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Landfill Leachate Generation and Its Impact on Water at an Urban Landfill (Jebel Chakir, Tunisia)

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Abstract

The current research examined the level of surface and groundwater contamination near a municipal solid waste landfill site in Tunis City. The site of Jebel Chakir is the largest and the first controlled in Tunisia, in operation since May 1999. It receives 1800 tons/day of municipal solid waste incoming from great Tunis. Water quality parameters (physico-chemical and heavy metals) of leachate, surface and groundwater samples were analyzed. The mean concentrations of all measured parameters except Salinity, Na_2SO_4 and Mg in groundwater conform to the stipulated World Health Organization potable water standards and the Tunisian Standard for Drinking Water Quality. The current results show insignificant impact of the landfill operations on surface and the groundwater resource. The existing soil stratigraphy at the landfill site consisting of clay intercalated with clay gypsum or chalky is deduced to have significantly influenced natural attenuation of leachate into the groundwater resource. The research recommends an upgrade of the solous landfill to a standard that would guarantee adequate protection of both the surface and the groundwater resources in the locality.

Keywords: Landfill; Leachate; Pollution; Groundwater; Drinking water quality

Introduction

Although landfill leachates have been proved to be toxic and recalcitrant, landfilling still remains one of the main methods for municipal and industrial solid waste disposal [1]. Leachate is generated as a consequence of rainwater percolation through wastes, chemical biological processes in waste and the inherent water content of wastes themselves [2-4]. Furthermore, landfill leachate generation remains continuous when water comes in contact with the solid waste. The discharge of landfill leachate can lead to serious environmental problems, since leachate contains four groups of contaminants: dissolved organic matters; inorganic compounds such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals such as cadmium, chromium, copper, lead, zinc, nickel; and xenophobic organic substances [5]. Contaminants carried in leachate are dependent on solid waste composition and on the simultaneously occurring physical, chemical and biological activities within the landfill [6]. Thus, heavy metals present in leachate can migrate away from the disposal site boundaries and may constitute a serious pollution threat for the water table and the soil around the landfill [7-9]. The impact of landfill leachate on the surface and groundwater has given rise to a number of studies in recent years [4,8,10].

In order to limit and control environmental impact of solid waste, the Tunisian government closed and rehabilitated uncontrolled dumpsites and constructed sanitary landfills similar to the landfill of Jebel Chakir which was the first to be built and also received the domestic waste of Tunis City since May 1999. Leachate generated by the site is kept in 13 storage basins. The leachate storage basins were not lined for prevention of leachate percolation to ground water and soil.

This paper studies the possibility of vertical and lateral percolation of the pollutants by evaluating the impacts on the water of neighbouring sites. Some remedial measures are also suggested to reduce further contamination of water via leachate percolation.

Materials and Methods

Site description

The Jebel Chakir is a 31.32 ha landfill site landfill located. The active landfill is situated at about 10 Km southwest of Tunis city and receives the municipal solid wastes produced by the private sector and the four governorates of Tunis, Ariana, Ben Arous and Manouba (Figure 1). It receives on a daily basis, 1800 tons of MSW of which 65% are organic matter [11]. The high moisture values in MSW contribute to the production of large quantity of leachate.

The soil stratigraphy of Jebel Chakir landfill consists of clay intercalated with clay gypsum or chalky. This lithology is capable of protecting the underlying confined aquifer from leachate contamination. This assertion could not be true of the water table aquifer which has high contamination risk potential [12].

The climate in Tunis City is typically Mediterranean, characterized by dry and warm summers (from June to August), and cool, wet winters (from December to February). The average annual precipitation varies across the Tunis City and much of the precipitation falls in late autumn and early winter where the month of November has the highest precipitation while August has the lowest. The annual precipitation in the city of Tunis is 480 mm. The annual average temperature is 19°C (minimum in January with 12°C and maximum in August with 27°C), and the average evaporation rate is 129 mm/month. The annual

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predominant wind direction is northward. The annual average wind speed (WS) is 5 m/s.

Leachate generation

The leachate collection system for the three cells is designed of independent hydraulic systems. The landfill liner system is composed of HDPE geomembrane placed over natural geological foundation. The leachate collection system is composed of a drainage layer of gravel and leachate collection pipes system.

Leachate generation rate for Jebel Chakir landfill has been periodically measured since May 1999. Figure 2 depicted the leachate measured for the period from 1999 to 2007.

For the three cells, the leachate generation is very high in summer period (from June to August). During this period the average of leachate generation is about 80 m^3/day, 100 m^3/day and 130 m^3/day, respectively for cell 1, cell 2 and cell 3. This large amount is caused by the large fraction of organic matter and the initial moisture content of waste (water content: 80% in summer).

The leachate is collected with high density polyethylene pipes (diameter 160 mm) and stocked in 13 storage basins of total capacity 130,000 m^3 without any treatment (Figure 1). These stocked leachates constitute a real threat to the fauna and flora in surrounding [13]. Tunisian regulations would not allow direct discharge of the leachates neither into a water body nor into the sewer system.

Samples and analysis

In an effort to investigate the extent of surface and groundwater contamination, three sampling points designated S1 to S3 were selected between 100 and 1000 m down-gradient of the landfill site while the leachate sample was designated L. Leachate samples were collected from 1m depth at the storage basins (Figure 1). Groundwater sample (S1) was collected from well in the vicinity of the landfill (the single well around the landfill of Jebel Chakir) while surface water (S2 and S3) samples were collected from Oued El Jazzar (Figure 3). Field sampling was done only at the end of the wet season (December, 2006), due to the high precipitation during this month.

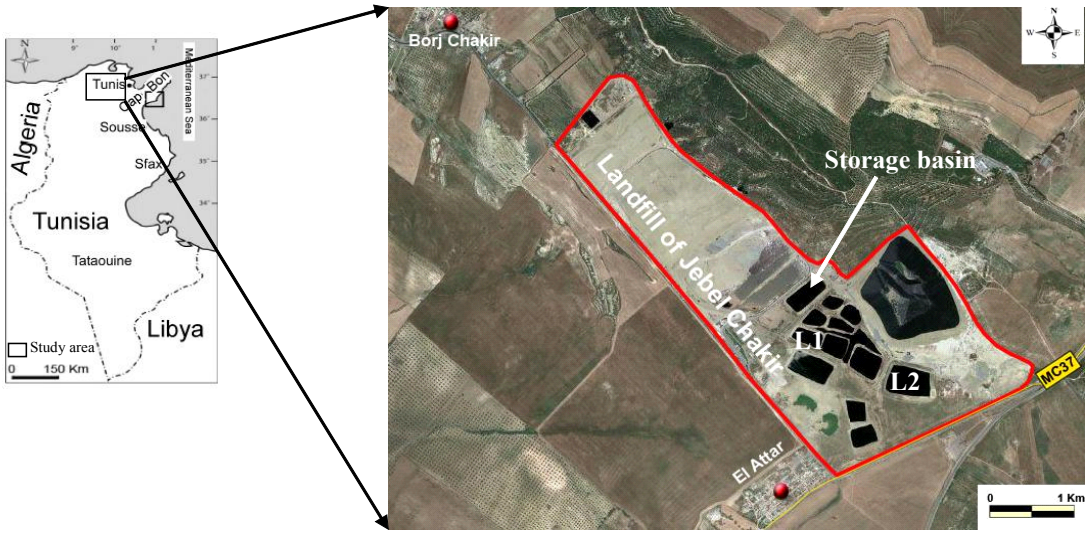

Figure 1: Landfill Jebel Chakir map with 13 basins of leachate storage (Google earth, 2011).

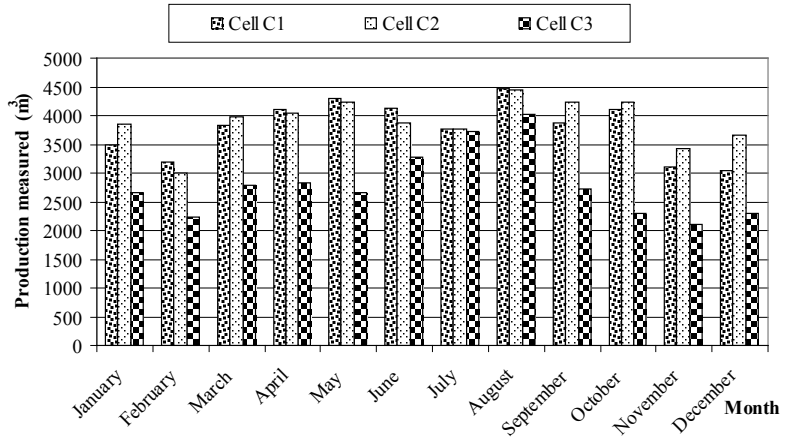

Figure 2: Leachate generation in the three cells at the landfill of Jebel Chakir (1999-2007).

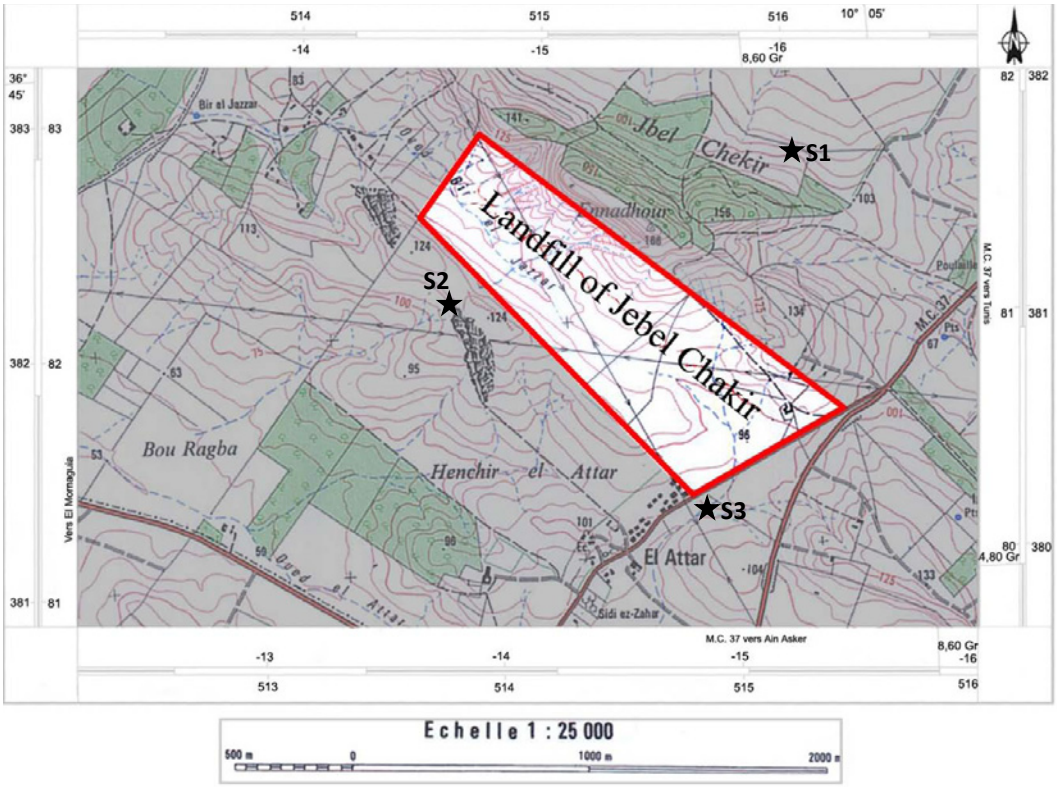

Figure 3: Map of Jebel Chakir landfill and position of the water sampling sites.

Details of the sampling points are presented in Table 1.

Water samples were collected in 1litre plastic containers and prior to collection as part of our quality control measures all the bottles were washed with non-ionic detergent and rinsed with de-ionized water prior to usage. Before the final water sampling was done, the bottles were rinsed three times with well water at the point of collection. Each bottle was labelled according to sampling location while all the samples were preserved at 4°C in the laboratory until used.

The electrical conductivity (EC), the salinity and pH were measured in situ by using a multi-parameter conductimeter (WTW Windaus LF 538) and a pH meter (WTW Windaus pH 538 with combine electrode).

The concentration in sodium (Na), chloride (Cl), sulfate (SO_4) and magnesium (Mg) were determined by NFT 90-003 AFNOR methods (1999) [14]. COD was measured following the MA-315 COD-1.0 [15].

The biochemical oxygen demand (BOD_5) was measured by using a BOD meter. The total nitrogen was determined using (NT) titremetric method EN 25663. The heavy metals (Fe, Cr, Zn, Cu, Cd, Ni, Pb, and Mn) were estimated by digestion in HF-NO_3-$HCLO_4$, and the concentrations of these elements in digestion solution were determined using an Atomic Absorption Spectrometer Perkin-Elmer Analyst 200.

Results and Discussions

Qualitative characterisation of leachate

The data in Table 2 summarises the analyses of leachate used in this work. It is alkaline mixture of dark colour.

The eclectic conductivity of leachate ranges from 36.5 to 42.8 ms/cm, which is higher than the domestic waste water and twice higher than the ones typically reported in literature [16]. This parameter shows the high minerals contents.

BOD consists of biologically degradable dissolved organics in the leachate. COD is a measure of chemically oxizdable components in leachate and reflects the amount of O_2 that is required by the bacteria to metabolize the existing organic substrate as well as the O_2 required by other oxidizable chemical compounds.

The COD and the BOD_5 values of two samples are much higher than the Tunisian regulation values for discharge in public sewer.

The leachate originating from the Jebel Chakir landfill has very high organic matter content (COD) is 21480 mg O_2/l on average while its BOD_5 is weak (5490 mg O_2/l on average). The ratio BOD_5 to COD indicates the degree of biodegradability of the leachate and provides indications regarding the age of a landfill and about biochemical alterations within the landfill [4]. It was 0.25 for the two samples, corresponding to the intermediate stage of leachate evolution. This reveals that the leachates are in the reactional step of anaerobic degradation.

The average concentrations of heavy metals: Cr, Zn, Cu, Cd, Pb, Ni and Mn are well below the Tunisian regulations for discharge in a

Sample	Sample Location	Depth to water level in wells
L1	Storage basin B5 (1m depth)	-
L2	Storage basin B8 (1m depth)	-
S1	1000 m from landfill	33.0
S2	150 m from landfill	-
S3	100 m from landfill	-

Table 1: Sampling Location.

Parameters	L1	L2	Mean (L1 & L2)	NT 106 002**
pH	8.25	8.15	8.20	6.5-9
Electric conductivity (ms/cm)	42.80	36.50	39.65	NA
COD (mg O_2/l)	20500	22460	21480	1000
BOD5 (mg O_2/l)	5780	5200	5490	400
BOD5/COD	0.28	0.23	0.25	0.4
Fe (mg/l)	20500	22460	21480	5
Cr (mg/l)	1.22	1.12	1.17	0.5
Zn (mg/l)	0.72	0.77	0.745	5
Cu (mg/l)	0.81	0.78	0.795	1
Cd (mg/l)	0.042	0.047	0.044	0.1
Ni (mg/l)	0.22	0.25	0.23	2
Pb (mg/l)	0.4	0.3	0.35	1
Mn (mg/l)	0.048	0.051	0.046	1

** Norm for the wastewater drained to public sewer, Tunisia
NA: Not available

Table 2: Physical and biochemical of Jebel Chakir leachate landfill site.

Chemical parameters	Samples			Tunisian Standard (NT 106 002) **	WHO standards [19]
	Groundwater sample	Rivers of Oued Bir El Jazzar			
	(S1)	(S2)	(S3)		
pH	7,9	7,6	7,8	6.5 < pH < 8.5	6.5-9.2
BOD (mg O2/l)	25	20	22	30	--
COD (mg O2/l)	80	60	65	90	--
Salinity (mg/l)	4900	1800	1900	--	1200
Na (mg/l)	949.9	190	200	300	200
Nitrogen (mg/l)	4	2	1	1	1.5
Chloride (mg/l)	1402	80	55	600	250
Mg(mg/l)	180	40	50	200	30
SO_4 (mg/l)	580	130	100	600	250
Cd (mg/l)	0.05	ND	0.005	0.005	0.01
Zn (mg/l)	0.30	0.15	0.2	5	5.0
Cu (mg/l)	0.45	0.25	0.3	0.5	1.0

** Norm for the wastewater drained to public water body, Tunisia
ND: not detected

Table 3: Chemical analysis of water samples collected around the landfill of Jebel Chakir.

public sewer. But the iron and the chromium exceed the limits set by Tunisian regulations.

The heavy metals in the leachate samples from landfill of Jebel Chakir show a typical composition compared to urban landfill leachates reported by Christensen et al. [17]. The relatively low concentration of analyzed heavy metals and the high BOD, COD and nitrogen concentration confirm the high organics content of the waste deposited in the landfill of Jebel Chakir [9].

As compared to leachates to European norm from controlled landfills, the effluents of Jebel Chakir landfill appear much less loaded in mineral pollutants but more in organic materials [18].

Evaluation of the pollution potential caused by the landfill leachate

In order to detect any potential pollution from the landfill to the surroundings, samples of surface and ground water from wells were collected and were analysed to the same parameters as in leachate samples (Figure 3).

The results of chemical analyses conducted on these water samples are presented in Table 3.

The results of pH measurement indicate neutral waters at the three samples. A low salinity is observed in the samples collected from the rivers of Oued El Jazzar: 1.85 g/l. A low concentration of chloride, sulphate, and magnesium is denoted in the samples S2 and S3.

A high salinity of 4.9 g/l is found in the groundwater samples. Salinity in surface and groundwater are not within the standard acceptable levels for drinking water by WHO [19].

This elevated value is probably caused by the salt in the Pliocene-Quaternary clay-sandy deposits and high evaporation in this zone [20]. Chloride, sulphate, and magnesium concentrations are high in the groundwater samples, which confirmed that the groundwater water is not drinkable.

The analytical results of chemical parameters for three water samples indicate the water quality satisfy the Tunisian regulation (NT 106 002). In addition, the heavy metals in the three water samples present a low value. It is clear that water analysed in the vicinity area of Jebel Chakir landfill are not affected by leachate percolation.

The lateral and vertical migration of pollutants is probably limited within the landfill of Jebel Chakir. Thus, clayey layers at the base of storage basin are acting as barrier against the lateral and vertical migration of pollutants towards the surrounding environment of the landfill. However, this aspect needs further investigations by drillings

wells of varying distance and depth for assessing potential pollution of water in time.

Conclusion

Landfill from the sanitary landfill of Jebel Chakir is most likely in methanogenic phase in which pH was 8.20. The BOD5/COD ratio (0.25) indicates that the two different leachates are old and stable. Most of parameters in Jebel Chakir landfill leachate exceed the permissible required for treated wastewater discharge determined by local standard. The concentrations of heavy metals in Jebel Chakir are above the standard acceptable levels of treated wastewater discharge determined by the local standard.

The results obtained in this study shows that the leachate generated from the landfill site has a minimal impact on the surface and groundwater quality in the locality. The soil stratigraphy of the site, being predominantly clay intercalated with clay gypsum or chalky, seems to have significantly influenced the low levels or absence of contaminants especially heavy metals in the groundwater samples.

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