Optimizing Leachate Management at Al-Hoceima Landfill: Investigating Bio-Pre-Treatment and Reverse Osmosis Approaches

Imane dira[1], *Aouatif* El abdouni[1], *Khadija* Haboubi[1], *Hasnae* El Allaoui[1], *Chaimae* Haboubi[1], *kawthar* El Ahmadi[1] , *Yahya* El Hammoudani[1], *Fouad* dimane[1], *Issam* Hanafi[1]

[1]Laboratory of Engineering Sciences and Applications, National School of Applied Sciences of Al Hoceima, Abdelmalek Essaâdi University, Al-Hoceima, Morocco.

Abstract. Leachate poses a significant risk to soil, rivers, and groundwater, necessitating effective collection and treatment strategies. This study evaluates an integrated leachate management approach at the Al-Hoceima landfill, combining biological pretreatment with reverse osmosis. Initial analyses revealed high organic content in the leachate, with BOD5 and COD levels at 1,530 mg O2/l and 10,805 mg O2/l, respectively, and an ammonium concentration of 4,827 mg/l. Biological pretreatment achieved a 66% reduction in COD and a 56.02% decrease in BOD5. Further purification via reverse osmosis significantly lowered COD and BOD5 by 97% and 98.46%, respectively, ensuring compliance with Moroccan environmental standards. These results demonstrate the effectiveness of our integrated approach in mitigating the environmental impact of landfill leachate.

Keywords: *Leachate Landfill, Physicochemical Analysis, Reverse Osmosis.*

1 Introduction

Morocco faces significant challenges in pollution control due to the rising volume of household and industrial waste, complicated by their diverse composition [1]. Contributing factors include population growth, urbanization, economic development, and evolving lifestyles [2]. Local communities struggle to manage this waste, hindered by its sheer volume and resource limitations [3]. At the Al Hoceima Waste Disposal Center, approximately 80 tons of Class I waste are landfilled daily, a common method across Moroccan landfills [4,5]. Yet, landfilling has its drawbacks, including odor emissions, biogas production, and potential leachate contamination [6].

Landfill leachate, a mix of rainwater, decomposing waste byproducts, and inherent moisture, contains dissolved organic matter, salts, heavy metals, and other pollutants [7]. Al Hoceima landfill has implemented an advanced treatment system combining biological pretreatment with reverse osmosis to address these issues. This study assesses both the untreated and treated leachate to determine the treatment's effectiveness in reducing environmental impact.

2 Material and Methods

The Al Hoceima landfill, situated 6 kilometers southeast of Al Hoceima city, occupies 34 hectares and serves a population of 140,000 from surrounding areas. It operates in a

Mediterranean climate with a non-permeable substrate that supports a temporary pond, despite regional groundwater deficits [8-11].
Analyses include suspended solids (SS), determined by centrifugation and drying at 105°C, and biochemical and chemical oxygen demand (BODn, COD) using standard dilution and titration methods. Total Kjeldahl Nitrogen (TKN), ammonium (NH4), and total phosphorus (TP) are measured following respective ISO and NF standards [17-24].

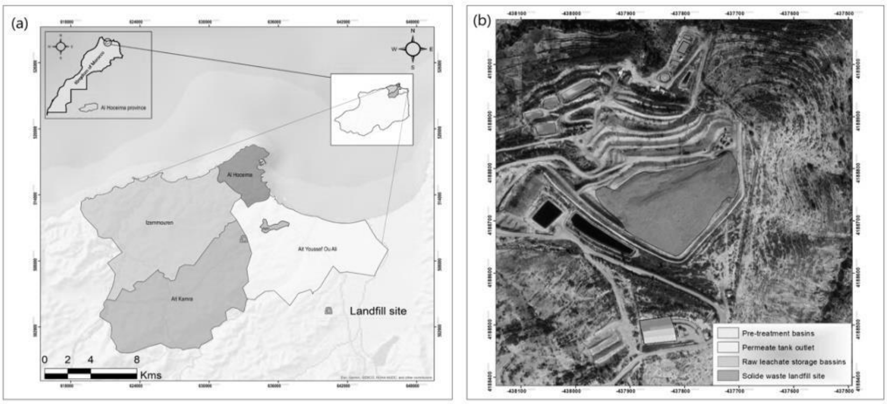

Fig.1. Geographical Coordinates of the Controlled Landfill in Al Hoceima City.

During the sampling phase at the Al Hoceima landfill site, key physical parameters such as pH, conductivity, and temperature were precisely measured using the "Accumet basic ab15" pH meter and "Intelligent pH YK-2001PH Conductivity Meter," adhering to NF T 90-008 and NF EN 27888 standards, respectively [13-16]. In the laboratory, suspended solids (SS) were quantified by the weight difference before and after centrifugation and drying at 105°C, as per AFNOR standard T 90-105-2 [17-18]. Biochemical (BODn) and Chemical Oxygen Demand (COD) were determined using dilution and titration methods, following NM ISO and NF standards [19-21]. Total Kjeldahl Nitrogen (TKN), Ammonium (NH4), and Total Phosphorus (TP) levels were analyzed in line with NM ISO and NF standards [22-24]. The leachate treatment involved a two-step process: biological pretreatment using aerated activated sludge to facilitate Biological Catalytic Oxidation (BCO) reducing the organic load, followed by reverse osmosis, which effectively removes all particulates and dissolved substances, ensuring the treated wastewater meets environmental safety standards [25,26].

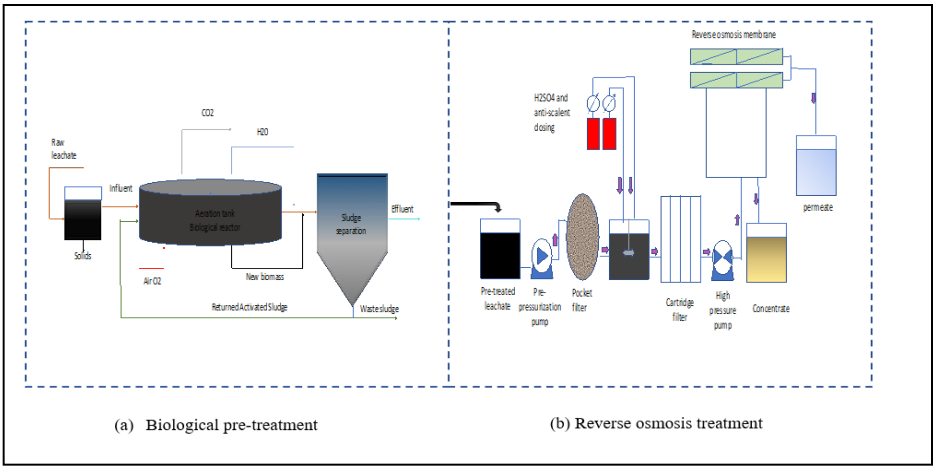

Fig.2. Primary Treatment Processes for Al Hoceima Controlled Landfill.

3 Results and discussions

The assessment of household waste leachate treatment focuses on measuring reductions in key parameters such as pH, temperature, COD, BOD5, suspended solids, total nitrogen, ammonium, total phosphorus, and electrical conductivity, collectively referred to as purification efficiencies. These benchmarks are crucial for evaluating the effectiveness of the treatment process. Data presented in Table 1 details the changes in these physicochemical parameters observed at various stages of the treatment.

Table 1. The results of physicochemical analyses of the leachates.

Parameters	**raw leachate C1**	**pretreated leachate C2**	**Permeat C3**
- Leachate temperature (˚C)	19,2	20	19,5
-PH	8,50	8,50	8,95
-Electrical Conductivity (mS/cm)	29,300	20.66	3,920
- DCO	10 805	3618	74,3
-DBO$_5$	1530	702	39,7
-Total Kjeldahl Nitrogen (NTK)	5253	450	257
-Ammonium (NH4+)	4827	347	250
-Total Phosphorus (PT)	58,6	7.40	0,426

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-suspended solids (SS)	55,7	108	4,01

During sample collection at 20°C, conditions were ideal for mesophilic microorganisms, which thrive between 20-40°C and are crucial for biological processes [27-28]. Leachate pH varied from 8.50 to 9.95, reflecting alkaline conditions likely due to low volatile organic compounds during the acetic fermentation stage, essential for methanogens [28-29].
Electrical conductivity changes in leachate were significant, initially at 29.3 mS/cm due to high soluble salts, which reduced by 29.46% after biological pretreatment and further by 81% post-reverse osmosis, indicating effective mineralization reduction [30-31]. COD levels dropped from 10,805 mg/L to 3618 mg/L after biological pretreatment and to 74.3 mg/L following reverse osmosis, showing significant organic pollutant reduction [32]. Similarly, BOD5 levels decreased from 1530 mg/L to 702 mg/L after biological treatment and further to 39.7 mg/L post-reverse osmosis, indicating substantial organic matter reduction [33].
Suspended solids initially increased post-biological pretreatment from 55.7 mg/L to 108 mg/L but drastically reduced to 4.01 mg/L after reverse osmosis [34]. Total Kjeldahl Nitrogen dropped from 5253 mg/L to 450 mg/L after biological pretreatment, showing a 91.43% reduction [34]. Ammonium levels decreased from 4827 mg/L to 347 mg/L after biological treatment and further post-reverse osmosis [35]. Total Phosphorus concentration significantly reduced from 58.6 mg/L to 7.4 mg/L after biological treatment and to 0.426 mg/L following reverse osmosis, demonstrating the effectiveness of the treatment process [36].

Table 2. Variation before and after treatment.

Parameters	Raw Leachate	Pretreated Leachate	Permeate
Temperature of leachate (°C)	**19.2**	**20**	**19.5**
pH	**8.5**	**8.5**	**7.95**
Conductivity (µS/cm)	**29.300**	**11.660**	**3.920**
COD (Chemical Oxygen Demand)	**10.805**	**3.618**	**74.3**
BOD (Biochemical Oxygen Demand)	**1.530**	**702**	**59.7**
NTK (Total Kjeldahl Nitrogen) mg	**52.53**	**4.5**	**257**
NH (Ammonia)	**4.827**	**347**	**250**
PT (Total Phosphorus)	**58.6**	**7.4**	**0.426**
MES (Suspended Solids)	**55.7**	**108**	**4.01**

4 Conclusion

Our study found high levels of both natural and synthetic pollutants in leachate from the Al Hoceima landfill. We demonstrated that a combination of biological pretreatment and reverse osmosis can reduce pollutants by up to 97%, aligning with Morocco's stringent water discharge standards. This method is not only technically sound but also cost-effective, representing a significant advancement in leachate management.
Yet, our work is far from complete. Further investigation is needed into the impacts of reverse osmosis concentrate, particularly concerning heavy metal pollution, to assess its

long-term environmental effects. It's also essential to evaluate the economic feasibility of scaling these treatments.
An important next step is to explore methods to minimize initial waste moisture, aiming to improve waste management at its source. Such proactive measures could enhance the effectiveness of disposal techniques and support sustainable waste management practices. This research underscores the urgent need for innovative solutions to tackle pollution, providing hope for regions grappling with waste management challenges. Continuing to refine and test these methods is crucial to ensure a cleaner, safer environment for future generations.

References

1. **H., El Fadili, M., Ben Ali, M., El Mahi, A. T., Cooray, & E.** A, **Mostapha Lotfi.** comprehensive health risk assessment and groundwater quality for irrigation and drinking purposes around municipal solid waste sanitary landfill : A case study in Morocco. *Environmental Nanotechnology, Monitoring & Management*, *18*, 100698. (2022)
   https://doi.org/10.1016/j.enmm.2022.100698
2. **M. H., El Jalil, H., Elkrauni, M., Khamar, A., Bouyahya, H., Elhamri, E., Cherkaoui, & A.** , **Nounah.** Physicochemical characterization of leachates produced in the Rabat-Salé-Kénitra Region landfill technical center and monitoring of their treatment by aeration and reverse osmosis. *E3S Web of Conferences*, *150*, 02013. (2020)
3. **N. E., Bada, O., Assobhei, A., Kebbabi, R., Mhamdi, & M.**, **Mountadar.** Caractérisation et prétraitement du lixiviat de la décharge de la ville d’Azemmour. *Environnement, Ingénierie & Développement*, *N°58-Avril 2010*, 30. (2010) https://doi.org/10.4267/dechets-sciences-techniques.3016
4. **A., Rassam, B., Bourkhiss, A., Chaouch, & M., Bourkhiss.** Caractérisation des lixiviats et évaluation de la pollution de la décharge de la ville dAl Hoceima/Maroc. *ScienceLib Editions Mersenne*, *4*(120602), 1-7. (2012)
5. **H., Chiguer, F., El Khayyat, O., El Rhaouat, R., Rifki, A., Bensaid, K., El Kharrim, & D.** , **Belghyti.**Evaluation de la charge polluante des lixiviats de la décharge contrôlée de la ville d’Essaouira (MAROC) [Evaluation of the pollution load of leachates from the landfill in the city Essaouira (MOROCCO)]. *International Journal of Innovation and Applied Studies*, *14*(3), 863. (2016)
6. **A., Charki.** Synthesis of leachate from the Al Hoceima controlled landfill and characterization (Morocco, North of Africa). *Moroccan Journal of Chemistry*, *10*(3). (2022)
7. **S., Renou, J. G., Givaudan, S., Poulain, F., Dirassouyan, & P.**, **Moulin.** Landfill leachate treatment : Review and opportunity. *Journal of Hazardous Materials*, *150*(3), 468-493. (2008)
   https://doi.org/10.1016/j.jhazmat.2007.09.077
8. **K., Haboubi, A., El Himri, I.** , **Hanafi.** Sources and Propagation Mechanism of Odor Nuisance in the Landfill of Al Hoceima, Morocco. *Biomed J Sci & Tech Res, 51(4).* (2023)

9. **K., Andaloussi, F., Dimane, K., Haboubi, I., Hanafi, &A. , El Himri.** Impact Des Facteurs De Pollution Sur La Qualite Des Eaux De La Zone Aval De La Vallee De L'oued Nekor (Al-Hoceima). *European Scientific Journal, 13(3).* (2017)
10. **A., Elabdouni, K., Haboubi, I., Merimi, & M.S.M El Youbi.** Olive mill wastewater (OMW) production in the province of Al-Hoceima (Morocco) and their physico-chemical characterization by mill types. *Materials Today: Proceedings.* (2020)
    https://doi.org/10.1016/j.matpr.2020.03.806
11. **Charki, A., El Ouarghi, H., & Ahari, M.** Treatability tests of synthetic leachate from the Al-Hoceima city-controlled landfill. *E3S Web of Conferences, 314, 07007.* (2021)
12. **R., Laribi, W., Chekaoui, & M. , Aberkan.** Suivi des paramètres de l 'évolution de la qualité physicochimique des eaux de source selon la méthode de stockage et de traitement. (2021)
13. **A., El Abdouni, S., Bouhout, I., Merimi, B., Hammouti, & K., Haboubi**. Physicochemical characterization of wastewater from the Al-Hoceima slaughterhouse in Morocco . Caspian Journal of Environmental Sciences, 19 (3), pp. 423-429. (2021)
    DOI: 10.22124/cjes.2021.4929
14. M., Elazzouzi, K., Haboubi, M.S., Elyoubi, **&** A. A El Kasmi. Developed Low-Cost Electrocoagulation Process for Efficient Phosphate and COD Removals from Real Urban Wastewater . ES Energy and Environment, 5, pp. 66-74. (2019)
    DOI: 10.30919/esee8c302
15. **AFNOR.** NF-T-90-008. Recueil des Normes Françaises. **(**2001)
16. **AFNOR.** NF-EN-27888. Recueil Des Normes Françaises. (1994)
    M., Elazzouzi, K., Haboubi, M.S., Elyoubi, A. El Kasmi. Development of a novel electrocoagulation anode for real urban wastewater treatment: Experimental and modeling study to optimize operative conditions . Arabian Journal of Chemistry, 14 (1), art. no. 102912, . (2021)
    DOI: 10.1016/j.arabjc.2020.11.018
17. **AFNOR**. T-90-105-2. Recueil Des Normes Françaises. (1997)
18. **A., EL Abdouni, K. , Haboubi, N. , Bensitel, S. , Bouhout, K., Aberkani, & M.S. , El Youbi.** Removal of organic matter and polyphenols in the olive oil mill wastewater by coagulation-flocculation using aluminum sulfate and lime. Moroccan Journal of Chemistry, 10(1), 191- 202. (2022)
    https://doi.org/10.48317/IMIST.PRSM/morjchem-v10i1.28852
19. **NM ISO 5815-1, NM ISO 5815-2** .Qualité de l'eau — Détermination de La Demande Biochimique En Oxygène Après n Jours (DBOn) — Partie 1 : Méthode Par Dilution et Ensemencement Avec Apport d'allylthiourée. (2012)
    https://doi.org/10.1016/j.apgeochem.2013. 03.008
20. **NM 03.7.54** - 2013. Qualité de l'eau - Détermination de La Demande Chimique En Oxygène (DCO).
21. **NM ISO 5663**-2001. Qualité de l'eau - Dosage de l'azote Kjeldhal - Méthode Après Minéralisation Au Sélénium.
22. **NM ISO 5664** (2001). Qualité de l'eau - Dosage de l'ammonium - Méthode Par Distillation Titrimétrie.
23. **NM ISO** 6878 (2012). Qualité de l'eau - Dosage Du Phosphore - Méthode Spectrométrique Au Molybdate d'ammonium.

24. **I. A., Tałałaj, P., Biedka, & I. , Bartkowska.**Treatment of landfill leachates with biological pretreatments and reverse osmosis. *Environmental Chemistry Letters*, *17*(3), 1177-1193. (2019)

    https://doi.org/10.1007/s10311-019-00860-6
25. **Z.** ,**Youcai.**Chapter 5—Leachate Treatment Engineering Processes. In Z. Youcai (Éd.), *Pollution Control Technology for Leachate from Municipal Solid Waste* (p. 361-522). (2018).

    https://doi.org/10.1016/B978-0-12-815813-5.00005-X
26. **M. V., Kevbrina, D. S., Okhapkina, D. S., Akhlynin, I. K., Kravchenko, A. N., Nozhevnikova, & V. F., Gal'chenko.** Growth of Mesophilic Methanotrophs at Low Temperatures. *Microbiology, 70(4), 384–391.* (2001)

    https://doi.org/10.1023/A:1010417724037
27. **K., Haboubi, A., El Abdouni, Y., El Hammoudani, F., Dimane, C., Haboubi.** Estimating Biogas Production in The Controlled Landfill of Fez (Morocco) Using The Land-Gem Model.Environmental Engineering and Management Journal,Vol. 22, No. 11, 1813-1820.(2023)

    http://doi.org/10.30638/eemj.2023.157
28. **S.**, **Trabelsi.**Etudes de Traitement Des Lixiviats Des Déchets Urbains Par Les Procédés d'oxydation Avancée Photochimiques et Électrochimiques : Application Aux Lixiviats de La Décharge Tunisienne "Jebel Chakir". PhD Thesis, Université Paris-Est. (2011)
29. **E., Derwich, Z., Benziane, & L., Benaabidate,** Etude des paramètres physico-chimiques caractérisant les lixiviats de la décharge publique de la ville de Sefrou (Maroc). *Environnement, Ingénierie & Développement.* (2009)

    https://doi.org/10.4267/dechets-sciences-techniques.246
30. **A., Touzani, Y., El Hammoudani, F., Dimane, M., Tahiri, , K. Haboubi**. Characterization of Leachate and Assessment of the Leachate Pollution Index – A Study of the Controlled Landfill in Fez. Ecological Engineering and Environmental Technology, 25 (4), pp. 57-69. (2024)

    Doi: 10.12912/27197050/183132
31. **J., Rochard.**Traitement de la pollution d'origine vinicole en Champagne [epandage, traitement par lit bacterien, stockage aere avec rejet etale]. (1986)
32. **J., Wu, H., Zhang, P.J., He, & L.M.** , **Shao.** Insight into the heavy metal binding potential of dissolved organic matter in MSW leachate using EEM quenching combined with PARAFAC analysis. *Water Research, 45(4).* (2011)

    https://doi.org/10.1016/j.watres.2010.11.022
33. **D., Kulikowska, & E.**, **Klimiuk.**The effect of landfill age on municipal leachate composition. *Bioresource technology, 99(13), 5981-5985.* (2008)
34. **Z., Mejraoua, & N.E.**, **Zine.**Caracterisation Physico-Chimique Du Lixiviat De La Decharge Sauvage De Meknes. *European Scientific Journal, ESJ*, *13*(33), Article 33. (2017).

    https://doi.org/10.19044/esj.2017.v13n33p154
35. **S., Hebabaze, C., Brand, Z., Moutaib, C., Riechelmann, S., Raffy, M., Kraume, & M., Chlaida.** Etude des performances d'un réacteur biologique séquentiel" SBR" pour le traitement des effluents d'une entreprise agroalimentaire marocaine [Performance of

a Sequencing Batch Reactor for the Treatment of Food Industry Wastewater in Morocco]. *International Journal of Innovation and Applied Studies, 9(2), 744.* (2014)