Study of Oum-Azza Landfill Leachates and Their Pollution of the Bouregreg River, Rabat - Morocco

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ABSTRACT

In Moroccan cities, the problem of solid household waste has arisen with great sharpness in recent two decades. In particular, the management of leachates and the neutralization of their environmental impacts. The need for Morocco to meet the environmental challenge and put itself in a logic of sustainable development has led to an awareness of this issue and the promulgation of the new law 28-00 on waste management and their elimination.

The objective of the present study is the characterization of the organic and mineral load of leachate from the Oum Azza landfill and the evaluation of its environmental impacts on the basin of Bouregreg river of Rabat. For this a campaign of 24 samples was undertaken in 2011 and completed in 2014-2017.

The physicochemical characterization of leachates has revealed that these liquid discharges are:

- *very high in organic matter with mean MES = 470mg / L; Average BOD_5 = 5522 mg of O_2 / L and COD = 12626 mg / L;*
- *very charged in mineral matter expressed in terms of electrical Conductivity (mean = 33969 µs / cm);*
- *have an average temperature of 24.5 °C and a pH of 8;*
- *a chloride concentration of 4289 mg / L;*
- *average sodium levels in the order of 3049 mg / L;*
- *average total nitrogen levels of 4090 mg / L and ammonia in the order of 3207 mg / L;*
- *average level of phosphates of the order of 35 mg / L;*
- *average sulphates levels of 35 mg / L.*

The Rabat landfill represents a real nuisance for health and the environment because of the toxic characteristics of pollutants and bad odors. It is therefore essential to treat these liquid discharges and install a WWTP to mitigate the environmental impact of leachate.

Key words: Oum Azza discharge, leachates, physicochemistry, Pollution, River, Rabat, Morocco.

1.INTRODUCTION

In Morocco, like all the countries of the world, socio-economic activities coupled with population growth and changes in consumption patterns generate a large production of household solid waste [1].

In the face of demographic, industrial, urbanistic and tourist development, the problem of waste has arisen with great acuteness. The amount of household waste produced poses a serious threat to the environment as the current conditions for the collection, transport, disposal, recycling or destruction of such waste are inadequate [2].

The dump of Oum Azza is located a few kilometers east of the city of Rabat, on the right bank of the A5 motorway from Rabat to Casablanca and Kenitra. Initially it was a wild dump located near the urban perimeter of El Menzeh center and Ouled Mbarek Commune. The proximity to the main wind direction facilitates the spread of smoke, odors and plastic bags to nearby cities.

Like other Moroccan cities, Rabat faces an exponential increase in the amount of household waste produced by its inhabitants. Unfortunately the landfilling of waste and the accumulation of leachates in large storage ponds has contributed to the birth of a new environmental problem due to their pollutant loads and the nauseating odors that emerge [3].

The present work aims to characterize and evaluate the pollutant load of the Oum Azza de Rabat landfill by physicochemical analyzes of raw leachates collected in 2011.

2.STUDY AREA

The region of Rabat-Salé-Zemmour-Zaër, which covers an area of 18194 km^2 or 1.3% of the country is bounded (Figure 1):

• North and Northeast by the Gharb-Chrarda-Beni Hssen Region;

• In the West by the Atlantic Ocean;

• East and South-East by the Meknes-Tafilalt Region;

• South and Southwest by Chaouia-Ouardigha Region.

The population of the Rabat-Sale-Kenitra amounts to 4552585 inhabitants, or 8.07% of the total national population, of whom 3172955 in urban areas and 1379630 in rural area of the total population. Total regional population with an average density for this region of 251.8 inhabitants / km^2. The national average is 41.7 inhabitants / km^2 [4].

The landfill of Oum Azza is chosen from the large number of landfills in Morocco. It is located in Rabat-Sale. This landfill produces a leachate that is suspected of causing environmental pollution of both groundwater and surface water as well as ambient air by the propagation of very bad toxic and allergenic odors [5].

The waste comes mainly from the transfer centers of Rabat, Sale and Temara. They are therefore transported by large trucks carrying 20 to 25 tons. Municipalities close to the site and some private organizations or companies bring their waste directly to the Oum Azza site. Treated waste is garbage, refuse from composting household waste and ordinary industrial waste. Production was estimated at 500 000 tons during 2011 [6].

2.1. Rainfall

The rainfall recorded by the Rabat-Sale airport weather station in the region is shown in Table 1. The water slide in Rabat during the whole of the year is about 555 mm. There are summer months (June, July, August and September) marked by very low rainfall. In contrast, November, December, January and February are marked by heavy rains [7].

Table 1: Annual means rainfall (mm) in 25 years.

Station	Jan	Feb	Mar	April	May	Jun	Jull	Aug	Sept	Oct	Nov	Dec

Rabat	85.1	72.6	64.9	54.6	19.8	6.5	0.48	1.05	5.5	42.3	79.5	111

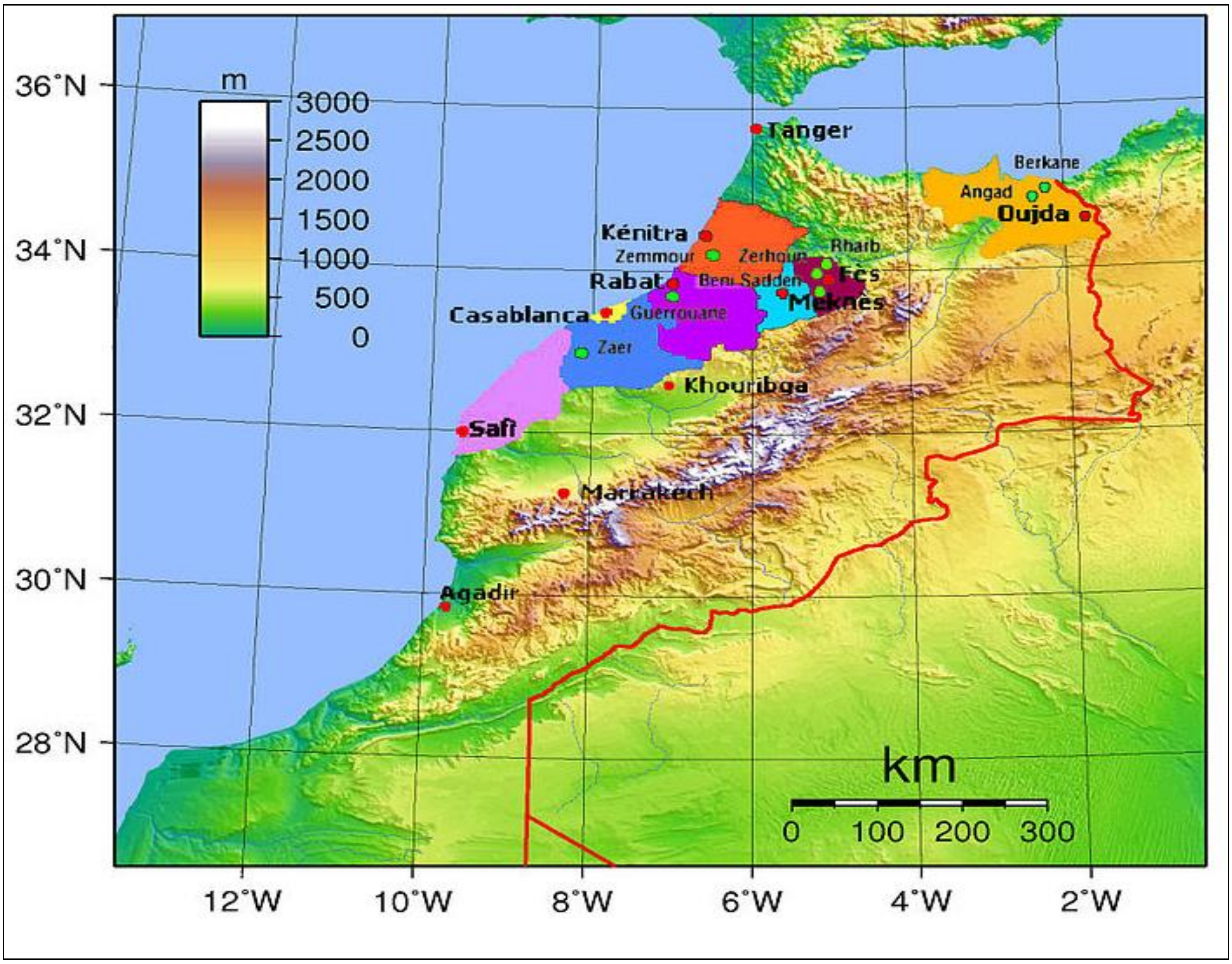

Figure 1: Location of the Rabat-Sale-Zemmour-Zaër region (MATEE 1997).

II.2. Temperature

The analysis of monthly temperatures (Table 2) indicates that the Rabat region appears to be one of the most temperate in Morocco since the annual temperature ranges between the mean maximum temperature and the average minimum temperature are about 9.5 ° C [7].

Table 2: Monthly average temperatures (T °C) in Rabat.

Jan	**Feb.**	**Mar**	**April**	**May**	**Jun**	**Jull**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
12,6	13,1	14,4	15,0	17,3	19,9	22,0	22,5	22.2	18,2	15,8	13,0

2.3. Wind

According to the wind rose provided by the Rabat weather station at Rabat-Salé airport, the prevailing winds in Rabat come from the western sector in winter, spring and autumn. They are followed closely by those from the North and South. Only the East sector winds play a relatively negligible role during the wet season. Note in the Atlantic region, the Gharbi, a westerly wind (actually from north-west to southwest) blows in any season on the western coast. Always fresh, it is also a source of moisture and precipitation. The desiccating Chergui is of little relevance to the Rabat region (Figure 2).

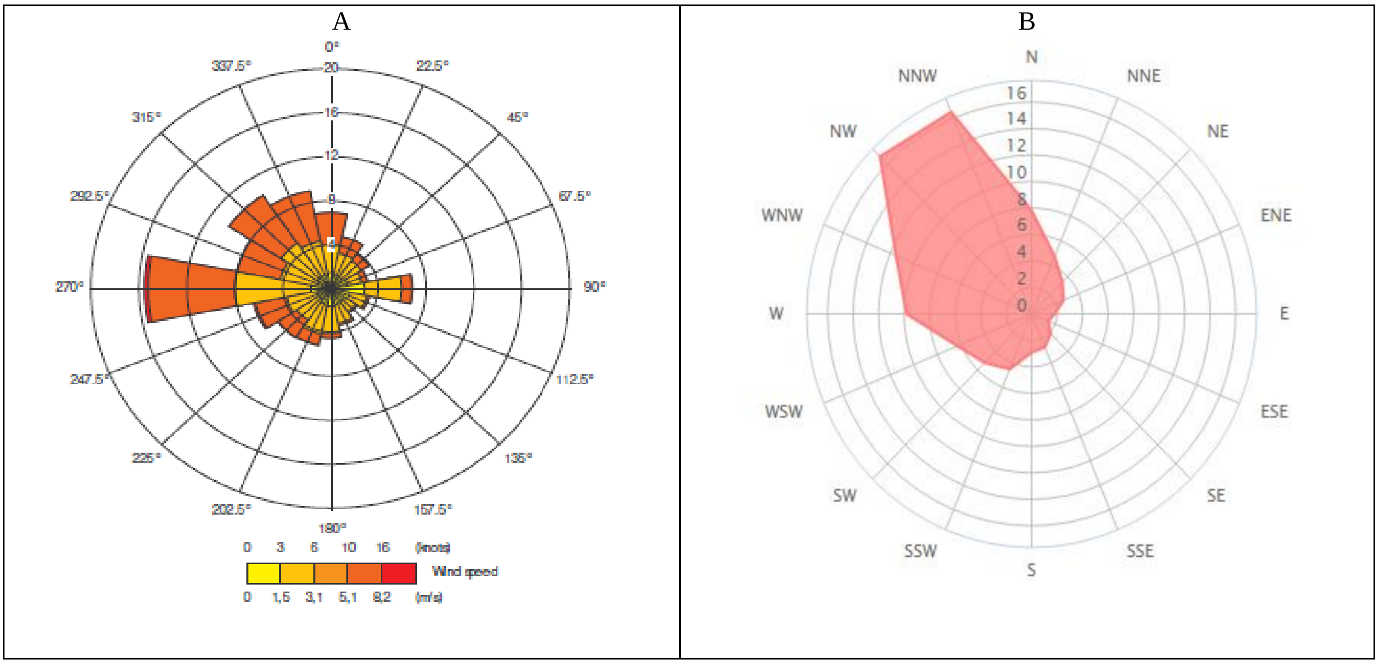

Figure 2: Wind frequency distribution (wind rose) from 1995 to 2004 (A) and 2017 (B).

2.4. Landfill of Oum Azza

The wild landfill is located in the rural commune of Oum Azza on the plateau of Aïn Aouda 20 km from Rabat. It is located between the Akrach river in the west and the reservoir of the Sidi Mohamed Ben Abdellah dam in the east, at a range between 160 and 200 NGM. Its area is about 110 Ha. The purpose of the landfill is to treat household and similar waste from the 13 urban and rural communes for a population of 572717 inhabitants with a maximum annual production of about 700,000 tons per year (Figure 3-4) [8].

Figure 3: Leachate storage pond at the Oum Azza landfill.

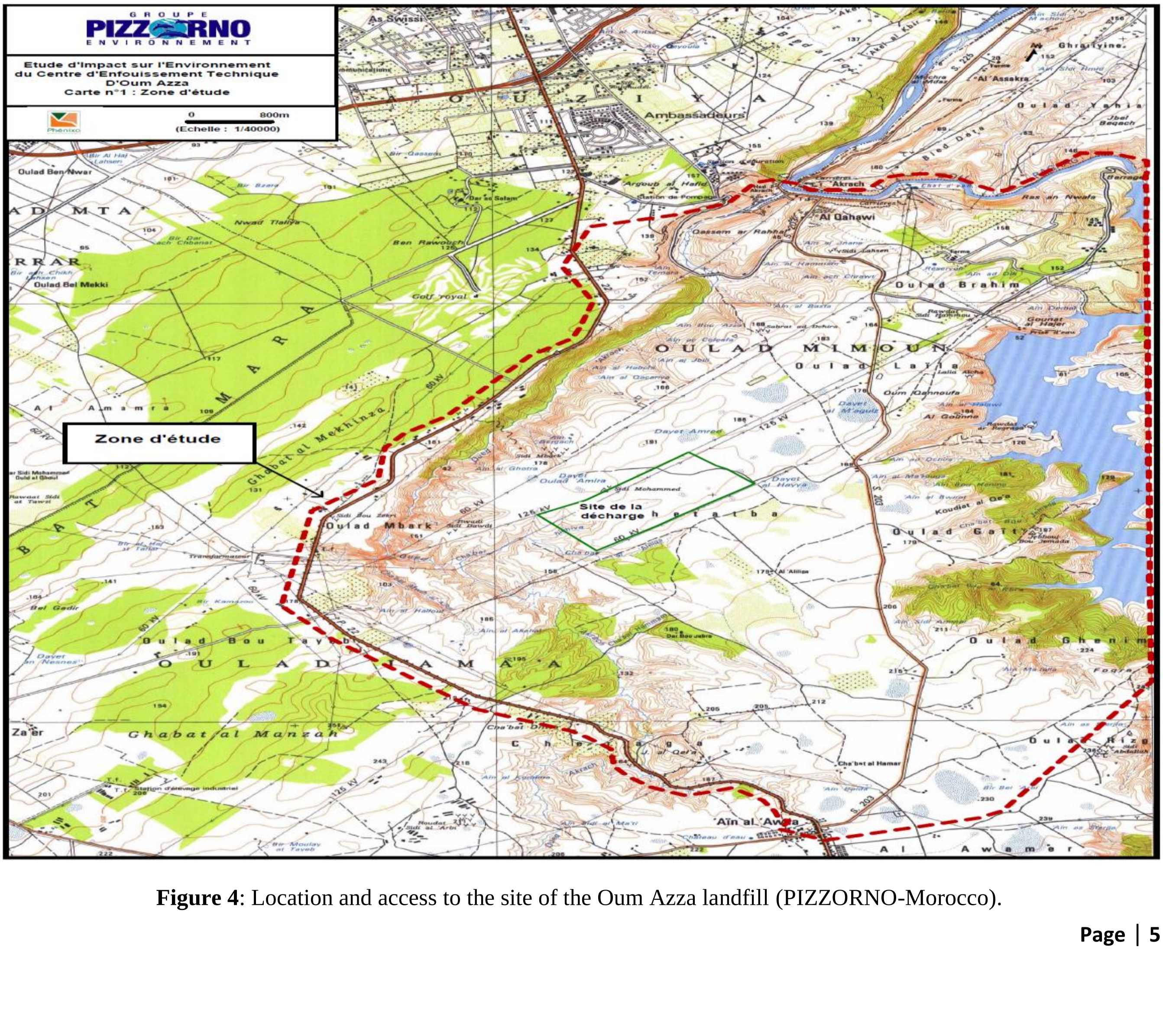

Figure 4: Location and access to the site of the Oum Azza landfill (PIZZORNO-Morocco).

3.MATERIAL AND METHODES

The physicochemical analyzes are carried out as follows [9-12]:

❖ **In the field:**

• The pH of the samples was measured using a Hanna pH meter;

• The temperature and the conductivity of the samples are determined by a conductivity meter of Cond315i / SET type, WTW82362;

❖ **Kenitra Faculty of Science Environmental Laboratory:**

• The chemical oxygen demand (COD) was determined using a DBC reactor;

• The biological oxygen demand (BOD5) consumed for 5 days was assayed using a DBOmeter;

• Suspended Materials MES were measured by filtration and assay;

• Ammonium and nitrogen were measured by the distillation method of Parnas and Wagner by a distiller;

• Sodium was measured using a flame photometer, type: JENWAY, CLINICAL PFP7;

• Sulfates (mg / l) were determined by the colorimetric method;

• Chlorides (Cl-) were dosed by Argentimetrie.designation.

4.RESULTS AND DISCUSSION

The pH is an indicator of water pollution. The recorded pH values during the study period ranged from neutrality at 7.3 to a basic pH of 8.8 with an average of about 8.06.

Measurements of leachate temperature give mean values of 24.52 ° C, maximum of 40 ° C and minimum of 10 ° C (Tables 3-4). Thermal exchanges between the atmosphere and the surface of cells or compartments are balanced [13]. So the rise of temperature during the summer and its fall during the winter are in concordance with the seasonal variation of the atmospheric temperature. The maximum value of the leachate temperature is above 30 ° C, considered as limit value of direct discharges in the receiving environment [14].

At the Oum Azza landfill in Rabat-Sale, there are high concentrations of nitrogen (1204 to 5804 mg / L) and ammonia (644-4480 mg / L). Similarly, the phosphate concentration is high and varies between 8.1 and 75.8 mg / L. In the leachate of the Rabat landfill, concentrations remain high in the unloading concerned.

During the 2011 campaigns, the electrical conductivity is higher and exceeds the standard of 2700 µS / cm and varies from 20115 to 47100 µs / cm. The concentration of Na + varies from 1308 to 4630 mg / L and that of Cl- also varies from 2340 to 7100 mg / L. At the same time, the concentration of sulphates is relatively modest and ranges from 16 to 55 mg / L.

The leachate from the Oum Azza landfill shows significant concentrations of suspended solids, ranging from 88 to 1480 mg/L. These high loads generate strong measurements of BOD_5 and COD. BOD_5 varies considerably between 761 to 12976 and 48801mg / L and the COD varies from 7296 to 23789 and even reaches 71880 mg / L.

Table 3: Physicochemical parameters of the leachate of the of Oum Azza Landfill.

Oum Azza	T°C	pH	CE	MES	DCO	DBO_5	Cl-	Na+	NH_4+	NTK	PT	SO_4^{2-}
S1	23,4	8,1	32800	392	13296	6126	6898	3446	1958	1960	17,8	37
S2	15	8,1	47100	211	18048	6526	3470	3010	3976	4340	8,1	47
S3	12	7,8	30100	298	18144	9638	2886	3020	2576	4844	75,8	21
S4	27	8,3	36900	662	10944	2956	4570	3200	4368	5880	40,8	45
S5	30,5	8,2	20115	567	7872	2406	4590	3020	3881	4095	46,4	42
S6	32	7,8	28000	99,5	7296	2756	5020	3470	3010	4396	19,9	34
S7	35	8,5	38500	308	11328	2876	7100	4630	4480	5908	42,9	49
S8	35	8,5	38500	308	11328	2876	4890	3450	4480	5908	42,9	54
S9	31,2	7,9	26600	161	10708	6461	5480	3680	2728	2982	22,7	55
S10	40	7,56	40200	730	23789	12301	5930	4270	3626	4480	26,7	37
S11	15,1	7,34	27060	1467	10160	12976	3028	1308	3330	3770	43,7	26
S12	18	7,9	35000	1480	7488	4800	2970	2560	3986	4410	45,2	20
S13	20,4	8,1	35720	88	7910	761	2560	2340	2499	3710	37,9	25
S14	22	7,9	35700	415	17203	7581	2800	2030	3850	4494	48,6	16
S15	10	8,8	37000	204	13065	3086	2340	2160	644	1204	16,5	22
S16	19,4	8	36725	390,8	15108	6312	4456	3169	3220	4256	35,6	37,5
S17	33,1	8,2	31279	320,6	9456	2729	5400	3643	3963	5077	38	44,8
S18	35,6	7,7	33400	445,5	17249	9381	5705	3975	3177	3731	24,7	46
S19	17,1	8	34096	730,8	11165	5841	2740	2080	2862	3518	38,4	21,8
S20	23,6	7,9	28315	813,4	9904,8	6553,8	4593,2	2803	3176,6	3443	35,2	36
S21	26,2	7,9	31860	93,8	7603	1758,5	3790	2905	2754,5	4053	28,9	29,5
S22	24,7	7,8	35333	481	19712	9840	3872	3107	3350,7	4606	50,3	24,7
S23	32,3	8,4	37967	426	11200	2902,6	5520	3760	4442,7	5899	42,2	49,3
S24	10	8,8	37000	204	13065	3086	2340	2160	644	1204	16,53	22

Table 4: Descriptive statistics of physicochemical leachate data

Variables	Observations	Minimum mg/L	Maximum mg/L	Mean	Error
T°C	24	10,00	40,00	24,52	8,77
pH	24	7,34	8,80	8,06	0,35
CE µs/cm	24	20115,00	47100,00	33969,58	5523,71
MES	24	88,00	1480,00	470,68	370,96
DCO	24	7296,00	23789,00	12626,74	4405,76
DBO_5	24	761,00	12976,00	5522,08	3375,81
Cl-	24	2340,00	7100,00	4289,51	1419,66
Na+	24	1308,00	4630,00	3049,81	781,74
NH_4+	24	644,00	4480,00	3207,60	1045,82
NTK	24	1204,00	5908,00	4090,34	1302,85
PT	24	8,10	75,80	35,24	14,63
SO_4^{2-}	24	16,00	55,00	35,06	11,97

Other analyzes were carried out on the raw and aged leachates as part of the evaluation of the remediation possibilities. The results are summarized in Table 5. The results showed that the leachate kept its pollutant load after several treatment trials [15-16].

Table 5: Results of leachate analyzes of the Oum Azza landfill.

	CE µs/cm	DCO mg/L	DBO_5 mg/L
Site 1 : Lixiviat brut	26880	71880	48801
Site 2 : Treated leachate	24600	45120	30744
Site 3: Treated leachate	25400	42320	22400
Site 4: Treated leachate	26300	38400	19368
Site 5: Treated leachate	20000	12500	1900
Site 6: Treated leachate	18000	9900	1390
Site 7: Treated leachate	17500	4830	600

The PCA Principal Component Analysis of the 24 sampling stations with the physicochemical parameters studied shows that the correlation between the temperature and the other parameters tested allowed us to note that there is a significant correlation with chlorides, sodium and sulphates with coefficients of r = 0.809; r = 0.798 and r = 0.690) (Table 6).

The PCA analysis (Figure 5) shows that the F1 axis expresses 34.45% of the variance and the F2 axis 22.52%, with 56.97% of inertia for the factorial plane F1F2 in a two-dimensional system of the twelve parameters studied. These considerations allowed us to obtain the graphical representation of the correlations between the different variables (Figures 6-8).

In the PCA analysis, the projection of the variables on the factorial plane F1-F2 (Figure 6) shows that pH, BOD5 and MES are negatively correlated with the F1 axis. On the other hand BOD5, COD, MES, Temperature, NPK, PT, NH4 + are correlated negatively with the axis F2. The analysis of the projection of the individuals on the factorial plane F1-F2 (Figure 7) allowed us to define a distribution of the stations along the axis F1 which is an increasing gradient of mineral pollution.

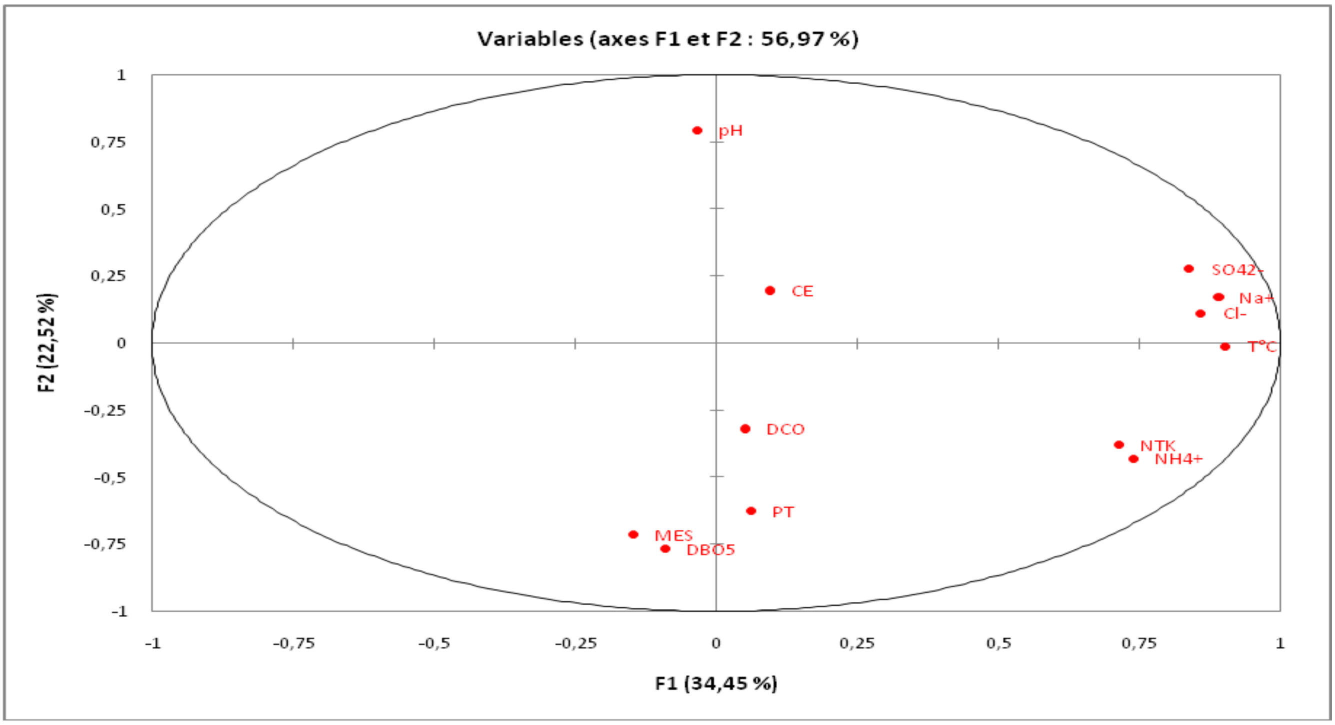

Figure 6: Projection of variables on factorial F1x F2 (56.66%)

Table 6: Correlation Matrix

Variables	T°C	pH	CE	MES	DCO	DBO_5	Cl-	Na+	NH_4+	NTK	PT	SO_4^{2-}
T°C	**1**	-0,142	-0,095	-0,125	-0,003	-0,068	0,809	0,798	0,590	0,540	-0,013	0,690
pH	-0,142	**1**	0,327	-0,443	-0,227	-0,721	-0,040	0,054	-0,231	-0,152	-0,220	0,170
CE	-0,095	0,327	**1**	-0,172	0,483	-0,016	-0,050	0,153	0,116	0,169	-0,271	0,067
MES	-0,125	-0,443	-0,172	**1**	-0,073	0,470	-0,134	-0,331	0,294	0,102	0,304	-0,244
DCO	-0,003	-0,227	0,483	-0,073	**1**	0,692	0,053	0,214	-0,025	0,007	0,014	-0,074
DBO5	-0,068	-0,721	-0,016	0,470	0,692	**1**	-0,001	-0,072	0,035	-0,045	0,174	-0,189
Cl-	0,809	-0,040	-0,050	-0,134	0,053	-0,001	**1**	0,873	0,408	0,330	-0,159	0,759
Na+	0,798	0,054	0,153	-0,331	0,214	-0,072	0,873	**1**	0,416	0,452	-0,085	0,735
NH_4+	0,590	-0,231	0,116	0,294	-0,025	0,035	0,408	0,416	**1**	0,911	0,400	0,501
NTK	0,540	-0,152	0,169	0,102	0,007	-0,045	0,330	0,452	0,911	**1**	0,554	0,411
PT	-0,013	-0,220	-0,271	0,304	0,014	0,174	-0,159	-0,085	0,400	0,554	**1**	-0,239
SO_4^{2}-	0,690	0,170	0,067	-0,244	-0,074	-0,189	0,759	0,735	0,501	0,411	-0,239	**1**

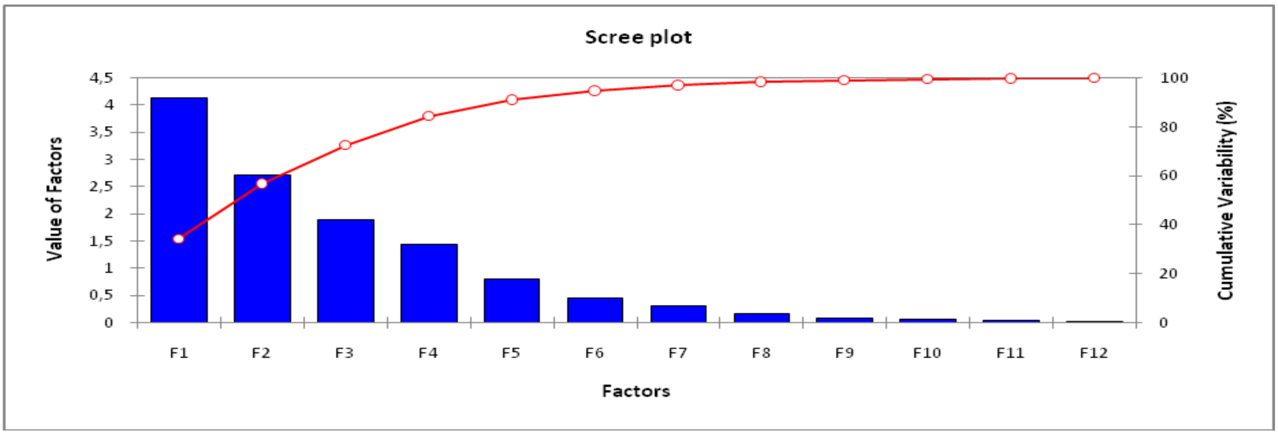

Figure 5: Diagrams of eigenvalues

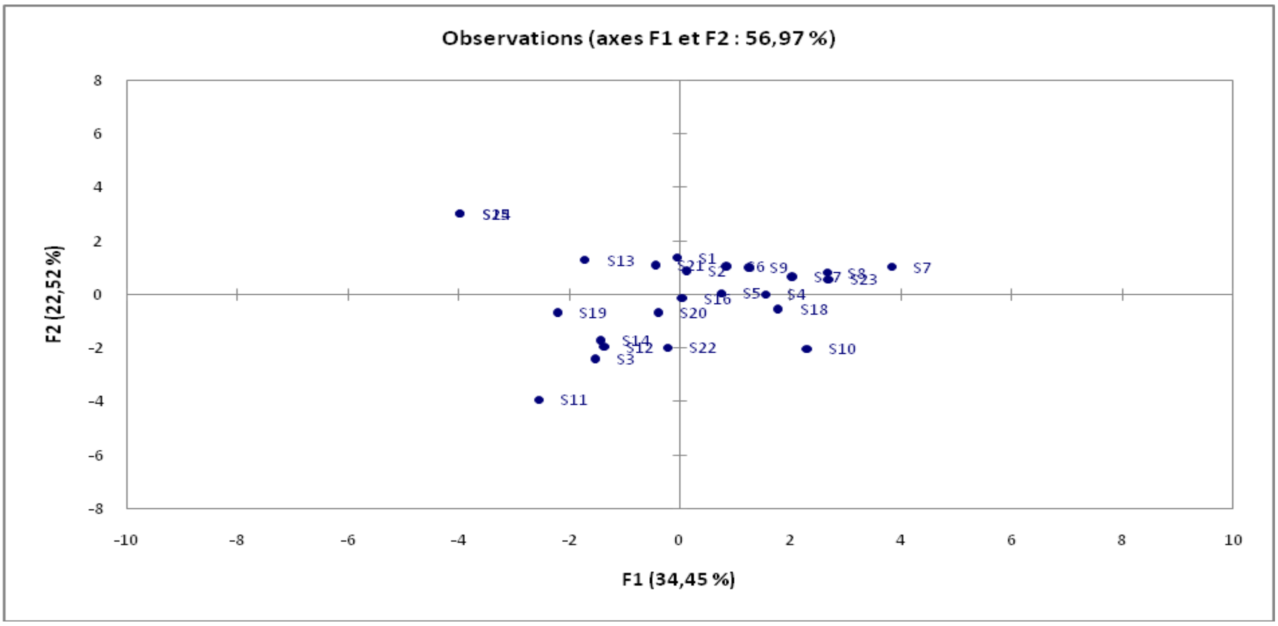

Figure 7: Projection of observations on factorial F1x F2 (65,31 %)

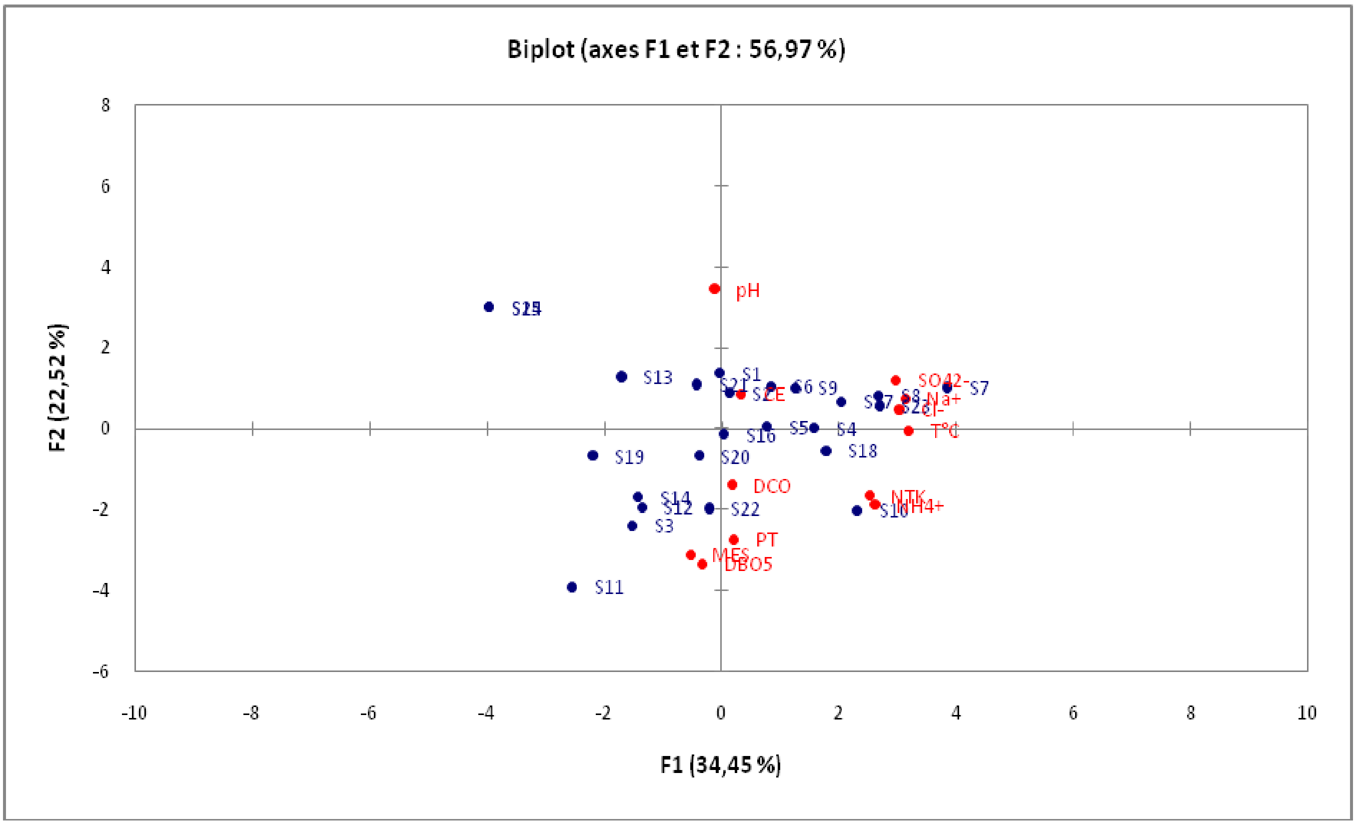

Figure 8: Projection of observations and variables on factorial F1x F2 (65,31 %).

5.CONCLUSION

The electrical conductivity reflects the total mineralization of water [9]. The average value recorded is 20115 µs / cm and is much higher than the Moroccan standards for the quality of water intended for irrigation (limit value <8700) and gives leachates a highly alkalizing power that is very dangerous for all cultivated plants [17].

The sodium has an average concentration of 3049.8 mg / L. This concentration of Na + ion is higher in leachate, and exceeds the Moroccan standard of water quality for irrigation. A large amount of sodium ions in the water affects the permeability of the soil and poses infiltration problems. This is due to the fact that the sodium present in the soil in exchangeable form replaces the calcium and magnesium adsorbed on the soil clays and causes the dispersion of the particles in the soil. This dispersion results in the alteration of soil aggregates. The soil then becomes hard and compact, reducing the infiltration rates of water and air, and consequently modifying the soil structure.

The sulphates ions (SO_4^{2-}) are sulphated compounds whose presence in water results from a contamination mainly related to the discharge of domestic and industrial effluents or a phenomenon of natural reduction of sulphates. The average value in leachate is of the order of 35 mg / L. They are the source of bad odors emanating from leachates.

The ammonium ion, NH4 +, is the reduced form of nitrogen. It comes mainly from the decomposition of natural proteins contained in phytoplankton and zooplankton. It can also be derived from the input of effluents from domestic, industrial or agricultural waste. The average value of the concentration of the NH4 + ion of the leachate of Oum Azza recorded during the study period is 3207 mg / L. According to the standard standard committee and Law 11-03, [14], ammonium does not meet discharge standards.

The chloride ions are anions of chlorine. This element is very abundant in the environment. It is present in water, soil, rocks, as well as in wastewater and leachate. The average chloride contents are 4289 mg / L. These results are consistent with those of previous studies [18-22].

In addition, the ammonium ion (NH_4 +), by nitrification is transformed into nitrites (NO_2-) and nitrates (NO_3-) and oxidized by the bacteria of the genus Nitrosomonas, then by the bacteria of the genus Nitrobacter [23]. Nitrates are very soluble in water; they migrate easily into the water table [24].

The average value of the BOD_5 of the leachates studied is 5522 mg of O2 / L and it is well above the limit value of the Moroccan standard of direct discharges which is 100 mg of O2 / L. Similarly, the COD value of 12626 mg / L exceeds the norm and can be the basis of a strong fermentation.

Bad odors systematically accompany a project of storage of household waste. Odors are due to the presence of hydrogen sulphide in the landfill gas and the decomposition of organic matter.

Landfill gas is composed of methane, carbon dioxide, oxygen, nitrogen, carbon monoxide, hydrogen, and hydrogen sulphide. Only carbon monoxide and hydrogen sulphide are likely to be toxic to humans, beyond a threshold.

Unfortunately in the project of Oum Azza, smells and fumes of gas have a real impact given the proximity of homes not far from the site of Oum Azza. This is the example of the El Manzeh housing estate about 2 km west of the project site. However, a dominance of the west sector winds closely followed by wind from the north significantly reduces the impact of odors and different gaseous emissions to this new subdivision [25-26].

This situation is exacerbated by the non-control and control of industrial, special and hazardous waste generally sent to wild dumps without pre-treatment [27-28].

In conclusion, the concentrations found in the raw leachates of Oum Azza exceed the standards for wastewater quality recommended by WHO [29] and [14]. In addition, spatiotemporal monitoring of several other factors such as pathogens, trace elements and pesticides must provide us with the true level of pollution. Thus, the area of the landfill is affected by biological and chemical pollution that puts at risk the underlying water table.

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