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Impacts of the dumping site on the environment: Case of the Henchir El Yahoudia Site, Tunis, Tunisia

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Abstract

The Henchir El Yahoudia landfill is one among many uncontrolled dumping sites in Tunisia with no bottom liner. It is located at the southeastern edge of Sijoumi Sebkha. The site has been exploited since 1963 until 1994. It constitutes a peculiar case because of its situation, its exploitation mode and the nature of buried wastes. Leachate analysis shows that they are strongly charged with nitrogen (especially ammoniacal and kadjedahl), organic compounds with a high biodegradability and a charge of metallic elements exceeding the Tunisian norm NT 106-002. Sediment analyses show that the highest rate of heavy metals and organic matter coincides with clay-richest layers, characterized by the highest specific-surface values. The percolation of these pollutants until the groundwater between 0.5 and 5 m has provoked a pollution characterized by high rates of organic matter (BOD, COD and nitrogen) and heavy metals. ***To cite this article: A. Marzougui, A. Ben Mammou, C. R. Geoscience 338 (2006).***

Résumé

Impacts des décharges sauvages sur l'environnement ; cas du site Henchir El Yahoudia, Tunis, Tunisie. Le site de Henchir El Yahoudia représente la plus grande et la plus ancienne décharge du Grand Tunis. C'est une décharge non contrôlée, qui a connu plusieurs phases d'exploitation. La localisation de la décharge en bordure de la Sebkha Es Sijoumi et la diversité des déchets qui y sont enfouis représentent les problèmes majeurs du site. Les polluants sont acheminés principalement par les lixiviats. Ces derniers renferment des teneurs en éléments traces, en matière organique et en éléments nutritifs qui dépassent la norme tunisienne NT 106-002, relative aux rejets des eaux usées dans le milieu naturel. En l'absence de tout système de collecte de lixiviats, ces effluents sont en contact direct avec le substratum de la décharge. Les analyses minéralogiques et géochimiques montrent que les niveaux argileux du substratum et, particulièrement les smectites, concentrent les éléments traces et la matière organique et représentent une barrière limitant la percolation de la pollution. Ceci n'a pas empêché la contamination de la nappe, dont le niveau statique est proche de la surface. ***Pour citer cet article : A. Marzougui, A. Ben Mammou, C. R. Geoscience 338 (2006).***

Keywords: Dumping site; Leachate; Substratum; Groundwater; Pollution; Heavy metals; Organic Matter; Tunisia

Mots-clés : Décharge ; Lixiviats ; Substratum ; Nappe ; Pollution ; Métaux lourds ; Matière organique ; Tunisie

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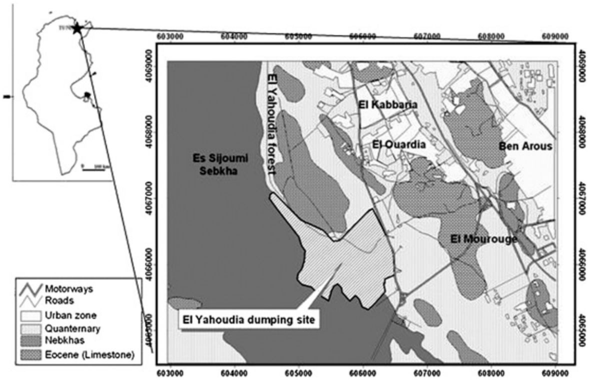

Fig. 1. Location and geological map of the study area.

Fig. 1. Carte géologique et de localisation du site d'étude.

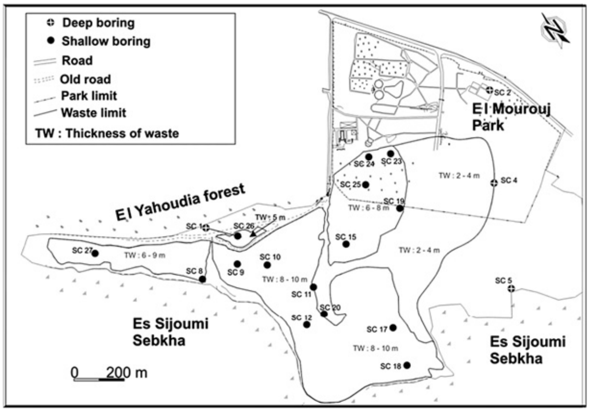

Fig. 2. Location map of the borings points.

Fig. 2. Carte de localisation des sondages.

1. Introduction

Landfilled wastes manifest slow decomposition, producing emanations of gases and outflow of leachates. Indeed, the waste mass shows various chemical reactions and complex evolutions that occur under the influence of natural agents, as rain and micro-organisms. These reactions lead to the biologic, physical, and chemical transformations of wastes. The intensity of the phenomenon is mainly related to the air and the humidity. These factors originate from the initial composition of solid waste, the operating mode of the landfill (anarchical or controlled) and the geological and hydrogeological conditions [10].

Leachate is increasingly considered to be a major source of groundwater pollution [11,40]. In fact, it has a complex nature; it typically contains high concentrations of conventional, non-conventional, and hazardous chemicals such as BOD, COD as well as the so-called 'chemicals hazardous' including heavy metals and numerous chemical compounds that may severely pollute environment [7,9,12,18,23,24].

Among the 68 dumping sites indexed in Tunisia, the Henchir El Yahoudia is located at 4–8 km south of Tunis; it borders the southeastern shore of the Sijoumi Sebkha (Fig. 1). The site, which is the most extended and the most ancient in Tunisia, has received the wastes of a population of 1.5 million habitants, which means around 4.7×10^6 tons/year. Here, wastes have been landfilled since 1969 and include municipal solid wastes and inert wastes (75%), sludge of waste water treating plants (20%) and industrial wastes (5%), health-care wastes (20%), with no preliminary treatment [39]. Thus, the urban location of the site can constitute a risk for the neighbouring population. The negative effects of this uncontrolled dumping site are clearly identified, such as nauseous smells, smoke generation and biogases emission, resulting in important carbon fluxes, sanitary risks, fires, asphyxiation of vegetation [13,16,19,32,35]. Previous studies following its closure in 1994 have indicated that leachates from the Henchir El Yahoudia site are negatively impacting groundwater and seriously damaging the environment of the Sebkha [40].

This paper studies the vertical and lateral percolation of the pollutants by evaluating the degree of the substratum contamination and its impact on the environment, when assuming the aggravation of the situation as related to increasing urbanization.

2. Analysis method

In order to characterize the dumping site, the Tunisian Environmental Protection Agency (ANPE) has conducted a field investigation in 2000. This study program consisted of two types of investigation works:

- outside the zone of wastes: four borings to depth of 30 m have been done;
- inside the zone of wastes: 20 shallow borings and 93 excavations were made at the site.

Representative samples of these borings have been taken (Fig. 2) for laboratory analyses that consist on mineralogical and geochemical characterisation.

The experimental procedure was as follows. X-ray spectra were recorded for identification of clay minerals using a diffractometer with Bragg–Bretano geometry. For that, orientated clay aggregates (normal, heated to 550 °C for 2 h and treated with ethylene glycol for 2 h) were prepared. The specific surface was measured by the methylene-blue method [14].

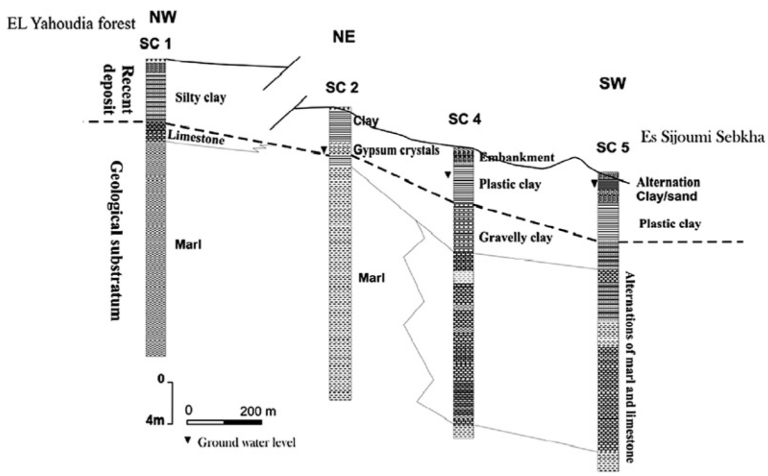

Fig. 3. Geological cross-section between SC1, SC2, SC4 and SC5 showing the lithological succession.

Fig. 3. Coupe lithologique passant par les sondages SC1, SC2, SC4 et SC5.

Total Zn, Cu, Pb, Cr, Mn contents in substratum samples were determined by digestion in $HF–HNO_3–HClO_4$, and the concentrations of these elements in the digested solution were measured by Atomic Adsorption Spectroscopy (AAS) [4].

The dosage of the TOC is achieved by coulometry with the help of the device Coulomat 702 [21].

3. Characterization of the Henchir El Yahoudia dumping site

3.1. Location

The dumping site is located east of the fault through of Sebkra Es Sigoumi (Fig. 1). The latter, located south of Tunis, is a part of a much extended hydrological watershed (230 km^2) and constituted the natural exsurgence of this watershed.

3.2. Morphology

The site can be morphologically divided into three sectors:

- an elongated area of 12 ha in the northwest, where a central dome with slight slopes towards the Sebkha is rising;
- the central sector organized in three domes, with heights up to 21 m [40] and covering an area of 47 ha;
- the third sector is the lowest part of the site located at the southeast and occasionally flooded by the water from the Sebkha during the wet season.

The cover layer presents some cracks, from which biogas and leachate are escaping. Some exudations are also observed at several places of the embankment's base.

The waste mass lies on the ground level of the site, slightly inclined toward the Sebkra whose elevation varies between 10 and 12 m; thus there are no correlations between the altitude and the waste thickness [40].

3.3. Substratum

On the eastern bank of Sebkra Es Sigoumi, as well as on the eastern and northern border of the El Yahoubia Forest, globigerinids-bearing Lower Eocene limestones outcrop. These limestones are capped by calcareous crust [33]. Black–grey Quaternary deposits, considered as 'lunette' deposits [8,22], cover the Henchir El Yahoudia Hill; their clay-fraction content is comprised between 30 and 45% and they present a high percentage of gypsum (up to 50%) in the coarse-grained fraction (>250 µm) [8].

This lithological succession is also observed in the borings in the dumping site.

The borings realized outside the dumping site indicated a lithologic sequence mainly formed by clay-sandy alternations and silty clay for the upper 6 m deposited on a 2-m-thick layer of white limestone. The remaining part of the sequence to 30 m depth is constituted of a fractured yellow-to-green marl and alternations of marl and limestone, as observed in the geological cross-section of Fig. 3.

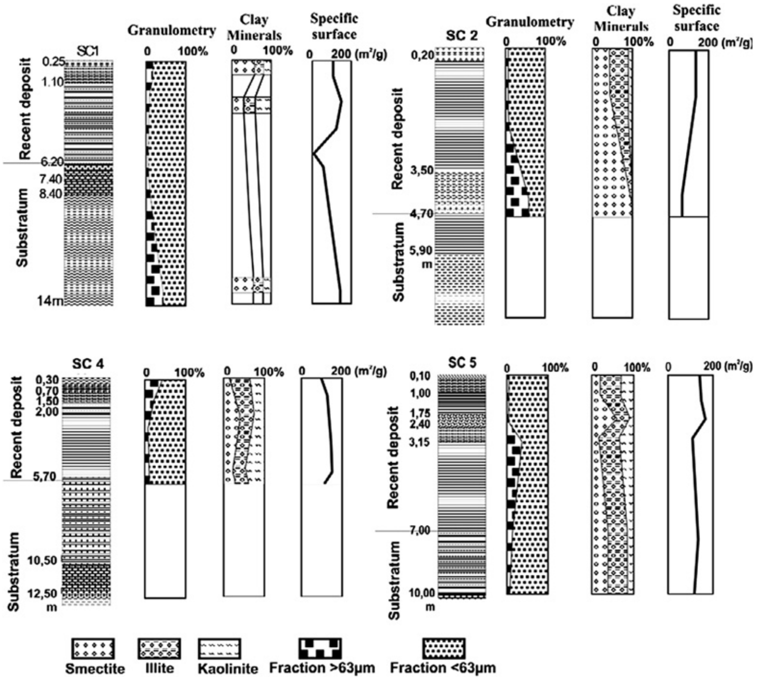

Fig. 4. Variation of fine fraction, coarse fraction, clay minerals and specific surface according to the depth in SC1, SC2, SC4 and SC5 borings.

Fig. 4. Variation verticale des teneurs en fraction fine, fraction grossière, des minéraux argileux et de la surface spécifique le long des sondages : SC1, SC2, SC4 et SC5.

4. Results and discussion

4.1. Leachate

Henchir El Yahoudia dumping site produces annually 65 000 to 70 000 m^3 of leachate from the 4.7×10^6 tons of buried waste [5], whose moisture rate is about 50% and content of organic matter between 4 and 34% [40]. This content is rather high as compared with those of the developing countries where the latter does not usually exceed 26% [15].

The maximum leachate levels were recorded at the central sector of the site in the form of a dome with a flow direction oriented to the Sebkha, as mentioned above. Leachate spurts were locally observed at some piezometers; this comes from an overpressure caused by the biogas dissolution and the high thickness of wastes and the cover layer.

The composition of the leachates shows that they can be classified among the household wastes and assimilated [15,16,33], characterized by a neutral pH and high contents of nutrient elements, above total nitrogen and organic matter (COD, BOD). These leachates are highly biodegradable and are loaded by heavy elements, especially Cu, Zn, Mn, Pb, Ni, and Cr, whose contents for the major part exceeds the Tunisian norm NT106-002 [28–30,40] relative to wastewater discharge in the environment. As compared to leachates from the discharge of El Jadida (Morocco), the effluents of Henchir El Yahoudia are however much lesser loaded in organic and mineral pollutants [11].

In the absence of drainage pattern, the leachates of El Yahoudia are in direct contact with the geological substratum and two migration types can be pointed out: a vertical and a lateral one. Zaïri et al. [40] noted a contamination of underground water testified by high contents of total nitrogen [28–30] (between 14 and 29.5 mg O_2/l) and in organic matter with BOD and COD comprised between 12 and 21 mg O_2/l and between 70 and 144 mg O_2/l, respectively. The contents in trace elements are low; the maximal values of Cu and Zn do not exceed 0.19 and 1.26 mg/l, respectively.

4.2. Mineralogical study

In order to evaluate the rate of pollutant retention by surficial deposits (‘lunette’ deposits) and by the substratum of Henchir el Yahoudia, a study of grain-size distribution clay-fraction composition and specific surface of clay minerals was performed, whose results for borings SC1, SC2, SC4 and SC5 are presented in Fig. 4.

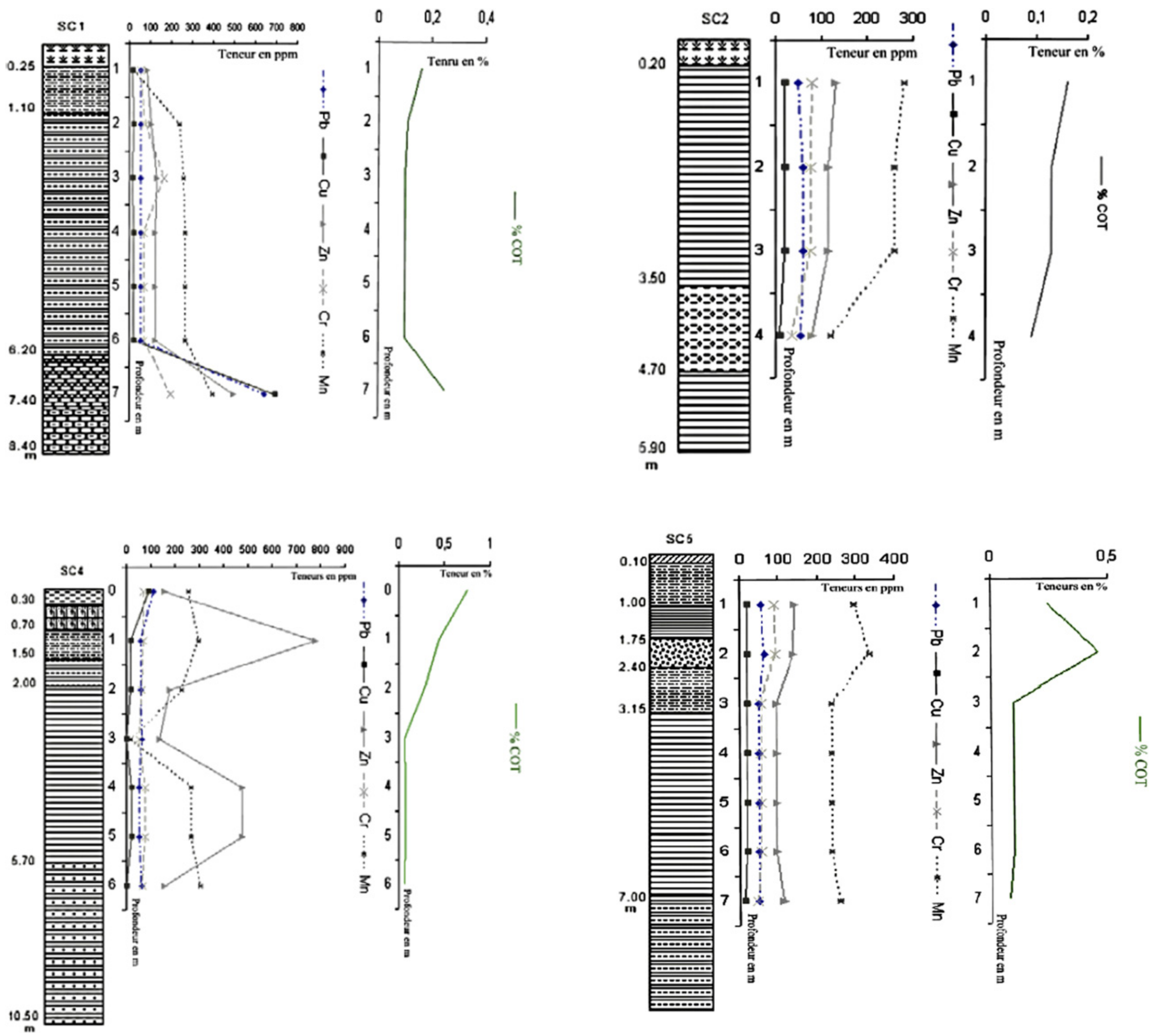

Fig. 5. Variation of heavy metals and total organic carbon (TOC) contents according to the depth on SC1, SC2, SC4 and SC5 borings.
Fig. 5. Variation verticale des teneurs en éléments traces (Zn, Pb, Cr, Cu et Mn) et en COT dans les sondages profonds SC1, SC2, SC4 et SC5.

As observed on that figure, substratum and surficial deposits are rich in <63 μm fraction (up to 60%). Clay mineral assemblage is composed of smectites, illites and kaolinites. Smectites whose content varies from 10% (SC25 – 7.60 m) to 85% (SC2 – 4 m) are likely to be responsible for the important specific surface measured, from 14 m^2/g (SC1 – 7 cm) to 225 m^2/g (SC27 – 8 m); the latter as well as high cation exchange capacity explains that the nature and composition of the minerals assemblage are very favourable to a strong metal sorption and pollutant retention capacity of the substratum [3,20,26,31,41].

4.3. Geochemical study

In fact, this assumption is verified in Fig. 5 and Tables 1 and 2: the contaminated levels, essentially enriched in heavy metals and organic matter, correspond to the highest fine-grained fraction and the most important specific surface values (Figs. 4 and 5) in the sedimentary columns.

As for the distribution of the different heavy metals vs. depth, it can be mentioned, first that the lowest concentrations are for Cr, Cu and Pb and the highest for Mn and Zn. For almost all the samples, the heavy metals contents are close to, or even less than the stan-

Table 1
Variation of Pb, Cu, Zn, Cr, Mn contents and TOC percentages between 0 and 2 m below the dumping site

Tableau 1
Variation des teneurs en Pb, Cu, Zn, Cr, Mn et du pourcentage du COT entre 0 et 2 m sous la masse des déchets

Samples	**Pb (ppm)**		**Cu (ppm)**		**Zn (ppm)**		**Cr (ppm)**		**Mn (ppm)**		**TOC (%)**	
	0 m	**2 m**	**0 m**	**2 m**	**0 m**	**2 m**	**0 m**	**2 m**	**0 m**	**2 m**	**0 m**	**2 m**
SC9	437	54	268	11	541	163	105	35	368	79	1.18	0.15
SC10	60	**85**	**359**	17	140	120	88	69	280	**19**	0.4	0.1
SC11	114	54	23	20	909	139	**53**	**80**	227	317	0.26	0.12
SC12	**425**	**30**	326	**7**	**2649**	188	99	**26**	**1641**	99	1.23	0.11
SC15	54	60	17	9	138	164	69	30	207	80	0.24	**0.09**
SC17	104	54	33	20	158	128	94	89	336	306	0.69	0.22
SC18	59	65	18	17	232	154	75	51	207	159	0.3	0.19
SC19	49	55	17	17	378	129	66	67	206	388	0.31	0.1
SC20	80	44	23	9	259	109	**101**	49	299	118	0.41	0.13
SC26	59	55	20	18	207	**429**	71	76	227	210	0.42	0.15
SC23	55	54	**14**	17	363	361	65	76	**199**	267	**0.1**	–
SC24	119	54	36	**58**	633	138	75	73	257	236	**0.1**	–
SC25	101	–	58	–	574	–	71	–	237	–	1.51	–
SC8	**45**	54	17	13	**99**	**74**	71	39	326	326	0.15	**0.26**
SC27	128	59	27	**58**	287	162	71	55	524	**524**	**3.08**	–
A	**50–100**		**30–60**		**100–200**		**50–100**		**–**		–	
B	**100**		**100**		**300**		**150**		**–**		–	
C	**3**		**1**		**3**		**2**		**2**		**0.01**	

(**A**) European norm [34].
(**B**) AFNOR [2,6].
(**C**) Detection limit (ppm).

dard values proposed for non-polluted soils [25], and for the French association of normalization [2], except for some samples taken under the waste mass (as for SC9, SC10, SC12 at 0 m). It is also important to notice that some concentrations are higher (as for Zn, Pb) than the critical values given by the European norm [34].

Second, there is a clear variation of the contamination rate through the sedimentary columns.

In fact, the borings drilled in the waste deposits show usually a decrease of heavy-metal concentration and of total organic carbon (TOC) percentage from the top to the bottom. The transfer of pollutants can be considered as effective beyond the first 2 m below the waste mass; but the percentages recorded are in the major part lower than the standard values recommended (Table 1). The deep borings show also a decrease of the metallic elements from the upper part to the lower part of boring, except boring SC1, in which there is an increase of the content of trace elements at 7 m depth; this is likely due to the situation of the boring in geomorphologically higher position (Fig. 6).

Third, the heavy metals concentrations recorded in the deep borings rarely exceed standard values (European one and AFNOR) [2,6,34] (Table 2), which proves that lateral migration of pollutants is less important than the vertical one.

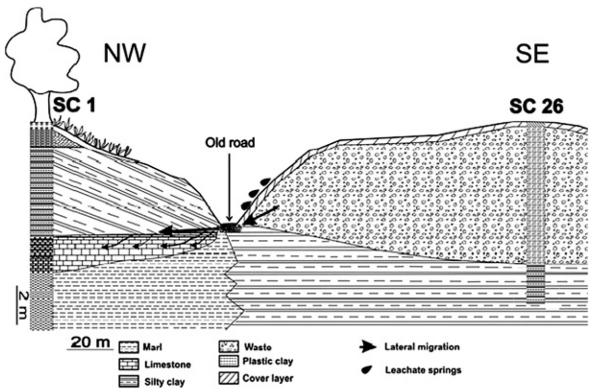

Fig. 6. Geomorphological cross-section between SC1 and SC26.

Fig. 6. Coupe géomorphologique passant par les sondages SC1 et SC26.

Indeed, the contents in metals and in TOC recorded inside the wastes zone are much higher than those recorded in borings located outside the zone of wastes (Tables 1 and 2). With one exception, SC1 sample, located near the waste mass, which is affected by a lateral migration of the pollutants (Fig. 6).

5. Conclusion

The production of leachates and biogas by the Henchir El Yahoudia dumping site constitutes a source

Table 2
Variation of Pb, Cu, Zn, Cr, Mn contents and TOC percentages at level of SC1, SC2, SC4 and SC5 according to the depth

Tableau 2
Variation des teneurs en Pb, Cu, Zn, Cr, Mn et du pourcentage du COT au niveau des sondages SC1, SC2, SC4 et SC5 en fonction de la profondeur

	Depth (m)	Pb (ppm)	Cu (ppm)	Zn (ppm)	Cr (ppm)	Mn (ppm)	TOC (%)
SC1	1	54	17	84	52	**17**	0.16
	2	55	18	105	78	240	0.11
	3	55	17	129	**165**	259	0.1
	4	54	18	123	71	266	0.1
	5	54	18	123	71	266	0.1
	6	54	18	123	71	266	0.1
	7	**644**	**694**	**495**	**198**	**396**	0.25
SC2	1	50	18	130	78	280	0.16
	2	60	18	114	76	259	0.13
	3	60	18	114	76	259	0.13
	4	55	9	79	35	119	0.09
SC4	0	**113**	**92**	157	71	256	**0.75**
	1	59	18	**779**	71	298	0.44
	2	59	18	177	64	226	0.28
	3	64	1	138	52	**17**	**0.06**
	4	54	20	**476**	78	265	0.07
	5	54	20	**476**	78	265	0.07
	6	64	1	157	68	305	**0.06**
SC5	1	54	20	142	88	294	0.25
	2	64	20	138	92	335	0.46
	3	49	18	94	54	238	0.1
	4	49	18	94	54	238	0.1
	5	49	18	94	54	238	0.1
	6	49	18	94	54	238	0.1
	7	50	13	114	47	259	0.08
	A	**50–100**	**30–60**	**100–200**	**50–100**	**–**	–
	B	**100**	**100**	**300**	**150**	**–**	–
	C	**3**	**1**	**3**	**2**	**2**	**0.01**

of pollution of the substratum, the groundwater and the Sebkha Sijoumi.

Based on the results of this work, the pollutants migrate beyond 2 m of depth under the mass of waste. Whereas the peripheral zones of the site present clay levels, rich on smectitic minerals, accumulating heavy metals and organic matter.

Substratum properties constitute a passive protection against the migration of the pollutants [17,27,31,36,38]. However, the high level of groundwater enhanced the direct infiltration of leachate, causing the contamination of the water table by various heavy metals and organic compounds.

To prevent further pollution we recommend rehabilitation of Henchir El Yahoudia site. Works of rehabilitation must be preceded by setting up a collection drain of leachate and an insulated extraction network routing the biogas from loss mass toward a treatment unit. The setting up of an impervious peripheral barrier, reaching the geological substrate, would be indispensable to prevent the lateral transfers of pollutants. Last, the final recovery must include an impervious protective layer in order to limit the pluvial water infiltration and an agricultural earth layer with an optimal thickness encouraging the growth of plants. In this, we integrate the site into its environment [1,37].

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