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Potentially Toxic Elements Concentration in Buried Solid Wastes in Henchir El Yahoudia closed landfill

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Abstract
Thirteen clayey to silty sludge samples collected from the municipal solid waste (MSW) landfill of Henchir El Yahoudia were measured for determining the concentration of potentially toxic elements (PTEs). The concentration is rather heterogeneous while the concentrations of V, Cr, Ni, Zn, As, Cd, Sb, Ba, Hg, and Pb, are abnormally higher than surrounding natural soil/sediment. According to the environmental regulation widely accepted, the waste deposits should be properly isolated for preventing further groundwater contamination.
Key Words
Landfill, Sludge, PTEs, Contamination

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 landfilling operation has been completed in 1999, and then a plan for landfill closure and land redevelopment is investigating by government authorities. To accomplish this investigation, assessment of toxicity of buried waste, in particular the contents of potentially toxic elements (PTEs; Alloway, 1995) is indispensable.

In this paper we report a result of PTEs analysis of the solid waste collected from the landfill at Henchir El Yahoudia, and make an assessment of its toxicity.

II. Samples and Methods

II-1. Samples

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

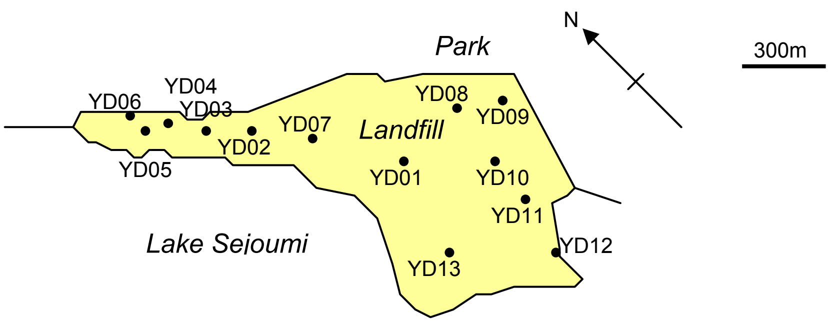

Figure 1: Location map for sampling site in the landfill at Henchir El Yahoudia.

Table 1: List of collected samples

Code	Latitude (N)	Longitude (E)	Contained solid waste	Matrix
YD01	36° 44' 02"	10° 10' 28"	hospital, metal, plastic, rubber, brick, glass, clothes	Sludge
YD02	36° 44' 17"	10° 10' 16"	leather, glass, brick, metal, plastic, shoes, paper	Sludge
YD03	36° 44' 19"	10° 10' 14"	plastic, hospital, clothes, rubber, glass, animal bone, metal, brick	Sludge
YD04	36° 44' 22"	10° 10' 11"	hospital, PET, plastic, tyre, metal, brick, glass	Sludge
YD05	36° 44' 22"	10° 10' 10"	plastic, metal, shoes, animal bone, fiber, paper, clothes, hospital, electric parts	Sludge
YD06	36° 44' 27"	10° 10' 06"	metal can, brick, plastic, wood, cosmetic, clothes ceramics, batteries, hospital, animal bones	Sludge
YD07	36° 44' 14"	10° 10' 19"		Sludge
YD08	36° 44' 02"	10° 10' 36"		Sludge
YD09	36° 44' 01"	10° 10' 40"		Sludge
YD10	36° 43' 56"	10° 10' 38"		Sludge
YD11	36° 43' 50"	10° 10' 33"		Sludge
YD12	36° 43' 45"	10° 10' 29"		Sludge
YD13	36° 43' 51"	10° 10' 20"		Sludge

Plate 1: Occurrence of solid waste in Henchir El Yahoudia landfill

The occurrence of exposed waste is greatly variuous, 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 matrix of fine-grained materials probably generated by decomposition of buried solid wastes (Plate 1). We collected the later materials for PTEs analysis. The samples are collected in March 2002. The site description is summarized in Table 1. The sample was dried under room temperature and sieved by 1.0 mm mesh. The finer fraction has been used for analysis.

II-2. Analysis of PTEs

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 or sludge 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, environmentalily concerned components like heavy metals or PTEs not bound to silicates are efficiently dissolved (Ure, 1995), which is indicative for the assessment of toxicity.

III. Results and Discussion

The results of PTEs analysis using aqua regia extraction method are summarized in Table 2, and the concentration level of each element is illustrated as box-whisker plot in Figure 2.

Table 2: Result of PTEs analysis by aqua regia extraction

ELEMENT	B	Na	Mg	Al	P	S	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga
unit	ppm	%	%	%	%	%	%	%	ppm	%	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm
YD01	29	0.201	0.45	1.30	0.249	0.78	0.62	12.60	2.20	< .001	32	114.9	353	3.40	9.5	34.9	243.18	839.2	4.1
YD02	28	0.035	0.23	1.30	0.046	21.56	0.38	7.09	2.20	0.008	23	853.4	89	1.66	3.1	30.4	162.39	367.7	4.9
YD03	16	0.103	0.47	1.63	0.089	0.75	0.64	12.40	2.80	0.010	36	45.6	265	2.26	7.8	23.8	41.33	149.3	4.8
YD04	26	0.469	0.53	1.36	0.153	1.32	0.79	11.15	2.40	< .001	30	56.3	343	4.88	9.7	43.1	64.37	682.4	4.5
YD05	21	0.180	0.49	1.65	0.148	0.51	0.79	13.10	2.70	0.003	36	45.7	284	2.06	7.9	25.0	53.53	175.5	4.8
YD06	15	0.047	0.46	1.66	0.121	0.45	0.56	12.40	2.50	0.010	37	52.3	285	2.58	8.5	26.6	72.86	1794.7	5.0
YD07	20	0.065	0.38	1.46	0.311	0.37	0.45	11.93	1.80	0.006	31	357.4	359	3.55	9.4	38.0	290.53	642.3	4.3
YD08	52	1.996	0.51	1.52	0.086	2.00	0.70	11.96	2.50	0.002	32	179.2	259	2.01	6.9	28.0	54.83	186.6	4.7
YD09	22	0.067	0.42	6.11	0.082	0.67	0.47	9.19	2.30	< .001	33	76.4	410	3.60	13.1	286.9	1882.52	1247.0	11.7
YD10	15	0.373	0.38	1.10	0.096	0.73	0.63	14.24	2.50	< .001	32	31.1	239	1.98	6.7	22.6	39.20	128.3	3.4
YD11	20	0.107	0.54	1.64	0.088	0.68	0.60	12.41	3.00	0.001	37	58.2	256	2.01	7.2	23.0	28.78	223.0	5.0
YD12	17	0.168	0.40	1.32	0.138	0.34	0.61	11.75	2.10	0.006	33	80.4	254	2.32	6.8	26.2	110.60	303.0	4.0
YD13	17	0.086	0.45	1.45	0.180	0.23	0.58	12.23	2.30	0.010	36	117.1	293	2.50	7.4	33.9	106.00	302.5	4.4
Detec. Limit	1	0.001	0.01	0.01	0.001	0.01	0.01	0.01	0.1	0.001	2	0.5	1	0.01	0.1	0.1	0.01	0.1	0.1

ELEMENT	As	Se	Sr	Mo	Ag	Cd	Sb	Te	Ba	La	W	Au	Hg	Tl	Pb	Bi	Th	U
unit	ppm	ppm	ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppb	ppb	ppm	ppm	ppm	ppm	ppm
YD01	23.8	0.3	683.3	3.43	2857	1.74	8.00	0.05	298.9	7.7	0.7	99	1115	0.10	414.76	3.85	2.3	0.8
YD02	6.2	0.1	251.5	0.89	168	0.25	1.28	0.15	30.1	4.7	< .1	5.2	37	0.09	41.62	0.19	2.4	0.3
YD03	6.3	< .1	549.6	1.30	237	0.33	0.81	0.04	198.1	9.7	< .1	22.8	109	0.12	70.56	0.41	2.8	0.6
YD04	19.6	0.9	799.6	2.52	346	0.47	8.26	0.06	175.6	7.6	0.1	13.4	120	0.10	409.20	0.56	2.9	1.1
YD05	6.6	0.3	600.9	1.21	409	0.46	2.15	0.05	206.9	8.9	< .1	17.2	232	0.11	147.84	6.93	2.7	1.1
YD06	5.8	< .1	560.3	1.10	198	0.95	0.81	0.06	183.4	9.2	< .1	9.6	288	0.12	46.81	0.29	2.5	0.6
YD07	12.9	0.9	461.2	2.45	3280	2.54	10.21	0.05	451.5	7.6	0.3	94.2	579	0.10	471.15	0.47	1.8	0.7
YD08	7.1	< .1	801.4	1.41	291	0.30	1.25	0.04	122.7	8	< .1	129.4	111	0.10	205.98	0.20	2.9	1.2
YD09	10.9	0.1	596.0	4.08	1114	1.06	2.51	0.05	153.8	7.1	2.5	194.8	89	0.11	145.19	12.93	2.8	0.9
YD10	9.9	0.3	536.6	1.68	187	0.96	2.29	0.05	173.7	7.7	< .1	9.5	346	0.08	185.74	0.17	2.3	0.6
YD11	7.6	< .1	638.6	1.13	284	0.27	0.84	0.06	179.5	9.5	< .1	18.8	181	0.11	82.52	0.17	3.1	0.9
YD12	7.5	0.1	437.2	2.43	800	0.40	4.62	0.05	237.5	7.3	< .1	60.4	306	0.07	256.51	0.18	2.2	0.6
YD13	6.9	0.4	456.5	1.21	621	0.54	2.19	0.06	240.4	8.7	< .1	49.8	130	0.09	253.27	0.23	1.9	0.7
Detec. Limit	0.1	0.1	0.5	0.01	2	0.01	0.02	0.02	0.5	0.5	0.1	0.2	5	0.02	0.01	0.02	0.1	0.1

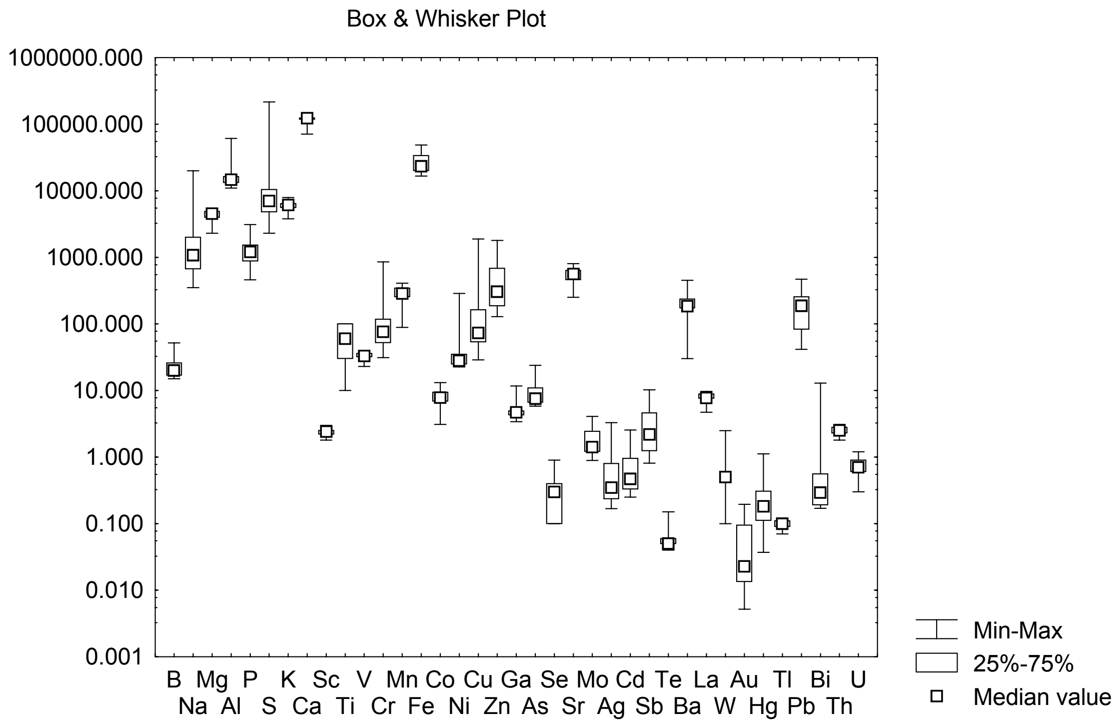

Figure 2: Box-whisker plot of the concentration of various elements in buried solid waste.

There are specific provisions restricting the land disposal of hazardous waste in many countries. These land disposal restrictions, e.g. abbreviated LDRs (Land Disposal Restrictions by United States Environmental Protection Agency (US EPA)), are sometimes called the *land ban* (Sellers,1999). LDRs prohibits the land disposal of certain wastes and specify treatment methods for other wastes. The LDRs apply to all substances including potentially toxic elements (PTEs). The list of PTEs in LDRs regulation is summarized as Table 3. LDRs also include requirements for treating certain wastes before land disposal. The US EPA established the treatment standards, where the underlying hazardous constituents in certain characteristic wastes must meet the Universal Treatment Standards (UTS). The UTS for restricted PTEs is also summarized in Table 3. Total fourteen PTEs are defined by the regulations. In these standards' values, data are given by the Toxicity Characteristic Leaching Procedure (TCLP; US EPA) or LT (Leaching Test; Japan). In present study we applied aqua regia extraction that is stronger extraction method than TCLP or LT. Therefore our data obtained from aqua regia extraction should be regarded as referenced values. We also attempted weaker sodium acetate extraction with a sample size of 50 grams to 10 times water dilution (Nasser, 2002; Table 4), which is expected to dissolve weakly bonded cations with clay and organics. The data can be correlated to those of LT or TCLP.

Table 3: Regulated value for PTEs concentration-leaching of hazardous waste

PTEs	Japan regulation (solid waste)*	US EPA regulation (solid waste)**	US EPA (hazardous nonwastewater universal treatment standards)***
Ag			0.14 mg/l TCLP
As	0.3mg/l LT[#]	5.0 mg/l TCLP[##]	5.0 mg/l TCLP
Ba		100.0 mg/l TCLP	100 mg/l TCLP
Be			1.22 mg/l TCLP
Cd	0.3mg/l LT	1.0 mg/l TCLP	0.11 mg/l TCLP
Cr	1.5mg/l Cr(VI) LT	0.60 mg/l TCLP	0.60 mg/l TCLP
Hg	0.005mg/l LT	0.2 mg/l TCLP	0.20 mg/l TCLP
Ni			11 mg/l TCLP
Pb	0.3mg/l LT	5.0 mg/l TCLP	0.75 mg/l TCLP
Sb			1.15 mg/l TCLP
Se	0.3mg/l LT	1.0 mg/l TCLP	5.7 mg/l TCLP
Tl			0.20 mg/l TCLP
V			1.6 mg/l TCLP
Zn			4.3 mg/l TCLP

[#] LT: Leaching Test by Japan Industrial Standards (JIS), with a sample size of 50 grams to 10 times water dilution, 6 hours shaking.
[##] TCLP: Toxicity Characteristics Leaching Procedure by US EPA, with a sample size of 10 grams to 20 times water dilution, 1.25 hours shaking.
* Ministry of Environment, Government of Japan
** US Environmental Protection Agency, Publication SW-846, Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods, Chapter 7
*** US Environmental Protection Agency, Land Disposal Restriction (LDR) Rules and Regulations 2002

Table 4: 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)

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

BDL: below the detection limit

According to the results of sodium acetate leach, 100% (US EPA standard) of samples in Ni, 17% (US EPA standard) of samples in Zn, 67% (Standard of Japan) or 58% (US EPA standard) of samples in Cd, and 58% (Standard of Japan) of samples in Pb appear hazardous levels in leaching.

Table 5: Basic statistics of aqua regia extraction data for selected PTEs (Unit: ppm)

Element	Mean	Minimum	Maximum	Std.Dev.
V	32.92308	23	37	3.81797
Cr	159.0769	31.1	853.4	225.981
Ni	49.41538	22.6	286.9	71.6295
Cu	242.3169	28.78	1882.52	499.444
Zn	541.6538	128.3	1794.7	501.414
As	10.08462	5.8	23.8	5.62062
Se	0.377778	0.1	0.9	0.31535
Ag	0.830154	0.168	3.28	1.03438
Cd	0.79	0.25	2.54	0.67897
Sb	3.478462	0.81	10.21	3.24938
Ba	204.0077	30.1	451.5	97.8404
Hg	0.280231	0.037	1.115	0.28943
Tl	0.1	0.07	0.12	0.01472
Pb	210.0885	41.62	471.15	145.255

The results of aqua regia extraction is suggesting us that the concentration of ten regulated PTEs, V, Cr, Ni, Zn, As, Cd, Sb, Ba, Hg, and Pb, indicates abnormally high values in comparing with the natural background concentration.

Those densely contaminated solid wastes buried in the landfill become a pollution source of PTEs for surrounding environment. Figure 3 shows possible contamination paths in and around the Henchir El Yahoudia closed landfill.

IV. Conclusions

(1) Concentration of potentially toxic elements (PTEs) in solid waste samples 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 risky level above the regulated values of land disposal restrictions (LDRs). 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) The PTEs are probably dissolved into landfill leachate and migrated into surrounding environment such as groundwater and lake, which may provoke environmental contamination. Appropriate countermeasure is recommended.

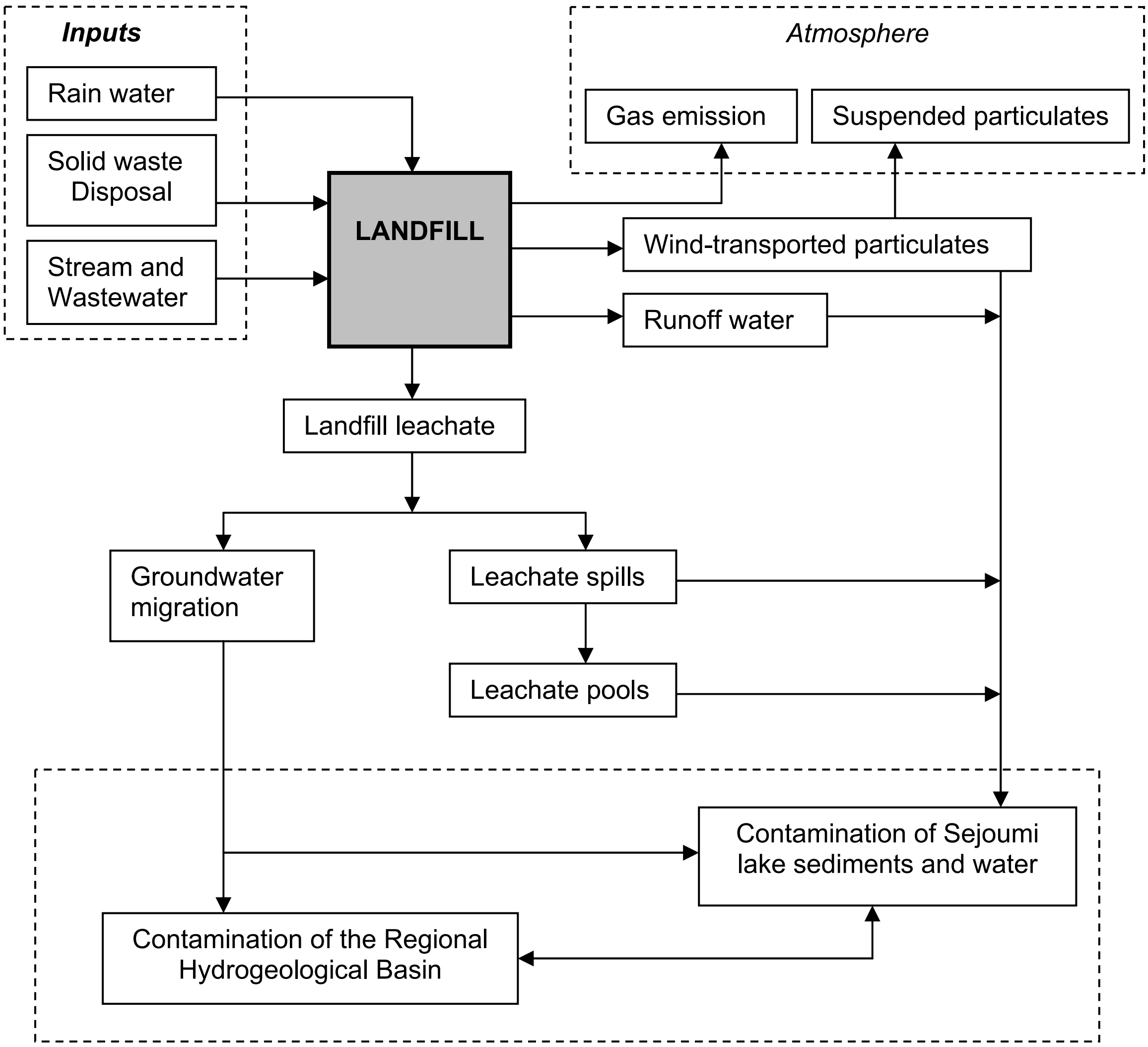

Figure 3: Landfill-caused contamination paths in and around Henchir El Yahoudia.

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References

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

Ibrahim, A.N, 2002, Environmental Pollution Assessment of the Henchir El Yahoudia Closed Landfill. *Memoire de Diplome d'Etudes Approfondies, INAT*, 81p.

Ministry of Environment, Government of Japan, 2001, *Environmental Quality Standards*.

Sellers, K., 1999, *Fundamentals of hazardous waste site remediation*. Lewis Publ., Boca Raton, 326p.

United States Environmental Protection Agency, 2001, Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods, US EPA Publication SW-846.

United States Environmental Protection Agency, 2002, *Land Disposal Restriction (LDR) Rules and Regulations.*

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