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Physico-Chemical Characterization of Leachate from the Moulay Abdallah Technical Landfill Center (Morocco)

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ABSTRACT

The physico-chemical characterization of the leachate from the Technical Landfill Center (TLC) of Moulay Abdallah (MA) which is intended for the treatment of Household Waste (HW) and Waste Assimilated to Household Waste (HWA) as well as the elaboration of the results of the study that was carried out on the leachate from the Oum Azza (OA) Technical Landfill allowed comparing the leachate from two TLCs located in two different regions and exploited in two different ways. The parameters studied are Organic Matter (OM), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD_5), Total Kjeldahl Nitrogen (TKN) concentration, NH_4^+ ion concentration, conductivity, Suspended Solids (SS), Total Phosphorus (TP) and pH. The choice of these parameters comes down to their usefulness for the sizing of the leachate purification processes (PP) of the leachates of Moroccan typology, produced by the population of a coastal city. The results of the analyses show that the leachates from the two TLCs have almost the same physico-chemical characteristics. Depending on the method of management of the leachate (storage or direct discharge to the wastewater treatment plant (WWTP)), the evolution over time of these characteristics differed from one TLC to the other and all of the main leachate parameters from the TLC MA have all tended to increase over the time of operation. This is in contrast to the leachate parameters from the OA TLC, which all tended to decrease.

Keywords: Leachate, characterization, waste, landfill, Moulay abdellah**.**

INTRODUCTION

As part of the implementation of its Environmental Policy, the Pizzorno Environment Group (GPE) has made scientific collaboration with the Moroccan university one of its main lines of action. Indeed, after having studied the leachate from the Technical Landfill Center of Oum Azza (Rabat region), GPE authorized the authors of this paper to study the leachate from a second TLC bordering the Atlantic Ocean, the TLC Moulay Abdallah. The particularity of this study, compared to the others, consists, in two essential points:

- First of all, the origin of the characterized leachate. In fact, they come from a TLC and not from a wild dump, which reinforces the representativeness of the characterization;
- Secondly, the duration covered by the sampling, which is 6 years (2012–2017). For the majority of similar studies, this duration did not exceed two years.

Presentation of the TLC MA

The TLC MA is located in the rural commune of Moulay Abdallah about 5 km south of the city of El Jadida. It has a total area of 28 hectares and compared to the TLC OA, it has the particularity TLC of being a coastal site on the Atlantic Ocean [Pizzorno Environment Group, 2004].

The commissioning of TLC MA took place on 16-11-2006 under a delegated management agreement. The operating service consists mainly of:
- Control, identification and weighing of incoming waste;
- The landfilling of waste following a sanitary landfill technique;
- Leachate treatment;
- The capture and burning of biogas;
- Environmental monitoring of the site.

The TLC receives, on average, 140 tons per day of Household Waste (HW). Leachate production is an average of 25 m^3/d [Groupe Pizzorno Environnement, 2008], it varies according to weather conditions (seasons), and the seasonal eating habits of the producing population. The HWs entering the TLC come mainly from the rural commune of Moulay Abdallah and the Municipality of El Jadida. In contrast, HWAs come from certain industries established in the region. They consist of organic waste, expired food products, non-recyclable plastic, soiled cardboard and textiles.

MATERIALS AND METHODS

The leachate subject of the study results from the landfilling activity of the HWs and HWAs at TLC MA. They were produced at the level of the landfill through two processes:
- Daily compaction of the waste, resulting in the release of its juice;
- The percolation of rainwater into the waste dome, following its infiltration through the area of uncovered waste. The passage of this water between the buried waste leads to its loading (concentration) by "leaching" chemical and microbiological elements contained in the waste, from the top to the bottom of the bin.

The leachate produced was drained gravitationally (sloping ground) from the bin to the storage manhole from where it was taken. The sampling frequency was quarterly (3 times/year) from 2013 to 2017.

The physico-chemical characterization of the leachates was financed by GPE-Maroc. Sampling and analysis were carried out at the "Centre d'Etudes et de Recherches de l'Environnement et de la Pollution (CEREP)" of the Laboratoire Public d'Essais et d'Etudes (LPEE). The methods that were used in the laboratory for the analysis and measurement of the various parameters are summarized in Table 1.

BOD_5 allows the evaluation of the biodegradable Organic Matter (OM) contained in the leachate, while COD allows the evaluation of the oxidizable matter in its totality. In the scientific literature, OM, BOD_5 and COD are linked by the following empirical relationship:

$$\mathrm{MO} = (2\mathrm{BOD}_5 + \mathrm{COD})/3 \quad (1)$$

The assessment of the biodegradability of the leachate is carried out through the BOD_5/COD ratio. It is called the biodegradability index (IB). This index is also used to characterize industrial pollution; it gives the indications on the origin of the pollution of water and especially on the possibilities of its treatment. NTK consists of biodegradable organic nitrogen (Norg) and ammoniacal nitrogen (NH_4^+). Thus, the leachate loading in Norg was obtained by subtracting the following: NTK – NH_4^+.

RESULTS AND DISCUSSION

The physico-chemical characterization of the leachate over the 6-year period is summarized in Table 2.

Table 1. Methods used for the analysis and measurement of the parameters evaluated

Parameter	Reference standard
pH	NF T 90-008 (2001) / NM ISO 10523-2001
Conductivity at 25°C	NF EN 27888 (1994)/ NF T 90-031 (1993)/NM ISO 7888 (2001)
Ammonia nitrogen (NH_4*)	NF T 90-015/1-2 (01/2000)/NM ISO 5664-1999/ NM ISO 7150-2-1999
Total Kjeldahl nitrogen (NTK)	NM ISO 5663-2000/ IS025663 (1994)/RODIER (2009)
Total phosphorus (PT)	NM IS06878-1999
Biochemical oxygen demand (BOD)	NF EN 1899-1 (1998) / NM 5815-1-2 2012
Chemical oxygen demand (COD)	NF T 90-101 (2001) / NM 03.7.54-2013
Suspended solids (SS)	NF EN 872 (2005)/ NMO3.7.052-1996

Table 2. Physico-chemical characterization of leachates from TLC MA between the year 2013 and 2017

Parameter	Minimum	Maximum	Average	Average/2	SD
pH	7.35	8.6	7.8	3.9	0.4
Temperature (°C)	9	30.2	24.9	12.4	5.3
Conductivity (ps/cm)	30 000	43 600	37 800	18 900	4 139.7
COD (mg of O_2/L)	7 450	21 312	13 743	6 871.5	3 743.8
BOD_5 (mg of O_2/L)	797	11 251	4 707.6	2 353.8	3 315.9
OM (mg/L)	3 125	14 604.7	7 719.4	3 859.7	3 401.4
NTK (mg/L)	3 472	6 272	4 690	2 345	866.8
NH_4^+ (mg/L)	3 080	5 152	4 027.3	2 013.7	968.4
N-organic (mg/L)	364	1 120	3 976	1 988	350
PT (mg/l)	28	93.8	46.7	23.4	16.2
SS (mg/l)	103	5 931	1 264.2	632.1	1 526.6
IB	0.1	0.6	0.3	0.2	0.2

Organic matter

The results are shown in Figures 1 and 2. According to these results:

- The graphs show that BOD_5, COD and OM varied in the same way over the 6 years. They all tended to increase;
- Record peaks in the leachate content of OM along the 6 years were recorded. These peaks (max 14,605 mg/l) occurred in summer between August and September (2012–2013) and between June and July (2014–2017). The leachate OM content of the leachate had a general tendency to increase over the 6 years;
- BOD_5 varied widely (see standard deviation) around a mean of 4708 mg/l. This parameter had a general tendency to increase. It reached its maximum in 2017 (11,251 mg/l);
- The average COD is 13,743 mg O_2/l. It varies between 7,450 mg O_2/l and 21,312 mg O_2/l. This parameter has undergone the same evolution as BOD_5;
- For comparison, the COD measured in 2014 by Mejraoua et al. on the leachate from the Meknes "wild" landfill varied between a minimum of 1205 mg O_2/l and a maximum of 9207 mg O_2/l [Mejraoua and Zine, 2017[;
- The average calculated IB is 0.3. According to Amokrane et al. [Amokrane, 1994], it characterizes intermediate type leachates (still biodegradable). The trend curve for this parameter shows a strong increase between 2012 and 2017. It varied between a minimum of 0.09 and a maximum of 0.57.

IB always peaks during the summer months. This is consistent with the variation in organic load (OM) of the leachate during this same period. As a comparison, the average OM in 2000 by Chofqui et al. for leachate from the El Jadida "wild" landfill was 0.067. The average OM in the El Jadida landfill was 0.067. The average OM in the El Jadida landfill was 0.067 in 2000 by Chofqui et al. It ranged from a low of 0.027 to a high of 0.1 (5). It characterizes stabilized type leachates (very low biodegradability) according to Amokrane [1994].

OM has had a general tendency to increase. Indeed, it is the leachate the biodegradability of which was gradually increasing between 2012 and 2017. Thus, during this time interval, the result of the biological and chemical reactions that took place in the MD landfill bin (which can be assimilated to a "bioreactor") was always the obtaining of leachates with a biodegradable character.

After the landfill activity has ceased, and after the final reclamation of the bin (closure and final sealing), the OM contained in the leachate will eventually be fully assimilated by the microbial ecosystems present in the landfill bin. Thus, OM will certainly tend to decrease until it reaches an average of less than 0.1.

The variation in the OM content (between 2012 and 2017) may be closely related to the variation in the dietary habits of the local HW-producing population. Indeed, the peaks in OM recorded may be due to the increased consumption of fruits and vegetables during the summer season. Some peaks can also be explained by the occurrence of particular events that impact the quality of the waste produced, such as "Ramadan" and the "sheep" festival.

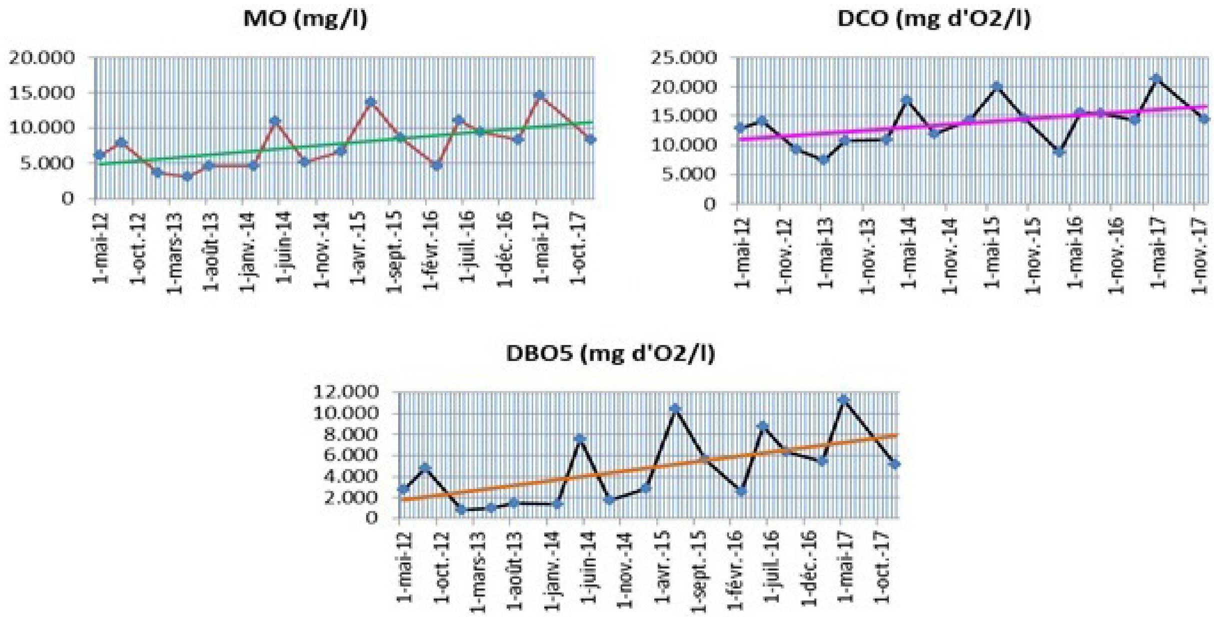

Figure 1. Evolution over time of the MO, BOD_5 and DCO content of leachate from engineered landfill of HW and HWA

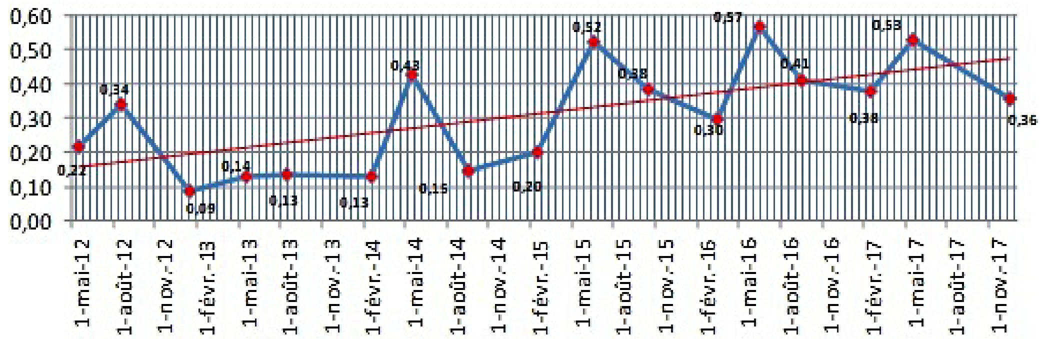

Figure 2. IB variation over time of leachate produced at TLC MA

Nitrogen

The results are shown in Figures 3 and 4. It should be noted that the measurement of the NH_4^+ ion content of the leachates was carried out for only three campaigns. This prevented the authors from verifying the relationship that may exist between the variation in the content of this element and that of NTK over the six years.

The results obtained allowed establishing the distribution of NTK between NH_4^+ and N_{org} (Table 3).

According to the results obtained:

- NTK varied around an average of 4690 mg/l. This parameter had a general tendency towards constancy. It reached its maximum of 6272 mg/l in April 2016. Peaks in the leachate content of this element were recorded

Table 3. Physico-chemical characterization of leachates fromTLC HOC between the year 2013 and 2017

Parameters	29-oct.-15	23-mars-16	29-juin-16	22-sept.-16	Average
NTK (mg/l)	3920	6272	3472	4760	4606
NH_4^+ (mg/l)	3304	5152	3080	4396	15932
N_{org} (mg/l)	616	1120	392	364	2492
NH_4^+ fraction	84.29%	82.14%	88.71%	92.35%	86.87%
N_{org} fraction	15.71%	17.86%	11.29%	7.65%	13.13%

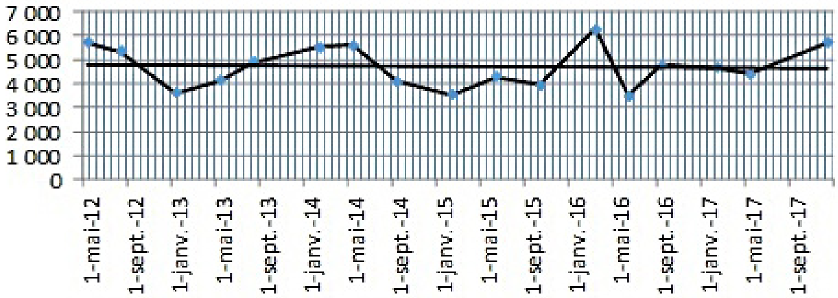

Figure 3. Evolution over time of the NTK content of the leachate from the technical landfill of HWs and HWAs

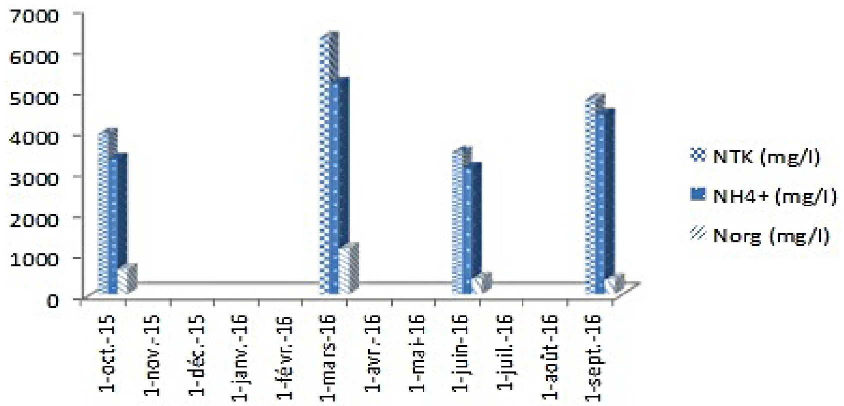

Figure 4. Distribution of NTK in leachates between organic and ammonia (NH_4^+)

along the 6 years, they generally appeared in summer;

- NH_4^+ is the indicator used by the operator of the TLC MA to assess the impact of its activity on the groundwater and surface water that are part of the site environment. This chemical compound is the main reducing agent in the leachate and can be a significant pollutant in the long term. It represents the major fraction of NTK with an average of 87% against an average of 13% of organic nitrogen.
- The NTK has not experienced a great variation along the 6 years; the trend curve is almost constant. This can be justified by the fact that this is the raw leachate that comes directly from the landfill bin (it is not stored as was the case with the leachate from the TLC OA). The intensity of the nitrogen assimilation and oxidation reactions is much lower than for leachate stored in a lagoon (the case of the TLC OA).

By way of comparison:

- The average NH_4^+ ion content of the leachate from the "wild" El Jadida landfill reached 104 mg/l after 16 years of operation [Chofqi et al., 2001]. It is less than 4027 mg/l, which is the average content measured in the leachate from the TLC MA after 6 years of operation.
- The average NTK content in the leachate from the El Jadida "wild" landfill reached 138 mg/l after 16 years of operation [El Bada et al., 2010]. At TLC MA, the average NTK leachate content reached 4690 mg/l after 6 years of operation.

Conductivity

The results are shown in Figure 5. According to the results obtained:

- The average conductivity is 37,800 µS/cm. It ranged from a maximum of 43,600 µS/cm to a minimum of 30,000 µS/cm.
- For comparison, the average conductivity of the leachate from the TLC MA is well above 11,610 µS/cm, which is the average found by El Bada et al. [2010] on the leachate from the Azemmour landfill.
- Conductivity tends to decrease over time.

This fact can be explained:

- On the one hand, by the decrease in the concentration of solutes (in the same rack) over time. This is due to the successive leaching of the buried waste by rainwater;
- On the other hand, by the continuous assimilation of minerals during the microbiological and physico-chemical processes which take place in the same bin.

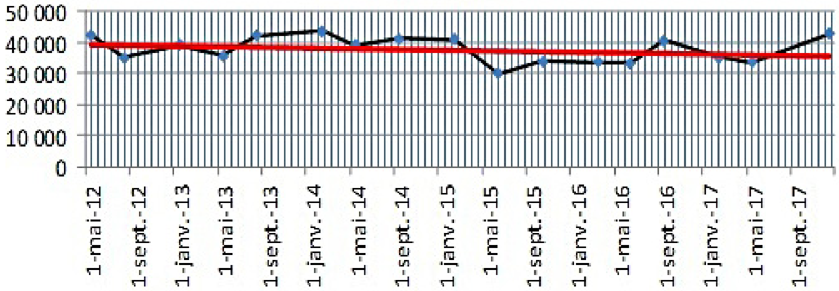

Figure 5. Temporal variation of conductivity (µS/cm)

Suspended solid

The results are shown in Figure 6. According to the results obtained:

- The average TSS leachate content is 1264 mg/l. It ranged from a minimum of 103 mg/l to a maximum of 5931 mg/l.
- The TSS leachate content has a tendency to increase over time. This can be attributed to two main factors:

On the one hand, the loading of leachate, in these materials, at the level of buried waste. This loading increases as the operation of the trap progresses. In fact, at the TLC MA, the operator covers "temporary" waste in the process of burying with soil. This is a preventive measure to reduce the release of bad odors.

On the other hand, the re-suspension of the settled matter contained in the leachate from the storage manhole (sampling point). In fact, the operator regularly sends the leachate from this manhole to the WWTP. This discharge certainly agitates and stirs the decanted materials.

Comparison of leachate from the two TLC OA and MA

The comparison between the physico-chemical characterization of the leachates of the TLC OA and those of the TLC MA concerns the concentrations of different elements measured during 5 years of operation [Oukour et al. 2020]. It is summarized in Table 4 and in the Figure 7:

On the basis of Figure 7, the concentration of leachate from TLC MA in TSS is higher than that of leachate from TLC OA. This fact may come back to the operating mode adopted by the TOC manager. The operator of the MA TLC carries out a daily provisional cover of the waste with soil, contrary to the operator of the OATLC who carries out provisional covers on a weekly basis.

On the other hand, to the way in which the leachate produced is managed. The MA TLC operator sends the leachate to a manhole before it is discharged to the WWTP. However, the operator of the MA TLC stores the leachate in large basins before sending it back to the WWTP. The leachate from the TO OA TLC then undergoes settling, which minimizes the TSS (very high residence time), unlike the leachate from the MA TLC, which is more frequently discharged to the WWTP without being stored in a tank (very low residence time).

The concentration of TLC MA leachate to ammonia nitrogen (NH_4^+) is higher than that of TLC OA leachate. This fact can also be explained by the way the leachate is managed, which is its storage at the TLC OA and its direct discharge to the

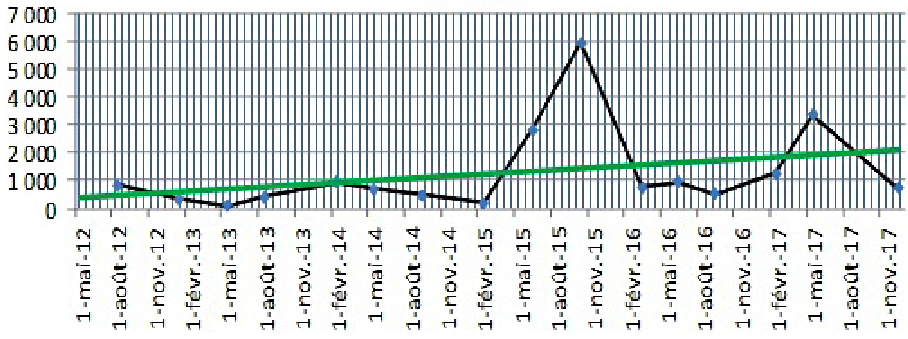

Figure 6. Temporal variation of suspended solid (mg/l)

Table 4. Comparison table between leachate from the MA CET and the OA CET

Parameters	Min		Max		Average	
	OA CET	MA CET	MA CET	OA CET	MA CET	OA CET
Con (µs/cm)	27 000	30 000	47 100	27 000	30 000	47 100
COD (mg O_2/l)	6 624	7 450	43 776	6 624	7 450	43 776
BOD5 (mg O_2/l)	761	797	25 501	761	797	25 501
MO (mg/l)	3 144	3 125	31 593	3 144	3 125	31 593
NTK (mg/l)	1 204	3 472	6 790	1 204	3 472	6 790
Azote ammoniacal (mg/l)	336	3 080	4 480	336	3 080	4 480
N-organic (mg/l)	140	364	4 235	140	364	4 235
PT (mg/l)	8	28	76	8	28	76
SM (mg/l)	88	103	730	88	103	730

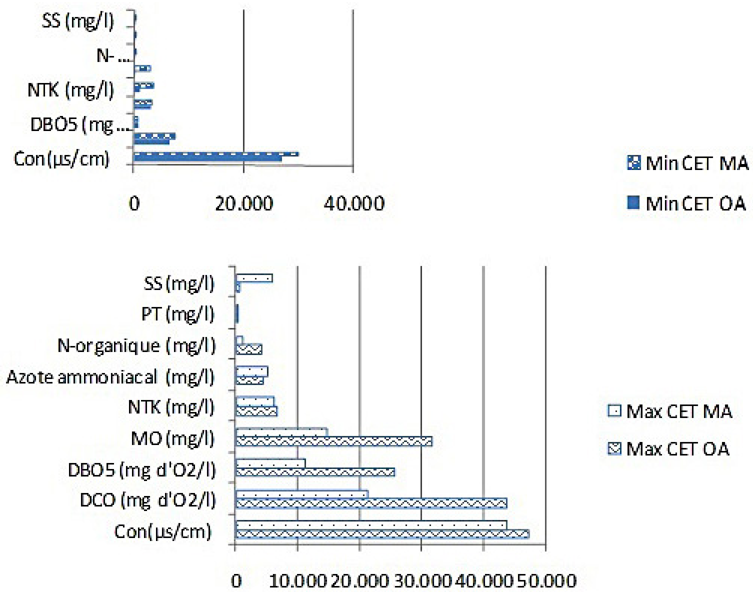

Figure 7. Comparison between leachate from the MA TLC and the OA TLC

WWTP at the TLC MA. During the leachate stay in the ponds, NH_4^+ ions are strongly assimilated by the bacteria, which is the case at the TLC OA.

CONCLUSIONS

The conducted study shows that the leachate from a TLC of HW and HHW is completely different from the leachate from a "wild" landfill. Thus, the physico-chemical characterization of the leachate from a "wild" landfill is no longer representative for the design and sizing of a WWTP for a TLC of HW and HLW.

At TLC MA, the COD, BOD_5 and MO content of the leachate tended to increase in the first six years of operation (site designed for 15 years of operation). The leachate during this phase was still biodegradable with an IB that tended to increase. The physico-chemical characterization of the leachate can be impacted by the way it is managed and by the way HW and HWA are managed.

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