Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2023.29916

307 (2023) 251–257
September

Treatment of household waste leachates of the city of Mostaganem using the up-flow anaerobic sludge blanket technique

Noreddine Guermoud[a,*], Habib Bouzid[b], Nouredine Benderdouche[a]

[a]*Department of Process Engineering, Laboratory of Structure, Development and Application of Molecular Materials (SEA2M), University Abdelhamid Ibn Badis of Mostaganem, BP 227 Route de Bel-hacel Mostaganem, Algeria, Tel.: +213 45 43 45 03; emails: guermoud27000@yahoo.fr (N. Guermoud), noredine.guermoud@univ-mosta.dz/benderdouchen@yahoo.fr (N. Benderdouche)*
[b]*Department of Process Engineering, University Abdelhamid Ibn Badis of Mostaganem, Algeria, email: habib_bouzid@yahoo.fr*

Received 13 May 2023; Accepted 23 August 2023

ABSTRACT

The present study investigates the physico-chemical characteristics of the fresh leachate of household waste at the entrance of the technical landfill center (CET-Sour) of the city of Mostaganem. The leachate is treated using the up-flow anaerobic sludge blanket (UASB) technique. The amount of household and similar waste attained about 61,775 tons as of 2021 corresponding to a daily generation of 0.91 kg per capita. This waste was essentially composed of organic matter (63.5%), paper (12.5%), plastic (14.7%), metal (1.1%) and glass (1.5%). The amount of leachate produced during the low and high-water periods in the city of Mostaganem varied between a minimum of 40,870 L in December 2021 and a maximum of 127,930 L in August 2021. Physico-chemical analysis of the leachates of the study area shows a high concentration of organic matter with a chemical oxygen demand (COD) of about 24,650 mg·O_2/L and a pH of 4.47. Application of the UASB technique under the climatic conditions of the study area to the leachate before direct discharge into the environment resulted in a COD abatement of 94% and a near neutral pH (pH = 6.89). The results obtained show that the UASB technique is suitable for fresh leachate treatment and could be used as an efficient process to reduce pollutant load.

Keywords: Leachate; Household waste; Anaerobic treatment; Up-flow anaerobic sludge blanket (UASB); Mostaganem

1. Introduction

Socio-economic activities, population growth and changes in consumption patterns generate a significant amount of urban solid waste. In 2020, national waste generation was estimated at 13.5 million·ton/y [1] resulting in large volumes of leachate with high organic load and large amounts of complex chemical compounds, which are difficult to degrade. According to Kaschl et al. [2], a large part of this waste is landfilled, which poses a real and permanent threat to the environment. The transition from the linear "all to the landfill" model, practiced to date, to a circular model more respectful of the environment and sustainable development, and economically profitable, must necessarily go through a better knowledge of the waste that society generates.

Leachate refers to water that has percolated through the waste and become laden with pollutants. The polluted effluents must be treated due to the increasing requirements of the discharge standards [3]. Several treatment techniques including reverse osmosis, anaerobic treatment, nanofiltration, chemical treatment, physico-chemical treatment, membrane bioreactor [4,5] have been utilized and are considered potentially effective for leachate treatment. The up-flow anaerobic sludge blanket (UASB)

* Corresponding author.

treatment is a technique that has been lately used for anaerobic treatment in many countries (Brazil, Colombia, Cuba, Mexico, Uruguay) [6].

This technique can operate even at low temperatures (5°C and 20°C), which facilitates treatment throughout the year [7]. The use of this system for the treatment of domestic wastewater is related to its excellent performance in the treatment of organic pollution [8–11].

Several authors [8,9,12,14] report that the performance of the system is directly linked to the organic load of the effluents and to the hydraulic retention time in the reactor. Chemical oxygen demand (COD) abatement after treatment by UASB generally attains values ranging from 80% to 95%.

In Algeria, treatment methods used by some municipalities are limited to biological depollution in aerated basins and reverse osmosis [13]. These techniques have proved inadequate as the purification efficiency of biological treatment is too low [10] while reverse osmosis remains a relatively expensive technique and produces a highly polluted concentrate that requires specific management and disposal [14,15]. The choice of a treatment technique must take into account its purification efficiency and cost effectiveness. Seasonal variations in the quantity and quality of leachate generated by household and similar waste in Algeria further complicate the choice of treatment, which remains a challenge to address.

The main objective of this study is to estimate the composition of the household waste of the city of Mostaganem and characteristics of the fresh leachate at the entrance of the nearby Sour Technical Landfill Center and to test the efficiency of the treatment by UASB by determining the adequate hydraulic residence time to achieve a COD removal rate of more than 90% to meet requirements. The choice of this technique is justified, on the one hand, by the climatic conditions of the city of Mostaganem where the hot season lasts more than 7 months with temperatures that remain above 13°C and which are considered very favorable to anaerobic treatment according to the UASB technique [7,10,12,16,17], and on the other hand, its relative low cost and ease of use.

2. Materials and methods

2.1. Study area

The city of Mostaganem is located in the northwest region, about 363 km west of Algiers, and is bordered by the Mediterranean Sea to the north and by Oran (Algeria's second largest city) (Fig. 1) to the west. It has an area of 2,269 km^2 and has a population of 907,140, 185,443 of which live in the city of Mostaganem (2021). It is a coastal city with 120 km of coastline. The climate is semi-arid, mild in winter and slightly humid at an altitude of over 500 m. Rainfall is irregular and varies between 250 and 500 mm/y. The average temperature is 18°C near the coast and 25°C inland [18]. Household waste from the city of Mostaganem is collected by packer trucks and evacuated directly to the Sour Municipality TLC. The center is located approximately 15 km northwest of the city of Mostaganem (Table 1). It includes 2 landfill cells, a weighbridge and three leachate recovery basins. The extension of the site is under study with the possibility of adding 2 additional landfills.

The Sour TLC covers an area of 14 hectares and is considered the largest in the Wilaya of Mostaganem. It entered

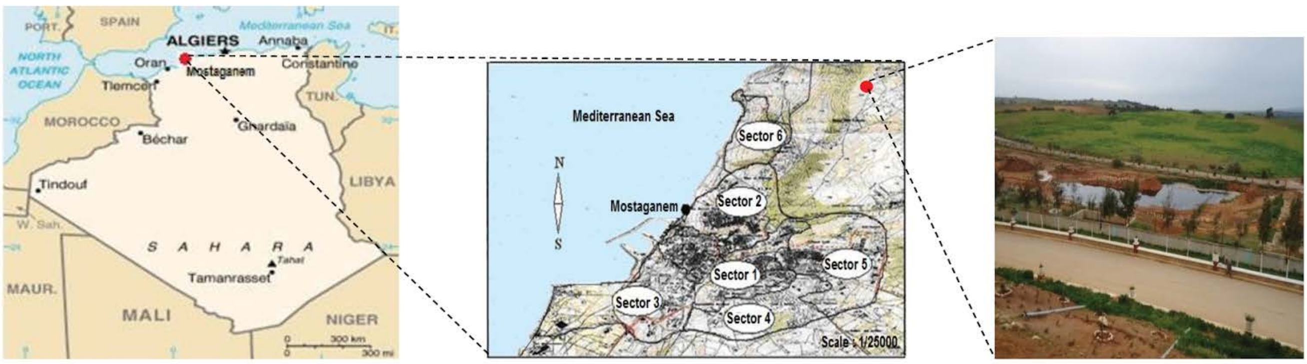

Fig. 1. Geographic location of the study area.

Table 1
Geographic characteristics of the Sour Technical Landfill Center

Technical Landfill Center of Sour/Mostaganem	
Geographic location	Located in the southwest of the municipality of Ain Tadless (Algeria)
Lambert coordinates	X = 279.40 m and Y = 295.85 m
Size of the site	14 ha
Distance from traffic routes	07 km from National Road 11
Site layout	Fenced
Site extension	Possible encroachment on agricultural land

its operational phase on November 1, 2011 receiving a daily average of 169 tons of household waste produced by the municipality of Mostaganem.

2.2. Determination of the household waste composition

To determine the composition of household waste in the city of Mostaganem, six sectors (housing area) were selected (Fig. 1). We took samples of 1 m^3 of waste from each truck. The waste loading vehicles were chosen randomly according to their rotation frequency and their collection route. The collection and transport of the household waste to the sorting center was carried out by the cleaning service of the city of Mostaganem. The waste was then dumped on a sorting platform. We sorted the dumped waste into different fractions using the quartering method [19]. A simplified classification with seven categories was adopted [20]. We then recovered the sorted materials in plastic bags, each category was weighed to determine its composition. The test was repeated every month during the study period, from January 2021 to December 2021 on a mass of 400 kg.

2.3. Quantitative evaluation and characterization of fresh leachate

Leachate volumes were measured at the end of the collection operation. The operation was carried out by emptying the leachate storage tank, which was located under the packing bucket, into a graduated container to determine the volume recovered. The determination of the recovered waste tonnage is deduced from the difference in weight at the start and end of the collection by daily weighing of the machines by a concrete weighbridge on site. The volume of leachate produced during transport to the Mostaganem municipal household waste landfill was monitored once a week from January to December 2021. Leachate characterization was carried out by COD determination using the Mohr's salt method [21]. Total suspended solids (TSS) were measured by the centrifugation method [22]. Electrical conductivity (EC) was measured *in-situ* using a HANNA EC-214 conductivity meter; pH and turbidity of the leachate were measured before and during the treatment using an OHAUS Starter 2100 pH meter and a HANNA HI2315 conductivity meter, respectively. Finally, ammonium and nitrate nitrogen were determined also with a spectrophotometer in the visible type G BOYER/ ANACHEM 320. All analyses were triplicated in order to ensure reproducibility and representativeness of the samples.

2.4. Experimental setup

The experimental setup used in this study is shown in Fig. 2. It is composed of a buffer tank and a UASB digester with a useful volume of 200 L, a height of 0.93 m, and a diameter of 0.58 m. The UASB digester is designed to treat approximately 1/10 of the waste produced daily. Optimization of the anaerobic conditions and the three-phase separation of sludge, leachate and biogas is facilitated by a metal colon which is connected to the ceiling of the digester and immersed in the leachate to a depth of 0.24 m. Leachate was fed continuously after daily recovery from the tippers during transport to the Sour landfill. To reduce the stabilization and adaptation phase of the methanogenic flora, the digester was seeded at the beginning of the tests with 3 kg of natural sludge, which helps biofilm formation. After commissioning, the reactor was filled with leachate for five months to create a biofilm suitable for the treatment process. The reactor was then emptied without altering the biofilm. The reactor was operated 10 d with a permanent flow for each hydraulic retention time (HRT).

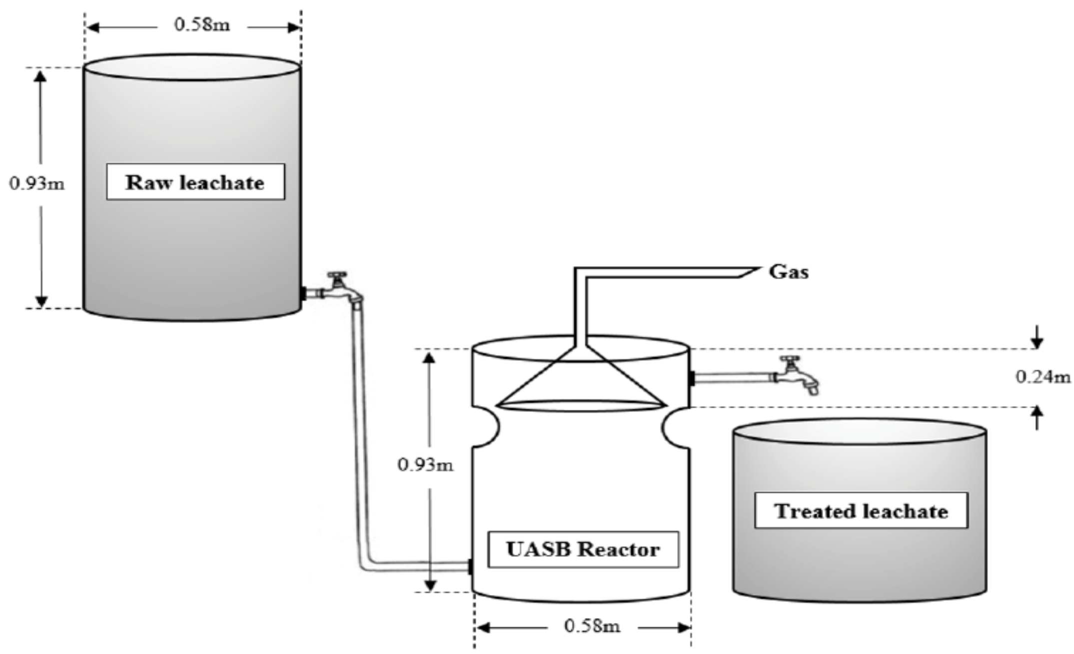

Fig. 2. Up-flow anaerobic sludge blanket experimental setup [23].

The purification yield was monitored by taking 1 L samples from the buffer tank at the outlet of the digester over a period of 6 d at intervals of 24 h, which corresponds to HRT of: 24, 48, 72, 96, 120 and 124 h. The test was done in triplicate in February and March 2021. These samples were then put into plastic bottles and then in an insulated case, and transported directly to the laboratory for analysis [22].

3. Results and discussions

3.1. Evolution of household waste generation in the city of Mostaganem

Table 2 shows the significant increase in the quantity of household waste generated in the city of Mostaganem from 2004 to 2021 [18] rising from 81.9 in 2004 to 169.3 ton/d in 2021, corresponding to a waste produced per inhabitant of 0.61 and 0.91 kg/cap·d. This steady increase can be explained by the natural population increase and the improvement in the standard of living.

3.2. Household waste composition

The average composition of the waste investigated was obtained by averaging the composition of all the sectors studied. The results of the analysis are illustrated in Fig. 3.

It can be seen from Fig. 3 that fermentable materials are in the majority (63.5%) compared to the other waste components. This is explained by the nutritional behavior of the inhabitants, who favor the consumption of vegetables and fruits due to their purchasing power, which corresponds to a more or less average income [24]. The proportions of paper and plastic are less important compared to the previous category; they are respectively around 12.5% and 14.7%. The share of other components such as metals, glass and miscellaneous constitute a significant fraction resulting from household activity. These results are similar to those found in other cities in Algeria and other countries (Bejaia, Constantine, Algiers, Chlef) [25–28] and other countries (Morocco, Tunisia, Mauritania, Egypt) [29–32].

Table 2
Evolution of the quantity of waste generated in the city of Mostaganem (2004–2021)

Year	2004	2008	2014	2021
Population (inhabitants)	134,390	142,696	157,796	185,443
Amount of household waste generated (ton/d)	81.9	105.7	138.9	169.3
Waste generated per capita (kg/cap·d)	0.61	0.74	0.88	0.91
Collection rate (%)	100	100	100	100

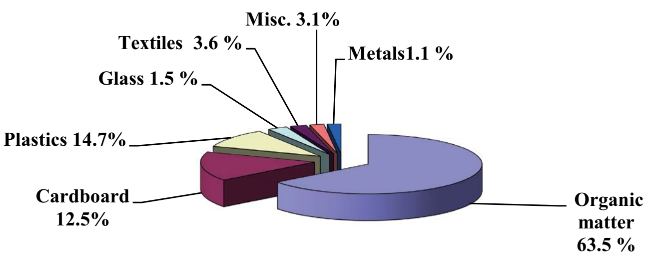

Fig. 3. Average composition of the household waste generated in Mostaganem city as of 2021.

3.3. Quantification and characterization of household waste leachates from the city of Mostaganem

Household waste leachates are effluents heavily loaded with organic, mineral pollutants and toxic elements [24]. The amount of leachate production varies depending on the nature and composition of the waste. In this study, the volume of leachate produced during the transport operation to the technical landfill center was monitored throughout 2021. The results obtained show that the leachate volumes varied between a minimum of 40,870 L in December 2021 and a maximum of 127,930 L in August 2021, giving a monthly average of approximately 74,850 L (Fig. 4). Leachate production increases in the summer season (July–August). This is probably due to the lifestyle of the inhabitants which favors the consumption of high-quality fruit and also the influx of tourists in this area.

3.4. Leachate treatment by the UASB technique

The physico-chemical quality of leachate varies considerably over time (for the same site) and in space (from one site to another). It depends on several factors such as the operating conditions of the landfill, the climatic conditions and essentially the nature of the waste and age of the landfill [33]. The physico-chemical composition of the leachate was determined on both the raw leachate and the UASB treated leachate to assess the effectiveness of this treatment technique (Table 3 and Fig. 5).

As shown in Fig. 5a–f, the physico-chemical parameters of leachate after UASB treatment significantly decreased since day one. This confirms the effectiveness of this treatment system.

pH is an indicator of the different stages of effluent degradation. Fig. 5a shows the evolution of pH as a function of HRT during treatment. The pH values measured for different periods of HRT depend on the concentration of volatile fatty acids. The pH monitoring indicates an acidic character with a value of 4.47 for raw leachate moving towards a value close to neutrality of 6.89 after 6 d in the UASB reactor. This increase in pH can be explained by a denitrification reaction in which the consumption of

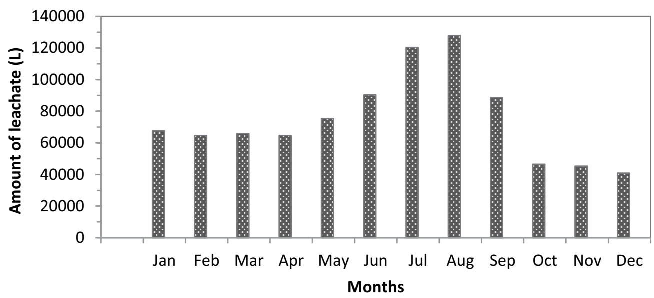

Fig. 4. Monthly leachate generation as of 2021.

protons, necessary to reduce nitrates or nitrites to molecular nitrogen and/or gaseous nitrogen oxide occurs [34,35].

As depicted in Fig. 5b, the EC decreased from approximately 25.73 mS/cm for the raw leachate, corresponding to the acidogenesis phase, to 7.56 mS/cm for a 6-d HRT, a decrease of 70.62%. Indeed, it is during this phase that leaching of charged species is the most important given the low pH that promotes their solubilization. In addition, higher EC values may also correspond to the accumulation of ions in the leachate recirculation process [36]. During processing, the EC decreased steadily as a function of HRT in the UASB reactor from day one.

Fig. 5c shows the evolution of suspended matter as a function of HRT. The initial TSS content in the raw leachate was 5,472 mg/L. As treatment progressed, the TSS decreased to 1,296 mg/L after a 6-d HRT, representing a removal efficiency of approximately 76.31%.

This significant decrease may be an indication of the active growth of biomass in the reactor, since more than 90% of suspended volatile matter is due to active biomass and the remaining 10% is due to non-biodegradable volatile matter and dead cells debris [37].

Turbidity as a function of HRT is shown in Fig. 5d. It decreases from 2,693 to 487 NTU after a 6-d HRT, with removal efficiency of about 81.91%.

The decrease in turbidity is due to the sedimentation of these particles by gravity under their own weight after disruption of the equilibrium symmetry [38]. Gerardi [39] obtained an almost identical result in a pilot plant where

Table 3
Physico-chemical characteristics of raw leachate

Parameters	Main values
Temperature, °C	24.6
pH	4.47
Electrical conductivity (EC), µS/cm	25,730
Turbidity, NTU	2,693
Total suspended solids (TSS), mg/L	5,472
COD, mg/L	24,650
NH_4^+–N, mg/L	48.6
NO_3^-–N, mg/L	167.8

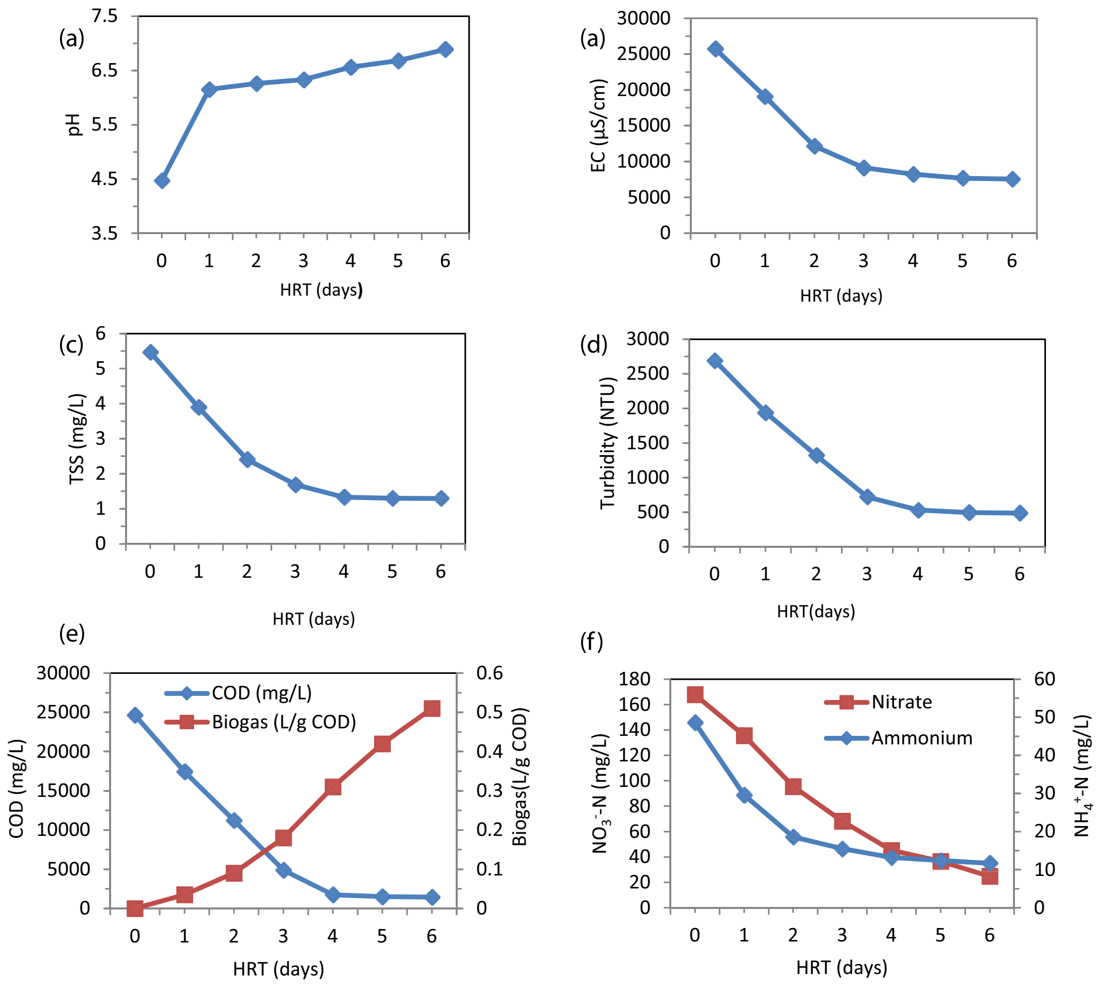

Fig. 5. (a) pH vs. hydraulic retention time. (b) Electrical conductivity vs. hydraulic retention time. (c) Total suspended solids vs. hydraulic retention time. (d) Turbidity vs. hydraulic retention time. (e) Chemical oxygen demand and biogas production vs. hydraulic retention time. (f) NH_4^+–N and NO_3^-–N vs. hydraulic retention time.

the removal efficiency reached 82.0%. In contrast, in a study by Iglesias et al. [40], turbidity removal attained 90% for a complete anaerobic-aerobic sequential process.

COD is one of the main parameters required by regulation. As shown in Fig. 5e, the high initial COD value of 24,650 mg/L, probably due to species accumulation during the leaching process, decreased considerably and appears to be stabilizing around 1,441 mg/L. This is consistent with the literature for leachate in the methanogenesis phase. COD shows a very significant reduction of 94.15% after a 6-d HRT with an average temperature of 24°C, which varied between 13.5°C and 28.8°C during the study period. This reduction in COD was accompanied by an increase in biogas production during processing.

The amount of biogas produced reached 0.51 L/g COD for a 6-d HRT (Fig. 5e) in agreement with Bohdziewicz and Kwarciak [45] results. In addition, about 37% of the biogas produced was methane.

For ammoniacal and nitric nitrogen, initial concentrations of approximately 48.6 and 167.8 mg/L, respectively were observed. As can be observed from Fig. 5f, the levels of NH_4^+–N and NO_3^-–N change in parallel with HRT. They both decreased gradually with HRT. The lowest NH_4^+–N and NO_3^-–N values were obtained for the 6-d HRT. They reached 11.7 and 24.8 mg/L for ammoniacal and nitric nitrogen, respectively. The relatively low efficiency of NH_4^+ nitrogen removal could be attributed to the assimilation of ammonia nitrogen by anaerobic bacteria, as reported in other publications [41,42]. However, the decrease in nitrate content is likely due to heterotrophic denitrification under anoxic conditions to reduce nitrate to nitrites and then nitrogen gas [43].

The UASB technique treatment of the leachate investigated shows a clear decrease of the EC due to the chemical exchanges between leachate and sediment. Moreover, the increase in pH from 4.47 to 6.89 after a stay of 144 h confirms the response of the system studied from the first hours of operation. The results obtained are encouraging, especially in terms of COD reduction, which is linked to the biodegradation of organic matters by anaerobic microorganisms during the path of leachate from the bottom to the top of the reactor, with biogas evolution. The results obtained compare favorably with other published results [44–46].

4. Conclusion

The treatment of leachate from household waste generated by the city of Mostaganem by the UASB technique made it possible to obtain a COD reduction of 94.15% with a hydraulic residence time of 6 d, an average temperature of 24°C and a pH close to neutral. The process has been shown to work efficiently from the first hours of operation. The experimental protocol applied has proven itself in the climatic conditions of the study area. The UASB reactor investigated is capable of treating 1/10 of the quantity produced daily in the city of Mostaganem. Anaerobic treatment of leachates from fresh household waste before disposal in landfill is strongly recommended knowing that biological treatment becomes difficult thereafter. Therefore, it is necessary to recover the liquid fraction before the waste is discharged to the landfill to minimize the impact of the discharge on the environment.

References

[1] Agence Nationale de Déchets (AND), Rapport sur l'état de la gestion des déchets en Algérie [Report on the state of waste management in Alegria], 2020, p. 152.

[2] A. Kaschl, V. Römheld, Y. Chen, The influence of soluble organic matter from municipal solid waste compost on trace metal leaching in calcareous soils, Sci. Total Environ., 29 (2002) 45–57.

[3] R.S. Poulain, J. Gagnaire, P. Moulin, Lixiviat de centre de stockage: déchet généré par des déchets [Landfill leachate: waste generated by wastes], Eau Ind. Nuis., 310 (2007) 3–43.

[4] H.I. Abdel-Shafy, A.M. Ibrahim, A.M. Al-Sulaiman, R.A. Okasha, Landfill leachate: sources, nature, organic composition, and treatment: an environmental overview, Ain Shams Eng. J., (2023) 102293, doi: 10.1016/j.asej.2023.102293 (in Press).

[5] W. Yan, Y. Wang, Y. Li, C. Rong, D. Wang, C. Wang, Y. Wang, Y.-l. Yuen, F.F. Wong, H.-K. Chui, Y.-Y. Li, T. Zhang, Treatment of fresh leachate by anaerobic membrane bioreactor: on-site investigation, long-term performance and response of microbial community, Bioresour. Technol., 383 (2023) 129243, doi: 10.1016/j.biortech.2023.129243.

[6] E. Foresti, Perspectives on anaerobic treatment in developing countries, Water Sci. Technol., 44 (2001) 141–148.

[7] G. Zeeman, G. Lettinga, The role of anaerobic digestion of domestic sewage in closing the water and nutrient cycle at community level, Water Sci. Technol., 39 (1999) 187–194.

[8] J. Liu, J.E. Zuo, Y. Yang, S.Q. Zhu, S.L. Kuang, K.J. Wang, An autotrophic nitrogen removal process: short-cut nitrification combined with ANAMMOX for treating diluted effluent from an UASB reactor fed by landfill leachate, J. Environ. Sci.-China, 22 (2010) 777–783.

[9] H. Sun, Q. Yang, Y. Peng, X. Shi, S. Wang, S. Zhang, Advanced landfill leachate treatment using a two-stage UASB-SBR system at low temperature, J. Environ. Sci., 22 (2010) 481–485.

[10] G. Lettinga, A.F.M. van Velsen, S.W. Hobma, W. de Zeeuw, A. Klapwijk, Use of the upflow sludge blanket (USB) reactor concept for biological wastewater treatment, especially for anaerobic treatment, Biotechnol. Bioeng., 22 (1980) 699–734.

[11] W.M. Wiegant, Experiences and potential of anaerobic wastewater treatment in tropical regions, Water Sci. Technol., 44 (2001) 107–113.

[12] L. Seghezzo, Anaerobic Treatment of Domestic Wastewater in Subtropical Regions, Thesis Wageningen University, Wageningen, The Netherlands, 2004, p. 172.

[13] W. Khalfallah, M. Mehdi, Z. Lounis, Z. Talbi, Traitement des lixiviats du Centre d'Enfouissement Technique de Hassi Bounif par l'utilisation de deux types d'adsorbants (Bentonite et Zéolithe LTA) [Treatment of leachate from the Hassi Bounif technical landfill center using two types of adsorbents (bentonite and zeolite LTA)], Algerian J. Environ. Sci. Technol., 5 (2019) 1185–1196.

[14] B. Christophe, Traitement des lixiviats des affluents complexes qui nécessitent un traitement poussé [Treatment of leachate from complex tributaries that require extensive treatment], Eau Ind. Nuis., 371 (2014) 49–58.

[15] L. di Palma, P. Ferrantelli, C. Merli, E. Petrucci, Treatment of industrial landfill leachate by means of evaporation and reverse osmosis, Waste Manage., 22 (2002) 951–955.

[16] T.-H. Tsui, H. Wu, B. Song, S.-S. Liu, A. Bhardwaj, J.W.C. Wong, Food waste leachate treatment using an up-flow anaerobic sludge bed (UASB): effect of conductive material dosage under low and high organic loads, Bioresour. Technol., 304 (2020) 122738, doi: 10.1016/j.biortech.2020.122738.

[17] K. Pinpatthanapong, T. Puengpraput, S. Phattarapattamawong, C. Phalakornkule, P. Panichnumsin, N. Boonapatcharoen, P. Paensiri, K. Malila, N. Ponata, T. Ngamcharoen, R. Jutakanoke, A. Setsungnern, Y. Tachapermpon, C. Treesubsuntorn, J. Boonnorat, Effect of propionate-cultured sludge augmentation on methane production from up-flow anaerobic sludge blanket systems treating fresh landfill leachate, Sci. Total Environ., 881 (2023) 163434, doi: 10.1016/j.scitotenv.2023.163434.

[18] Ministère de l'Aménagement du Territoire et de l'Environnement (MATE), Manuel d'information sur la gestion des déchets

solides ménagers [Information Manual on the Management and Elimination of Urban Solid Waste], 2021, p. 162.
[19] R. Gillet, MSW Management and its Application in Developing Countries, OMS Publisher, PUND, Vol. 1, Copenhagen, Denmark, 1985.
[20] ADEME: MODECOM, Méthode de caractérisation des ordures ménagères. Guide ADEME, coll: Connaitre pour agir [Household Waste Characterization Method. Guide ADEME, coll: Know to Act], 1993, p. 61.
[21] M. Bouyer, Demande chimique en oxygène, Fiche DCO [Chemical oxygen demand-Fiche DCO], Version 1, 2008, pp. 1–3.
[22] J. Rodier, L'analyse de l'eau [Water Analysis], Dunod, 9ème édition, Paris, France, 2009, p. 1600.
[23] F. Benyoucef, A. Makan, A. El Ghmari, A. Ouatmane, Solid household waste characterization and fresh leachate treatment: case of Kasba Tadla city, Morocco, Environ. Eng. Res., 20 (2015) 363–369.
[24] N. Guermoud, F. Ouadjnia, F. Abdelmalek, F. Taleb, A. Addou, Municipal solid waste in Mostaganem city (Western Algeria), Waste Manage., 29 (2009) 896–902.
[25] SNGID, Rapport sur l'État des lieux sur la gestion des déchets en Algérie [Report on the State of Play on Waste Management in Algeria], Mission 1, 2020.
[26] N. Tahraoui Douma: Valorisation par compostage des résidus solides urbains de la commune de Chlef [Recovery by Composting of Solid Urban Waste from the City of Chlef, Algeria], Thèse de doctorat, Université de Limoges, France, 2013, p. 195.
[27] Agence TAD, Rapport de synthèse sur la gestion des déchets solides municipaux A Mostaganem [Synthesis Rapport, MSW Management in Mostaganem], Service municipal de l'environnement à Mostaganem, Algérie, 2004, p. 149.
[28] B. Bouhadiba, F. Mezouari, Y. Kehila, G. Matejka, For an integrated management of municipal solid waste in Algeria. Systemic and methodological approaches, Int. Rev. Chem. Eng., Rapid Commun., 2 (2010) 426–429.
[29] A. Rassam, B. Bourkhiss, A. Chaouch, L. El Watik, H. Chaouki, M. Ghannami, Caractérisation de lixiviats des décharges contrôlées au Maroc et solutions de traitement: cas de lixiviats de la ville d´Alhoceima [Characterization of leachate from controlled landfills in Morocco and treatment solutions: case of leachate from the city of Alhoceima], Sci. Lib. Environ., 4 (2012) 1–9.
[30] H. Louati Halouani, City of Sfax (Tunisia): The Mediterranean Integrated Sustainable Waste and Resource Management Network for Local and Regional Authorities, International Conference, Mahdia, Tunisia, Nov. 13–14, 2012.
[31] S.O. Aloueimine, Méthodologie de caractérisation des déchets ménagers à Nouakchott (Mauritanie): Contribution à la gestion des déchets et outils d'aide à la décision [Methodology for the Characterization of Household Waste in Nouakchott (Mauritania): Contribution to Waste Management and Decision Support Tools], Thèse de doctorat, Université de Limoges, France, 2006.
[32] B. Djemaci, La gestion des déchets municipaux en Algérie, Analyse et prospective et éléments d'efficacité [The Management of Municipal Household Waste in Algeria, Analysis and Prospective and Elements of Efficiency], Thèse de doctorat, Université de Rouen, France, 2012.
[33] Y. Jirou, M.C. Harrouni, M. Belattar, M. Fatmi, S. Daoud, Traitement des lixiviats de la décharge contrôlée du grand Agadir par aération intensive [Treatment of leachate from the Agadir controlled landfill by intensive aeration], Rev. Maroc. Sci. Agron. et Vétérinaires, 2 (2014) 59–69.
[34] Y.Z. Peng, S.J. Zhang, W. Zeng, S.W. Zheng, T. Mino, H. Satoh, Organic removal by denitritation and methanogenesis and nitrogen removal by nitritation from landfill leachate, Water Res., 42 (2008) 883–892.
[35] J.P.K. Jokela, R.H. Kettunen, K.M. Sormunen, J.A. Rintala, Biological nitrogen removal from municipal landfill leachate: low-cost nitrification in biofilters and laboratory scale in-situ denitrification, Water Res., 36 (2002) 4079–4087.
[36] D.R. Reinhart, B.A. Al-Yousfi, The impact of leachate recirculation on municipal solid waste landfill operating characteristics, Waste Manage. Res., 14 (1996) 337–346.
[37] H. Rizvi, N. Ahmad, F. Abbas, Start-up of UASB reactors treating municipal wastewater and effect of temperature/sludge age and hydraulic retention time (HRT) on its performance, Arabian J. Chem., 8 (2015) 780–786.
[38] S.M. Raghab, A.M.A. El Meguid, H.A. Hegazi, Treatment of leachate from municipal solid waste landfill, HBRC J., 9 (2013) 187–192.
[39] M.H. Gerardi, The Microbiology of Anaerobic Digesters, John Wiley & Sons, Inc., New York, USA, 2003.
[40] J.R. Iglesias, L. Castrillón Peláez, E. Maranon Maison, H. Sastre Andrés, A comparative study of the leachates produced by anaerobic digestion in a pilot plant and at a sanitary landfill in Asturias, Spain, Waste Manage. Res., 18 (2000) 86–93.
[41] K.J. Kennedy, E.M. Lentz, Treatment of landfill leachate using sequencing batch and continuous flow up-flow anaerobic sludge blanket (UASB) reactors, Water Res., 34 (2000) 3640–3656.
[42] S. Chen, D.Z. Sun, J.S. Chung, Simultaneous removal of COD and ammonium from landfill leachate using anaerobic-aerobic moving-bed biofilm reactor system, Waste Manage., 28 (2007) 339–346.
[43] Y. Fernández Nava, E. Maranon, J. Soons, L. Castrillón, Denitrification of wastewater containing high nitrate and calcium concentrations, Bioresour. Technol., 99 (2008) 7976–7981.
[44] C. Neena, P.S. Ambily, M.S. Jisha, Anaerobic degradation of coconut husk leachate using UASB-reactor, J. Environ. Biol., 28 (2007) 611–615.
[45] J. Bohdziewicz, A. Kwarciak, The application of hybrid system UASB reactor-RO in landfill leachate treatment, Desalination, 222 (2008) 128–134.
[46] H. Khattabi, L. Aleya, J. Mania, Lagunage naturel de lixiviat de décharge [Natural landfill leachate lagooning], Sciences de l'eau, 15 (2002) 411–419.