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Distribution of metallic trace elements (ETM) in surface soils around the Mediouna discharge (southern of Casablanca)

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The objective of present research was to characterize the surface soils located at 300, 600 and 1000 m of an uncontrolled landfill. The work also aims to evaluate the levels and spatial distribution of metallic trace elements (Cd, Pb, Cu, Ni, Zn, Cr, Co and As) in these soils. Soil samples were collected in 36 points around the landfill. Results showed that Cd, Pb, Zn are concentrated in the soils rich in clay and carbonates, and in organic matter, located at 300 m from the landfill. The basic pH of all soils enhances the retention of these metals. On the other hand, As present in soils at 300, 600 and 1000 m at concentrations slightly higher than those of referenced soils were apparently mobilized by water from the solid/water interfaces. The other metals Cu, Ni, Co, Cr are present at very low concentrations.

Capsule Summary: The soil at 300, 600 and 1000 m from landfill was characterized and metallic trace elements (Cd, Pb, Cu, Ni, Zn, Cr, Co and As) were estimated.

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INTRODUCTION

Population growth and industrial development of cities increase the concentration of metals in the environment (Mokhtaria al., 2007). Solid waste landfilled is rarely inert. Numerous physicochemical and biological reactions occur not only between the waste and the receiving environment (soil, geological substratum, tablecloths, etc), but also in and between these wastes (Sbaa et al., 2001).

In general, the waste in landfills affects soil and table of water (M'leyeh et al. 2002). The mobility and retention of metal ions depend on the chemistry of these elements, the nature of the soil and the phenomena of exchanges at the soil/water interface (Iqbal, 2016).

Table 1: Contents in percent of $CaCO_3$, clay, silt and sand.

	Clay		Silt		Sand		$CaCO_3$	
Depth	0-10	20-30	0-10	20-30	0-10	20-30	0-10	20-30
300 m from the discharge								
A1	8	7.61	17.15	18.06	74.85	74.32	7.92	9.58
A2	24.04	23.92	13.85	14.26	62.11	61.82	19.17	20.83
A3	6.71	7.59	16.73	18.65	76.57	73.76	7.08	7.92
A4	3.81	3.77	22.9	22.6	73.29	73.63	8.75	6.67
A5	11.07	12.24	16.2	15.09	72.74	72.67	12.08	11.67
A6	10.71	11.53	30.1	29.3	59.19	59.16	26.67	28.83
600 m from the discharge								
B1	6.67	7.51	17.87	18.19	75.47	74.31	10	8.33
B2	7.15	5.17	18.99	26.61	73.87	68.22	5.83	7.08
B3	4.82	3.87	17.54	22.63	77.64	73.5	5.83	5.42
B4	8.69	7.64	25.67	24.23	65.63	68.14	10	5
B5	1.91	2.18	22.85	21.47	75.24	76.35	7.5	7.92
B6	7.21	8.42	18.14	16.09	74.65	75.5	9.17	11.67
1 km from the discharge								
C1	8.12	6.84	19.27	18.41	72.61	74.76	10.83	8.33
C2	7.95	6.52	16.14	19.98	75.92	73.51	12.08	11.25
C3	2.64	2.12	23.71	20.55	73.65	77.33	7.92	6.67
C4	4.82	3.87	17.54	22.63	77.64	73.5	12.17	9.08
C5	9.38	9.83	20.02	20.48	70.6	69.69	7.92	6.67
C6	8.38	7.06	21.36	20.9	70.26	72.04	10.42	7.5

In the context of landfill waste management, many work has been carried out on the retention of metals in neighboring soils and their impact on the environment (Nhari et al., 2014, Baghdadi et al., 2015, Kouame et al., 2006, M'leyeh et al., 2002, Adlehcen and al., 2014).

The objective of this work is to study the impact of solid waste from a public Discharges on neighboring soils. In the landfill that is the subject of our work (Mediouna/Casablanca), the waste is discharged directly without any pretreatment. After soil characterization, the study examined the determination of certain ETM content in these soils. The aim being to better understand the retention processes of these metals in soils according to their physico-chemical characteristics. Soil metals taken at two depths and at different distances and different directions were measured by ICP-AES. Soil mineralogy was characterized by DRX and the major elements were determined by X-ray fluorescence. Some physico-chemical parameters such as pH and organic matter were also determined.

MATERIAL AND METHODS

Site characteristics

The Mediouna landfill is located on the southern side of Casablanca and one kilometer on the northern side of Mediouna municipality. The main road (PR7) which passes in its proximity connects Casablanca to Marrakech (Fekri and al. 2012). Since 1989, the site has received all waste from Casablanca region, which includes domestic, industrial and hospital wastes without prior treatment (Fekri, 2007). The landfill currently receives 4000 tons of waste per day, representing approximately 1300 m^3/day of leachate (Chichaoui, 2008; GDH, 1991) with a high polluting load. Characterized by a semi-arid climate, the area has an annual rainfall of 323.5 mm, an average temperature of 19 °C and a high atmospheric humidity. The dominant wind direction is north-north. The wind blows from the landfill to the Mediouna (Ecomed, 2007; Fekri, 2007).

Sampling strategy of soil

Samples were collected from soils A, B and C at 300, 600 and 1000 m, respectively from the center of the landfill. For each distance, samples were collected:

1. At two depths, the first is between 0 and 10cm, the second is between 20 and 30cm
2. From 6 directions separated by an angle of 60 °, denoted Ai, Bi and Ci.

Before any measurement, all soils are air-dried and screened through a stainless steel screen with a diameter of 2 mm.

Sample treatment and analysis

Each soil was air dried, sieved and analyzed in the laboratory using standard techniques. The granulometric study was carried out by Mastersizer Hydro 2000 g (Malvern). The soil pH was determined in water and 0.1 M KCl solutions with a

Table 2: Values of pH of water and KCl of soil studied

	pH_{H2O}		pH_{Kcl}		$pH_{H2O} - pH_{Kcl}$	
	0-10	20-30	0-10	20-30	0-10	20-30
A1	8.32	8.38	7.97	7.93	0.35	0.45
A2	8.53	8.53	8.38	8.35	0.15	0.18
A3	7.92	8.14	7.88	7.65	0.04	0.49
A4	8.29	8.23	8.12	7.98	0.17	0.26
A5	7.99	7.93	7.59	7.62	0.40	0.31
A6	8.73	8.67	8.38	8.59	0.35	0.08
B1	8.06	7.59	7.81	7.30	0.25	0.29
B2	8.19	8.06	7.69	7.55	0.50	0.52
B3	8.27	8.28	7.78	8.42	0.49	-0.14
B4	7.7	7.85	7.50	7.60	0.20	0.25
B5	7.88	7.74	7.70	7.54	0.18	0.20
B6	8.37	8.5	7.96	8.11	0.41	0.39
C1	8.11	7.89	8.02	7.70	0.09	0.19
C2	7.68	7.79	7.44	7.68	0.24	0.11
C3	8.26	8.01	8.07	7.67	0.19	0.35
C4	8.16	8.09	7.44	7.70	0.72	0.39
C5	7.76	7.61	7.51	7.22	0.25	0.39
C6	8.16	8.47	7.84	8.23	0.32	0.24

soil/solution ratio of 1: 2.5. The organic material was determined by dehydration and calcination in an oven at 450 °C for 4 hours. The calcium carbonate content $CaCO_3$ is measured according to the Brag method using a Bernard calcimeter. Total organic carbon was determined using Anne titrimetric method. After digestion of the organic matter, nitrogen was determined by etching with concentrated sulfuric acid at the boiling point followed by a Kjeldahl distillation of 2 g of 2 mm sieved soil (Bremmer, 1965).

The cation exchange capacity (CEC) was determined by centrifugation in 1N ammonium acetate buffered medium at pH 7.0 to saturate the soil with NH_4^+cations (Metson 1956). K and Na were measured with a flame spectrophotometer while Mg and Ca were determined with an atomic absorption.

The X-ray diffraction analysis (XRD) was carried out by a diffractometer called X'Pert Pro PANalytical PDM. The analysis by ICP-AES is carried out after hot mineralization of the soils by aqua regia (1/3 of HNO_3 and 2/3 of HCl). The main major elements in oxide form are determined by the Axios system. It is a low-wavelength dispersion X-ray fluorescence spectrometer (1 kW)

RESULTS AND DISCUSSION

Physicochemical characteristics of soil

The particle size study (table 1) shows that the content of the clay fractions varies from 1.91% to 24%. Elevated values are observed in soils at 300 m from landfill. For all distances separating the soil from the landfill, silt and sand concentrations vary respectively from 16% to 30% and from 59% to 77%. This composition confers to these soils a texture, essentially, sand-loam.

According to Table 1, the $CaCO_3$ content varies from one soil to another:

1. At 300 m from landfill, it varies from 7% to 26%, maximum values are observed in samples A2 and A6 also rich in clay (24, 04 and 11, 53% clay);
2. At 600 m, it varies from 5% (B2 and B3) to 10% (B1 and B4);
3. At 1000 m, it is between 8% (C3 and C5) at 12% (C2 and C4).

Similar results were reported by Baize (Baize 2000). Consequently, calcareous-dominated soils with high pH and abundance of Ca ions are favorable for the retention of metal and semi-metal complexes. This retention capacity increases with the content of the clays and semi metal (As) saturation of the retention complexes.

The values of pH_{H2O} and pH_{KCl} vary between 7.7 and 8.76 (Table 2), so all the soil samples showed an alkaline pH. The (pH_{H2O}–pHKCl) values generally less than 0.5, indicate that analyzed soils have a low reserve of acidity.

Table 3: Organic matter (OM), organic carbon (OC) and total nitrogen (TN) contents (%) of studied soil

	OM (%)		OC (%)		TN(%)		OC/TN		Soil classification	RHF
Depth	0 - 10	20 - 30	0 - 10	20 - 30	0 - 10	20 - 30	0 - 10	20 - 30		
300 from discharge										
A1	2.10	1.36	0.97	0.52	0.073	0.033	13.28	15.75	L H	1.2 – 2.9
A2	0.96	1.92	0.4	0.22	0.028	0.019	14.28	11.57	P H	< 1.8
A3	1.6	1.6	0.67	0.67	0.046	0.036	14.56	18.61	P H	< 1.2
A4	0.61	0.79	0.56	0.3	0.037	0.02	15.13	15	P H	< 1.2
A5	2.51	2.72	1.4	1.48	0.133	0.118	10.52	12.54	L H	1.2 – 2.9
A6	5.06	5.06	1.83	1.96	0.141	0.114	12.97	17.19	N H	3 – 6.9
600 from discharge										
B1	1.56	1.68	1.47	1.39	0.089	0.083	16.51	16.74	L H	< 1.2
B2	2.75	1.45	1.63	1.3	0.159	0.131	10.25	9.92	L H	1.2 – 2.9
B3	1.65	1.46	0.74	0.66	0.058	0.046	12.75	14.34	P H	< 1.2
B4	1.01	1.15	0.5	0.58	0.035	0.062	14.28	9.35	P H	< 1.2
B5	2.50	2.52	1.55	1.58	0.094	0.097	16.48	16.28	L H	1.2 – 2.9
B6	1.07	1.17	1.46	1.21	0.082	0.071	17.8	17.04	P H	< 1.2
1 km from discharge										
C1	1.68	1.68	1.21	1.44	0.092	0.097	13.15	14.84	P H	< 1.2
C2	1.44	1.44	0.92	0.9	0.056	0.06	16.42	15	P H	< 1.2
C3	1.01	1.01	0.65	0.63	0.032	0.039	15.47	16.15	P H	< 1.2
C4	2.12	2.18	1.27	1.3	0.079	0.079	16.07	16.45	L H	1.2 – 2.9
C5	2.57	2.50	1.58	1.57	0.09	0.09	17.55	17.44	L H	1.2 – 2.9
C6	1.68	1.28	1.2	0.98	0.076	0.063	15.78	15.55	P H	< 1.2

L H : Low in humus, P H: Poor in humus, N H: Normal in humus, RHF = Rate of humus Fromation

The alkaline pH results from the presence in the leachates, of some substances fermentable and cardboards and papers or special garbage, rich in alkali and alkaline earth metals. (Koledzi et al. 2011).According to previous works, the carbonates, especially in calcite form (Blanchard, 2000) and certain oxides (MgO, CaO) (García et al. 2004), increased the basic character of the soils. Knowing that alkaline pH leads to the metals retention in the soil (Blanchard, 2000), the analyzed soils are therefore favorable to the metals retention. This phenomenon will be taken into account in the exploitation of the element contents results.

Organic matter OM

Concentration results show (Table 3) that; (i) at 300 m from the discharge and the depth (0-10cm) OM varies between 0.61% (A4) and 5.06% (A6). The same trend has been noted for soil between 20 cm and 30 cm. (ii) at the other two distances (600 and 1000 m), OM contents are lower than those observed at 300 m.

The values of organic carbon and total nitrogen ratios of most analyzed soils (tabl.4) are greater than 12. In this case, soils are characterized by reduced biological activity and slow decomposition of the organic matter (LCA, 2008). On the other hand, the A5 (0-10 cm), B2 and B4 (20-30 cm) soils with a C/N ratio less than 12 have a relatively good organic decomposition (LCA 2008). Table 4 shows that humus amount in analyzed soils with dominant silty / sandy texture, varies between 1.2% and 9.9%.

Exchangeable cations and cation exchange capacity

Table 4 also shows that cation exchange capacity evolves in the following decreasing direction Ca^{2+}> Mg^{2+}> Na^{+}> K^{+}. Table 4 shows that analyzed soils are characterized by a low CEC. According to ChristophKessel (ChristophKessel, 2006), the cation exchange capacity at the soil/soil solution interface is very low.

Major elements results

Data shows that major elements have same behavior for all distances. Similar results have been reported by Badraoui (Badraoui, 1988) in the same region. The values of MgO, P_2O_5, K_2O, MnO and CaO decreased from surface to depth, while Al_2O_3, SiO_2, Fe_2O_3 and TiO_2 levels increased from the surface

to the deep layers. The contents of major elements are superior to those found at the level of Earth's crust, except for MgO, K_2O, MnO and CaO.

C5 (1 km, Southeast) and C6 (1 km, southwest). In addition to these two structures, the two spectra reveal the presence of berlinite, sillimanite and quartz.

Table 4: Cations exchange capacity and exchangeable cations

Sample	Exchangeable cations								CEC (cmol/Kg)	
	Mg (cmol/kg)		Ca (cmol/kg)		Na (cmol/kg)		K (cmol/kg)			
depth	0 - 10	20 - 30	0 - 10	20 - 30	0 - 10	20 - 30	0 - 10	20 –30	0 - 10	20 - 30
300 m from discharge										
A1	1.5	1.265	5.5	5.8	0.11	0.11	0.06	0.06	6.12	6.67
A2	0.982	0.922	4.1	4.1	0.04	0.05	0.04	0.04	6	5
A3	0.875	1	4.4	4.5	0.05	0.05	0.02	0.02	4.68	5
A4	2.875	1.66	5	4.9	0.18	0.18	0.09	0.1	5.25	5.23
A5	2.75	2.7	6.3	6	0.05	0.06	0.03	0.03	9.5	8
A6	1.5	1	4	4.3	0.47	0.47	0.14	0.15	7.12	7.06
A 600 from discharge										
B1	1.25	0.98	4	5	0.05	0.05	0.04	0.04	5.43	5.12
B2	2.125	2	5.5	5.12	0.08	0.06	0.04	0.03	5.93	5.6
B3	1.3	1.18	3.7	3.6	0.05	0.05	0.03	0.03	6	6.34
B4	0.625	0.66	3.75	3	0.07	0.08	0.16	0.15	5.93	4
B5	0.98	1.55	4.1	4.9	0.05	0.06	0.03	0.03	6.56	5.5
B6	1.25	1.66	3	3.67	0.05	0.05	0.02	0.02	7	6.4
A 1 km from discharge										
C 1	1.3	1.18	2.7	3.6	0.05	0.05	0.04	0.04	4	5.67
C2	0.5	0.6	4	3.4	0.05	0.05	0.02	0.02	6.875	6.45
C3	0.65	0.86	2.5	3	0.05	0.04	0.02	0.02	5.35	5.2
C4	0.98	1.55	3	3.4	0.05	0.05	0.02	0.04	7	6
C5	1.25	1.66	2	2.1	0.05	0.04	0.02	0.04	5.5	5.3
C6	0.875	0.7	3.75	3.1	0.04	0.04	0.03	0.04	4.5	5.7

Mineralogical composition

The preliminary diffractograms analysis was performed and data shows that all soil can be represented by two types of DRX spectra.

The first one represents the soils containing illite (K Al_2 (OH) $_2$, (Al, IF_3 (O, OH) (10), it concerns the samples: A4 (300 m, East), B4 (600 m East), C2 (600 m, Northwest), C3 (1 km, Nordest) and C4 (1 km, East). The second spectrum represents soils containing kaolinite (Al_2O_3, $2SiO_2.2H_2O$);. This spectrum represents the following soils: A1 (300 m, west) A5 (300m, southeast), A6 (300 m, southwest), B1 (600 m, west), B2 (600 m, Northwest), B3 (600 m, Nordest), B5 (600 m, southeast), B6 (600 m, southwest), C1 (300 m, west),

ETM measurement

The results of ETM analysis in soils by ICP-AES are gathered in table 5. Measurement results of Ni, Cd, Cu, As, Pb, Zn, Cr and Co show a substantial variability of their concentrations in analyzed soils. For each element, this variation depends on the physicochemical characteristics of soil. For each direction, concentrations vary as;

1. Zn: between 238.66 and 1016 mg/Kg at 300 m and from 124.42 to 156, 87 mg / Kg at 600 m and between 116.46 to 180.71 mg/Kg at 1000 m.
2. Cd: between 2.68 and 18.48 mg/Kg at 300m and 0.80 to 10.97 mg/Kg at 600m and from 0.59 to 2.85 mg/Kg at 1000 m.

Table 5: Concentrations (mg/Kg) of measured elements in soil around the landfill

Metals	Cd		Cu		Ni		As		Pb		Zn		Co		Cr	
depth	0 - 10	20 - 30	0 - 10	20 - 30	0 - 10	20 - 30	0 - 10	20 - 30	0 - 10	20 - 30	0 - 10	20 - 30	0 - 10	20 - 30	0 - 10	20 - 30
300 m from discharge																
A1	4.35	4.40	6.58	3.72	12.53	4.12	6.48	10.46	116.03	120.59	411.37	475.88	0.42	0.80	18.58	15.99
A2	10.30	12.95	9.45	13.42	11.46	9.08	11.26	10.19	133.08	140.78	557.48	545.04	4.73	3.73	39.82	39.47
A3	2.68	3.99	61.76	59.27	17.19	19.23	10.40	13.18	250.07	270.63	355.27	371.02	1.75	3.17	42.92	44.11
A4	5.20	7.06	15.22	10.30	5.98	7.12	14.06	11.68	125.61	145.25	238.66	394.59	1.68	0.85	27.92	21.99
A5	14.67	16.33	20.44	53.23	7.43	7.12	13.40	12.92	35.50	70.94	470.46	479.18	1.37	1.10	26.70	46.99
A6	18.48	23.26	92.99	94.53	20.49	24.26	9.24	9.35	190.90	196.80	1016.04	1050.31	24.20	23.73	44.79	28.35
600 m from discharge																
B1	0.80	0.73	5.48	5.81	4.29	1.54	2.49	13.90	18.64	28.63	153.19	212.06	0.50	1.04	11.96	25.63
B2	10.91	25.92	6.59	3.09	4.06	5.27	10.44	12.15	19.26	16.61	127.05	106.84	0.51	0.41	20.08	20.96
B3	10.97	6.40	26.33	3.03	40.59	4.54	10.52	12.01	28.21	29.81	124.42	115.34	3.29	1.01	188.71	21.80
B4	3.32	4.71	23.54	22.11	8.80	7.58	20.78	6.96	37.53	39.37	143.12	156.74	1.17	1.13	35.09	31.74
B5	0.51	0.50	6.67	4.72	3.84	2.81	8.19	8.23	20.32	43.15	156.87	144.08	1.01	1.20	14.25	14.06
B6	0.46	0.30	9.14	6.30	4.71	8.76	6.74	7.87	17.81	19.24	128.76	149.10	1.11	1.28	13.38	16.14
1 km from discharge																
C1	0.59	1.07	4.75	3.42	4.56	40.50	10.60	11.24	19.91	21.94	116.46	103.26	0.59	0.64	19.71	46.55
C2	2.85	1.37	3.16	3.69	3.77	3.04	10.09	9.86	18.95	17.14	136.10	124.38	0.41	0.37	16.71	16.12
C3	1.19	6.09	3.97	2.54	4.66	3.86	11.90	11.16	16.66	19.02	172.30	138.90	0.40	0.30	20.33	19.07
C4	1.16	1.44	42.86	37.25	10.29	9.18	15.78	5.96	38.97	42.82	232.34	252.08	1	1	32.09	28.74
C5	0.62	0.51	23.42	11.69	8.54	14.94	26.05	16.10	28.31	21.96	180.71	122.49	3.26	2.58	44.12	79.04
C6	0.46	0.30	6.59	3.09	4.06	5.27	7.08	7.17	37.87	39.67	146.87	134.08	0.62	0.91	19.99	17.79

Table 6: Normalization values of metal contents relative to those of the terrestrial crust (Bowen, 1979; Winter, 1993) and a so-called normal soil (David et al., 2005; Winter, 1993)

Element	Average value à 300 m	NS	ST1	TC 1	ST2	TC2	ST3
Cd	9.28	0.35	26.51	0.15	61.86	0.15	61.86
Pb	141.86	35	4.05	10	14.18	14	10.13
Zn	508.21	90	5.64	79	6.43	70	7.27
Co	5.69	8	0.71	30	0.18	25	0.22
Ni	19.37	50	0.38	90	0.21	84	0.23
Cr	33.45	70	0.47	140	0.24	102	0.33
Cu	34.41	30	1.15	68	0.51	60	0.57
As	10.8	6	1.8	2.1	5.14	1.8	6
As (600m)	9.85	6	1.64	2.1	4.69	1.8	5.47
As (1 km)	13.59	6	2.26	2.1	6.41	1.8	7.55

NS: normal soil (Bowen, 1979); TC1: terrestrial crust (David et al., 2005); TC2: terrestrial crust (Winter, 1993)
ST1: Standardization (Bowen, 1979); ST2: Standardization (David et al., 2005); ST3: Standardization (Winter, 1993)

3. Pb: between 35.50 and 190, 9 mg/Kg at 300 m and from 17.80 to 28.21 mg/Kg at 600m and between 16.66 to 37.87 mg/Kg at 1000 m.
4. Cu: varies between 15.22 and 92.99 mg/Kg at 300 m and from 5.48 to 23.64 mg/Kg at 600 m and from 16.66 to 3.16 mg/Kg at 1000 m.
5. Ni: between 6, 98 and 20.49 mg/Kg at 300 m and from 4.06 to 40.59 mg/Kg at 600m and between 4.56 to 10.29 mg/Kg at 1000 m.
6. Co: from 0.42 to 24.20 mg/Kg at 300 m and from 0.6 to 3.29 mg/Kg at 600 m and between 0.41 to 3.26 mg/Kg at 1000m.

7. Cr: between 18.56 and 44.79 mg/Kg at 300 m and from 11.96 to 188, 71 mg/Kg to 600 m and between 16.71 to 44.12mg/Kg to 1000 m.

Whereas, for the semi metal, As concentration varies between 6.48 and 14.06 mg/Kg at 300 m and from 2.49 to 20.79 mg / Kg at 600 m and between 7, 08 and 26.05mg/Kg to 1000 m. Analysis of these data shows that:

1. For all distances and directions the content of all elements varies slightly with the depth between 0 and 30 cm;
2. For Cr and Ni, it is noted that concentrations are maximum at sample A6.
3. For Cd, Zn, Pb, Cu, Co, the soil concentrations at 300 m are higher than those observed at 600 and 100 m. The increase in concentration, more marked for Zn, Pb and Cd, caused by the discharge, can be attributed to the retention of these metals by the active phases of these soils.

As content increases with the distance, this may be due to the chemical or bacterial oxidation which leads to the mobility of large quantities.

The technical committee ISO/TC 190 decided to give no precise definition to the words pollution and contamination. This position is dictated by the fact that the risks of disturbing the natural functioning of ecosystems are not caused essentially by natural or anthropic increase in metal contents, but are mainly linked to the chemical forms generated by their interaction at the solid/water/plant interfaces. Taking into account this hypothesis, we have focused our discussion on the distribution of Cd, Zn, Pb, Ni, Co, Cr, Cu and As around the Mediouna discharge:

By comparing their content by normalization with data of the terrestrial crust (Bowen 1979) and those of a so-called normal soil (David et al., 2005; Winter, 1993) taking into account the physicochemical characteristics of analyzed soils.

Standardization with respect to three references (Table 6) aims to surpass the pedological similarity hypothesis (content of clay, iron, carbon, limestone and CEC of the same order). The analysis of the calculated values shows that:

(i) Zn, Pb, Cd are concentrated in soils at 300 m. Their retention is manifested by low levels in the soils at 600 m and 1000 m according to soil characteristics.

(ii) Ni, Cu, Cr and Co have low contents relative to the reference soils used, this may be due to their low contents or low retention in these soils.

(iii) As has a slight increase in soils, according to the following sequence: at 1000 m > soil at 300 m > soil at 600 m.

This can be attributed to the mobility of arsenic in an alkaline medium and basic pH of the studied soils. Basic pH values and high values of clay, carbonate and organic matter concentrations are observed in soils at 300 m from the landfill site. These conditions promote metal retention, in the form of complexes or simply adsorbed at the clay / carbonate / organic material interfaces. This justifies the high values of Cd, Pb and Zn concentrations, generated by waste from the landfill. On the other hand, As, partially retained by soils can pose a risk to the surrounding water system.

The behavior of the analyzed elements agrees well with their geochemistry mentioned in Förstner works (Förstner, 1989). Indeed, the work of Förstner, assumes that As is among the most relatively mobile elements, whereas ions, like those of Cd, Pb and Zn, are very weakly mobilized under these conditions.

CONCLUSIONS

The study was undertaken in the general context of metals behavior at the soil / water / plant interfaces. The objective is to understand the phenomena of their transfer from one compartment to another and the identification of their reaction mechanism and their chemical form. The problematic finds its normal application in the precise evaluation of the environmental risks and facilitates the development of depollution processes to be undertaken. In this work, which is the first step of the project, we focused our study on the behavior of the ETM in the solid compartment. These are the soils surrounding an uncontrolled landfill (Médiouna-Casablanca). The obtained results show the texture of the whole soil is of sand-silty type, with variable amounts of clay. Elevated values of clay, organic matter and carbonate are encountered in soils at 300 m from landfill. This gives these soils a very low cation exchange capacity and a high retention capacity of the metals. The alkaline pH of the soils and the high Ca-ion values confirm this hypothesis. Under these conditions, Cd, Pb and Zn, generated by waste from landfill, are retained in the soils located at 300m from the discharge. Their retention can be attributed to their binding to the clay- humic complexes and/or by adsorption on the carbonate phase. For all distances, Ni, Co, Cr and Cu are present in soils at low concentrations. On the other hand, As mobilized from the soil is transported by water.

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