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PHYSICO-CHEMICAL CHARACTERIZATION OF MEKNES MUNICIPAL LANDFILL LEACHATE AND ASSESSMENT OF THE SEASONAL EFFECTS USING PCA

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Abstract

The increase of population and the bad management of municipal solid waste (MSW) lead to a spectacular increase of the landfill leachates volume. These effluents represent a very harmful threat that can affect the environment and the ecosystems, their control and treatment became the first occupation of the authorities. In this context, this study contributes to characterize the landfill leachate composition and how its changes over different seasons.
The results have shown an intermediate leachate with high concentration of organics and minerals components, with an average of 16 455.71 mg O_2/L for COD, 6681.86 mg O_2/L for BOD5, 2469.57 mg/L for Suspended matter (SM), 2990 mg/L for Ammonium and 31259.71µS/cm for Electrical Conductivity (EC).
The leachate parameters seasonal variations were revealed by the principal analysis component (PCA); an explorative tool. Conferring to PCA results, we can define the correlation between the parameters concentrations and the climatic conditions (Temperature and precipitations). The parameters such as electrical conductivity, suspended solids, BOD_5, COD, ammonium, correlate positively with temperature values, that means, the warmer is the season, the higher are the values. While for pH, dissolved oxygen and nitrates values, there is a negative correlation, which means that their loads increase during cold and rainy periods.
This work helps to understand the composition of landfill leachates, to induce the seasonal effect on it and to guide the treatment chain to attend the most stringent discharge standards.

Key words: characterization, correlation, leachate, season, variations

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1. Introduction

The waste production is increasing each year. Landfilling is the most used technique for waste management in the most countries (Sohail et al., 2017; Vaverkova and Adamcova, 2018). It represents an economical option because landfills offer the possibility of accumulating large amounts of solid waste with a very low cost as compared to other waste management methods (Sohail et al., 2017). This process produces some dangerous and complex sub-products including gas and leachate, that needs to be treated and well-managed to provide great risks on the environment and on human health at local and global level. These risks include fires and explosions, vegetation damage, unpleasant smells, groundwater pollution and air pollution (Calvo et al., 2005). Landfill leachate can be also the cause of cancer and many other infectious diseases for the population exposed to landfill leachate harmful matters (Abd El-Salam and Abu-Zuid, 2015).

In the same way, many researches were conducted to estimate the human health impacts and groundwater contamination, that are related to the

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high rate of microbial, toxic and carcinogenic compounds as ammonium, lead and plumb, contained in landfill leachate (Alslaibi et al., 2011; Regadío et al., 2012; Li et al., 2014; Pantini et al., 2015). Al-Khadi, 2006 and Fatta, 1999 had also affirmed that leachate is considered as one of the major threats to groundwater; this threat severity is depending on the concentration of contaminants in leachate and their toxicity, the permeability and the type of soil in vicinity, the water depth and the direction of groundwater flow.

Leachate is formed of pollutants from the wastes buried in landfills by the action of water percolation through these massifs via physico-chemical and biological reactions. Typically, these liquids contain organic and inorganic materials, biodegradable but also refractory to biodegradation. Beside these, heavy metals are also present in municipal landfill leachate, the chemical reactions like Reduction-oxidation and adsorption-desorption are the major mechanisms that lead to the mobilization of heavy metals in the environment. The metals solubility may increase because of leachate reducing-condition that converts the ionic form of metals (Jones et al., 2006). Furthermore, leachate composition depends on many factors which can be listed as the type of solid waste, biodegradation stage, degree of compaction in landfill, age of waste and climatic conditions.

Over time, the composition of leachate changes and get mature to reach the stabilization stage. It was shown in many researches (Kouame, 2007; Naveen, 2016; Trabelsi, 2012) that as landfill age increased, organics concentration decreased; due to the decomposition of biodegradable matters by microorganism. After a certain period of time, there are only recalcitrant substances left. The landfill leachate composition differs also from a season to another. According to Gamar et al., (2017a) temperature and rain are the influential factors in the leachates generation and composition; Waste contain an initial water amount, the rainfall contribute in the water balance in it, while the temperature intervene in waste degradation processes (oxidation and hydrolysis) and also in the degradation speed, by affecting the progression of the bacterial and the chemical reactions (Liu et al., 2012).

Leachate represents a significant environmental problem even if the landfill doesn't contain any dangerous waste (Sohail et al., 2017). Its release without any adequate treatment may lead to serious environmental problems, such as eutrophication, bioaccumulation, pollution of ground water and surface waters, soil degradation, pollution and health issues.

The leachate composition's characterization is a crucial point to choose the appropriate and efficient treatment. After having qualified and quantified it, it will be necessary to opt for a process that will reduce or concentrate the pollutants. The understanding of the organic matter composition bounds the treatment choice towards biological processes for young landfill leachates and towards physicochemical processes for aged ones. The volatile fatty acids fraction decreases with landfill age, so that the biological treatments become ineffective for stabilized landfill leachates. On other hand, the physico-chemical and membranes treatment technologies can be a good alternative (Baig et al., 1996).

The objective of this study is to determine the composition of Meknes landfill leachate in order to define the components and their concentration and the variations of these parameters over the seasons, as a result we can evaluate the pollution potential, explain the seasonal effect and propose an appropriate treatment.

2. Material and methods

2.1. Study location

Meknes Municipal landfill site (Fig. 1) is located 5 km far from the city, and 400 m from the nearest population (Around 200 houses), at the following coordinates: x: 483600 et y: 370000; it extends over an area of 11 ha, this site received all waste of the city since 2002 but it had been restored in 2014 by SUEZ Environment. It belongs to the basin of Meknes-Fez, to the confines of its limit with the pre-Rif wrinkles area.

The site is located on a wedge ledge with a slope of 4%, between Boufkrane River in the West and Ouislane River in the East, just before their confluence in the North. It also contains 2 thalwegs joining Boufkrane River which drains the whole landfill and which the direction is NE-SW. The leachate flow direction coincides perfectly with the landfill structural surface which is the SSE-NNW, with a leachate flow velocity of 1.6 m/s.

For the hydrogeology, the landfill is located at the northern limit of the Meknes-Fez aquifer. The soil of the current landfill is constituted by Marlous lithological formations from Miocene that form the substratum of the upper groundwater; this type of soil texture is known by a week water infiltration, the permeability of the landfill site soil is around 4.29 x 10^{-7} cm/h.

The total population served by this landfill is estimated to 835 695 inhabitants. The current tonnage is amount 193 052 tons per year, with an average daily production of 529 tons per day. In 2034, this tonnage will increase to 326 678 tons per year, equivalent 895 tons per day. The main waste received by Meknes city municipal landfill is household waste with 88.8 % (Table 1), their characterization had showed a high contain of organic matter about 71.3 % (Table 2).

The climate of Meknes city is semi-arid to temper, the winters are cool and rainy and the summers are dry and hot. More than 95% of precipitation falls between October and May. The distribution of monthly average rainfall is irregular over the year with an almost dry summer season (15 mm or 2.6% of the average annual rainfall); winter receives almost 45% of average annual rainfall, the rainiest month is December (103 mm or about 18% of average annual rainfall).

Table 1. Landfill waste type

Waste type	***Percent %***
Household waste	88.8
Household and similar waste	4.4
Green waste	0.8
Industrial waste	1
Construction waste	4.5
Slaughterhouse waste	0.5

Table 2. Characterization of Meknes municipal waste

Fraction	***Percent %***
Biodegradable mater	71.3
Paper and cardboard	5.73
Plastic	7.23
Glass	2.7
Metals	1.3
Various	9.2

Autumn and spring receive almost the same share of rain with 24 and 29% of average annual rainfall, respectively. The monthly average temperature distribution shows that the hottest month is August (42° C) and the coldest month is January (9.8° C). These values rise gradually from January and evolve into a summer character in July and August. The wind directions recorded in Meknes weather station show the importance of winds blowing from the West, South-West and South; these winds represent averages of 28, 34.9 and 19.4% of all directions respectively.

2.1. Leachate sampling and analyses

To achieve the goal of this study, several samples were collected in different season during 2016 and 2017. Bottles of polyethylene previously washed by nitric acid and then by the distilled water, were used to store the leachates coming from the storage basin (Fig.1. B).

Leachate Samples were transported in a cooler to the laboratory, in order to be analyzed in the following 24 hours. All the parameters analysis was carried out according to standard methods for examination of water and waste water (APHA-AWWA-WEF, 2005). The temperature (T), dissolved oxygen (O_2), Potential of hydrogen (pH) and electrical conductivity (EC) were metered in situ using a Multi-parameter.

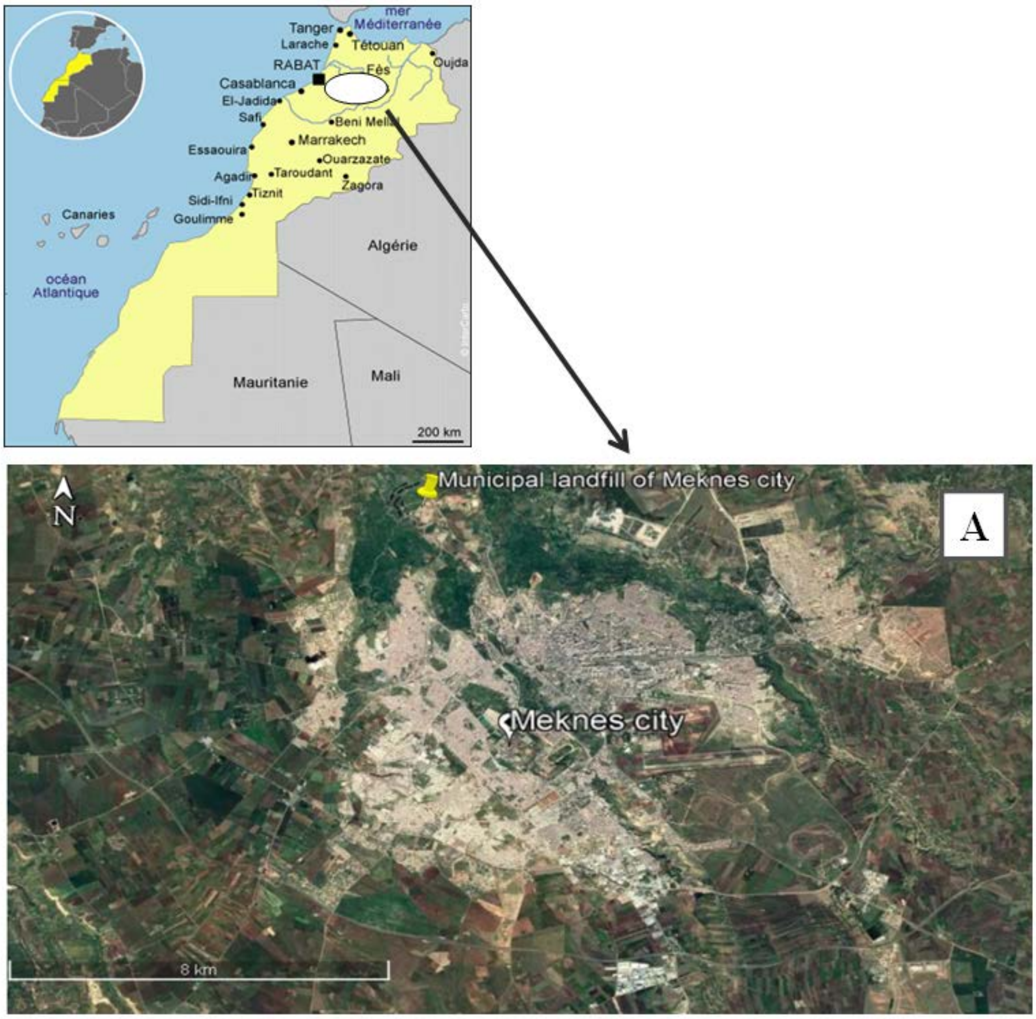

Fig. 1. Study location maps. **A**: Meknes city, **B**: The municipal landfill of Meknes city

Analyses of heavy metals (B, Cd, Cu, Fe, Hg, Ni, Pb and Zn) were performed in the laboratory CUAE2TI in the Faculty of sciences in KENITRA. Samples were analyzed using Inductively Coupled Plasma (ICP) type PerkinElmer Optima 8000, after being purified by a membrane filter of 0,45µm.

Table 3. The methods used to determine the different parameters analyzed in leachate

Parameter	*Method*
Suspended Matter (mg/L)	Gravimetric method
BOD_5 (mg O_2/L)	Electrometric method
COD (mg O_2/L)	Open reflux method
Nitrates NO_3^- (mg/L)	Spectrophotometry
Ammonium NH_4^+ (mg/L)	Spectrophotometry
Hydrocarbon (mg/L)	IR spectrometry
Sulfates SO_4^{2-}(mg/L)	Gravimetric method
Orthophosphate PO_4 (mg/L)	Spectrophotometry
ML	Inducted coupled plasma (PerkinElmer Optima 8000)

The results of the samples collected over the different seasons were analyzed by the principal component analysis method using XLSTAT software. It's a multivariate statistical procedure which is used to reduce the dimensionality and the complexity of the datasets that still contains most of the information. The main objective of this method is to find a set of uncorrelated variables that is able to explain most of the variance of the concentration seasonal variations (Jolliffe, 1986).

3. Results and discussion

3.1. Leachate characterization

The works conducted by Bakraoui et al. (2017); Benyoucef et al. (2015); and Naveen et al. (2016) showed high values of organic pollution which can reach over 20000 mg /L for the COD and 6000 mg/L for the BOD5. The mineral pollution is notably interpreted by important levels of electrical conductivity and ammonium. Şchiopu et al. (2009) had also confirmed that the results of Tomesti landfill leachate (Romania) represent high levels of BOD, pH and heavy metals and exceed the accepted norms. As a result, leachates are considered as complex industrial effluents (Keenan et al., 1983; Parveaud et al., 1993; Renou et al., 2008). Table 2 shows the result of physico-chemical characteristics of the leachate From Meknes landfill in different periods of 2016 and 2017.

3.1.1. Temperature

The temperatures recorded vary from 28.9 to 18 °C. Maximum values were reported during the summer season when high values of temperature in Meknes City were noted.

3.1.2. Electrical Conductivity (EC)

This parameter reflects the amount of salinity and minerals contained in leachate's samples. It's depends on climatic condition and the incoming waste type. The bacteria present in household waste are the responsible of the oxidation, the hydrolysis and the remineralization of organic matters, wherefrom the leachate becomes rich in mineral elements (Driskill, 2013).

The EC values listed oscillate around 37 216 µS/cm and 19 500 µS/cm, high values are seen in dry season, due to the effect of temperature on bacteria's activity and on the aqueous fraction evaporation. Hassan and Ramadan, (2005) had found that the mean value of conductivity was 41637 µS/cm in Alexandria landfill leachate; this finding confirmed the values reported in this study.

3.1.3. pH

The pH values are influenced by several factors as the landfill age, the temperature, the volatile organic compounds and the dioxygen concentration.

Table 4. The physico-chemical composition of Meknes landfill leachate

	Sample 1 (Mar/16)	***Sample 2 (Jun/16)***	***Sample 3 (Sep/16)***	***Sample 4 (Dec/16)***	***Sample 5 (Apr/17)***	***Sample 6 (Aug/17)***	***Sample 7 (Nov/17)***	***Min***	***Max***	***Average***	***SD (±)***
Climate temperature	20	35	36	17	29	40	21	17	40	28.29	9.05
Precipitations (mm)	50	9	6	86	47	22	95	6	95	45.00	35.49
Temperature (Leachate)	21	26.9	26.3	18	25.3	28.9	20	18	28.90	23.77	4.08
pH	7.4	7.7	7.79	7.21	7.9	8.01	7.75	7.21	8.01	7.68	0.28
Conductivity (µS/cm)	19500	36300	36000	26100	33 600	37216	30102	19500	37216	31259.71	6520.26
Suspended Matter (mg/L)	1960	3010	2900	1567	2100	3450	2300	1567	3450	2469.57	668.11
BOD_5 (mg O_2/L)	5020	5200	7900	5502	6078	10850	6223	5020	10850	6681.86	2072.93
COD (mg O_2/L)	12365	16620	18826	11096	12779	31050	12454	11096	31050	16455.71	6995.60
BOD_5/ COD	0.41	0.31	0.42	0.49	0.47	0.35	0.50	0.31	0.50	0.42	0.07
Dissolved oxygen (mg/L)	1.62	1.18	0.96	2.72	1.24	0.81	2.6	0.81	2.72	1.59	0.77
Nitrates NO_3^- (mg/L)	18	16,3	15.62	21,8	18.3	12	19.16	12	21.80	17.31	3.09
Ammonium NH_4^+ (mg/L)	1956	2818	2636	1802	2017	2990	1890	1802	2990	2301.29	495.28
Hydrocar (mg/L)	5	14.8	8.5	9	11	13.41	14.21	5	14.80	10.85	3.57
Sulfates SO_4^{2-} (mg/L)	1576	1446	1400	1302	1513	1467	1345	1302	1576	1435.57	94.98
Orthophosph PO_4 (mg/L)	31.74	35.4	32.5	35.8	31.7	35.2	31.2	31.20	35.80	33.36	2.01
Al (mg/L)	2.47	2.7	2.89	3.53	2.96	2.23	3.12	2.23	3.53	2.84	0.43
Fe (mg/L)	3.2	3.4	3.77	4.32	3.81	3.72	3.83	3.20	4.32	3.72	0.35
Cu (mg/L)	0.7	0.77	0.84	1.01	0.9	0.72	0.79	0.70	1.01	0.82	0.11
Zn (mg/L)	0.34	0.37	0.35	0.42	0.38	0.22	0.38	0.22	0.42	0.35	0.06
Cd (mg/L)	***	***	***	***	***	***	***	***	***	***	***
Pb (mg/L)	***	***	***	***	***	***	***	***	***	***	***

****: Under the limit of detection*

The degradation of the organic compounds contained in landfill leachate is generating carbon dioxide and ammonia, the carbonic acid dissociates to produce hydrogen cations and bicarbonate anions which influence the level of the system pH (Naveen et al., 2014). This reaction is affected by temperature, whence the seasonal fluctuation of pH's leachate values.

As well, the more leachate is stabilized the more pH is higher. The pH of young leachate is around 6.5 while stabilized landfill leachate has a pH higher than 7.5 (Naveen et al., 2016) because of the decrease of volatile compounds over time (Kjeldsen et al., 2002). The results show that the pH range is between 7.21 and 8.01 during winter and summer respectively. These pH values could be considerate as set in the acceptable range of drinking water pH (6.5 - 8.5) recommended by N.M. 03.7.001, (1991).

3.1.4. Suspended matter

The leachate shows high value of suspended matter (SM), due to the abundance of dissolved organic and inorganic materials. SM values differ from 1567 mg/L to 3450 mg/L. The low values are observed in wet season because of the dilution by rainwater. Indeed, during the rainy season, leachates receive a significant amount of water, leading to a considerable dilution of chemical elements (Kouame, 2007).

In comparison with the concentrations found by Gamar et al. (2017a) in El hajeb municipal landfill leachate (940.9 mg/L), Meknes landfill leachate is more charged and may have a significant effect on light penetration, therefore the inhibition of the photosynthesis.

3.1.5. BOD and COD

The values recorded of COD oscillated between 31050 mg O_2/L and 11096 mg O_2/L, these concentrations are much higher than the Standards ($COD_{limit\ value}$ = 500 mg O_2/L according to VLR, 2014).

For BOD, the values vary between 10850 mg O_2/L to 5020 mg O_2/L, with an average concentration of 6682 mg O_2/L, it's more than 60 times superior to the reference value ($BOD_{5\ limit\ value}$ = 100 mg O_2/L according to VLR, 2014).

The results obtained were compared to those reported previously in the Table 5. Those values are in the same range; the difference can be referred to the age, nature, the quantity of waste and the different climatic conditions. According to Christensen et al. (2001), these factors control the variability of pollutant loads.

Table 5. The leachate composition from different landfills

	Rabat Landfill (Bakraoui et al., 2017)	***Beni mellal Landfill (Benyoucef et al., 2015)***	***Mavallipura landfill (Naveen et al., 2016)***
COD (mg O_2/L)	11 520	23500	10400
BOD_5 (mg O_2/L)	6710	--	1500
Electrical conductivity (µS/cm)	--	26930	4120
Ammonium NH_4^+ (mg /L)	--	1990	1803

These parameters can help us to calculate BOD/COD ratio; is recognized as a biodegradability indicator that defines the landfill leachate maturity. During the stabilization process, the microorganisms decompose the biodegradable matters so that the BOD/COD ratio decreases over time. (Ahmed and Lan, 2012). The decrease of BOD/COD ration reduces the leachates susceptibility to be treated by the conventional biological processes because of the non-biodegradable matters are left in effluent.

According to Amokrane (1994), if BOD/COD ratio is higher than 0.5, it reflects a young leachate and when it's less than 0.1, it's a stabilized leachate, otherwise if it's between 0.1 and 0.5 it represents intermediate leachates. The BOD/COD values oscillate between 0.31 and 0.50 with an average of 0.42. The studied leachates are intermediate leachates; this means that the final stage of the leachate's molecules degradation has not been yet reached (Ahel et al, 1998). These values show that leachate from Meknes landfill is rich in biodegradable organic matters.

3.1.6. Dissolved oxygen

The values of the dissolved oxygen are ranged between 2.72 mg/L and 0.81 mg/L. The Maximums were reached in wet season; because in hot season with high temperature, the oxygen becomes less soluble leading to a decrease of its concentration. The low concentration in summer can also be explained through the increase of oxygen consumption by microorganisms that over-multiply once the temperature raises. (Tahiri et al., 2017). The study conducted by Gamar et al. (2017a) had indicated as well low dissolved oxygen concentrations, with a maximum of 1.49 mg/L in wet season and 0.65 mg/L in hot season.

The low concentration recorded cannot support aerobic needs of the microorganisms; this may lead to the generation of anaerobic conditions, the bad smell and the septic conditions. In the same context, Aluko et al. (2003) had proved that the lack of dissolved oxygen causes serious problem as the eutrophication and the aquatic population's asphyxiation.

3.1.7. Orthophosphate PO_4

The presence of Ortho-phosphate in leachate is caused by the degradation of phosphor-proteins and phospholipids contained in the waste organic fraction (Toor et al., 2006). This effluent contains no-negligible amounts of PO_4 that can be useable and beneficial for irrigation reuses instead of their direct release, in order to prevent eutrophication and degradation of the receiving environments.

The results show that the concentration of orthophosphate PO_4 oscillates between 31.20 mg/L and 35.70 mg/L, the contents recorded are relatively constant over the two seasons. In Ivory Coast, Kouassi et al. (2014) found in the Akouedo landfill leachate a mean value of 128.74 mg/L, these results were much higher than the findings of the current study.

3.1.8. Sulfate SO_4^{2-}

The results indicate an average of 1435.57 mg/L, the high values were recorded in March 1576 mg/L and low values in December 1302 mg/L. the results showed that the sulfate concentrations keep the same range the whole year. The results of El-jadida landfill leachate samples published by Chofqi et al. (2004) have also showed a high concentration of sulfates (1150 mg/L). These values exceed by far the standards of release; the limit value recommended in VLR (2014) is 600 mg/L.

The sulfate in landfill leachate is coming from the decomposition of organic matter, industrial waste such as synthetic detergents, and other waste like construction wastes, dredged river sediments and wastewater treatment sludge. The waste organic fraction is degraded and mineralized in whole or in part by an intermediate metabolite with the aid of aerobic microorganisms, the sulfate is the final result of those metabolites, after that it's reduced to H_2S; a harmful gas responsible for the bad smells in landfills (Robinson and Lucas, 1985; Berthe, 2006).

3.1.9. Nitrates NO_3^-

The nitrates present in leachate are formed primarily through the oxidation of ammonium to nitrite and then to nitrates via the nitrification reaction (Naveen et al., 2014). The nitrate formation rate depends on the bacterial biomass, the concentration of dissolved oxygen, pH, the temperature and the initial concentration of ammonium (Mabrouk, 2009).

The nitrates in Meknes landfill leachate oscillated between 21.80 mg/L and 12 mg/L, which low concentration is due to the low concentration of dissolved oxygen; principal agent for the ammonium oxidation. In other hand, Gamar et al. (2017a) found that the average value of nitrates was 68.24 mg/L for El hajeb municipal landfill leachate.

3.1.10. Ammonium NH_4^+

En general, the finding represents a high level of ammonium in the samples. The registered values of ammonium vary from 2990 mg/L in dry season, to 1802 mg/L wet season. Benyoucef et al. (2015) and Naveen et al. (2016) have showed that the leachate collected from Beni mellal landfill and Mavallipura landfill respectively, represented also high Ammonium concentrations (1990 mg/L and 1803 mg/L respectively). The high concentrations recorded in hot season are explained by the fact that the activity of the nitrifying bacteria is optimal only in a certain temperature interval, outside this range the nitrification process is inhibited. In addition to that, the pH affects also the concentration of ammonium. According to Morrill et al. (1967) at law pH values, the nitrification processes decelerate due to the suppression of the nitrifying population.

As a result of the high values listed previously, several environmental problems and toxic effects can be generated such as dissolved oxygen decrease in receiving water, reuse unsuitability, and degradation of sanitary conditions for the population (De Renzo, 1978; Welander et al., 1997).

3.1.11. Hydrocarbons

The results have shown maximum values in June and November, respectively by, 14.8 and 14.2 mg/L, these records are respecting the Moroccan standards of release (Limit value = 15mg/L) (VLR, 2014).

The presence of these molecules in leachate may come from natural sources as the conversion of organic molecules through chemical or biological processes, or from anthropogenic sources as the deposit of Tires, shredded car residues, plastic waste, fiberglass, oils, solvents and lubricants (Neff et al., 2005). These substances represent a huge level of toxicity and may limit the supply of oxygen in surface water (Abha and Swaranjit Singh, 2012); they are relatively stable and poorly soluble in water, but very soluble in fats and strongly adsorbable to soils and suspended solids, which promote the bioaccumulation in human and animal tissues. Their health impacts can be very significant (decreased immune response, neurotoxic effect, irritation of the respiratory tract ...).

3.1.12. Heavy metals (Fe, Al, Pb, Zn, Cu, Cd) Fe > Al > Cu > Zn > Pb >Cd

Heavy metals represent a major threat to the environment and several health risks due to their toxicity. They are interfering with metabolic processes or getting accumulated in body and food chain, increasing ecological problems and causing mortality or dangerous diseases such as cancer. This excessive damage is due to oxidative stress induced by the formation of free radical (Baun and Christensen, 2003). The landfill of Meknes receives just 1% of industrials waste (Table 1), the heavy metals in leachate are coming from the household solid waste like batteries, consumer electronics, ceramics, light bulbs, and lead based paints.

Table 2 shows that the order of heavy metals concentration is Fe > Al> Cu> Zn > Pb> Cd from highest concentration to lowest concentration. Although Gamar et al. (2017b) recorded another order of heavy metals concentrations in Elhajeb dump, which is Mn > Zn> Ni> Cr >Al> Pb> Cu> As> Co > Cd > Hg from highest concentration to lowest.

Fe and Al represent the most abundant metals by 3.61 mg/L and 2.86 mg/L respectively, while the other metallic elements were just in trace concentrations. These values indicate the disposal of steel scrap; this can be presented by the brown dark color of the leachate which is a result of the oxidation of ferrous elements in leachate (Chu et al., 1994).

Heavy metals concentrations was only in trace because they remain trapped in the waste, these results corroborate those obtained by Baccini et al. (1987) who estimate that more than 99.9 % of the heavy metals are still trapped in the landfill after 30 years. The heavy metals concentration is severely affected by the landfill leachates age. In earlier stages (<5 years), leachates are characterized by a heavy load up to 2 g/L and a relatively low pH (<6.5); as result of the production of volatile fatty acids during this phase. When leachate gets older, the waste stabilizes and the volatile fatty acids become scarce. As a result, the pH tends toward neutrality, which decreases the solubilization of heavy metals, so the metal load becomes negligible (Trabelsi, 2012). Yao et al. (2018) had suggested the recirculation of landfill leachate as method to reduce the bioavailability and the toxicity of the leached amount of Zn.

Meknes landfill leachate results were compared with those from other landfills (Gamar et al., 2017; Naveen et al., 2016) and showed that the leachate metal composition of Meknes landfill leachate is typical for a landfill with dominant household character, but the Fe and Al concentrations found were higher than the drinking water standards (N.M. 03.7.001, 1991) and the standards of long time waste water reuse (SEEE, 2007).

3.2. Principal components analysis: Correlation between the concentrations and seasonal effect

The evaluation of landfill leachate components seasonal correlations was determined using the Principal Component analysis on the collected samples results, to show the changes of the physico-chemical parameters over the different season. This analyzes help to establish the linkages between the biotic and the abiotic parameters and to interpret some observed phenomena. The Table 6 represents the Correlation analysis between the leachate samples physico-chemical parameters and the climatic conditions (temperature, rain) to show the seasonal trends.

Table 6. The correlation coefficients between the parameter's concentration and the climatic conditions

	Temperature (Climate)	***Precipitations***
Temperature (Leachate)	0.79872174	-0.880145654
pH	0.794114723	-0.490091215
Electrical Conductivity	0.864155206	-0.595592936
Suspended matter	0.93205681	-0.7561271
DBO5	0.69536395	-0.38711448
DCO	0.819397183	-0.591911514
Dissolved Oxygen	-0.88899581	0.931808985
NO_{3-}	-0.902427122	0.770911752
NH_4^+	0.944751703	-0.861260029
Hydrocarbons	0.429541235	-0.060752299
sulfates	0.237115395	-0.438079524
PO_4	0.265951545	-0.237175732
Al	-0.618321246	0.634011013
Fe	-0.257565947	0.493022993
Cu	-0.377878383	0.396787092
Zinc	-0.666449168	0.492942094
Cd	-	-
Pb	-	-

The PCA have reduced the number of characters by the construction of new synthetic characters or other principal components based on linear combination of the initial characters.

Table 7 gives an approach of the different variables according to their affinities and their groupings. We have retained the first two component parameters because they demonstrate 78.40 % of total inertia (Table 7). The projection of the physicochemical parameters according to these 2 axes makes it possible to define the relation between the values and the seasonal effect.

The leachate composition is severely affected by the temperature variation (Kim et al., 2006), Conferring to the results (Table 6), it can be seen that all the parameters except sulfates, orthophosphates and hydrocarbons exhibited highest correlation up to 0.98. The following parameters: electrical conductivity, suspended solids, pH, BOD_5, COD, ammonium, correlate positively with temperature values, which means, the warmer is the season, the higher are the values. Similar results were obtained by Gamar et al. (2017c), the concentrations of these parameters represent strong value in hot periods because of the concentration phenomena. Gamar et al. (2017c) have also reported that the pH diminishes in summer, this was in disagreement with the current finding; the leachate discussed in this manuscript was characterized by a neutral to basic pH character in summer, but in wet season we observe a decrease of pH values might be due to acidification of the storage basin by the rain water. While for dissolved oxygen and nitrates values, there is a negative correlation, they increase during rainy periods. As for sulfates, orthophosphates and hydrocarbon, they were not having a significant seasonal variation because they represent a low correlation factor. This was in contradiction with the results found by Gamar et al. (2017c); in El hajeb landfill leachate, sulfate and orthophosphates values correlate strongly with the temperature, but in our case we didn't observe a great change over the seasons, which come to that their concentrations depend especially on the type of the waste buried in the discharge. It's noted that heavy metals are also slightly influenced by the seasonal effect, and this is due to the impact of pH on their solubilization.

For more evidences on seasonality, we had examined the results of the factorial maps (Figs. 2-3) which are the results of PCA. It's the projection of the multi-dimensional space of variables on to an optimal plane, where correlations can be visually interpreted. Each line in the plot (Fig. 2) represents one variable. The lines which form acute angles mean that the variables are positively correlated, those which form straight angles are independent variables and for those which represent obtuse angles they are variables with negative correlation.

The correlations circle reveals different opposite groups of variables; those that correlate positively with climatic conditions, and those that correlate negatively. Fig. 2 affirms that the parameters in the left side of the diagram vary together, if Climate temperature increases, they tend to increase as well. From Fig. 3, we have determined three groups. June, September and August: The parameters of this group correlate positively with the climate temperature and negatively with the rain precipitations and characterized by high concentrations of Suspended matter, COD, BOD, pH, conductivity and Ammonium.

November and December: This group correlates negatively with the climate temperature fluctuations and reveal high values of Dissolved oxygen, Nitrates, zinc and Al. March and April: those months are an intermediary phase between dry and wet season, where the parameters showed average values. From the factorial maps above (Fig. 3), we can conclude that the strong pollution is noticed during the first group (June, September and August), this could probably be due to the increase of the heat which generally boosts the evaporation and the bacteria's activity. This statistical study has also revealed the heavy metals that their solubility is more related to pH oscillations.

4. Conclusions

This study allows the assessment and the understanding of the seasonal variations effect on landfill leachate quality using PCA, to choose the adequate treatment and to maintain suitable conditions during the treatment process. The physico-chemical characterization of Meknes landfill leachate has shown a large mineral and organic load. The organic contents are reflected by high values of COD (11096 to 31050 mg O_2/L), BOD_5 (5020 to 10850 mg O_2/L), and suspended matter (1567 to 3450 mg/L).

Table 7. Representation of the Eigen value of the different variables

	F1	***F2***	***F3***	***F4***	***F5***	***F6***
Eigen Value	**10.80**	**3.31**	1.33	1.27	0.94	0.57
Variability (%)	**59.99**	**18.41**	7.37	7.04	5.22	1.98
Accumulated variability %	**59.99**	**78.40**	85.76	92.80	98.02	100.00

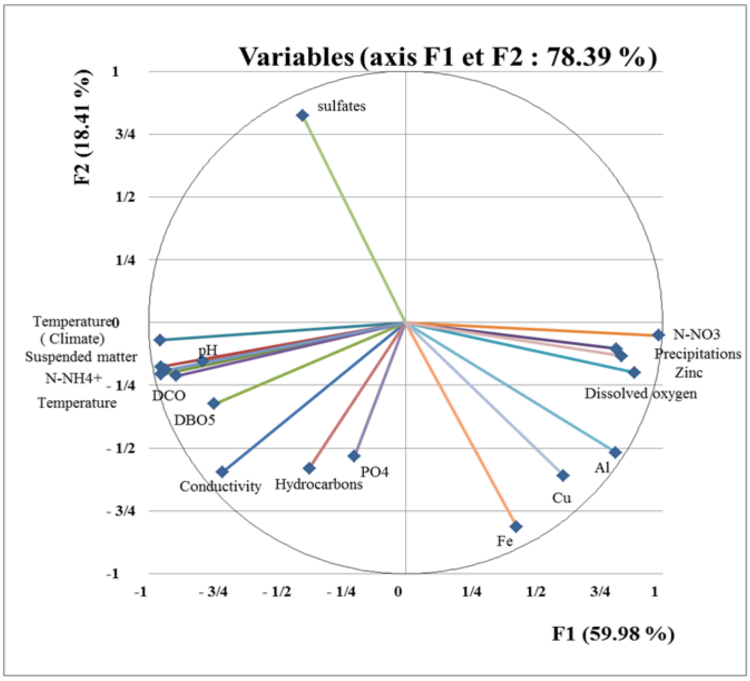

Fig. 2. Factorial map of landfill leachate physico-chemical parameters

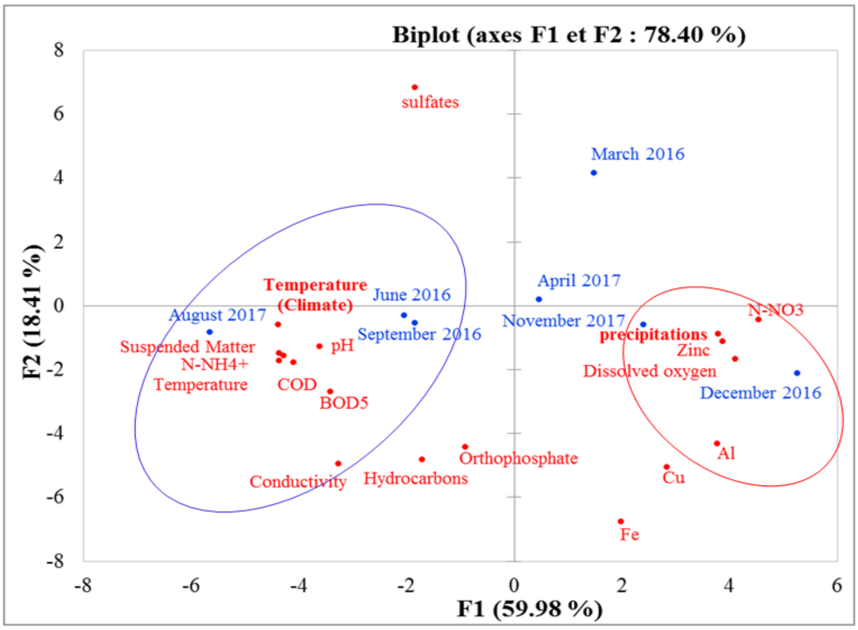

Fig. 3. Factorial map of the projection of individuals (Months) and physico-chemical parameters concentration

As for the mineral pollution, it is translated by the high electrical conductivity, NH_4^+ and sulfates values (average is respectively, 31259.71 µS/cm, 2301.29 mg/L and 1435.57 mg/L). The Fe and Al were the most abundant metals by 3.61 mg/L and 2.86 mg/L respectively. These values exceed by far the national and international standards of the direct release and the irrigation reuse. The finding values confirm that the waste dumped is predominantly municipal waste. The pH value and the BOD5/COD ratio, obtained are typical of an intermediate household landfill reaching the stabilization stage.

From the characterization results, we recommend a biological treatment by nitrification to reduce the huge amount of ammonium and it need to be combined with a membrane treatment as ultra-filtration to eliminate minerals and heavy metals. This suggested treatment can produce a permeate within the standards of irrigation reuse and avoid having a very charged concentrate that is going to be more harmful to the environment, especially that this landfill is near to population and water resources. In order to guarantee smooth functioning of the proposed treatment, we advise to be more restricted in term of the type of waste dumped in the landfill.

The principal component analysis (PCA) used for the seasonal effect explanation expose a high correlation for the most of the parameters; whether with a positive or a negative coefficient. While some other parameters (Sulfates, orthophosphates and hydrocarbon) the values stay relatively stable over the different season.

According to PCA, we can highlight a strong pollution noted especially during June, August and September. This could probably be due to the increase of the heat which generally favors the evaporation and the bacteria's activity. The seasonal fluctuations of the studied parameters need to be taken in consideration in the treatment facilities dimensioning to avoid the undersizing/oversizing problems.

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