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Evaluating pollution potential of leachate from landfill site, from the Tangier city and its impact on groundwater (Tangier - Northern Morocco)

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ABSTRACT:
Leachate from municipalities' landfills represents a potential health risk to ecosystems in generally and human populations in particularly. This study which was taken during year from 2010 to 2011was focused to study the physicochemical evaluation of the leachate from the landfill of the Tangier city (north of Morocco).
The analyses of the sampled leachate revealed strong content of biodegradable organic matter (BOD =166.78 mg/l, COD=2397.25 mg/l and BOD/COD=0.069) and of SM (SM = 577.97 mg/l). Contents in nitrate (NO_3=199.77 mg/l) were also revealed. The discharge of the Tangier city is characterized by an old leachate.
The long-term monitoring of the evaluation of physicochemical parameters in polluted leachate, on how environmental conditions change over time, could then lead to models useful in the prediction of natural attenuation in aquifers. Therefore, an adaptable and efficient treatment process must be used to eliminate the wide range of pollutants present in leachate.
Key words: Leachate, Landfill, groundwater, potential, risks, Tangier, Morocco.

I. Introduction

Leachate is a polluted liquid emanating from the base of the landfill, which contains innumerable organic and inorganic compounds (Papadopoulou et al., 2007).

The composition of leachate depends upon the nature of solid waste buried, chemical and biochemical processes responsible for the decomposition of waste materials, and water content in total waste (Fatta et al., 1999; Mor et al., 2006).

Groundwater is an important component of the natural water cycle; its hydrogeochemistry depends largely on, and is directly influenced by the quality and recharge of the percolating surface waters. Pristine groundwater is generally oligotrophic, and its chemistry is influenced by the type of rock and minerals it passes and dissolves (Drever, 1982). The environmental characteristics of groundwater, such as temperature, pH or dissolved oxygen, remain relatively constant during all seasons.

Water quality parameters such as pH, dissolved oxygen, turbidity and electrical conductivity (salinity) are important indicators of ecosystem health and can provide a measure of damage to Victorian waterways attributed to human activity. Significant deviation of these parameters from 'natural' levels can result in ecosystem degradation and may impact environmental qualities and beneficial uses (EPA Victoria, 2003).

In the landfills, from the deposition phase, the waste is subject to degradation processes related to biological and physicochemical complex reactions (Saadi et al., 2013). The water penetrates into the soil and produces leachate and biogas containing organic and mineral substances. Thus, this could generate pollution mainly organic and metal type in relationship with the natural biodegradation of waste confined and their anthropogenic activities. This phenomenon release many toxic substances into the environment, including the atmosphere, groundwater and effluents (Rivas et al., 2003; Daoudi et al., 2013; Saadi et al., 2013).

In recent years, the landfill of the household remains the most common method used in Morocco. Then, the need appropriate choice of the landfill method is to avoid any damage to the environment. The underlying soils must necessarily be sealed and have a high capacity containment of contaminants (Freyssinet et al., 2002).

The main objective of this study is the physicochemical evaluating of leachate controlled

discharge in the Tangier city, and to assess its impact on groundwater.

II. Materials and methods

Study Site

The landfill of Tangier city is located in southeast of this city at 5 Km from the center of the city on the road (RN2) into Tetouan. It is put into operation in the early 1970 on land belonging to the private domain of the State. The legal nature of the land encouraged its extension to the top of the hill "Biar Tahra" and to reduce its visibility from the RN2, the discharge was gradually pushed towards the northern slopes of the hill.

The site receives daily about 300.00 tons per years of household waste, having a high fermentable element (web1). The leachate from the biodegradation of the waste is accumulated at three storage bays for their evaporation and aeration treatment. In addition, so as to develop this study, 2 sites were chosen and defined as below (**Fig. 1**).

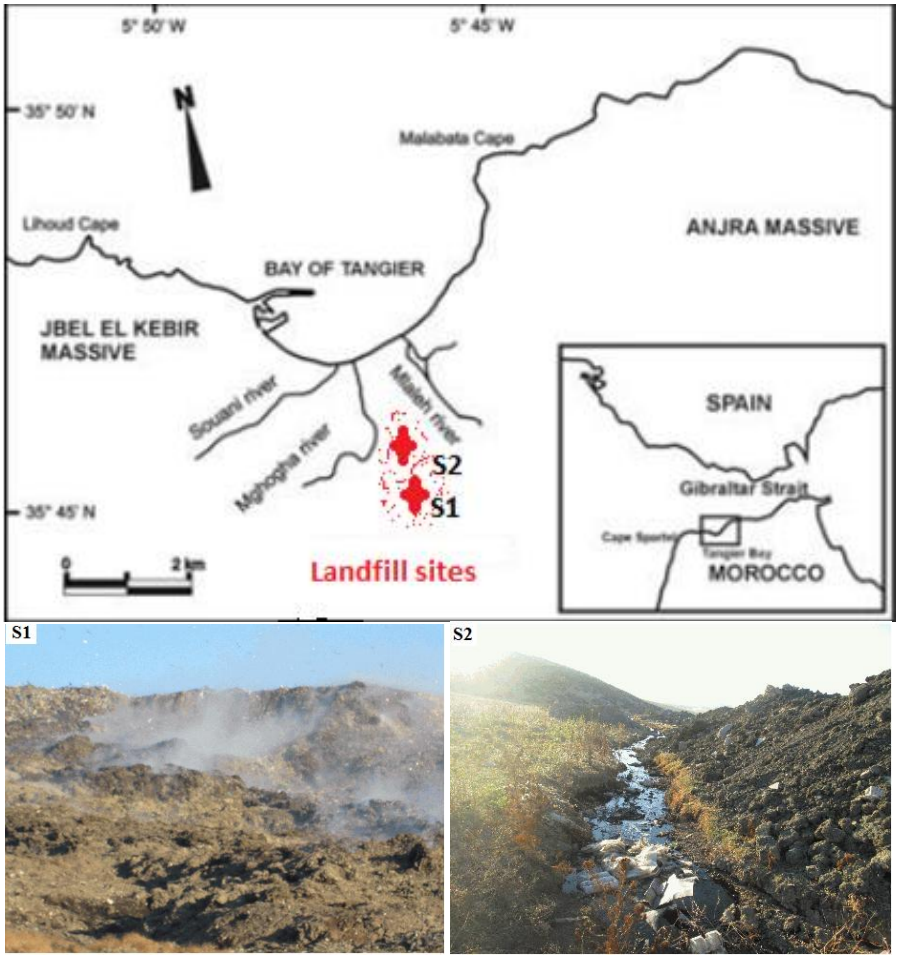

Figure 1: Site of sample collection (Tangier - Morocco)

III. Sampling

The leachate samples were collected in 2 sites according to the AFNOR methods. The mean volume of each sample is 1 liter. The leachate samples were filled into polyethylene bottles.

Analysis methods

The samples were taken during 4 periods (2 campaigns per year during 2010-2011). Thus, for physicochemical parameters, 18 parameters were analyzed especially: T°C, pH, suspended matter (SM), total organic carbon (TOC), chemical oxygen demand (COD), biological oxygen demand (BOD), fluorides (F), chlorides (Cl), nitrites (NO_2), nitrates (NO^-_3), sulfates (SO_4^{2-}), phosphates (PO^{3-}_4), ammonium (NH^+_4), potassium (K^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), sodium (Na^+) and phosphor (P).

Cations and major anions (Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, NO_2^-, PO_4^{3-} and SO_4^{2-}) were determined by ion chromatography after diluted and filtered on a membrane of porosity 0.2 µm cellulose nitrate. Some of the samples that were below the

detection limits for nitrate and NH^{+}_{4} (0.5 mg/L) of the freshwater laboratory of the CNRST was analyzed by the author in the marine laboratory of the CNRST in Stellenbosch, where the detection limit for NO^{-}_{3} and CNRST was 0.01 mg/L. The biochemical oxygen demand (BOD_5) was measured by using a BOD meter. COD was determined by NFT90 10 AFNOR methods.

The water samples for the analyses of dissolved organic carbon (TOC) were first filtered through a 0.45µm microporous membrane filter prior to analysis. The analysis was performed by an autoanalyser using the persulphate – ultraviolet oxidation method for total organic carbon.

Results

Spatiotemporal evaluation of physicochemical parameters

To study the spatial and temporal evaluation of physicochemical parameters, we analyzed, initially, the evaluation of the value of each parameter. The results are presented in figure 2, 3, 4, 5, 6 and 7.

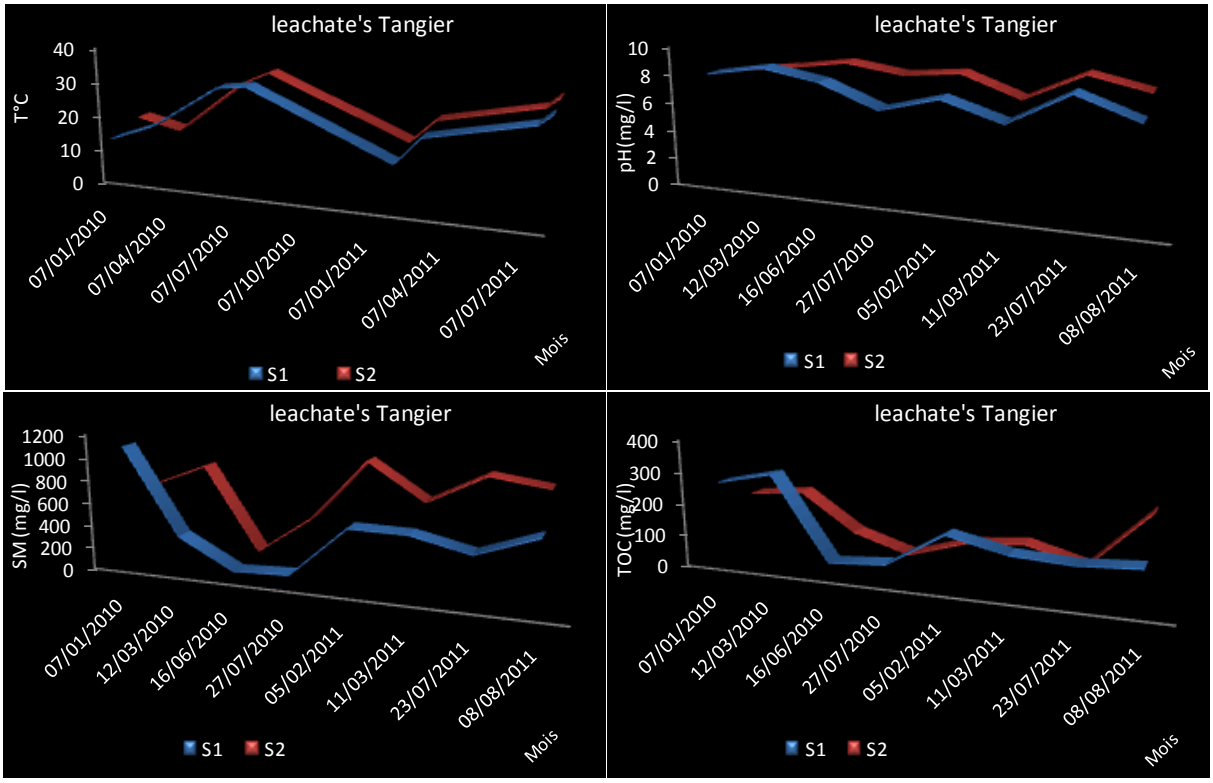

Figure 2: Spatial and temporal evaluation of the physicochemical parameters (T°C, pH, SM, TOC) of the Tangier's Leachate

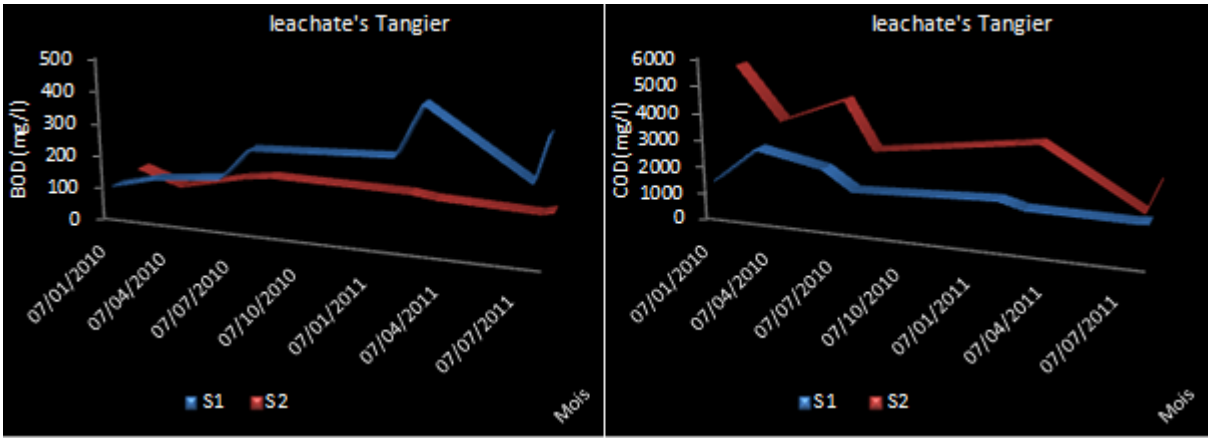

Figure 3: Spatial and temporal evaluation of the physicochemical parameters (COD, BOD) of the Tangier's Leachate

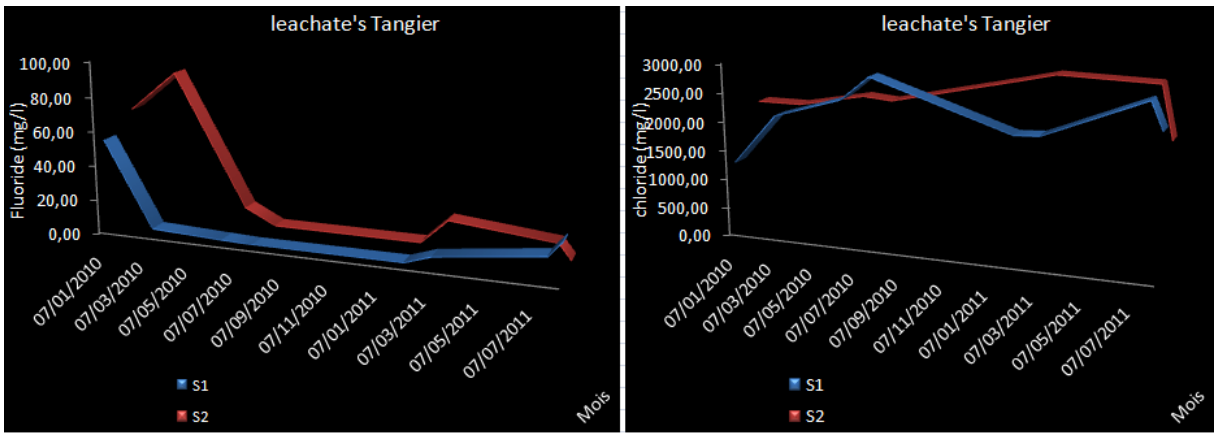

Figure 4: Spatial and temporal evaluation of the physicochemical parameters (F^-, Cl^-) of the Tangier's Leachate

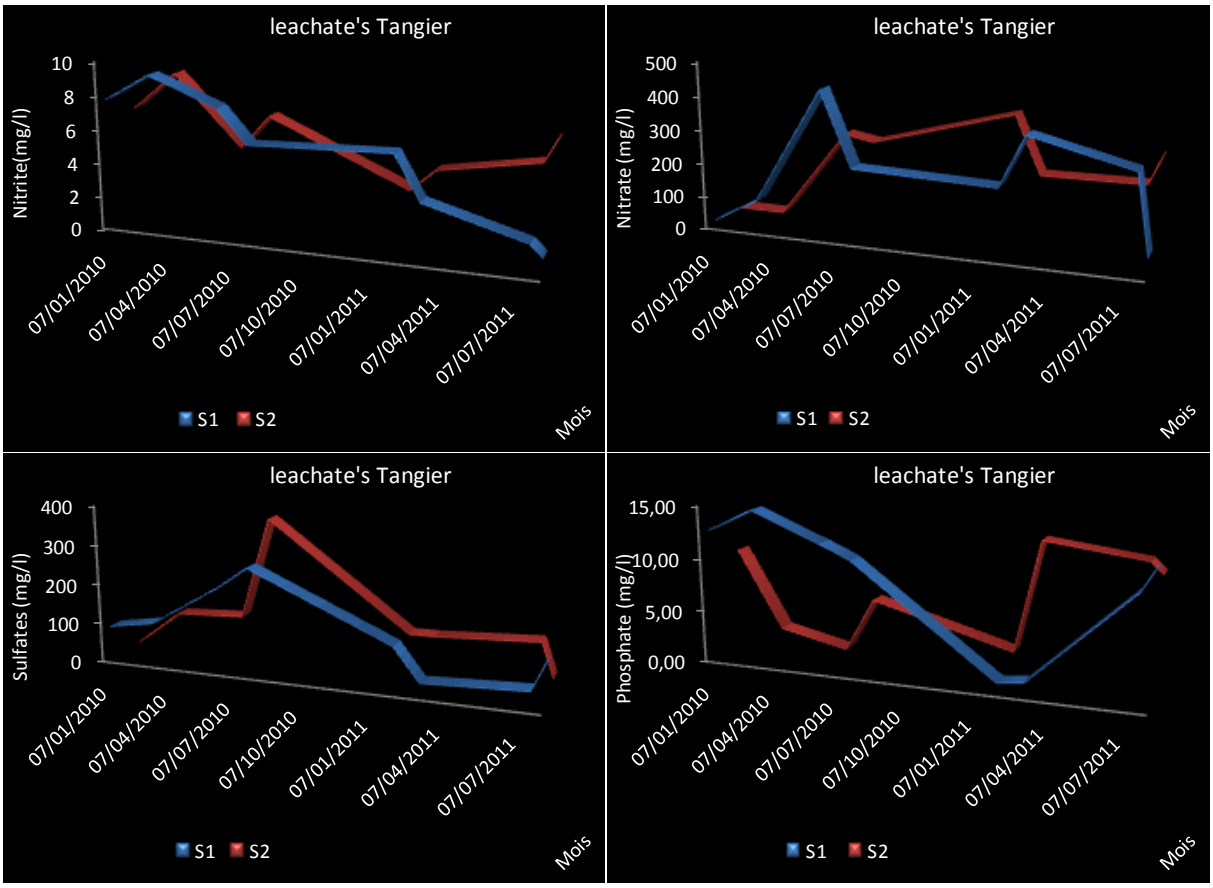

Figure 5: Spatial and temporal evaluation of the physicochemical parameters (NO^-_3, NO^-_2, SO^{2-}_4, PO^{3-}_4) of the Tangier's Leachate

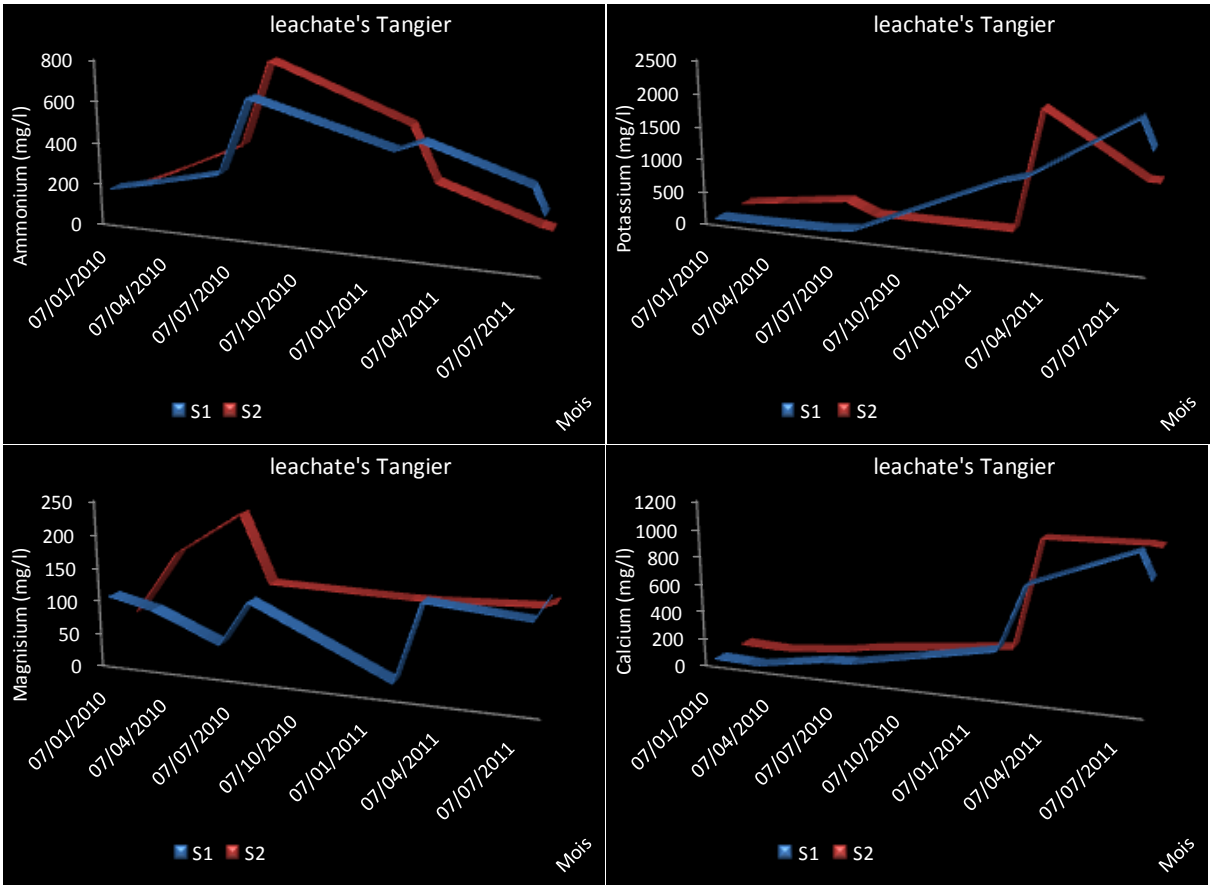

Figure 6: Spatial and temporal evaluation of the physicochemical parameters (NH^{+}_{4}, K^{+}, Mg^{2+}, Ca^{2+}) of the Tangier's Leachate

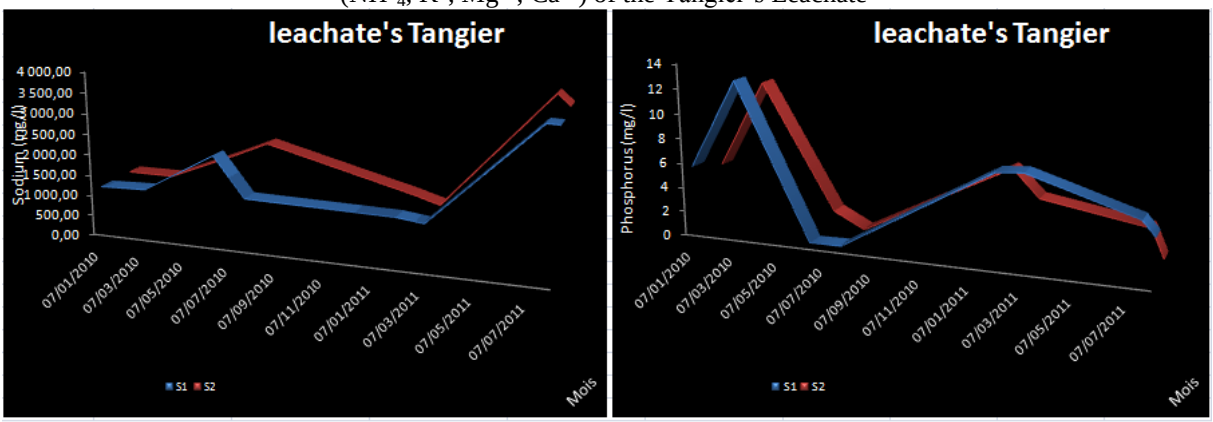

Figure 7: Spatial and temporal evaluation of the physicochemical parameters (Na^{+}, P) of the Tangier's Leachate

The water **T°C** varies from 12 to 31°C during the winter to summer season. Indeed, it varies between 12°C found in Station 1 (07/01/2010) and 31°C noted in Station 2 (08/08/2011). The **pH** is relatively stable and alkaline for all stations. The mean concentration (pH=7.78) was detected relatively high in our study. The mean values of this parameter remain relatively high in the Tangier's leachate. Thus, the pH values are similar for the different samples. The pH values were relatively normal (6.2 recorded in S1 and 8.9 detected in S2) and do not constitute any threat to the ecosystems.

SM represents all the mineral and organic particles contained in water. The values of the SM were ranged from 67 mg/l in the S1 (16/06/2010) to 1001 mg/l in the S2 (05/02/2011). The mean concentration SM (577.97 mg/l) was detected in all stations. This can be explained by the result of a brutal hydrological event. The high values for **TOC** during both seasons are mainly due to decomposed and undecomposed product of organic wastes.

Indeed, the TOC contents are important and vary from 42 mg/l was recorded in S1 (16/06/2010) to 235 mg/l was noted in S2 (08/08/2011), which militates in favor of redox conditions, favorable to the accumulation and preservation of organic matter.

The high values for **BOD** and **COD** are indicative of high organic matter in the wastes. The determination of BOD, and COD gave us information about the water quality of industrial and urban wastes in different effluents. Indeed, the high COD values (5321 mg/l), were detected in winter (07/01/2010), do not necessarily imply a pollution problem since the primary production of the forests at this site greatly contribute to the organic matter content. The mean concentration of COD was 2397.25 mg/l. This value does not explain that enrichment of the organic matter. The **BOD** expresses the quantity of oxygen required for biodegradation of organic matter from water. General, all wastewater is heavily loaded with organic matter. **BOD** values are moderate with an elevated level (423.65 mg/l) in station 1 at winter (11/03/2011) and corresponding low values (55 mg/l) in station 2 at winter (12/03/2010). The mean annual values were 166.78 mg O_2/l. This can be explained by behaves like streams that are converted to house the outlet wastewater rich in organic matter and nutrients. **BOD/COD** ratio is 0.069 recorded in our study. This report is decreasing during periods and stations.

The values of the **F** were ranged from 0.12 mg/l recorded in the S1 at 27/07/2010 to 88.11 mg/l detected in the S2 at 12/03/2010. The mean concentration SM (18.04 mg/l) was detected in all periods. The high level of Cl are recorded during the summer, the average is 2358.92 mg/l

The **NO_2** concentration was varied from 0.94 to 9.24 mg/l. The minimum **NO_2** values were recorded during the summer season (08/08/2010) in station 1 and the maximum values were recorded during winter season (12/03/2010) at the station 1. The recorded highest **NO_3** value during winter season could be mainly due to the organic materials received from the Tangier harbor. The increased **NO_3** level was due to fresh water inflow and terrestrial run-off during the winter season. Another possible way of **NO_3** entry is through oxidation of ammonium (NH_4^+) from nitrogen to nitrite formation. The **NO_3** constitute the final stage of the oxidation of nitrogen. Their presence in water certifies that, if the source of pollution is organic, the assimilative is active. The mean concentration NO_3 was noted 199.77 mg/l in all station.

Higher concentrations of the **SO_2** (265.91 mg/l) were obtained in station 1 at summer (27/07/2010). However, lower concentrations of this parameter (14.98 mg/l) were noted in station 2 at winter (07/01/2010). The higher **PO_4** concentrations (14.65 mg/l) at winter (12/03/2010) were found in station 1 from the leachate of Tangier. But the lower values (0.45 mg/l) at summer (16/06/2010) were noted in station 2. In station 2 at summer, NH_4 level was varied from 99 mg/l (08/08/2011) to 782.61 mg/l (27/07/2010).

Higher **K^+, Mg^{2+}, Ca^{2+}** and **P** concentrations (2063.62 mg/l, 223.91 mg/l, 1041.35 mg/l and 12.69 mg/l) were obtained in the station 1 at summer, and lower **K^+, Mg^{2+}, Ca^{2+} and P** values (11.62 mg/l, 15.72 mg/l, 0.17 mg/l and 0.0020 mg/l) were detected in station 1 at winter. Leachate generated by the landfill is rich in **Na^+**, with a mean levels of 1916.74 mg/l with maximum concentrations (3865.94 mg/l) are recorded during at season summer.

IV. Discussion

Landfill leachate from of the Tangier city contains many minerals often highly toxic contaminants. Their composition is specific to each discharge, and it varies depending on the type of waste, the age of the landfill and the weather. Leachate comes from the waste water, the meteoric precipitation and the groundwater water (Matejka, 1994).

The **pH, TOC, COD, Cl^-, NO_3, SO^{2-}_4, NH^+_4, K^+, Mg^{2+}, Ca^{2+}, Na^+** show maximum levels in summer season and low values are recorded in winter season. Contrary in the other elements in our study, the maximum values are recorded during the winter season while low levels are recorded during the summer season.

Examination of the results presented in figures 2, 3, 4, 5, 6 and 7 shows that the leachate studied accuses a diverse and high pollution load. Indeed, the **T°C** in our study is relatively homogeneous. Overall, the mean value of **T°C** (22.75°C) is bellow at 30°C, considered as soon as limit value of direct waste (CNS, 1994). The liquid discharges showed temperatures oscillating between 12 and 31°C, largely depending on climate and air temperature. The **T°C** is considered as a factor influencing the biodegradation of waste (Berthe, 2006). Indeed, the decrease in temperature shows a decrease in bacterial biodegradation activity.

The mean **T°C** (22.75°C) remains related to the local conditions. These concentrations are similar to those found in other sites (Belle, 2008; Saadi et al., 2013), suggesting that this increase is due to natural influences and anthropogenic (Sarkar et al. 2007).

Leachate produced by the discharge of Tangier city is basic. The average annual of **pH** is near 8. Leachate produced by the discharge of Tangier city is basic. The average annual of **pH** is near 8. These high values coincide with high temperatures values recorded for the same period of the year 2011. The inter-annual variation of **pH** shows a slight high

with aging discharge: from winter 2010 to summer 2011.

The waters in our study show a pH varies in relation to probable fluctuations in organic load.The mean values are alkaline of pH. This alkalinity is due to the buffering effect of ocean waters. Other authors have shown that the pH of the leachate landfill of the Oujda city is buffered (**Table 1**). The pH is about 8 because of the buffer system developed by the carbonates and bicarbonates (Belle, 2008; Saadi et al., 2013).

High concentrations of **SM, NO_3 and pH**, this increase can only be explained by the basic character of Landfill Leachate studied and secondly, their strong mineral and organic load (Aluko et al., 2003; Saadi et al., 2013).

Table 1: Analysis of leachate discharge from the city of Tangier with respect to the typical European average.

Site	Tangier	AL Hoceima	El Jadida	Larache	Tangier	Allemande	French
pH	7.78	6		7.87	7.6	7.5	7.62
SM	577.97			4.07			23.4
TOC	137.31				765		339
COD	2397.25	76 450	1005	44750			1064
BOD	166.78	38 200	55.33-66.43				114
F	18.04				0.31		
Cl	2358.92	3000	5680	18415	3 990	2 000	395
NO_2	5.46						23.9
NO_3	199.77				3	3	366
SO4	114.99		1823	240	217		274
PO4	7.97			0.56			6.63
NH4	332.58	2000				500	376
K	648.05						278
Mg	113.58						50.9
Ca	409.34						233
Na	1916.74						389
P	4.49				4.5	1	
Reference	Presente study	Rassam et al., 2012	Chofqi et al., 2004	Er-Raioui et al., 2011	Burkhardt et al., 2006		Belle (2008)

Our results for **SM** are lower to those detected by sever authors (Belle, 2008). But higher concentrations of SM were found in our study compared with those recorded by several authors (Saadi et al., 2008). This is a characteristic common to all domestic waste dumps (Christensen, 2001; Khattabi, 2002).

Contents of **organic matter** of the leachate designated by landfill, expressed in **BOD** and **COD** are relatively low. The seasonal variation of BOD shows that it is during the summer it has the lowest values. Indeed, BOD levels (266 mg/l) were high in our study as compared to the concentration found in the previous study (BOD=55.33 mg/l; Chofqi et al., 2004; **Table 1**). However, higher concentrations of BOD (38200 mg/l) were found in the leachate from Al Hoceima landfill (Rassam et al., 2012; **Table 1**), compared with those detected by leachate in Tangier landfill (266 mg/l). Khattabi (2002) showed that there was a clear correlation between the increase in the T°C and decrease of the BOD. Indeed, during in season summer, there is a warming of leachate allowing for increased activity of bacteria. Those above will allow the degradation of biodegradable organic matter present in the leachate. In winter, the T°C of the juice of the discharge start to decrease, thus constituting a limiting factor of the bacteria become increasingly unable to transform the biodegradable organic matter , which leads to an increase of the **BOD** during this period. Throughout the site, the concentration of **BOD** (166.78 mg/l) is relatively high compared to that detected in other sites such as the leachate in France (Belle, 2008; **Table 1**) where it was noted 155 mg/l in new cashier.

The report of BOD/COD, which reflects the "potential" biodegradation of leachate, decreases very rapidly with age from central storage of waste. Close to 0.7 values are reached on Young sites. While older leachate displays below 0.05 reports. Next the stage of biological evolution of waste three types of leachate were distinguished (Millot, 1986, Chian and DeWalle, 1976, Amokrane et al., 1997):

- Young leachate: DBO5/DCO > 0.3: characterized by relatively high biodegradable organic load.
- Intermediate leachate: the organic load decreases.

- Older or stabilized leachate: characterized by low organic load, mainly composed of humic substances.

BOD/COD ratio is 0.069 recorded in our study. This report is decreasing during periods and stations. Finally, all these studies show that the discharge of the Tangier city is characterized by an old leachate.

We clearly notice a decrease in organic content in the first campaigns for leachate in our study during 2010; this decline was more moderate for those of 2011. Overall, we note that there has been a decline organic matter for the Tangier city that reflecting a loss of power of the stock of biodegradable material.

High mean values of **COD** (2397.78 mg/l) indicate water pollution, which is linked to sewage effluents discharged from Tangier city, industrial (free zone) and agricultural practice. The input of anthropogenic contaminants causes an increase of COD concentration that is responsible for increasing the concentrations in nutrients and organic carbon in the fresh surface waters of the river. The high levels of **Cl** are recorded during the summer and coincide with maxima of the **T°C**. This can be explained on the one hand the fact that during this period of summer. There is a low precipitation phenomena can cause dilution of leachate, which leachate become increasingly rich in **Cl**. Higher concentrations of **Cl** (5680 mg/l) were found in the leachate from El Jadida landfill (Chofqi et al., 2004; **Table 1**), compared with those recorded by landfill in Tangier (773.92 mg/l).

The mean values of $\mathbf{NO_3}$ (199.77 mg/l) were relatively low compared to those observed in the same leachate landfill of the Tangier city (Belle, 2008; **Table 1**) where the mean values in new cashier were detected of the NO_3=366 mg/l. But higher mean NO_3 concentrations (199.77 mg/l) were obtained in our study compared to those obtained in landfill old (NO_3=126 mg/l; Belle, 2008; **Table 1**). Another study showed that the agriculture and urban activities are major sources of the phosphorus and nitrogen in aquatic ecosystems (Carpenter et al., 1998).

The higher levels of $\mathbf{SO_2}$ are recorded in summer, where the phenomena of bacterial biodegradation are very intense and conditions of the environment that are very reductive. The sulfates are then reduced sulfides which are among the gasses released not responsible for bad odor discharge. The mean $\mathbf{SO_2}$ levels of 114.99 mg/l in all stations of our study are lower to those reported by Chofqi et al. (2004) in El Jadiad's landfill. The mean value was 1823 mg/l (**Table 1)**.

The evaluation of $\mathbf{NO_3}$ is opposite with that of ammonium, this corresponds to bacterial denitrification mineralization from $\mathbf{NH_4}$ to nitrate. This phenomenon is not observed in 2010. It is further noted lower overall trend of $\mathbf{NH_4}$, but with significant variations. The mean concentrations of $\mathbf{NH_4}$ (332.58 mg/l) recorded in our study were lowest compared with those detected by other authors (Rassam et al., 2012; **Table 1**). **P** for the decline is free during the first campaigns before stabilizing; this evaluation is similar for 2 years of leachate from Tangier city.

V. Conclusion

Domestic waste landfill is a complex system whose operation involves many interactions. Highlight the impact of a discharge cannot be confined to a single discipline, as the areas involved are different. Indeed, the evaluation of the leachate generated by the landfill of Tangier city showed that leachate is older, conveying an important mineral and organic pollution load. Moreover, the study of physicochemical parameters in our study showed that there was not an evaluation in the quality of the leachate. But, the other organic and inorganic parameters were noted the evaluation of leachate at the stage of biogas which corresponds to a decrease of their toxicity and thus improve the quality of the groundwater.

Globally, the characterization of the leachate generated by the landfill of the Tangier city showed that leachate of this area is stable, conveying an important mineral and organic pollution load.

Finally, leachate treatment and control of their potential groundwater infiltration can help to mitigate upstream pressure on the water surface. The leachate treatment today has important economic and financial issues. All this leads to several questions: is there a sufficiently effective method to meet the standards?

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