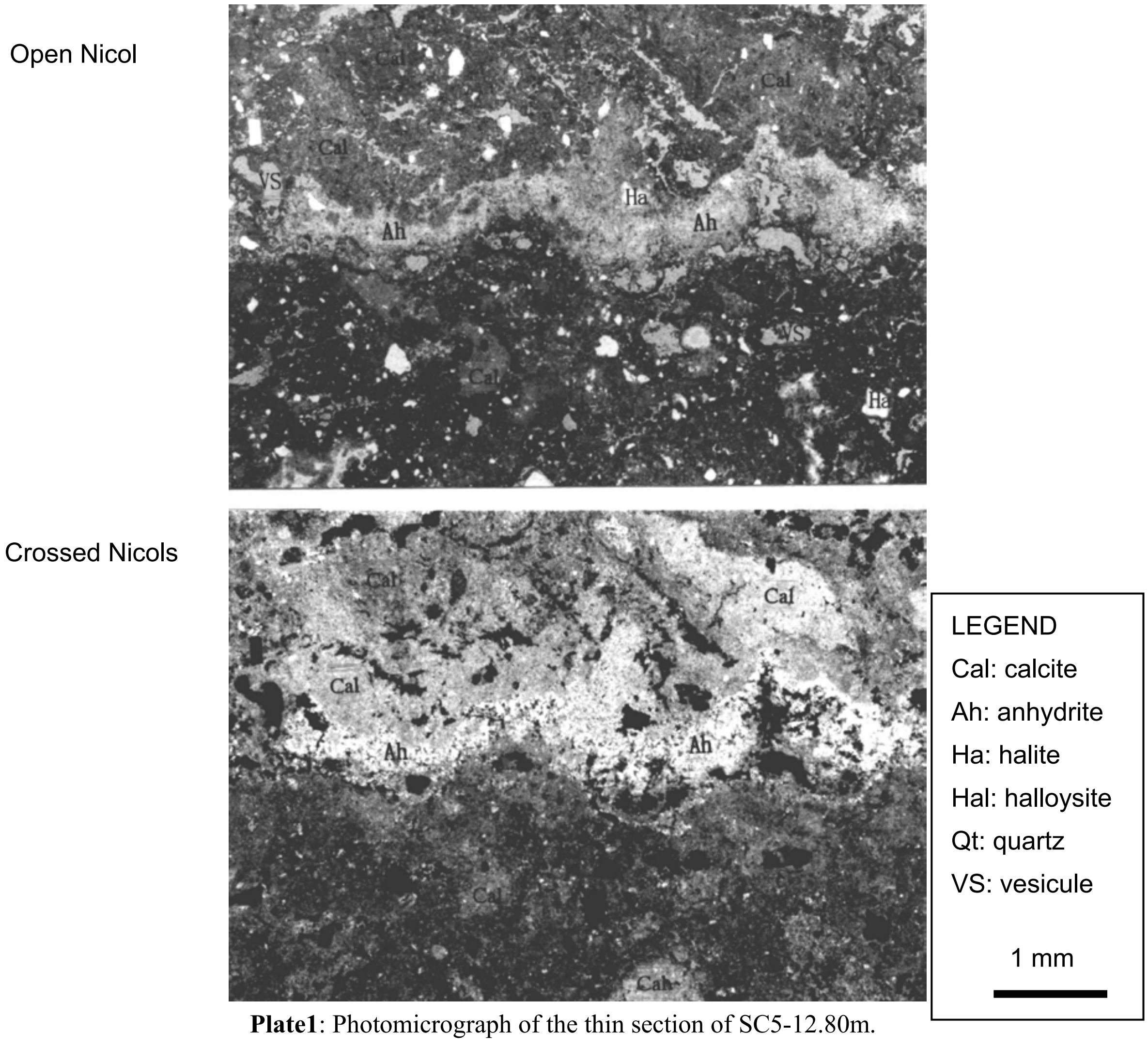


Plate1: Photomicrograph of the thin section of SC5-12.80m.

IV-2. Subsurface Sediment Contamination

The results of aqua regia extraction are summarized in Table 1. The variation of concentration is shown in the Figure 4 (B, As, and Se), Figure 5 (Ti, V, Cr (total), Co, Ni, Cu, and Zn), Figure 6 (Mo, Ag, Cd, Sb, Hg, and Tl), and Figure 7 (Ba, La, and Pb).

In general, the surface soil (-0.10m) and immediately-underlying fine-grained sediment layers are densely contaminated, where the concentration of almost all elements including PTEs extracted were the largest among that of all sequence. It is probably caused by the direct migration of pollutants from ground surface. The area is outside the landfill compound but the conditions are quite similar to a landfill because of a lot of illegal solid waste disposals. The sediments collected from underlying three permeable layers normally show relatively lower concentrations of PTEs, while inter-permeable layers consisting silt and clay are always showing higher concentrations of non-metal and metal pollutants. The lowest part of the sequence that is composed of calcareous deposit of evaporite exhibits comparatively lower concentrations of pollutants.

Table 1: The results of chemical analysis using aqua regia extraction (unit: ppm). Shaded parts are the data of permeable layers.

Depth (m)	B	Na	Mg	Al	P	S	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga
0.10	32	4110	10500	20400	1070	1800	7300	100300	3.4	60	46	62.8	362	25300	10.6	23.9	36.68	333.5	6.9
0.30	27	3310	10700	22100	560	900	6500	99800	3.6	10	48	54.3	335	23200	10.1	24.1	16.91	79.7	7.4
0.60	35	2550	12500	23600	550	1100	6300	97800	4.1	40	51	47.8	280	23800	10.0	24.5	12.56	60.6	8.2
0.95	26	3410	10400	21300	590	1300	5700	103200	4.2	40	46	44.9	299	23100	10.4	23.4	11.28	58.9	7.5
1.50	22	3390	9800	23000	720	3900	5800	105300	3.9	60	46	50.8	288	24700	10.7	25.4	12.12	65.5	7.9
2.00	21	5960	7300	19200	700	1200	4200	111400	4.2		42	43.9	245	24700	10.2	24.2	14.34	63.7	6.3
2.35	49	5100	24600	16400	660	1900	5300	112200	2.8	30	33	31.7	197	16400	7.3	17.3	12.40	43.0	4.9
3.00	7	410	2100	2200	170	500	700	91200	0.7		10	6.9	81	4500	1.3	3.6	3.22	12.4	0.7
4.05	17	2880	4400	7700	330	1800	2400	157200	1.6		23	17.9	120	11800	3.4	9.4	8.73	24.8	2.3
4.20	15	2970	4800	7500	310	1500	2300	167000	1.6		21	18.0	131	11500	3.6	10.7	8.83	31.0	2.3
4.80	32	14940	24600	16600	520	38500	5900	85200	3.2		41	31.1	256	19200	7.9	16.5	12.30	47.5	5.0
5.60	43	20540	22100	21500	810	5400	8000	86000	3.8	50	37	39.6	329	21200	9.8	20.3	14.47	65.5	6.5
6.70	42	13890	12500	19000	460	9200	6500	100500	3.5		39	38.8	273	20900	8.6	19.3	8.99	45.8	6.1
7.70	15	4540	3000	6400	180	600	1900	114400	1.3		20	14.7	116	9200	3.4	7.5	4.17	18.2	1.9
8.50	22	7560	4500	12600	290	700	3800	114500	2.3	60	37	24.3	214	16400	8.8	14.4	9.15	34.3	3.7
9.25	32	10160	6100	19800	210	900	6300	129400	3.0		41	34.6	238	20000	9.1	16.8	8.99	35.5	5.7
9.80	17	3670	3500	5300	150	1100	2000	259200	0.9	100	18	14.9	160	5200	2.6	5.1	3.59	11.2	1.9
11.00	7	1430	2300	3000	180	1000	1000	254700	0.8	120	16	12.1	79	5100	2.0	5.9	5.17	10.0	1.0
12.00	6	3340	2100	2800	170	2600	1000	232600	0.7		12	12.1	72	6700	2.0	6.8	5.49	14.7	1.0
12.50	23	11300	4100	13100	140	800	4200	92300	2.7	50	37	25.6	126	16600	7.3	16.3	9.02	33.7	4.2
12.80	12	6350	2800	5300	110	1000	2000	268100	1.0		11	12.2	118	4500	2.3	6.8	6.28	10.0	1.9
	1	10	100	100	10	100	100	100	0.1	10	2	0.5	1	100	0.1	0.1	0.01	0.1	0.1

Depth (m)	As	Se	Sr	Mo	Ag	Cd	Sb	Te	Ba	La	W	Au	Hg	Tl	Pb	Bi	Th	U
0.10	7.4	0.3	311.3	0.85	0.241	1.95	0.71	0.04	210.7	13.1		0.0086	0.094	0.18	52.52	0.31	3.3	0.9
0.30	5.9	0.5	286.2	0.55	0.058	0.32	0.20	0.03	192.8	13.4		0.0059	0.043	0.16	30.54	0.16	3.4	0.8
0.60	4.8	0.5	298.6	0.45	0.057	0.21	0.12	0.03	239.6	13.1		0.0099	0.023	0.16	15.90	0.15	3.7	0.9
0.95	4.4	0.6	293.4	1.08	0.013	0.22	0.09	0.04	164.7	11.8		0.0074	0.024	0.13	12.69	0.14	4.1	1.0
1.50	3.7	0.6	352.0	0.93	0.013	0.22	0.09	0.03	162.7	11.0		0.0030	0.023	0.14	9.73	0.14	4.0	0.9
2.00	4.1	0.4	382.9	1.20	0.025	0.27	0.08	0.02	149.4	11.9			0.011	0.11	8.22	0.14	4.6	1.0
2.35	3.0	0.2	701.4	0.16	0.176	0.13	0.09	0.04	190.3	8.8			0.009	0.11	9.46	0.10	2.9	1.2
3.00	1.4		307.1	0.27	0.011	0.09	0.11		64.9	2.7			0.006	0.02	3.87	0.02	0.6	0.3
4.05	3.2	0.4	513.0	0.59	0.013	0.14	0.13	0.03	141.6	5.8	0.3	0.0007	0.011	0.05	5.95	0.06	1.8	0.6
4.20	2.9	0.3	509.4	0.69	0.015	0.14	0.13	0.03	148.9	5.8	0.4	0.0078	0.009	0.05	6.07	0.06	1.7	0.7
4.80	3.3	0.4	166.0	0.73	0.248	0.09	0.10	0.03	69.3	8.5		0.0010	0.020	0.10	13.05	0.10	3.6	0.9
5.60	1.4	0.6	322.3	0.27	0.176	0.15	0.07	0.02	180.1	11.7		0.0032	0.079	0.14	13.69	0.14	4.6	1.2
6.70	5.1	0.1	658.0	0.96	0.050	0.16	0.12	0.04	173.6	11.0		0.0011	0.028	0.13	11.42	0.12	4.3	0.8
7.70	3.0	0.2	192.0	0.46	0.012	0.08	0.11	0.02	59.2	4.8		0.0056	0.084	0.05	4.97	0.05	1.5	0.3
8.50	4.7	0.1	262.1	1.10	0.012	0.14	0.12	0.02	122.0	7.5		0.0067	0.022	0.08	8.20	0.08	2.8	0.6
9.25	4.3		267.2	0.49	0.007	0.17	0.11	0.03	295.9	11.2		0.0026	0.020	0.15	11.65	0.12	3.9	0.6
9.80	2.7		537.5	0.29	0.024	0.13	0.19	0.03	202.0	3.7		0.0040	0.020	0.06	5.04	0.04	0.8	0.6
11.00	2.5	0.3	378.4	0.54	0.019	0.18	0.17	0.04	135.3	4.5		0.0021	0.019	0.04	4.73	0.07	0.8	0.5
12.00	3.9	0.5	449.6	1.02	0.020	0.14	0.19	0.04	131.8	4.2		0.0013	0.015	0.04	5.07	0.04	0.7	0.5
12.50	5.8	0.3	202.7	0.67	0.006	0.13	0.18	0.02	49.7	9.8		0.0017	0.005	0.11	8.42	0.11	3.3	0.4
12.80	1.7	0.5	255.6	0.23	0.030	0.15	0.11		72.6	3.9		0.0091	0.007	0.07	4.17	0.04	1.0	0.5
	0.1	0.1	0.5	0.01	0.002	0.01	0.02	0.02	0.5	0.5	0.1	0.0002	0.005	0.02	0.01	0.02	0.1	0.1

The relative diminution of pollutants in the permeable layers and relative augmentation of pollutants in the inter-permeable layers are probably due to natural attenuation effects such as adsorption and ion-exchange by clay particles that are plentiful in the inter-permeable layers consisting of finer materials.

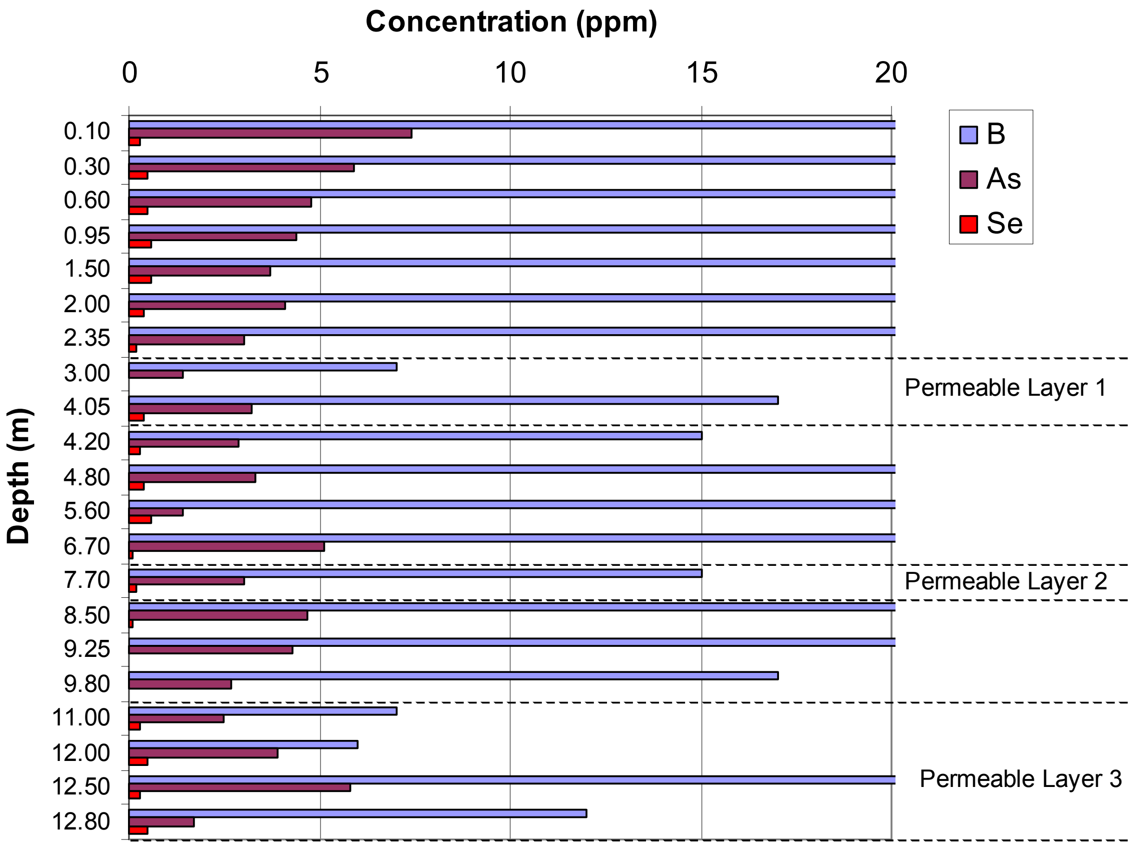
IV-3. Scandium Normalization

In general, metal contents of sediments strongly depend on the granular composition of the deposits. Geochemical normalization is the estimation of the ratio between the contents of the various heavy metals and the content of a conservative element, such as Al, Sc, or Li, where the conservative elements are mainly present in the fine-grained fractions (de Groot, 1995). According to de Groot (1995) Sc shows a very conservative behavior within estuaries. In our study we also applied Sc normalization.

The variations of Sc normalization for each element are illustrated in the lower part of Figures 4 to 7. The result of Sc normalization reveals that non-metal pollutants, As and Se, exhibit sudden increase at the horizons of permeable layers, which means these non-metal organic pollutants are essentially much more migrated into the permeable layers (=aquifers).

We could recognize a similar trend of Sc normalization values, an increase in the horizon of the permeable layers, for Cu and Sb, but generally metal pollutants do not clearly correspond to the lithostratigraphy.

Thus the contamination of subsurface sediments in studied area was occurred through two path ways, (i) mixing and migration (infiltration) from ground surface, and (ii) migration from contaminated groundwater. The former involve almost all non-metal and metal pollutants, but the later does non-metal pollutants, As and Se, and metal pollutants, Cu and Sb.



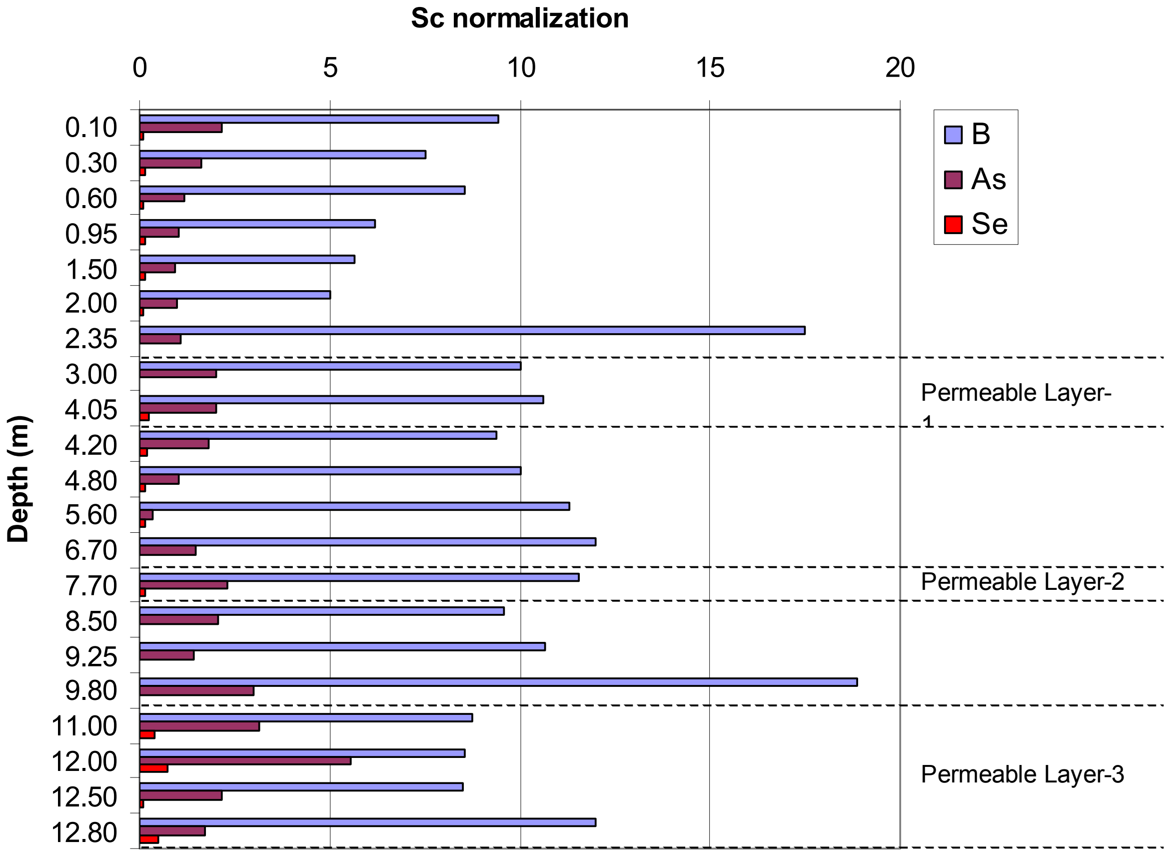
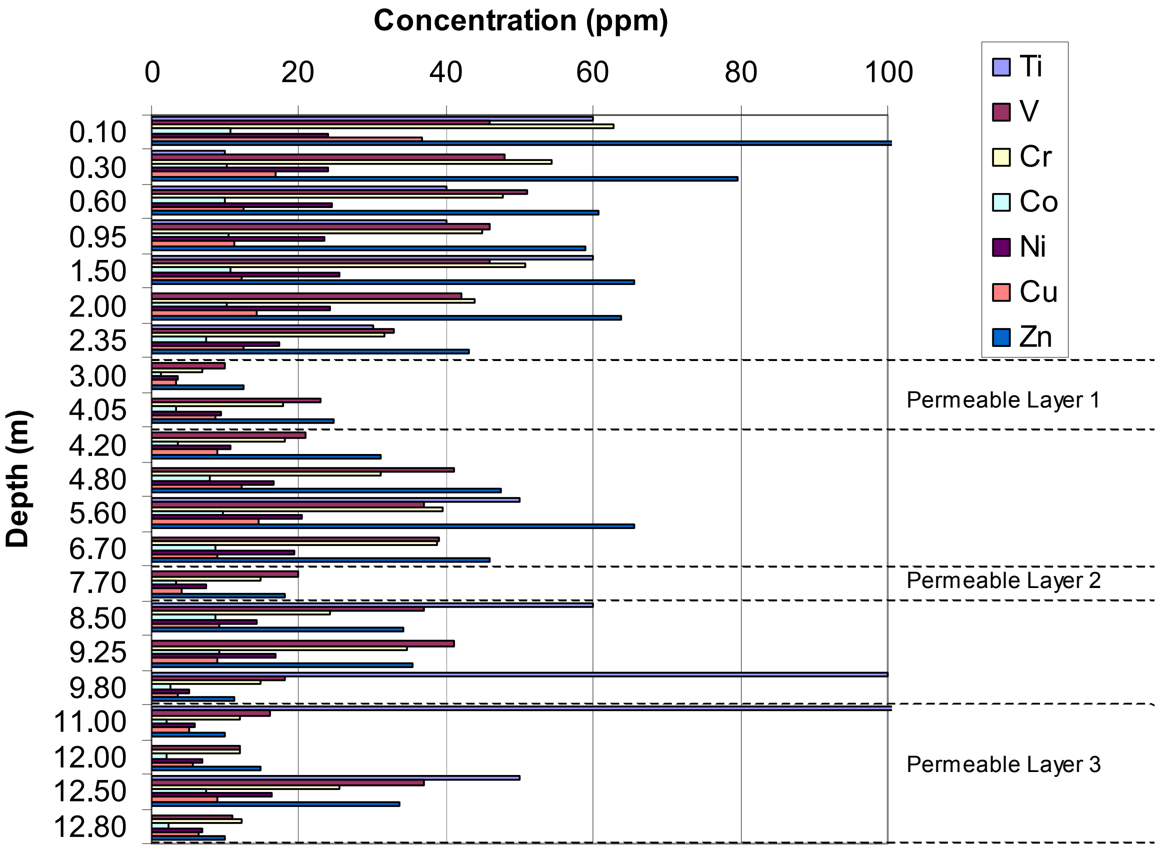


Figure 4: Variation of the aqua regia extracted concentration of non-metal pollutants, B, As, and Se, and the variation of Sc normalization values.



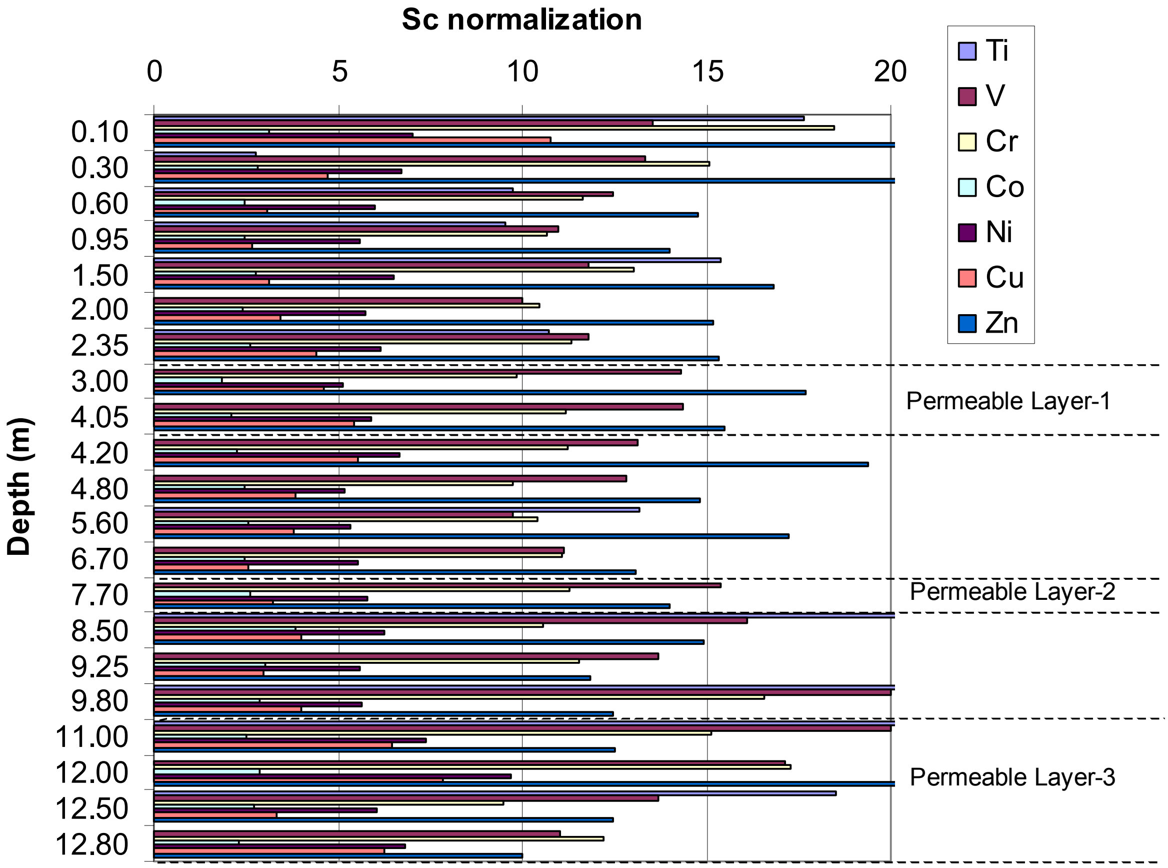
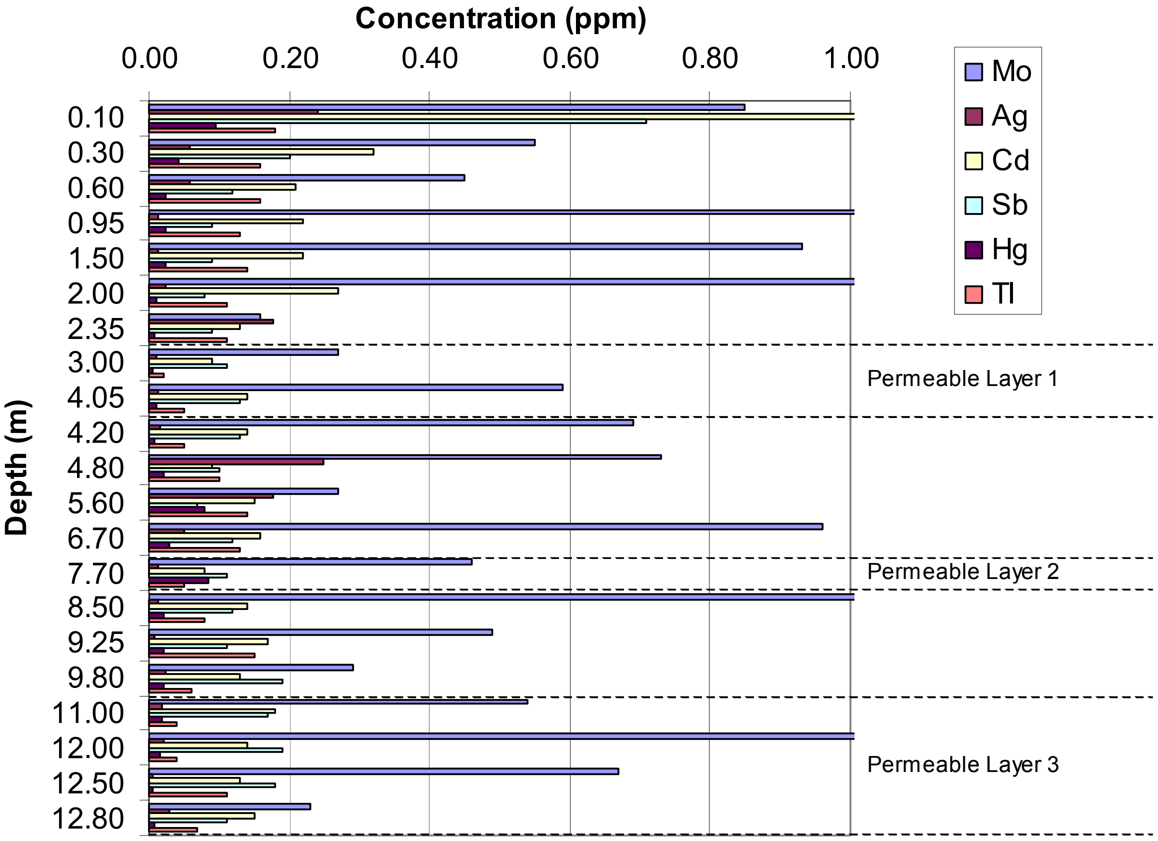


Figure 5: Variation of the concentration of aqua regia extracted metal pollutants, Ti, V, Cr (total), Co, Ni, Cu, and Zn, and the variation of Sc normalization values.



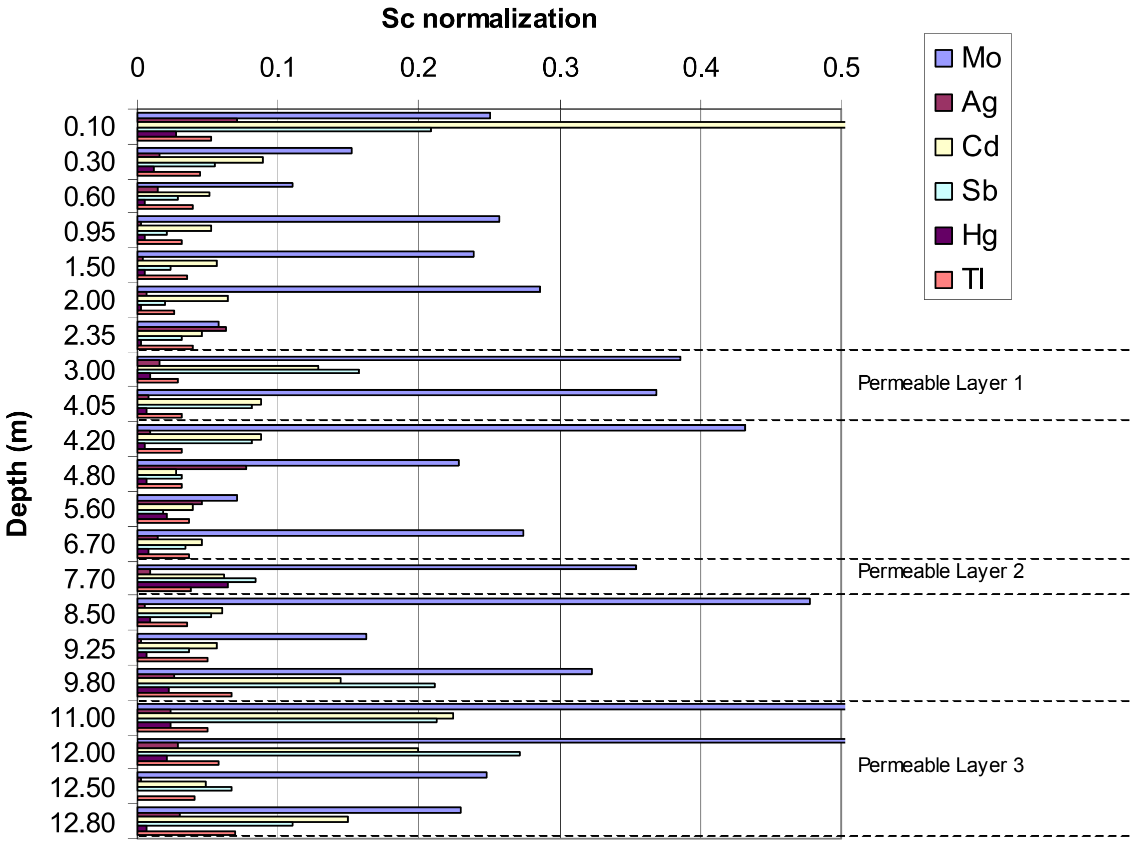


Figure 6: Variation of the concentration of aqua regia extracted metal pollutants, Mo, Ag, Cd, Sb, Hg, and Tl, and the variation of Sc normalization values

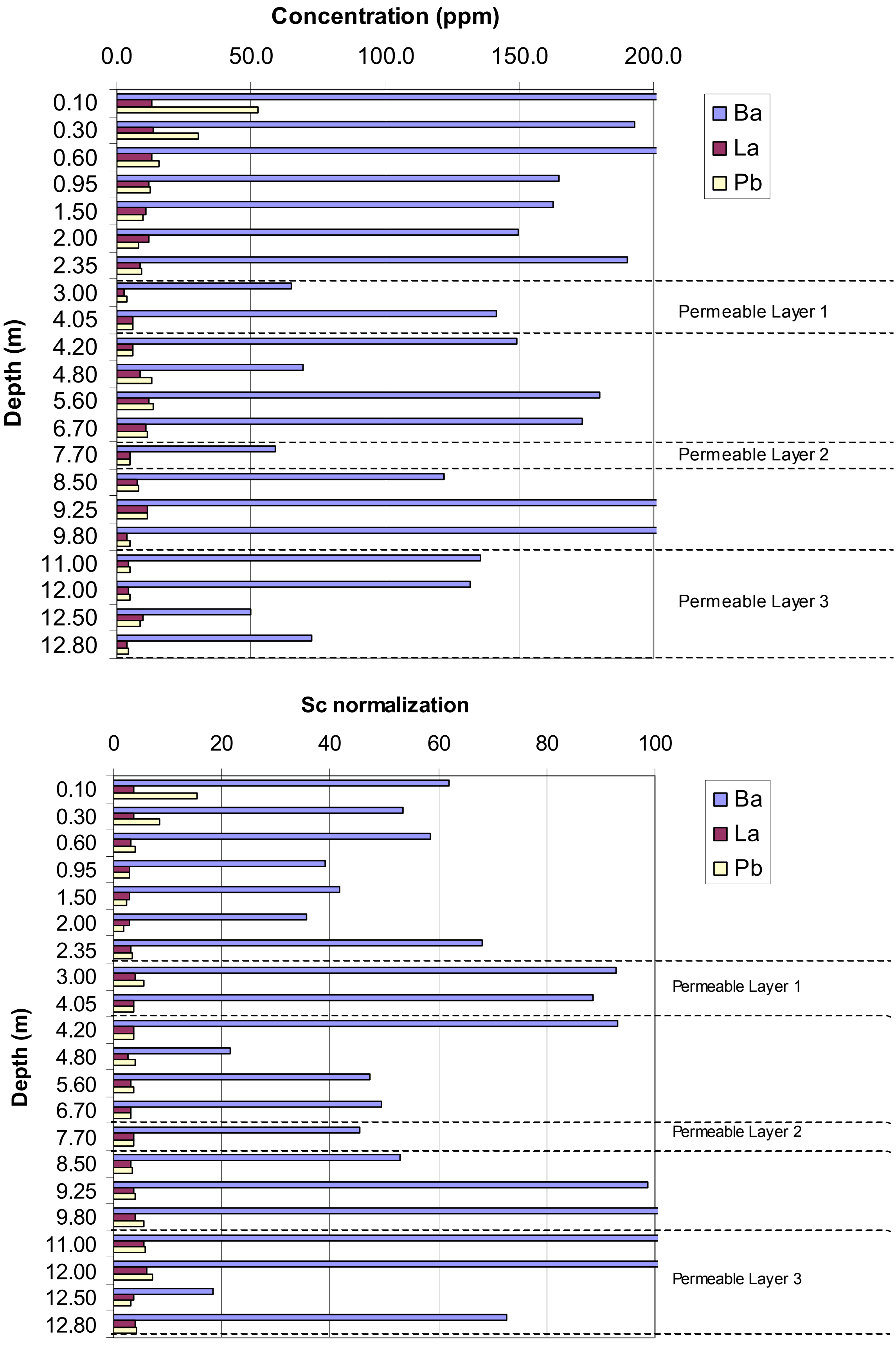


Figure 7: Variation of the concentration of aqua regia extracted metal pollutants, Ba, La, and Pb, and the variation of Sc normalization values.

V. Conclusions

(1) The SC5 borehole core samples were analyzed by aqua regia extraction method.
(2) The most contaminated part is uppermost part of the sequence. In general, the sediments collected from three permeable layers showed relatively lower concentrations of PTEs, while inter-permeable layers consisting silt and clay always exhibit higher concentrations of non-metal and metal pollutants.
(3) The relative diminution of pollutants in the permeable layers and relative augmentation of pollutants in the inter-permeable layers are probably due to natural attenuation effects such as adsorption and ion-exchange by clay particles that are plentiful in the inter-permeable layers consisting of finer materials.

Acknowledgements

We thank ANPE for the permission of borehole core sampling. We also thank Mohamed Boulhouni and Fethi Boushila of Laboratoire Eau & Environnement, INRST for their help in sample preparation. This collaborative study was carried out as a part of technical cooperation programme between INRST and JICA.

References

Alloway, B.J., 1995(ed.), *Heavy Metals in Soils*, *2nd Edition*. Blackie Academic & Professional, Chapman & Hall, London, 368p.

De Groot, A.J., 1995, Metal and sediments: A global perspective. In Allen, H.E. (ed.), Metal Contaminated Aquatic Sediments, Ann Arbor Press, 1-20.

Sothom, A., Yoshida, M., Bousselmi, L., Jedidi, N., Ghrabi, A., and Ferchichi, M. (2000) Characterization of leachate of Henchir El Yahoudia landfill. *Proc.Internl.Conf. Wastewater Treatment and Reuse Adapted to Mediterranean Area*, 17-20.

Ure, A.M., 1995, Methods of analysis for heavy metals in soils. In Alloway (ed.), *Heavy Metals in Soils, 2nd Edition*. Blackie Academic & Professional, Chapman & Hall, London, 58-102.

Yoshida, M., Kallali, H., Ayari, F. and Cheberli, M., 2001, Sequential Leaches of Contaminated Soils at the Municipal Solid Waste Landfill at Henchir El Yahoudia, Tunis, and Possible As, Se, and Hg Pollution. *Water, Waste, and Environment Research*, 2, (1-2) (in press)