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# Physicochemical Characterization of the Leachate of the Tamelast Landfill Site, Grand Agadir (Morocco)

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**ABSTRACT**

During the last decade, the Grand Agadir has faced a huge production of solid waste, similarly to all other Moroccan cities. Indeed, these solid wastes are composed of the organic matter fraction in 77%. This solid waste is buried in the landfill of Tamelast, which, with its undersized leachate storage ponds, is the source of many environmental problems. Thus, the development of a landfill site meeting environmental standards has become an urgent need. This study aims to highlight the current state of waste management in Grand Agadir, while assessing the polluting load of leachate produced at the Tamelast landfill. This was achieved by taking samples of young leachate at the outlet of the purge, followed by medium and old leachate from the storage tanks (Pond N°2 & N°3). In addition to the olfactory nuisances still persistent at the landfill area, the results of the physicochemical characterization showed that the leachates produced, if not treated effectively, would generate great environmental and health risks to the surrounding environments, by their high organic and mineral load. The electrical conductivity reflecting the mineral load, reaches a maximum value of 130 mS/cm and a minimum value of 16 mS/cm. The maximum measured values of $BOD_5$ and COD were, 43251 $mgO_2/L$ and 90240 $mgO_2/L$, respectively, indicating high biodegradable and non-biodegradable organic pollutant load. Total dry solids ranges between 231 mg/l and 9696 mg/l, which exceeds the allowable discharge limits for liquid pollutant. The analysis of heavy metals has shown strong values in terms of Iron, Silver, Nickel, and Manganese, which, similarly, exceed the limits of the standards for liquid pollutants released into natural fields.

**Keywords:** landfill, leachate, physicochemical characterization, Tamelast, Agadir, Morocco.

## INTRODUCTION

In Morocco, solid waste production is steadily increasing because of population growth and the intensification of economic activity. For a long time, the mode of disposal of household solid waste adopted usually was through its burial in open places. These places eventually were abandoned without taking into account their adverse effects on surface water, groundwater, air and soil. These sites constitute a risk to human health and a strong environmental threat (Jirou et al., 2014a,b). One of the impacts of landfilling is the production of liquid effluents rich in organic and mineral matters and metals, called leachate. The leachate is formed from the percolation of rainwater through the waste and constitutes a source of pollution (Hakkou et al., 2001). However, Morocco, like other developed countries, is showing a strong commitment to environmental protection

and the adoption and enforcement of the law 28-00 on waste management and disposal (Hakkou et al., 2001).The rational management of solid waste is a challenge for all producers, decision makers, researchers, professionals and managers involved. This is a crucial step forward in terms of environmental protection and the promotion of sustainable development (ElKadi et al., 2015). The composition and nature of household waste in Morocco remain different from those in industrialized countries. The difference concerns several parameters; in particular, the water content and the proportion of fermentable organic matter (Saoudi & Chrifi, 2007). Leachate is one of the major constraints for the management of landfills. In fact, because of their pollutant load, they represent a real threat for the environment and/or human health. Their composition varies from one discharge to another, depending on the nature and age of the waste, the climatic conditions and the topography of the site (Abouri et al., 2019; El Baghdadi et al., 2015). The composition of leachate varies over time; the leachate must undergo a different purification treatment before being discharged into the receiving environment. The Tamelast controlled landfill in Grand Agadir is among the sites that suffer from the problem of management and treatment of leachate. It generates a significant amount of these liquid effluents (Jirou et al., 2014a,b). The Grand Agadir is confronted with an increasing production of waste related to the growing consumption and demographic evolution. The produced waste is currently buried in the new controlled discharge of Tamelast, but this landfill is confronted by many environmental problems, such as the under-sizing of the storage ponds leachate and odor nuisance etc., It has become necessary to find a new site to establish a new controlled discharge (Asouam et al., 2021).

The present work is part of this process and aims to address the problem of solid municipal waste as a global matter and the particular problem of the region of Agadir landfill leachate. The present paper describes the analyses of the leachate collected of the Tamelast technical landfill in Agadir. Moreover, the risks posed by these leachates and the degree of contamination of the groundwater were estimated (Hakkou et al., 2001). As a perspective, this work plans to determine the qualitative aspects of the leachate, a prerequisite for characterizing the pollutant load as well as estimate the risks posed by the leachate with regard to the degree of contamination of the groundwater (Hakkou et al., 2001). For this purpose, an analysis of the geological and hydrogeological contexts, as well as a program of sampling and physicochemical analyses of the water upstream and downstream of the landfill were carried out (Asouam et al., 2021).

## MATERIALS AND METHODS

### Description of the Tamelast landfill

The controlled Tamelast landfill (Figure 1) is located 6 km north-east of Agadir city and it is sheltered in a NW-SE valley. It is a part of the junction area between the High Atlas and the

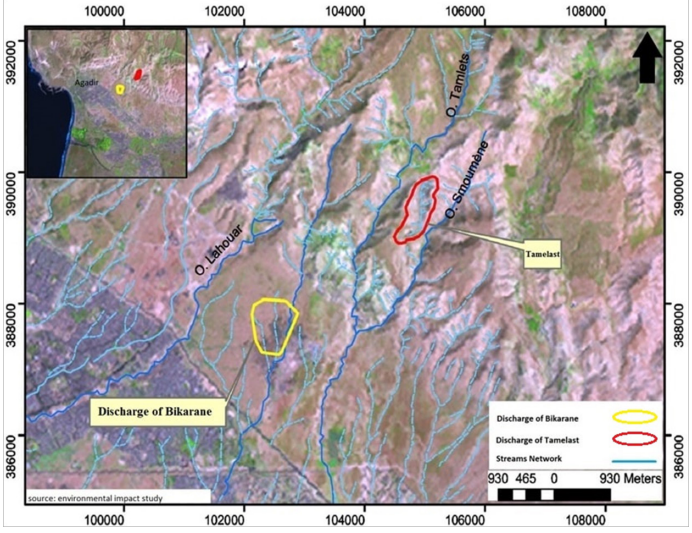


**Figure 1**. Geographic situation of the landfill of Tamelast of Agadir

western plains of Souss. This landfill has been in use since 12th April 2010.

## General data of the Tamelast landfill

Agadir city has a population of 421844 inhabitants (2014 Moroccan census). The Tamelast landfill was built to serve Agadir city and has a design capacity of 2424000 Tons over 10 years (Table 1).

The landfill has a set of disposal areas, hydraulically independent, themselves made up of cells, in which the waste is stored. The construction of the Tamelast landfill aims to manage a controlled system for the municipal waste of the large city of Agadir taking into account the following elements:

- The establishment of a system adapted to the needs and capacities of the urban municipality of Agadir,
- Reduce the risks of groundwater pollution;
- Limitation of health risks and other nuisances affecting public health;
- Securing the landfill and minimizing the risks, in particular the risks of explosion, triggering of uncontrolled fires, subsidence, slipping, flooding and the release of unpleasant odors.

## Characterization of municipal solid waste (MSW)

### Quantitative characterization of MSW

In order to estimate the quantities of waste produced at the level of the study area (Figure 2 and 3), the demographic growth, socio-economic development of the area and in particular the development of the tourist sector are mainly taken into account.

For the estimation of the solid waste from year to year, the following formula is used:

$$Qn = RPD \cdot Pm \cdot (1+ (TAD / 100)) \; n\text{-}m \; 350 \quad (1)$$

where: $Qn$ - quantity of waste produced (tones/year); $RPD$ - ratio of daily waste production adopted for each municipality and urban center, determined by: (The quantities of waste weighed at the Agadir landfill / Quantities obtained from interviews conducted with officials from different municipalities in this area); RPD = Q2017 / 350; $Pm$ - the current habitants' number (based on 2014 Moroccan census).

Certainly, the yearly amount of solid waste received at the landfill appears very high and is continuously increasing (Figure 3).

Thus, the waste is stored in two lockers or cells, the first locker (N°1) with an area of 5 ha

**Table 1**. Tamelast landfill technical characteristics board

| Designation | Information and details |
|---|---|
| The geographical coordinates | N 30°26'29", W 9°30'40" |
| Covered urban centres | Agadir – Aourir – Taghazout – Drarga – Dcheira – Inezgane – Ait melloul – Laklia – Temsia – Ouled Taima |
| Opening date | April 12, 2010 |
| Total landfill area | 41 hectares |
| Estimated life of the landfill | 25 years |
| Total tonnage to be stored over 10 years | 2424000 Tons |
| Tonnage received as of December 31, 2017 | 2540705.75 Tonnes (daily intake of 800 to 850 Tonnes) |
| Waste storage lockers | Locker 1:<br>Area: 5 ha (in operation since April 12, 2010) |
| | Locker 2:<br>Area: 6 ha (in operation since June 24, 2014) |
| Leachate pond | 5 ponds:<br>Storage capacity: 118962.63 $m^3$ |
| | 1 pond (in operation)<br>Storage capacity: 40,000 $m^3$ |
| Leachate treatment | Natural evaporation and recirculation |
| Daily leachate flow | 80 to 100 $m^3$/day |
| The volume of leachate stored | 108622.63 $m^3$ |
| Yearly recirculating rate | 20000 to 30000 $m^3$ (depending on weather conditions) |

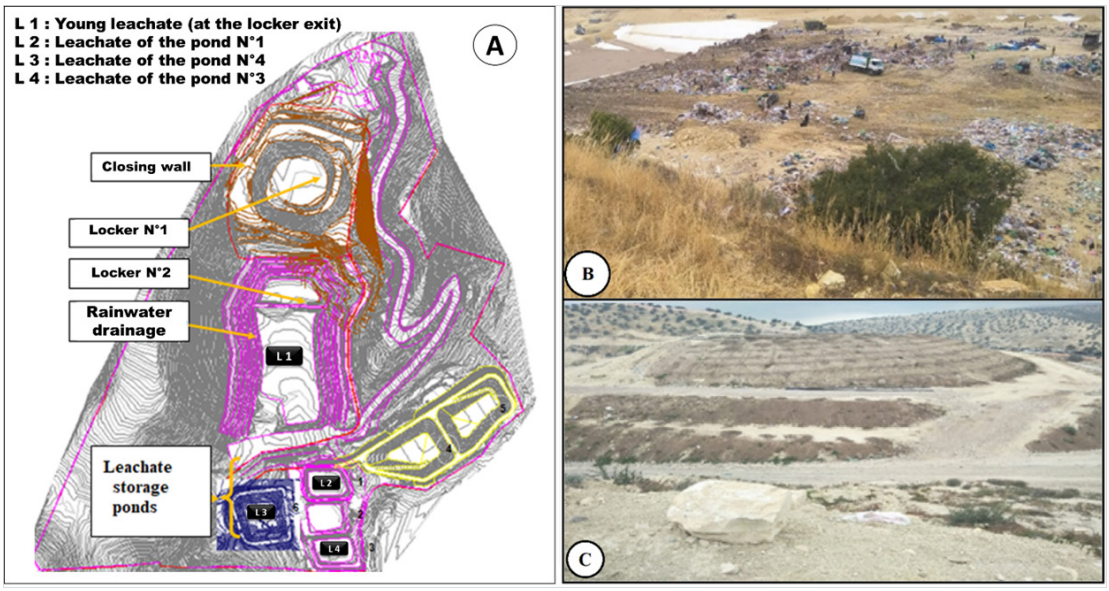


**Figure 2.** Tamelast Technical Landfill scheme and leachate sampling point (A), Locker N°2 in operation (B), Closed and rehabilitated locker N°1 (C)

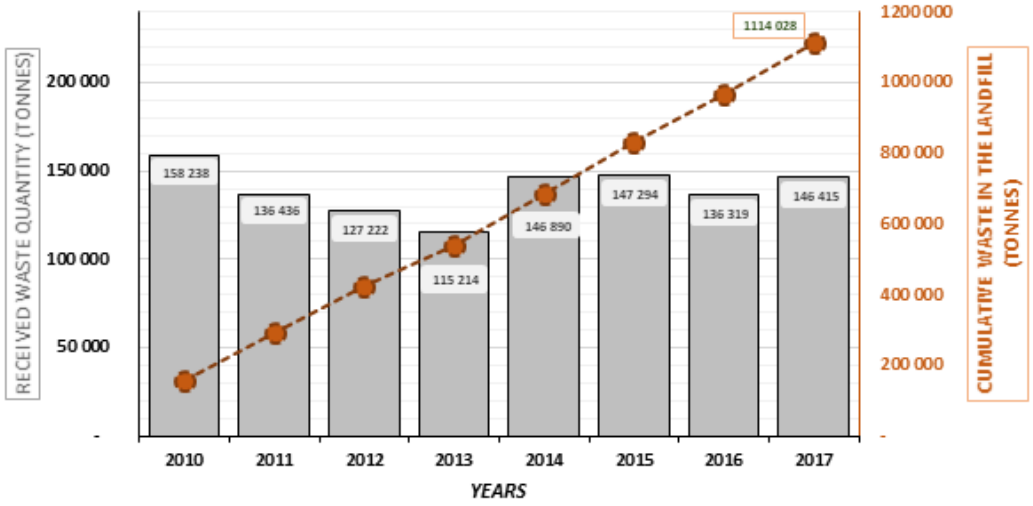


**Figure 3.** Quantitative variation of solid waste received and buried at the landfill of Tamelast

exploited on April 12th, 2010, and the second locker (N°2) with an area of 6 ha exploited on June 24th, 2014 (Figure 2). Besides, the optimal storage capacity in the bins was exceeded in 2016, resulting in an earlier fill of two years compared to the planned schedule.

## Qualitative characterization of MSW

The average composition of household waste in the municipalities of the study area does not differ from that of the other regions of Morocco; they are characterized by the predominance of organic fraction (Figure 4) (ElKadi et al., 2015).

## Characterization of leachate

The Tamelast landfill consists of five leaching ponds that are full (Figure 2A) with a total storage capacity of around 118962.63 $m^3$ until the end of 2017, with a daily flow ranging between 80 and 100 $m^3$/day, for the five ponds. While the sixth pond, which is reached 80% of its construction, is of a storage capacity of 40000 $m^3$. As for the leachate treatment, it is only made by natural evaporation and recirculation that reaches 20000 to 30,000 $m^3$/year, depending on the weather conditions. Consequently, this leachate causes several threats for the surrounding environment and habitants, namely, with the olfactory odors, the

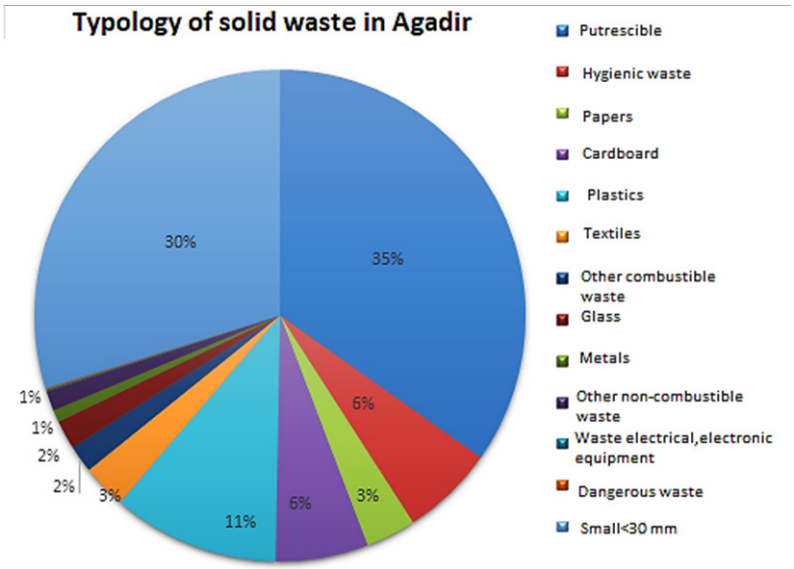


**Figure 4**. Solid waste typology at the landfill of Tamelast (Grand Agadir)

possibility of overflowing leachate outside storage ponds, and the reduction of the landfill operational time with the increase of volume of leachate storage ponds (these leachate storage ponds can be used as landfill cells).

In order to estimate the environmental risks of untreated leachate from the Tamelast landfill in Grand Agadir related to the direct disposal of this type of effluent into the natural medium without any prior treatment, it is necessary to determine the physicochemical and bacteriological characteristics of this leachate. Thus, four leachate samples (L1, L2, L3 and L4) were taken from different sections of the storage ponds at the Tamelast landfill in 2017 (Figure 2A).

The following parameters: pH, temperature and conductivity were measured in the field using specific devices. The leachate samples collected were transported to the laboratories in insulated containers at a temperature of 4°C, respecting the storage conditions required by the standards. The main indicators of pollution that were evaluated are:

- pH, Temperature (T), Electrical Conductivity (EC), and Total Dry Solids (TDS)
- COD, $BOD_5$, Sulfide and Phenol index.
- Total hydrocarbons; nitrates, chlorides, major cations, heavy metals and mercury.

These analyses were carried out in accordance with the analytical procedures based on national and international standards.

## RESULTS AND DISCUSSION

The characteristics of the leachate from municipal solid waste in the Tamlaste landfill can generally be represented in terms of basic parameters such as pH, COD, $BOD_5$, $BOD_5$/COD ratio (Abouri et al., 2019). The results of the analyses pertaining to the leachate of the Tamelast landfill are comparable to those of other technical landfills in Morocco. The results of the physico-chemical analyses of the studied leachate are presented in (Table 2).

The values in Table 2 represent the value for each point of the leachate pond.

### Temperature (T), Hydrogen potential (pH), and Electrical conductivity (EC)

The temperature of the leachate varies according to the seasonal temperatures of the Grand Agadir. The value for each point of leachate pond in the Agadir landfill measures an average of 15.9°C, a maximum value of 16.9°C, and a minimum of 14.4°C recorded in December 2017.

The temperature has a very important role in the increase of biochemical or microbial activity as well as in the water evaporation rate from the substrate.

Generally, the pH varied according to the age of the landfills. In the considered case, the pH of the leachate of the Tamelast landfill ranges from 5.9 to 8.65 with an average of 7.9. The pH of the young leachate is less than 6, whereas the pH of the old landfill leachate is higher than 8.5.

**Table 2.** Physico-chemical composition of the leachate of the Greater Agadir landfill

| Parameters | Leachate samples | | | | Standard limits |
|---|---|---|---|---|---|
| | L1: Young leachate | L2 : Basin No. 1 | L3: Basin No. 4 | L4: Basin No. 3 | |
| Temperature ° C | 16.9 | 16.4 | 15.6 | 14 | 35 |
| pH | 5.9 | 8.6 | 8.45 | 8.7 | 6.5-8.5 |
| EC (mS/cm) | 15.9 | 28.2 | 98.9 | 129.9 | 2.7 |
| COD ($mgO_2$/L) | 90240 | 9062 | 38976 | 56256 | 1000 |
| $BOD_5$ ($mgO_2$/L) | 43251 | 1369 | 22601 | 26801 | 500 |
| TDS (mg/L) | 9696 | 231 | 406 | 475 | 600 |
| Sulfides (mg/L) | <0.96 | 2 | 2 | 1 | 1 |
| Oils and fats (mg/L) | 631 | 4.71 | 6.08 | 5.8 | 50 |
| Phenol (mg/L) | 0.924 | 0.71 | 1.18 | 1.7 | 1 |
| Hydrocarbons (mg/ l) | 17.4 | 0.29 | 0.22 | 0.3 | 20 |
| Nitrates (mg/l) | 19.6 | 7.9 | 8.6 | 21 | 50 |
| Chlorides (mg/l) | 4165 | 7976 | 40768 | 63367 | |
| Al (mg/l) | 28 | 0.82 | 1.42 | 0.8 | 10 |
| Ag (mg/L) | 0.144 | 0.45 | 1.53 | 2.1 | 0.1 |
| Ba (mg/L) | 1.77 | 0.1 | 0.18 | 0.2 | 1 |
| Cd (mg/L) | 0.024 | 0.06 | 0.01 | 0 | 0.2 |
| Co (mg/L) | 0.071 | 0.1 | 0.22 | 0.3 | 1 |
| Cr (mg/L) | 0.353 | 0.58 | 1.12 | 1.4 | 2 |
| Cu (mg / l) | 1.49 | 0.19 | 0.49 | 0.4 | 1 |
| Fe (mg/L) | 240 | 5.32 | 17.3 | 20 | 3 |
| Mn (mg/L) | 9.7 | 0.05 | 0.08 | 0.1 | 1 |
| Ni (mg/L) | 0.395 | 0.74 | 1.97 | 2.6 | 0.5 |
| Pb (mg/L) | 0.54 | 0.04 | 0.08 | 0.1 | 0.5 |
| Sb (mg/L) | <0.010 | 0.06 | 0.06 | 0.1 | 0.3 |
| Sn (mg/L) | 0.072 | 0.03 | 0.05 | 0.1 | 1 |
| Sn (mg/L) | 0.188 | 0.44 | 0.2 | 0.3 | 2 |
| Zn total (mg/L) | 6.2 | 0.58 | 1.23 | 1.4 | 5 |
| Hg (mg/L) Hg | 0.015 | 0.03 | 0.01 | 0 | 0.1 |

Globally, the pH average of leachate produced at the Tamelast landfill is slightly neutral to alkaline. These values are within the lower and higher pH limits of the Moroccan standard limit, which are 6.5 and 8.5. During different stages of the development of a landfill, the pH values obtained in the leachate could be related to the low concentration of volatile organic compounds (Saadi et al., 2013). The pH remains a good indicator of the different phases of degradation and alteration of waste (Elmaghnougi et al., 2018).

The electrical conductivity of the Tamelast leachate is very high, ranging between 15.9 and 129.9 mS/cm for the four-leachate samples. This range indicates a high mineralization activity and also the high load of chloride ions. The leachate is characterized by high electrical conductivity since the landfill receives industrial waste, agri-food and waste from the port of Agadir that contains high load of salts. It is recommended for landfill managers to adopt a separating system and treatment of industrial waste generated by the port's activities, which lead to decrease the salt load of the leachate emanated from the household wastes (Jirou et al., 2014).

## COD, $BOD_5$

The studied leachate is characterized by high levels of organic matter, in terms of COD values, which reaches 90240 $mgO_2$/L for the first sample (L1: young leachate at the exit of the locker). In terms of $BOD_5$, the maximum value is 43251 $mgO_2$ /l, reported for the first same sample (L1).

The $BOD_5$/COD ratio was between 0.47 and 0.57. This indicates high biodegradability potential of the leachate produced at the Tamelast landfill, which is similar to the majority of Moroccan landfills, as reported by Saadi et al. (2013). The $BOD_5$/COD ratio indicates that biological processes may be suitable for the treatment of fresh leachate due to a higher fraction of biodegradable organic matter, while the physico-chemical processes are more adapted to the treatment of stabilized leachates, due to their high non-biodegradable organic material fraction (Abouri et al., 2019). Generally, several factors influence the production and composition of leachate. The biochemical and physical transformations commonly cause changes in the moisture content and affect the age of the landfill. Indeed, the volume of leachate is mainly affected by the initial moisture content of the waste, the composition of the waste, the mode of operation of a landfill, as well as climatic and hydrogeological conditions (Arabi et al., 2020). These factors vary considerably from one landfill to another (Słomczyńska & Słomczyński, 2004).

### Heavy metals and major ions

The concentration of heavy metals in the sampled leachate meets the discharge standards with the exception of Iron (240 mg/L), Silver (1.49 mg/L), Nickel (2.6 mg/L), and Manganese (9.7 mg/L) exceeding the standard limits recommended by the environment authorities, which are fixed at 3 mg/L, 1 mg/L, 0.5 mg/L, and 1 mg/L, respectively All of these results show that releasing leachate into the environment near the landfill is a source of contamination. According to the analyses of the leachate that were carried out, the average values of the physicochemical parameters show the leachate as responsible for a diversified and high pollutant load. The leachate stock of the Grand Agadir landfill has a negative impact on the environment, especially on the air quality of the neighborhoods of the city of Agadir and adjacent areas. All leachate samples show a metallic pollution with high heavy metals concentration (Mekaikia et al., 2007).

Three types of leachate have been distinguished in the literature: young leachate, which is characterized by a relatively high organic biodegradable load, the intermediate leachate with a decreased organic load, and finally, the stabilized leachate, which is mainly composed of humic refractory substances resulting from the biodegradation process. Due to their variable composition over time, the different types of leachate must undergo different purification treatments before they are released into the receiving medium. This study may formulate a direction for future research: monitoring of landfill waste deposition to analyze the actual and potential natural, technological and social threats, with the aim to support the equity and the sustainability, thus, increasing of availability and accessibility of resources toward climate change and social change (McCarthy et al., 2018; Koh et al., 2016).

## CONCLUSIONS

The leachate emanated from the solid waste buried in the Tamelast landfill is characterized by high organic load and exceeds the values to be directly discharged in the environmental areas. These organic materials under anaerobic degradation process lead to an important mineral charge, mainly reflected by high electrical conductivity. Moreover, this leachate produced in significant volumes and with no specific treatment, is stocked into evaporating ponds, and deeply affects the quality of air due to its odor load. Unpleasant smells are often driven by the wind, which is a nuisance to the population of neighboring areas. In addition, the nearest habitants are highly exposed to the volatile substances coming from these leachate ponds, as well as to a direct entry of contaminated water, when leachate is released to the environment and reaches surface or groundwater (during recreational water activities). In summary, the solid waste at the landfill of Tamlast is subjected to the degradation processes related to complex biological and physicochemical reactions. The organic and mineral substances that generate pollution are mainly of organic and metallic types. It must be due to the natural biodegradation of confined waste combined with the anthropogenic components that release several toxic substances into the environment. The two direct resources for the population living near a landfill are air and water. Experts have already analyzed the problem of the leachate of the Agadir landfill, and have been led to implementing several solutions currently used in Morocco, as evaporation (natural or forced) in specific ponds, physico-chemical treatment, and combined treatment. For the Tamelast landfill, an in-depth

technical study is required to establish the most appropriate method to adopt a specific treatment.

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