JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2022, 23(11), 89–94
https://doi.org/10.12911/22998993/153006
ISSN 2299–8993, License CC-BY 4.0

Received: 2022.07.26
Accepted: 2022.09.14
Published: 2022.10.01

Impact of Landfill Leachate on Groundwater Quality – A Comparison Between Three Different Landfills in Morocco

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ABSTRAT

In this work, physicochemical and bacteriological analyses of leachate collected from three different landfills in the Marrakech region in Morocco were carried out. The results showed that the leachate is highly loaded with organic matter, chemical and bacteriological elements and some heavy metals, this load depends of the nature of landfill (rural or urban) and also of its age (young or old), the values of the parameters exceed the limit values for discharge into the natural medium. Physicochemical and bacteriological analyses of groundwater from wells downstream of these landfills were also carried out; The results showed that they had medium to poor quality according to the type of landfill. This is due to the presence of organic matter, total coliforms, total phosphorus and total nitrogen in many studied wells.

Keywords: landfill; leachate; pollution; groundwater.

INTRODUCTION

In Morocco, water resources are in danger because of discharges from industrial activities [Smahi et al. 2013; Benaddi et al. 2022a]. These discharges are loaded with organic matter, heavy metals, and phenolic compounds [Dregulo and Bobylev 2021; Benaddi et al. 2021; Benaddi et al 2022b]. Among these discharges, the olive mill wastewater, effluents from tanneries or landfill leachates, can be mentioned [Hamidi et al. 2013; Benaddi et al. 2020], the latter of which is considered the most highly loaded with toxic elements, Waste that is not collected properly ends up in nature and constitutes visual and olfactory pollution. When it decomposes, its components (plastic particles, certain molecules, etc.) are released and pollute the environment. These components persist for long periods in nature, for example plastic persists from 500 years to 1000 depending on its type [Chamas et al. 2020]. Landfills are considered the last option in the waste hierarchy; they can contaminate soil and water [El kharmouz et al. 2013]. Water pollution is considered one of the most dangerous effects of landfills, especially in semi-arid countries such as Morocco, where water is becoming increasingly scarce and therefore the preservation of water resources against pollution becomes necessary.

Numerous physico-chemical and biological reactions occur both between the waste and the environment in which it is located (rock, soil, groundwater, percolation water), but also within the waste of various origins [Kjeldsen et al. 2009]. The evolution of waste in landfills and their interactions with the external medium lead to the dispersion of polluting flows, essentially through the emergence of leachate which results from the implementation of physico-chemical and biological solution of the polluting elements in percolation waters. This water (leachate) is loaded with dissolved organics matter [Shouliang et al. 2008], Inorganic macrocomponents [11], Heavy metals [Chu et al. 2019] and Xenobiotic organic compounds [Shouliang et al. 2008]. The infiltration of these pollutants into groundwater or their flow to the stream can lead to degradation of groundwater [Vaverková et al. 2019; Podlaseket al. 2021]. For this reason, several studies have also been conducted in the sense of finding an adequate treatment of leachate [Djeffal et al. 2019]. At the level of Marrakech region in Morocco, the inhabitants of the region produce on average, 0.6 kg/inhabitant per day. This household waste, mixed with industrial and hospital waste is dumped in many landfills in the region. The leachates from landfill, containing bacteriological, organic and mineral pollutants, stagnate inside the landfill or leave the discharge under rainy conditions; they can subsequently infiltrate through the subsoil and lead to degradation of groundwater. The objective of this work was to carry out a comparative study concerning the characterization of leachate issue from three landfills in the Marrakech region and study also the impact of these landfills on groundwater quality in this region. In this context, certain elements were used as an indicator of organic, inorganic and bacteriological pollution in leachate and groundwater adjacent to the landfill.

MATERIALS AND METHODS

The studied leachates were collected from three different landfills: the first is a controlled landfill existing in the commune of Ouled Dlim (L1) consists in receiving all the waste of the urban city of Marrakech, the second is an abandoned landfill in the commune of Harbil (L2) received the waste of the urban city of Marrakech during the previous 50 years and the third is a wild landfill in the commune of Sidi Ezzouine receiving all the waste of the rural commune of sidi Ezzouine (L3). The characteristics of these landfills are summarised in Table 1. The water analysed was collected from the wells downstream of the landfills studied. To avoid the degradation of samples, they were kept it in a dark place at a temperature of 4°C until analysed.

Temperature, pH, Turbidity, Electrical conductivity, and dissolved oxygen were measured using a multi parameter probe model HI 9829 (HANNA, Woonsocket, RI, USA). Total suspended solids (TSS) were determined after filtering a sample through a Millipore filter (0.45 μm) and drying the retained residue at 105°C for 120 min (AFNOR-T90-105) [AFNOR, 1997] ; COD was determined by a digestion followed by colorimetric dichromate method (AFNOR-T90-101) [AFNOR, 1997]; The biological oxygen demand (BOD5) is determined according to the respirometric method T90-103 of AFNOR (1983). Total phosphorus (TP) was performed by molybdate and ascorbic acid method after potassium peroxodisulfate digestion (AFNOR-T90-023) [AFNOR, 1997]; PO43– was performed by molybdate and ascorbic acid method (AFNOR-T90-022); Total Kjeldahl nitrogen (TKN) is determined by the T90-110 method of AFNOR (1983). NH4+ was determined by indophenol method (AFNOR-T90-015) [AFNOR, 1997]; Total coliform (TC) and fecal coliforms (FC) count was performed according to the AFNOR Standard NF EN ISO 9308-1 [AFNOR, 1997] in TTC Tergitol medium. The dishes were incubated at 37°C for TC and 44.5°C for FC for a period of 24 h and then the number of forming colony units was calculated. The analysis of heavy metals in the leachate and well water was carried out using an ICP-AES spectrometer (ULTIMA).

RESULTS AND DISCUSSION

Organic matter

The leachates from three landfills, the characteristics of which were defined previously in Table 1, were analyzed. The results obtained are

Table 1. Characteristics of studied landfills

Province	Commune	Landfill	Area (Ha)	Quantity of waste (tonnes/day)	Volume of leachate (m^3/day)	Year of landfill start-up
Marrakech	Municipality Ouled Dlim	Controlled landfill (L_1)	182	1000	1250	2016
Marrakech	Municipality of Harbil	Abandoned wild landfill (L_2)	8	Currently does not receive waste it is abandoned	Its quantification is difficult since it infiltrates directly into the water table	1966–2016
Marrakech	Municipality of Sidi Ezzouine	Wild landfill (L_3)	20	15	20	2010

summarized in Table 2. Analysis of these results shows that the leachate of the controlled landfill (L1) and the Landfill in Sidi Ezzouine (L3) are acidic with a pH of 6.3, but the pH of the abandoned landfill (L2) is basic (pH equal 8), which is due to the fact that L1 and L3 are young landfills against L2 which is an old landfill and the leachates generated during the initial period of landfill operation are characterized by acidic pH due to the presence of carboxylic acids and bicarbonate ions. With age, the pH of leachates changes from acidic to alkaline. It is usually in the range of 8–8.5 pH, which is associated with the formation of alkaline compounds [Słomczyńska and Słomczyński 2004; Wdowczyk and Szymanska-Pulikowska 2021].

Electrical conductivity of leachate issues from the three landfills is around 20000 µs/cm, this value exceeds the limit value of discharge of leachate in natural medium and it is greater compared to what found by other authors [Przydatek and Kanownik 2021]. The concentrations of COD, BOD5, MES of the leachate of the three landfills are important and exceed the general limit values of discharge into natural medium, the important value have been recorded at L1 landfill due to the fact that Marrakech is an urban city characterized by a wide variety of industrial and household waste. On the other hand, the low value of organic matter have been recorded at L2 landifill due to the biodegradability of organic matter over time of exploitation [Aoun and Bouaoun 2006], the value recorded at L3 is not important since Sidi Ezzouinne is a rural city so the waste does not contain much organic matter, given the way of life of citizens in the rural world. The value of oils and fats obtained at L1 is 2068.5 mg/l, which is higher than that of general discharge limits into natural medium (30 mg/l), this is due to the wide variety of industrial and household wastes as mentioned previously, the value of oil and grease at L2 and L3 are low and do not exceed 60 mg/L. The high turbidity value at L1 is due to the presence of colloidal matter and suspended solids with large concentrations, which prevents the penetration of light into the basins of collected of leachate which explains the low concentrations of dissolved oxygen recorded at L1 that inhibits the development of microorganisms in the environment and makes the biodegradability of the leachate very difficult.

To study the impact of landfill discharge without any treatment on the quality of groundwater downstream of the studied landfills, the water collected from wells downstream of these landfills was analysed as well. The results showed that the well located downstream of the landfill Oulad Dlim (WL2) has a very poor quality, due to the low value of dissolved oxygen and the significant increase in conductivity, turbidity and high value of organic matter, same problem is recorded at the level of the well located downstream of the landfill Sidi Ezzouinne (WL3) with a lower degree of pollution compared to WL2, which shows that landfills have impacted the quality of groundwater in a significant way, in the case of the well located downstream of L1, the quality of the water is medium in terms of conductivity, dissolved oxygen and oil and grease but it is bad in terms of organic matter (Table 3); Therefore the use of the basins for the collection of leachate partially protects the water resources in this area but also due to that L1 is an young landfill and the pollution of groundwater depending of the age of landfill as mentioned by many authors [Przydatek and Kanownik 2021].

Chemical and bacteriogical parametrs

Chemical analysis of the leachate studied showed that the values of total nitrogen Kjeldahl (TNK) and total phosphorus (TP) are very important and exceed the limit values for release into the natural medium which are 40 mg/L and 15 mg/L, respectively (Table 4). Other authors in their works also emphasized that ammonium

Table 2. Analyses of leachates issues from different landfills in the Marrakech region

Province	Commune	Landfill	T°	pH	Electrical conductivity (us/cm)	Turbidity	Dissolved O_2 (mg/L)	Suspended material (mg/l)	COD (mg/l)	BOD (mg/l)	Oil and grease (mg/l)
Marrakech	Ouled Dlim	Controlled landfill	25.00	6.30	19964.00	10108.00	0.17	6030.67	25160.06	3973,33	2068,50
Marrakech	Harbil	Abandoned wild landfill	35.90	7.90	20040.33	3967.67	0.67	3660.67	1398.55	99,33	62,20
Marrakech	Sidi Ezzouine	Wild landfill	26.20	6.50	19833.33	763.33	1.50	1772.00	3492.91	455,67	64,38
Limit values for discharge into the natural medium			30,00	5.5–9.5	2700.00	.	.	100	500.00	100.00	30.00

Table 3. Analyses of water collected from adjacent wells to the studied landfills

Province	Commune	Well	T°	pH	Electrical conductivity (us/cm)	Turbidity	Dissolved O_2 (mg/L)	Suspended material (mg/l)	COD (mg/l)	BOD (mg/l)	OM (mg/L)	Oil and grease (mg/l)
Marrakech	Ouled Dlim	(WL_1)	25.10	8.73	2113.00	4.85	4.00	23.30	30.00	3.30	12	<0.5
Marrakech	Harbil	(WL_2)	27.80	8.03	9125.33	13.10	1.93	82.67	138.77	41.67	74	10.80
Marrakech	Sidi Ezzouine	(WL_3)	23.70	7.43	4136.00	28.50	5.66	41.33	46.91	2.17	17.1	7.60

Table 4. Chemical and bacteriological analysis of studied leachates

Province	Commune	Landfill	T°	pH	NH^{4+} (mg/l)	TNK (mg/l)	PO_4^{3-} (mg/l)	TP (mg/l)	FC (UFC/100 ml) $*10^{-4}$	TC (UFC/100 ml) $*10^{-4}$
Marrakech	Oulad Dlim	Controlled landfill	25.00	7.20	1962.68	2595.04	22.86	1023.21	11.70	613.34
Marrakech	Harbil	Abandoned wild landfill	35.90	7.90	288.43	597.89	2.56	108.87	3.57	586.67
Marrakech	Sidi Ezzouine	Wild landfill	26.20	6.17	474.09	788.85	10.83	106.85	54.34	322.34
Limit values for discharge into the natural medium			30.00	5.5-9.5	.	40	.	15	.	.

nitrogen belongs to the main pollutants occurring in landfill leachates [Tatsi and Zouboulis 2002; Kjeldsen et al. 2009]. On the other hand, the values of TNK and TP are very important in the case of L1 compared to L2 and L3, in fact, L3 is a rural landfill characterized by the reception of inert waste due to the way of life of citizens in the rural world and L2 is abandoned landfill, therefore, chemical elements have undergone natural treatments during the years of closure [Przydatek and Kanownik 2021]. Such high concentration value of untreated ammonia leads to stimulated algal growth, decreased performance of biological treatment systems, accelerated eutrophication, promoted dissolved oxygen depletion, and increased toxicity of living organisms in water bodies [Jokela et al. 2002; Aziz et al. 2004; Qarani et al. 2010] mentioned that ammonia removal has become an important concern in leachate, since its level continues to be dangerous and poisonous over long periods. The value of faecal coliforms varies from 3 to 50 * 104 FC (CFU/100 ml) depending on the type of discharge. In fact, fecal coliforms are very important in L3. This can be explained by the fact that faecal coliforms are considered a more accurate indication of animal or human waste than total coliforms and since L3 is a rural landfill, which explains the value of fecal coliforms in this landfill. On the other hand, the value of total coliforms varies from 300 to 600 *104 CFU/100 ml, depending on the type of discharge. In fact, total coliforms are important in L1, which justified the BOD5 and dissolved oxygen values found previously; indeed, the high bacterial load requires more oxygen to degrade the organic matter [Maqbool et al. 2011].

The characterization of the water of the wells located downstream of the three landfills has shown that the quality of WL1 is good chemically and bacteriologically this is due to the fact that the discharge is young and controlled, so the use of watertight basins for the collection of leachate has protected the water resources against chemical pollution currently, but it is always necessary to ensure the tightness of the basins. On the other hand, the water quality of LW2 is very bad chemically and bacteriologically (Table 5); therefore, the exploitation of this landfill for several years has led to the pollution of water resources in this area, the quality of LW3 is good chemically and bacteriologically except that the value of phosphorus made the quality of thus water poor. However, this is not due to the landfill; perhaps, it may be related to the geology of the area or the massive use of fertilizers in this area since it is a rural area.

Heavy metals

Monitoring of metal pollution reveals the existence of a relatively large arsenic load in the three landfills, which is higher than the limit value for discharge into natural environment, other elements also have significant levels but remains slightly below the Moroccan standard for general

Table 5. Chemical and bacteriological analyses of water collected from adjacent wells to the studied landfills

Province	Commune	Well	T°	pH	NH^{4+} (mg/l)	TNK (mg/l)	PO_4^{3-} (mg/l)	TP (mg/l)	FC (UFC/100 ml)	TC (UFC/100 ml)
Marrakech	Oulad Dlim	(WL_1)	25.10	8.73	0.10	4.01	0.06	0.30	79.67	261.67
Marrakech	Harbil	(WL_2)	27.80	8.03	7.00	43.17	0.70	0.68	3370.00	9236.67
Marrakech	Sidi Ezzouine	(WL_3)	23.70	7.43	0.11	2.43	0.71	0.73	82.67	193.33

Table 6. Analyses of heavy metals of studied leachates

Province	Commune	Landfill	T°	pH	As (ppm)	Pb (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	Hg (ppm)	Ni (ppm)
Marrakech	Oulad Dlim	Controlled landfill (L_1)	25	7.2	0.171	<0.05	0.008	0.49	0.428	<0.01	<1	1,09
Marrakech	Harbil	Abandoned wild landfill(L_2)	35.90	7.90	0.35	0.12	0.01	0.06	2.25	0.38	<1	0,40
Marrakech	Sidi Ezzouine	Wild landfill (L_3)	26.2	6.2	0.728	<0.05	0.002	<0.01	0.037	0.11	<1	<0,01
Limit values for discharge into the natural medium			30.00	5.5-9.5	0.1	1	0.25	0.5	2	2	0.05	5

limit values for discharge into natural medium. However, the value of chromium in the L2 exceeds the discharge limit value due to the fact that L2 received previously waste from the industrial tannery units before its closure. Analysis of the water from the wells downstream of the three landfills showed good quality of all the wells in terms of heavy metals (Table 6), the absence of these metallic species in groundwater is explained by their adsorption by particulate and organic constituents of leachate and subsoil [El kharmouz et al. 2013], Indeed, Pitt et al. showed that at a pH close to 7 (pH of the leachate of the discharge), copper, reduces to Cu2+, which is the main form of copper complexed with organic matter [Pitt et al. 1994]. Musy et al. showed that Pb has a very high affinity for suspended solids, and up to 99% of the Pb can be fixed to it [Musy and Soutter 1991].

CONCLUSIONS

At the end of this work relating to the chemical and bacteriological characterization of landfill leachate in the Marrakech region in Morocco, it can be concluded that these are effluents with acidic pH, representing a high content of organic matter, suspended matter, chemical and bacteriological elements. These levels exceed the limit values for discharges of industrial waste water in natural medium. As a result, it was found that the direct discharge of landfill leachate into natural medium without any treatment led to pollution of well water downstream of the studied landfills.

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