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Potentially Toxic Elements Concentration in Decomposed Waste Residues Collected from a Closed Solid Waste Landfill

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I. Introduction

The landfill at Henchir El Yahoudia is an open-dumping type municipal solid waste (MSW) landfill located near the Lake Sejoumi, which had been operated since 1960s. The disposed materials consist of mainly municipal wastes collected from Greater Tunis region while some hazardous wastes such as industrial and hospital wastes were untidily mixed with the municipal solid waste. The dumping operation was completed in 1999, and then the landfill site has been capped and closed for redevelopment of the land.

In this paper we report a result of potentially toxic elements (PTEs; Alloways, 1995) analysis of decomposed solid waste residues collected from the closed landfill site, and make an assessment of its toxicity. This study was partly carried out as a technical cooperation between INRST (Institut National de Recherche Scientifique et Technique, Tunisie) and JICA (Japan International Cooperation Agency).

II. Samples

The samples analyzed were collected from the exposures of buried solid waste deposits in the landfill at Henchir El Yahoudia, the southwest of Tunis City. The locations of sampling sites are shown in Figure 1.

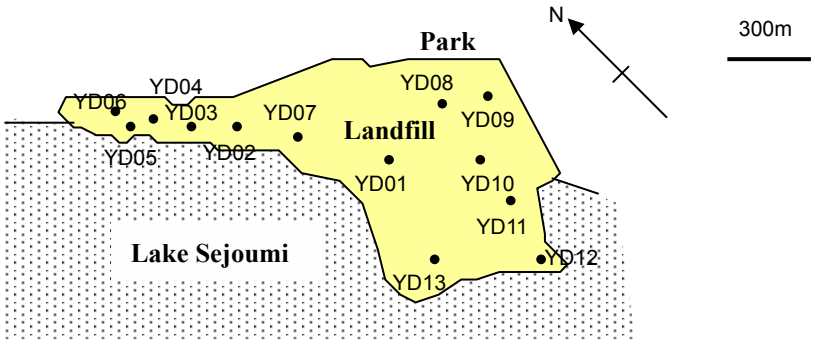

Figure 1: Location map for sampling site in the landfill at Henchir El Yahoudia, Tunisia.

The occurrence of exposed waste is greatly various, but generally it can be distinguished macro-scale solid waste such as plastic, glass, metal, wood, leather, brick fragments, and hospital wastes, and sludge-like waste residue of fine-grained materials generated by years or decades decomposition of dumped solid wastes. We collected the later materials for PTEs analysis. The samples are collected in March 2002. The sample was dried under room temperature and sieved by 1.0 mm mesh. The finer fraction has been used for analysis.

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III. Method of 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 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 PTEs not bound to silicates are efficiently dissolved (Ure, 1995), which is indicative for the assessment of toxicity.

The aqua regia extraction is, however, stronger extraction method than Toxicity Characteristic Leaching Procedure (TCLP; US EPA, 2001) or Water Leach Test (Japan). In order to assess the solubility (toxicity) of PTEs, weaker sodium acetate extraction with a sample size of 50 grams to 10 times water dilution has been carried out, which is expected to dissolve weakly-bonded ions with clay and organics (Table 2). The data can be correlated to those of Water Leach Test (Japan) or TCLP.

IV. Results

The result of element analysis of solid wastes using aqua regia extraction is summarized in Table 1. It suggest that the concentration of 10 regulated PTEs, V, Cr, Ni, Zn, As, Cd, Sb, Ba, Hg, and Pb, shows abnormally high values in comparing with the natural background concentration.

Table 1: Basic statistics of aqua regia extraction data for selected PTEs (Unit: mg/kg)

Element	Mean (mg/kg)	Minimum	Maximum	Standard Dev.
V	32.9	23	37	3.8
Cr	159.08	31.1	853.4	225.98
Ni	49.42	22.6	286.9	71.63
Cu	242.317	28.78	1882.52	499.444
Zn	541.65	128.3	1794.7	501.41
As	10.08	5.8	23.8	5.62
Se	0.38	0.1	0.9	0.32
Ag	0.8301	0.168	3.280	1.0343
Cd	0.790	0.25	2.54	0.679
Sb	3.478	0.81	10.21	3.249
Ba	204.01	30.1	451.5	97.84
Hg	0.2802	0.037	1.115	0.2894
Tl	0.100	0.07	0.12	0.014
Pb	210.089	41.62	471.15	145.255

Table 2: Results of strong acid extraction (HNO_3+HCl+HF) (mg/kg) and toxicity characteristics leaching (mg/l) using 0.1N sodium acetate solution for five heavy metals (Ibrahim, 2002). BDL: Below Detection Limit

Sample	Cu		Ni		Zn		Cd		Pb	
	Acid	Leach	Acid	Leach	Acid	Leach	Acid	Leach	Acid	Leach
YD1	228.82	3.1	223.82	32.1	819.34	2.3	6.79	BDL	8.99	0.2
YD2	182.91	19.7	121.94	30.0	226.89	232.0	6.20	3.1	1.00	1.6
YD3	12.00	2.6	211.96	19.9	143.97	2.2	0.00	BDL	8.00	BDL
YD4	56.73	4.6	270.73	20.2	846.02	2.8	1.99	1.0	16.92	2.5
YD5	38.86	0.1	96.66	28.7	142.50	2.1	1.59	0.5	10.96	1.8
YD6	51.93	2.1	163.77	26.9	190.73	8.2	0.80	BDL	16.98	BDL
YD7	223.64	2.3	195.69	29.3	668.93	3.0	3.29	3.6	2.00	BDL
YD8	37.95	2.3	100.87	23.5	149.81	2.0	13.48	2.5	2.00	0.5
YD9	128.74	3.2	309.38	24.2	91.82	1.8	5.19	BDL	13.97	1.0
YD10	52.88	3.5	264.42	18.9	104.77	2.6	4.69	5.2	16.96	0.4
YD11	42.94	5.0	229.66	28.0	145.78	2.9	2.70	3.1	12.98	1.3
YD12	120.96	5.2	103.97	24.7	271.92	2.6	11.40	3.0	7.00	BDL

According to the results of sodium acetate leach, 100% of samples in Ni (based on TCLP), 17% of samples in Zn (based on TCLP), 67% (based on Japan's regulation) or 58% (based on TCLP) of samples in Cd, and 58% of samples in Pb (based on Japan's regulation) exhibit hazardous levels.

V. Conclusions

(1) Concentration of potentially toxic elements (PTEs) in decomposed waste residues collected from Henchir El Yahoudia landfill were examined using three acid, aqua regia and sodium acetate extarctions.

(2) The sodium acetate extraction proved that four PTEs, Ni, Zn, Cd, and Pb, are hazardous level above the regulated values of land disposal restrictions (LDRs; US EPA, 2002). In addition to these elements, other six PTEs, V, Cr, As, Sb, Ba, and Hg, are also showing abnormal concentrations based on aqua regia extraction.

(3) Those decomposed solid waste residues in the landfill become a pollution source of PTEs for surrounding environment. Soluble components of PTEs in the residues are eventually dissolved into landfill leachate and migrated into surrounding environment such as groundwater and lake.

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