Algerian Journal of Environmental Science and Technology
September edition. Vol.8. Nº3. (2022)
ISSN : 2437-1114
www.aljest.org

Characterization and treatment of leachates from three Technical Landfills Centers in Algeria by the electrocoagulation and the electro-Fenton process

Y. Medkour[a]*, R. Kerbachi[a], F. Boumechhour[b], S. Khenchelaoui[a], R. Djettene[a], A. Teffahi[a].

[a] Department of Environmental Engineering, National Polytechnic School 10, Avenue Hassen Badi El-Harrach BP 182, Algiers, Algeria;
[b] Department of Environmental Engineering, Faculty of Science of Engineers, University of Boumerdes. Avenue du 1er Novembre 35000 Boumerdes, Algeria.

*Corresponding author: medkouryacine2020@gmail.com.

ARTICLE INFO

Article History :

Received ***: 21/08/2020***
Accepted ***: 09/02/2021***

***Key Words*:**

Landfill leachate;
Leachates characterization;
Leachates treatment;
Electrocoagulation;
Electro-Fenton.

ABSTRACT/RESUME

Abstract: *The objective of this study was to characterization and COD removal of leachates from three Technical Landfills Centers in east of Algeria. The leachate was collected from KHELIL, BBA, and HAMICI landfill site and treated by electrocoagulation and electro-Fenton process. The characterization study of leachates showed that the latter have a high organic, mineral (high chemical oxygen demand) and nitrogen load. The measured Chemical oxygen demand reaches very high values, with an average of about 4624; 7666 and 25041 mg O_2/l for the leachate of BBA, KHELIL and HAMICI respectively. The effect of various parameters including current density, pH, stirring speed, the inter-electrode distance and H_2O_2 dosage were studied. The findings, in this study show that the removal efficiencies of Chemical oxygen demand by electrocoagulation treatment were respectively 75%, 93%, 57% and 71.7%, 83%, 78.3% by Electro-Fenton treatment for the landfill centers of KHELIL, BBA and HAMICI respectively. The maximum COD removal was obtained at pH = 5.5 and pH = 3 for the Electrocoagulation and Electro-Fenton process respectively. The inter-electrode distance and the current intensity were 1.7 cm and 2.3 A (742 A/m^2) for the two process.*

I. Introduction

The landfill is the most common technology used to dispose municipal solid residues in countries worldwide (Joseph et al., 2016), the later has been identified as one of the most serious environmental problems which needs to be addressed urgently for environmental protection. After landfilling, the water contained in the waste and that brought by the precipitation favor the process of the biodegradability of fermentable organic matter within the mass of waste and then produce leachates that are loaded with organic and inorganic compounds as well as suspended particles.These highly charged leachates must be treated before discharge into a natural environment. The major risk associated with leachate production is contamination of the surface waters (Millot, 1986; Ramade, 1998).

The mechanisms of leachate genesis are very complex: they are biological and physico-chemical in nature (Renou et al., 2008).According to the landfill age, the leachate can be classified into three types: young, intermediate, and old (Millot, 1986; Ramade, 1998). The characteristics of the leachate also vary with regard to its composition and volume, and biodegradable matter present in the leachate against time (Malina et al., 1996). The pH of initial landfill is 4.5 - 7 and can go up to 6.6 - 7.5 with passage of time (Naveen et al., 2017; Joseph et al., 2016).

The diversity of the compounds present in the leachates responds to a variety of treatment processes that can be combined such as: Aerobic and Anaerobic Biological Treatment (Malina et al., 1996; Bodzek et al., 2006) and Physiochemical treatment such as air stripping (Hasar et al., 2009), oxidation (Chiang et al., 1995), reverse osmosis (Hasar et al., 2009) and active carbon adsorption (Li et al., 2010). The most recent are the electrochemical techniques that have experienced great growth, including electrocoagulation, processes and electro-Fenton (Bouhezila et al., 2011; Muhammad Umar et al., 2010).

Electrochemical oxidation of pollutants in wastewater is fulfilled through two different approaches, indirect oxidation, where a mediator is electrochemically generated to carry out oxidation, and direct anodic oxidation, where pollutants are destroyed on the anode surface (Chiang et al., 1995). Electrochemical oxidation of landfill leachate under appropriate conditions can remove most COD (Li et al., 2010).

Recently, conventional, electrocoagulation and electro-Fenton processes have been investigated for landfill leachate treatment. The electrocoagulation has proven many advantages simplicity, efficiency, environmental compatibility, safety and selectivity, for a low cost (Bennajah, 2007). Electro-Fenton has been reported as one of the most effective method to degrade a variety of refractory compounds in landfill leachate (Atmaca, 2009). Catalysis of hydrogen peroxide by ferrous sulfate, which is Fenton's reagent, is one of the most common advanced oxidation processes. The electro-Fenton process is based on the in-situ production of the Fenton reagent (H_2O_2 / Fe^{2+}) (Fenton, 1894). H_2O_2 and Fe^{2+} react together within the solution to generate the hydroxyl radicals following the Fenton reaction. So this is the Fenton reaction assisted by electrochemistry (Gulsenet al., 2004).

Our work focuses on the study of leachates from three technical landfills in east of Algéria, firstly attempts to characterize landfill leachate through the determination of the global parameters of organic pollution, mineral and nitrogen. In a second part of the study, we will present the results of treatments performed using the following methods: Electrocoagulation (EC) and Electro-Fenton (EF), The effect of operational parameters such as current intensity, inter-electrode distance, magnetic stirring speed and pH evolution was explored to determine the optimum conditions. At last, we have compared the performance of these methods.

II. Materials and methods

II.1. Landfill site description and leachate characteristics

Leachate utilized in this study was collected from three Technical Landfill Centers KHELIL, BBA, and HAMICI located in Algeria. KHELIL Landfill was founded in 2011, located 04 km northeast of Meriouet town, and has served 10 ha area for 24 tonnes municipal solid waste a day. BBA Landfill located 05 km northeast of Bordj Bou Arreridj town, is constructed on a total area of 17 hectares; the daily solid waste entering the plant is approximately 152 t. HAMICI Landfill is located west of Algiers, which had the capacity to sustain about 1700 tonnes of waste.

Samples were collected manually from KHELIL, BBA, and HAMICI landfill in a closed container and stored in obscurity at T= 4 °C, the quantity of 2 L from leachate was used for characterization and 25 to 30 L was used for treatment. Chemical analysis was performed during the following 2 days, leachate was characterized using the standard methods summarized in Table 1.

II.2. Reactor design

The experimental device used in this study is illustrated in Figure.1. The electrocoagulator was made of cell (beaker 1L), with a special mounting supporting a two irons sheets used as sacrificial electrodes. A pair of anodic and cathodic iron electrodes with dimensions of 6 × 5 × 0.1 cm (L × W × T) with an active surface of 30 cm^2.The experiments were realized with 600 mL of the leachate placed into the electrolytic cell, the electrodes were connected to a DC power supply, current density varied (500 –1000 A/m^2). All the experiments were performed in batch mode at room temperature and the leachate are treated during 90 min. Samples are taken in order to calculate the COD abatement, experiments were repeated to avoid the experimental error.

The E-Fenton experiments were carried in the same reactor as that described in the electrocoagulator process. The same electrodes are also used. 600 mL of leachate was placed in an electrolytic cell and desired amounts of hydrogen peroxide (H_2O_2) with a purity of 30 % were added before the electrical current was turned on.

Algerian Journal of Environmental Science and Technology
September edition. Vol.8. Nº3. (2022)
ISSN : 2437-1114
www.aljest.org

Table 1. Principle and reference of pollution analysis technique

Parameter	Methods	Method reference
temperature	Thermometer (Direct measure)	NF T90-100
pH	Direct measure (HANNA pH-meter)	NF T90-008
Redox potential	Direct measure (HANNA pH-meter)	NF T90-008
conductivity	Conductivity-meter	NF T90-031
DCO	Bichromate oxidation + spectrometry (Thermo-reactor CR 2200)	ISO 6060
BOD_5	OxiTop	ISO 5813
NH_4^+	Colorimetric	ISO 7150
NO_3^-	Colorimetric	T 90-012
NO_2^-	Colorimetric	ISO 5667
SO_4^{2-}	Colorimetric	German method developed by the approved laboratory of the SEAAL
PO_4^{3-}	colorimetric	ISO 6878
Cl^-	Titration	NF T 90-014
HCO_3^- et CO_3^{2-}	pH-meter, HANNA (TA et TAC), Titration	NF T 0-036
Heavy metals	Atomic absorption spectroscopy	NF T 90-112 ISO 82-88

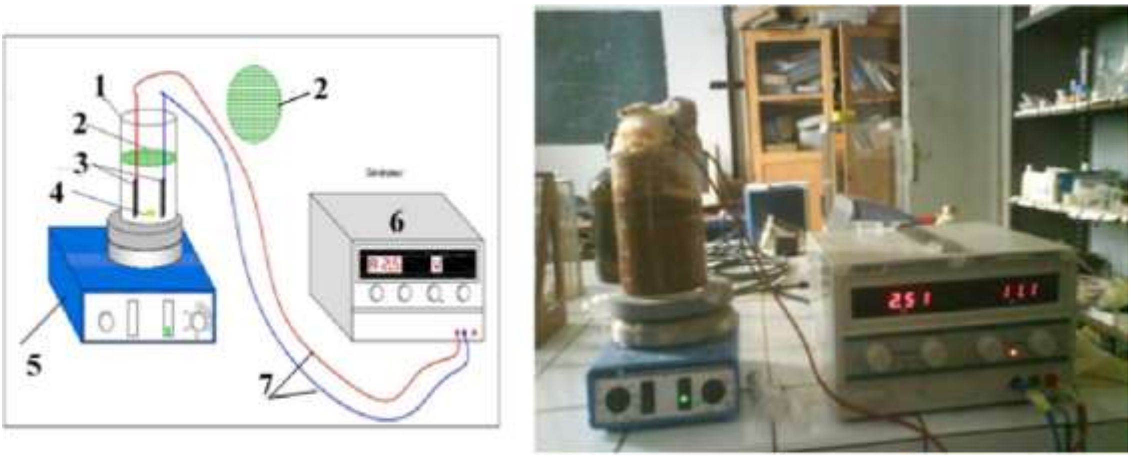

Figure 1. The electrochemical reactor in the laboratory experiments. (1) Beaker, (2) filter, (3) electrodes, (4) magnetic bar-stirrer, (5) magnetic stirrer, (6) DC power supply, (7) electric wire.

III.Results and discussion

In this section, results obtained during the study are given and discussed.

III.1. Leachate Characteristics before treatment

Table 2 summarizes the results of the physico-chemical analysis of the leachate samples, which were highly variable, from BBA, KHELIL and HAMICI Landfill before treatment. They were focused on the evaluation of the organic load and its biodegradability and the mineral load. pH values of leachate (BBA, KHELIL and HAMICI) of the landfill site were 8.1, 8.3 and 7.8 respectively.
The carbonic acid, which occurs from the degradation of organic matter, dissociates with ease to produce hydrogen cations and bicarbonate anions, which influence the level of pH of the system. Dissolved materials and gases shift the pH of natural water either to acidic or alkaline side.

According to our characterization, pH above 7 can carry a greater load of dissolved substances and are capable of supporting a good plant life (Naveen et al., 2017). pH means that the leachate is at the start of methanogenic phase. The alkaline nature of leachate is an indicator of the mature stage of the dumping site (Jorstad et al., 2004).
Conductivity is an indicator of the degree of salinity and mineral contents of leachate. This high conductivity values reflects a high salinity resulting a very strong leaching of waste. The salt content in the leachate is due to the presence of: Cl^-, NH_4^+, HCO_3^-, SO_4^{-2}, Na^+, Ca^{2+}, Mg^{2+} and K^+.

The BOD_5/COD ratios indicate evolution of biodegradation rate for the organic matter in the leachate and the age the landfill (Hui, 2005). The values of COD and BOD_5/COD of the present studies showed that the low BOD_5/COD (~ 0.1) values indicative of a stabilized leachate for BBA landfills. Unlike for KHELIL landfills where the BOD_5/COD values of the leachate samples were ranging from 0.25 to 0.4 revealed medium aged leachate samples. The young leachate primarily comprises of undecomposed organic compounds that are readily biodegradable, that further find in the HAMICI landfill where the ratio of BOD_5/COD is 0.3.However, these findings are similar to those reported by (Millot, 1986; Boumechhour et al,. 2013).

***Table 2**. Characteristics of leachate collected from all three sites (BBA, KHELIL and HAMICI).*

Characteristics	**BBA**		**KHELIL**		**HAMICI**		**Standard***
	Mean	Range	Mean	Range	Mean	Range	
Color	Darkbrown	/	Blackish	/	Blackish	/	
Odour	Unpleasant	/	Unpleasant	/	Unpleasant	/	
pH	8.07	7.83 – 8.33	8.33	7.99 – 8.51	7.87	7.87	6.5 à 8.5
Conductivity (ms/cm)	14.50	12.50 – 16.60	21.88	19.90 – 23.50	19.10	19.10	
Redox potential(mv)	-52.87	(-40) – (-78.50)	-66.12	(-58) – (-87.50)	-81.60	-81.60	
COD mg O_2/l	462499	2666 - 5666	25041.66	21333 - 33000	7666.66	7666.66	120
BOD_5 mg O_2/l	437.5	320 - 500	8300	7200 - 9000	2300	2300	35
BOD_5/COD	0.09	0.08 – 0.12	0.34	0.25 – 0.40	0.30	0.30	
COT (mg/L)	/	/	/	/	/	/	
NH_4^+ (mg/l)	3654.80	2467 - 5511	3490.78	2388.40 – 5065.61	4566.92	4566.92	
NO_3^- (mg/l)	87.82	27.77 – 191.19	120.50	32.67 – 233.66	290.84	290.84	
NO_2^- (mg/l)	0.47	0.23 – 068	1.27	0.59 – 7.72	1.77	1.77	
PO_4^{3-} (mg/l)	2.07	0.37 – 6.94	3.56	2.51 – 3.95	1.97	1.97	10
SO_4^{2-} (mg/l)	2374.85	1785.5 – 3571.42	856.82	714 - 1142	6142.85	6142.85	
Cl^- (g/l)	6285	1278 – 8307	8876.5	7745 - 9585	4260	4260	
HCO_3^- (mg/l)	6900.6	3660 – 12962.5	13877.5	12200 - 14640	15250	15250	
MES (g/l)	15.4	13.4 – 19.4	33.78	29.33 – 41.30	19	19	0.035
MVS (g/l)	4.27	2.98 – 5.55	12.43	10.7 – 13.78	6.99	6.99	
Fe (mg/l)	0.44	0.44	1.39	1.39	0.70	0.70	3
Cu (mg/l)	0.25	0.25	0.21	0.21	0.23	0.23	0.5
Zn (mg/l)	0.11	0.11	0.33	0.33	0.38	0.38	3
Leachate types	Intermediate to stabilised		Young		Intermediate		

*Standard of the Environmental Quality (Sewage and Industrial Effluents) Regulation 2006 (Algeria).
COD, chemical oxygen demand;
BOD_5, biological oxygen demand after 5 days; BOD, biological oxygen demand.

III.2. Treatment by Electrocoagulation process

III.2.1. Influence of current intensity (I)

In a monopolar reactor, to determine the effects of current intensity on COD removal efficiency by increasing its value from 1.5 to 3A. The treatment efficiency seemed to be slightly increasing with increasing current intensity. The results are shown in Fig. 2.

When current density was increased from 1.5 to 3A, the efficiency of COD removal was also under the 40 % in the first 20 min and are obtained around the 50% in the end of treatment. According to Fig. 2, the rate COD abatement reaches its maximum values for current intensity = 2.3 A (742 A/m^2), the same results are obtained by (Bouhezila et al., 2011; Ilhan et al., 2008; Gandhimathi et al., 2015). This can be explained by the fact that the current density determines the dose rate of coagulant, and adjusts the flow and size of bubble production, therefore influences floc growth which can influence the effectiveness of electrocoagulation; the size of bubble decreases with increasing current density (Ilhan et al., 2008; Can et al., 2006; Mohammadizaroun et al., 2014; Hakizimana et al., 2017).The pollutant removal efficiency was influenced by a number of operating factors, including anode materials, pH, current density (Mameri et al., 2001; Mollah et al., 2001), Cl-concentration (Li et al., 2010; Chen, 2004; Kobya et al., 2008).

III.2.2. Influence of pH

The pH parameter is one of the main factors limiting the performance of processes related to electrocoagulation treatment. (Li X et al., 2011; Hakizimana et al., 2017 ; Tezcan et al., 2018). Figure 3 illustrates the effect of pH on the rate of COD abatement, pH values range from 4 to 8.

As seen in the figures, an important change in COD removal efficiency was found the best performance is achieved for a pH = 5.5. These findings are similar to those reported by (Tezcan et al., 2018; Kobya et al., 2008; Oliveira et al., 2017; Muhammad Umar et al., 2010; Zhang et al., 2006).The effect of pH on electrocoagulation kinetics can be attributed to the different iron hydroxide species that form in electrocoagulation. A pH below optimal can inhibit oxidation, the $[Fe (H_2O)]^{2+}$ formed reacts relatively slowly with H_2O_2, producing less OH radical (Gallard et al., 1998).in addition, exceptionally low pH can inhibit reaction between Fe3+ and H_2O_2 (Pignatello, 1992).

III.2.3. Effect of stirring speed (v)

The experiments were carried out using various stirring speed values was increased from 100, 125, 150, 200, 350, to determine the effect of mixing on the efficiency of this process. As shown in Fig. 4, the COD removal efficiency increase by about 60%, after 30 min of treatment time when the magnetic stirring speed was increased from 100 rpm to 350 rpm.

The results obtained after optimization of the stirring speed are summarized in the followed graph. From these results, it can be seen that the COD reduction efficiency is maximum for a stirring speed of 150 rpm, the same results of EC process efficiency are obtained by (Bouhezila et al., 2011).

III.2.4. Effect of inter-electrode distance (e)

In a monopolar reactor, the electrical field can be controlled by varying the current intensity, but the other parameters are fixed. In order to investigate the effect of inter-electrode distance on the efficiency of electrocoagulation process, the parametres of reactor was fixed at pH = 5.5, V = 150 rpm and I = 2.3, such that the electrode was positioned using various inter-electrode distance values (1, 1.7, 2.4, 3.1, 3.7) apart. Fig. 5 shows the COD, removal efficiency using various inter-electrode distance at the same experimental conditions obtained (Mohammadizaroun et al., 2014; Hakizimana et al., 2017).

The COD removal efficiency increase by about 60%, after 30 min of treatment time for the inter-electrode distance value was 1 and 1.7 cm and reach to a value more than 75% in the end of treatment, the same results are obtained by (Bouhezila et al., 2011). The inter-electrode distance retained for the treatment of leachate was 1.7 cm, COD abatement ratio of about 75% was obtained.

According to the previous results, the optimal parameters influencing the good functioning of electrocoagulation are retained and applied for leachate treatment of the three Landfill; the performance of EC treatment at different reaction times was evaluated in order to compare the removal efficiency of COD. It was observed that maximum removal of COD obtained is 93 % for the leachate landfill of BBA and 75%, 57% for the KHELIL and HAMICI landfill leachate respectively. The results are represented by the figures 6. Electrocoagulation allows us to reach a good efficiency of the COD for landfill, (Bouhezila et al., 2011, Zhang et al., 2006).

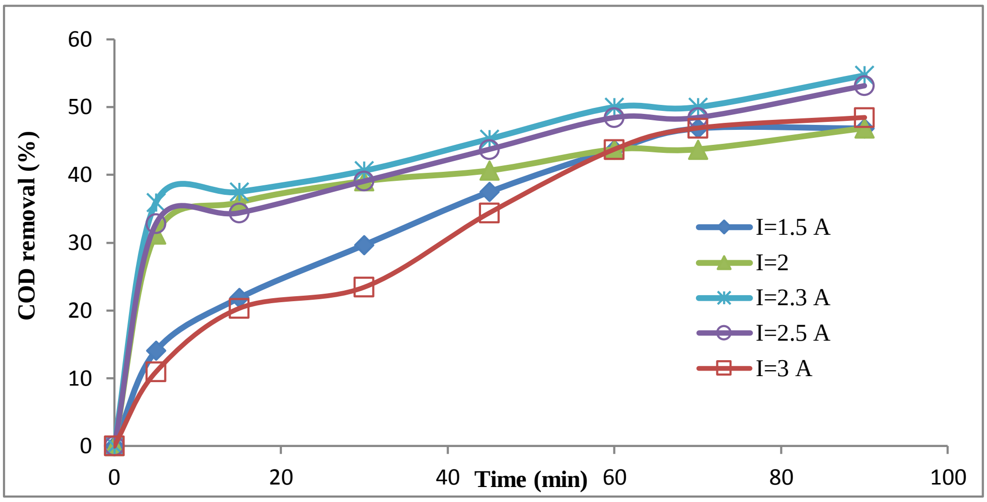

Figure 2. *Effect of current intensity on the rate of COD abatement as a function of time. (Number of electrodes = 2, inter-electrode distance = 1.7 cm, Stirring speed = 150 rpm, and pH = 8)*

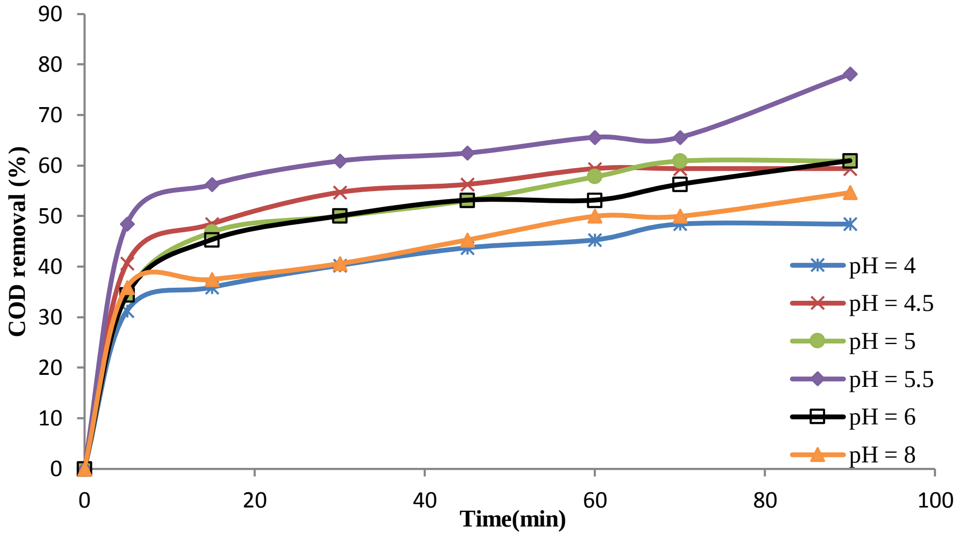

Figure 3. *Effect of pH on the rate of COD abatement as a function of time (Number of electrodes = 2, e = 1.7 cm, v = 150 rpm and I = 2.3 A).*

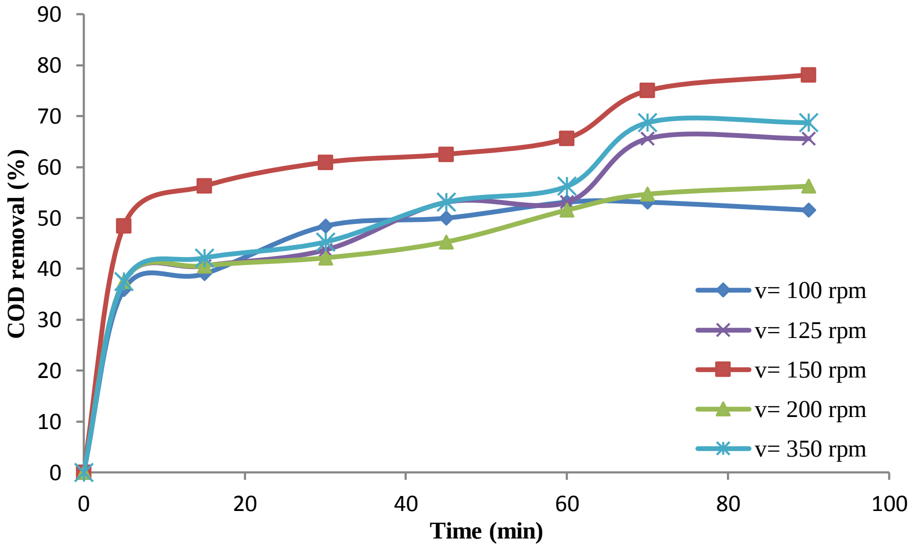

Figure 4. *Effect of agitation speed on COD abatement rate (Number of electrodes = 2, e = 1.7 cm, pH = 5.5, and I = 2.3 A)*

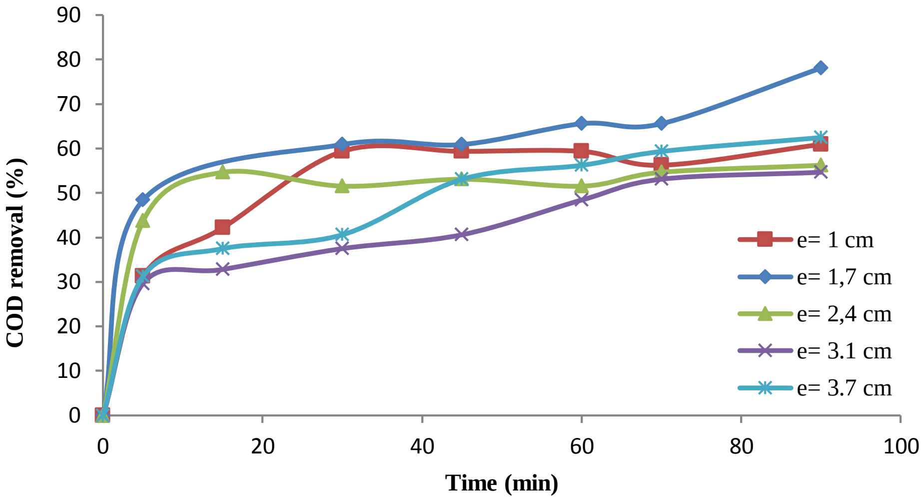

Figure 5. *Effect of the inter-electrode distance on the rate of reduction of the COD as a function of time (number of electrodes = 2, pH = 5.5, V = 150 rpm and I = 2.3 A)*

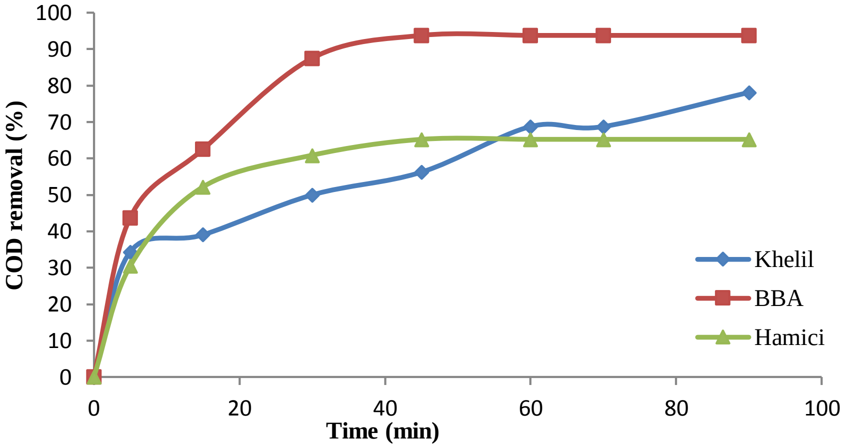

Figure 6. *Evolution of COD abatement performance for each leachates of the three landfill as a function of time (number of electrodes = 2, pH = 5.5, V = 150 rpm and I = 2.3 A, e=1.7cm).*

III.3. Treatment by Electro Fenton process

In the same reactor, the electro-Fenton process treatment follows the same steps as those of electrocoagulation with the same parameters already optimized (V = 150 rpm, I = 2.3 A and e =1.7 cm). The difference can be summed up in two points the pH and the concentration of H_2O_2
Experimental parameters were varied during electro Fenton in order to determine the optimum value of pH were adjusted to 3, 4 and 5.5; (Muhammad Umar et al., 2010; Cotman et al., 2010) were found a similar pH optimum and The addition of a concentration of H_2O_2 [H_2O_2] = 4 to 10; the same value which was used in literature (Tuhkanen, 2004; Crittenden et al., 1998; Lopez et al., 2004), for the reduction of COD contents.

III.3.1. Influence of concentration of [H_2O_2] (g/l)

The effect of concentration on the rate of COD abatement are illustrate in the Figure 7; the concentration was various to the values of 4, 6, 8 and 10. Found maximum removal of COD at [H_2O_2] = 8, these findings was similar to those reported by (Li et al., 2010; Joseph et al., 2016; Roudi et al., 2018; Gautam et al., 2019).

III.3.2. Influence of pH

Figure 8 illustrates the effect of pH on the rate of COD abatement; pH values various from 3, 4 and 5.5.As seen in the figures, It is found that the best performance is achieved for a pH = 3. These findings are similar to those reported by (Muhammad Umar et al., 2010; Zhang et al., 2006; Joseph et al., 2016; Khajouei et at., 2019).

For Electro-Fenton process, pH is an important parameter as it controls production of hydroxyl radicals and ferrous ion concentration. Found maximum removal of COD at pH = 3, these findings are similar to those reported by (Atmaca, 2009; Joseph et al., 2016; Roudi et al., 2018; Gautam et al., 2019).

COD removal efficiencies obtained under similar operational conditions are presented in Fig. 9.It is seen from this figure that electro-Fenton allows us to achieve a good COD removal efficiency; it was obtained as 71.69 %, 83.02 % and 78.3 % and BOD_5 abatement of 96.5, 78.7 and 88.7% for the KHELIL, BBA and HAMICI landfill respectively. Similar results was found by (Zhang et al., 2006; Li et al., 2010; Gautam et al., 2019) were obtained.

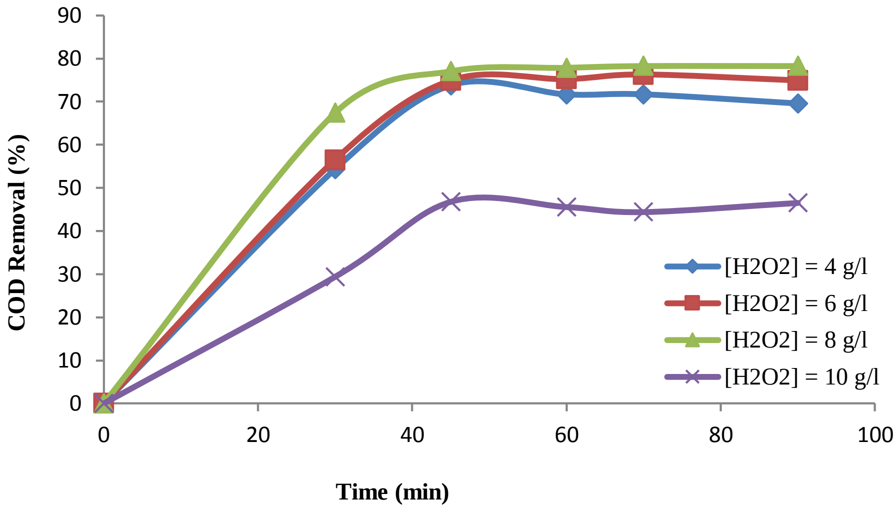

Figure 7. *Evolution of COD abatement performance for each leachates of the TLC as a function of time (number of electrodes = 2, pH = 5.5, V = 150 rpm, I = 2.3 A, e=1.7 cm).*

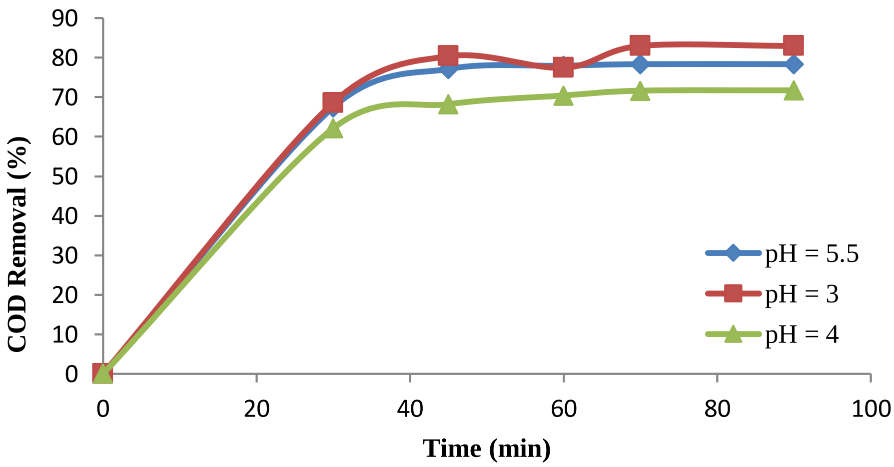

Figure 8. *Evolution of COD abatement performance for each leachates of the TLC as a function of time (number of electrodes = 2, V = 150 rpm, I = 2.3 A, e=1.7 cm, $[H_2O_2]$ = 8 g / L).*

Algerian Journal of Environmental Science and Technology
September edition. Vol.8. Nº3. (2022)
ISSN : 2437-1114
www.aljest.org

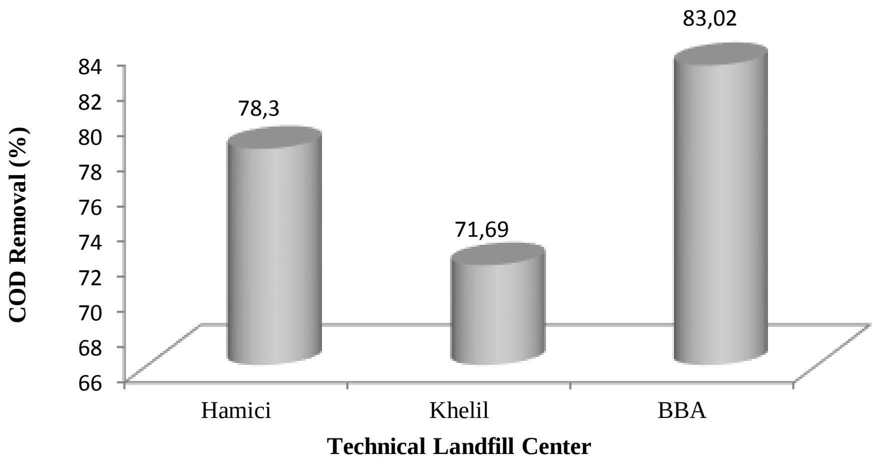

Figure 9. *COD abatement performance for each leachates of the TLC as a function of time (number of electrodes = 2, pH = 3, V = 150 rpm, I = 2.3 A, e=1.7 cm, [H_2O_2] = 8 g / L).*

III.4. Leachate Characteristics and Comparison after EC and EF treatment

Table 3 and Table 4 summarize the results of leachate characteristics, which were highly variable, from BBA, KHELIL and HAMICI Landfill after treatment. Color and odor in leachate was reduced considerably after electrocoagulation and electro-Fenton treatment ;(Kim et al., 1997) reported decolorization efficiency as high as 92% in Fenton treatment of a mature leachate. And, (Lin et al., 2000; Roudi et al., 2018; Khajouei et al., 2019) found that leachate after electro-Fenton treatment was colorless and odorless.

It is seen from Table 3 and Table 4 that the treatment of leachate generated from KHELIL and BBA landfill was less effective with electro-Fenton compared to electrocoagulation, this is probably due to inorganic anions such as Cl^- and SO_4^{2-} which significantly affect the reaction rates of Fenton systems. These inorganic anions can complex iron (II) and iron (III) and thus modify the distribution and reactivity of iron. Thus, the (Laat et al., 2004) observed that Fe^{2+} and $FeCl^+$ had the same reactivity towards hydrogen peroxide while FeSO4 is more reactive than Fe^{2+}. On the other hand, for the iron (III) / H_2O_2 system, the presence of the Cl^- and SO_4^{2-} ions considerably reduces the rate of formation of hydroxyl radicals because the formation of iron (III) complexes with these two anions decreases the concentration of complexes hydro peroxides, which inhibits the rate of regeneration of iron (II). I the leachate from KHELIL and BBA contains very high concentration of chlorides, was respectively 9230 and 7810 mg / L. On the other hand, for the leachates of HAMICI this concentration is much lower, hence a better yield of electro-fenton than electrocoagulation.

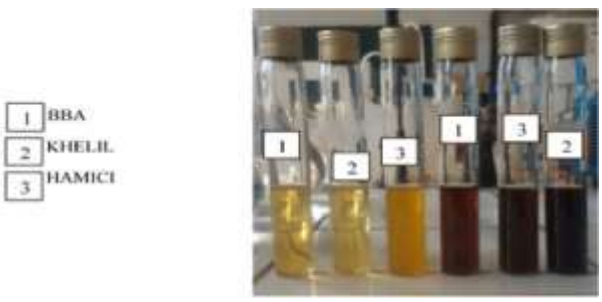

Figure 10. *The result of landfill leachate before and after treatment by EC*

Figure 11. *The result of landfill leachate after treatment by EF.*

Table 3. *Characteristics of leachate from all three sites (BBA, KHELIL, HAMICI) after treatment by EC.*

Characteristics	KHELIL	BBA	HAMICI	standard
Color	Yellowish	Yellowish	Yellowish	
pH	8.79	7.36	8.67	6,5à 8,5
conductivity.(ms/cm)	26.2	19.4	20.9	
Redox.potential(mv)	-123	-45.3	-118.5	
COD mg O_2/l	6666.66	333.33	3333.33	120
BOD_5 mg O_2/l	600	68	430	35
BOD_5/COD	0.09	0.05	0.099	
NH_4^+(mg/l)	2020.99	2572.17	4356.95	
NO_2^- (mg/l)	0.04	0.002	0.16	
NO_3^- (mg/l)	34.31	13.07	102.94	
PO_4^{3-} (mg/l)	0.065	$8.16*10^{-3}$	0.106	10
SO_4^{2-} (mg/l)	14857.14	18142.85	6258.5	
Cl^- (g/l)	6745	7100	4260	
HCO_3^- (mg/l)	915	305	610	
Fe (mg/l)	1.190	0.802	2.806	3
Cu (mg/l)	0.289	0.291	0.348	0.5
Zn (mg/l)	0.248	0.155	0.179	3

Table 4. *Characteristics of leachate from all three sites (BBA, KHELIL, HAMICI) after treatment by EF.*

Characteristics	KHELIL	BBA	HAMICI	standard
Color	Yellowish	Yellowish	Yellowish	
pH	5.69	5.59	7.74	6,5à 8,5
conductivity.(ms/cm)	29.7	19.2	23.3	
Redox;potential(mv)	45.4	-94.4	-102	
COD mg O_2/l	10000	1666.66	3000	120
BOD_5 mg O_2/l	250	96	260	35
BOD_5/COD	0.25	0.057	0.086	
NH_4^+(mg/l)	1811.02	2047.24	3989.5	
NO_2^- (mg/l)	0.20	0.04	0.12	
NO_3^- (mg/l)	34.31	11.43	11.34	
PO_4^{3-} (mg/l)	0.33	3.47	0.33	10
SO_4^{2-} (mg/l)	6285.7	5142.8	6285.5	
Cl^- (g/l)	1056	6745	3550	
HCO_3^- (mg/l)	2135	457.5	1220	
Fe (mg/l)	72.12	0.514	3.783	3
Cu (mg/l)	0.150	0.204	0.190	0.5
Zn (mg/l)	0.260	0.265	0.165	3

IV. Conclusion

This research, which is part of Characterization and treatment of leachates from three Landfills (BBA, KHELIL and HAMICI) in Algeria by the electrocoagulation and the electro-Fenton process. Leachate analysis of three landfills showed a high concentration of organic, inorganic and nitrogen load constituents in KHELIL landfill. Based on BOD_5/COD ratio the BBA, KHELIL and HAMICI landfill leachates were found to be stabilized, medium aged and young respectively. The measured COD reaches very high values, with an average of about 4624; 7666 and 25041 mg O_2/L for the leachate of BBA, KHELIL and HAMICI respectively. As indicated in this survey, the processes electrochemical can be effectively exploited to treat landfill leachate; treatment trials were carried out by the electrocoagulation (EC) and electro-Fenton (EF) methods with very interesting abatement yields.

The influence of variables such as stirring speed, current density, inter-electrode distance and pH on the removal efficiency of COD has been studied. The removal percentage has a tendency to increase with the increase in current density and stirring speed. The optimum operational conditions for electrocoagulation and electro-Fenton process was (number of electrodes = 2, inter-electrode distance (e) = 1.7 cm, pH = 5.5, V = 150 rpm and I = 2.3 A), (number of electrodes = 2, inter-electrode distance (e) = 1.7cm, pH = 3, [H_2O_2] = 8 g / L, V = 150 rpm and I = 2.3 A) respectively.COD removal efficiency was obtained as 75%, 93%, and 57% for KHELIL, BBA and HAMICI landfill respectively in EC process. On the other hand, the efficiency in EF process was obtained as 71%, 83%, and 78% for KHELIL, BBA and HAMICI landfill respectively in the same situations. The results of analyses for leachate after treatment have revealed that the treatment of leachate generated from KHELIL and BBA landfill was less effective in COD removal with electro-Fenton compared to electrocoagulation. Electrocoagulation and electro-Fenton both contribute to the removal of pollutants from leachate, and their relative importance depends on leachate characteristics and reaction conditions. Depending on the leachate age, electro-Fenton treatment can be implemented alone or in tandem with other technologies such as biological treatment for leachate treatment.

- However, the establishment of an in-situ leachate treatment unit within each landfills in order to avoid the risks linked to the transport of this water to external treatment units.

- Also, an evaluation of the costs of treatment by EC and EF and the carrying out of trials on a pilot or semi-industrial scale is considered interesting. For suitable management of leachate, effective containment of leachate with improved collection facilities is necessary.

V. References

1. Atmaca, E. Treatment of landfill leachate by using electro-Fenton method. *Journal of Hazardous Materials* 163. 1 (2009) 109-114.
2. Bennajah. M. Treatment of Liquid Industrial Waste by Electrocoagulation / Electro flotation in Airlift Reactor. *PhD Thesis, National Polytechnic Institute of Toulouse* (2007).
3. Bodzek, M.; Moysa, E.L.; Zamorowska, M. Removal of organic compounds from municipal landfill leachate in a membrane bioreactor. *Desalination* 198 (2006) 16–23
4. Bouhezila, F.; Hariti, M.; Lounici, H.; Mameri, N. Treatment of the OUED SMAR town landfill leachate by an electrochemical reactor. *Desalination* 280. 1-3 (2011) 347-353.
5. Boumechhour, F.; Rabah, K.; Lamine, C.; Said, B. M. Treatment of landfill leachate using Fenton process and coagulation/flocculation. *Water and Environment Journal* 27. 1 (2013) 114-119.
6. Can, O. T.; Kobya, M.; Demirbas, E.; Bayramoglu, M. Treatment of the textile wastewater by combined electrocoagulation. *Chemosphere* 62. 2 (2006) 181-187.
7. Chen, G. Electrochemical technologies in wastewater treatment. *Separation and purification Technology* 38. 1 (2004) 11-41.
8. Chiang, L. C.; Chang, J. E.; Wen, T. C. Indirect oxidation effect in electrochemical oxidation treatment of landfill leachate. *Water research* 29. 2 (1995), 671-678.
9. Cotman, M.; Gotvajn, A. Ž. Comparison of different physico-chemical methods for the removal of toxicants from landfill leachate. *Journal of Hazardous Materials* 178. 1-3 (2010) 298-305.
10. Crittenden, J. C.; Hu, S.; Hand, D. W.; Green, S. A. A kinetic model for H_2O_2/UV process in a completely mixed batch reactor. *Water research* 33. 10 (1999) 2315-2328.
11. De Laat, J.; Le, G. T.; Legube, B. A comparative study of the effects of chloride, sulfate and nitrate ions on the rates of decomposition of H_2O_2 and organic compounds by Fe (II)/H_2O_2 and Fe (III)/H_2O_2. *Chemosphere* 55. 5 (2004), 715-723.
12. Fenton, H. J. H. LXXIII. Oxidation of tartaric acid in presence of iron. *Journal of the Chemical Society Transactions* 65 (1894) 899-910.
13. Hakizimana, J. N.; Gourich, B.; Chafi, M.; Stiriba, Y.; Vial, C.; Drogui, P.; Naja, J. Electrocoagulation process in water treatment. *A review of electrocoagulation modeling approaches. Desalination* 404 (2017) 1-21.
14. Hasar. H.; S.A. Unsal.; U. Ipek.; S. Karatas.; O. Cınar.; C. Yaman.; C. Kınacı. Stripping/ flocculation/ membrane bioreactor/reverse osmosis treatment of municipal landfill leachate. *Journal of Hazard Mater* 171 (2009) 309–317
15. Hui, T.S. Leachate Treatment by Floating Plants in Constructed Wetland. Master's Thesis. *University Teknologi Malaysia, Malaysia*. (2005).
16. Joseph, B. A.; Katoch, S. S. Study of Landfill Leachate Treatment Using Photo-Fenton Process. *AReview. Age (years)* 5 (2016) 5-10.
17. Jorstad, L.B., Jankowski, J., Acworth, R.I. Analysis of the distribution of inorganic constituents in a landfill leachate-contaminated aquifer. *Astrolabe Park, Sydney, Australia. Environ. Geol* 46. 2 (2004), 263-272.
18. Ilhan, F.; Kurt, U.; Apaydin, O.; Gonullu, M. T. Treatment of leachate by electrocoagulation using aluminum and iron electrodes. *Journal of hazardous materials* 154. 1-3 (2008) 381-389.
19. Gallard, H.; De Laat, J.; Legube, B. Effect of pH on the oxidation rate of 33 630 organic compounds by Fe-II/H2O2, mechanisms and simulation. *New Journal of Chemistry* 22. 3 (1998) 263-268.
20. Gandhimathi, R.; Babu, A.; Nidheesh, P. V.; Ramesh, S. T.; Anantha Singh, T. S. Laboratory study on leachate treatment by electrocoagulation using fly ash and bottom ash as supporting electrolytes. *Journal of Hazardous, Toxic, and Radioactive Waste* 19. 3 (2015) 04014033.
21. Gautam, P.; Kumar, S.; Lokhandwala, S. Advanced oxidation processes for treatment of leachate from hazardous waste landfill. *a critical review. Journal of Cleaner Production* 237 (2019) 117639.
22. Gulsen, H.; Turan, M. Treatment of sanitary landfill leachate using a combined anaerobic fluidized bed reactor and Fenton's oxidation. *Environmental Engineering Science* 21. 5 (2004) 627-636.
23. Khajouei, G.; Mortazavian, S.; Saber, A.; Meymian, N. Z.; Hasheminejad, H. Treatment of composting leachate using electro-Fenton process with scrap iron plates as electrodes. *International Journal of Environmental Science and Technology* 16. 8 (2019) 4133-4142.
24. Kim, Y. K.; Huh, I. R. Enhancing biological treatability of landfill leachate by chemical oxidation. *Environmental Engineering Science* 14. 1 (1997), 73-79.
25. Kobya, M.; Delipinar, S. Treatment of the baker's yeast wastewater by electrocoagulation. *Journal of hazardous materials* 154. 1-3(2008) 1133-1140.
26. Li, X.; Song, J.; Guo, J.; Wang, Z.; Feng, Q. Landfill leachate treatment using electrocoagulation. *Procedia Environmental Sciences* 10 (2011) 1159-1164.
27. Li, W.; Zhou, Q.; Hua, T. Removal of organic matter from landfill leachate by advanced oxidation processes. *A review. International Journal of Chemical Engineering* (2010).

28. Lin, S. H.; Chang, C. C. Treatment of landfill leachate by combined electro-Fenton oxidation and sequencing batch reactor method. *Water Research* 34. 17 (2000) 4243-4249.
29. Lopez, A.; Pagano, M.; Volpe, A.; Di Pinto, A. C. Fenton's pre-treatment of mature landfill leachate. *Chemosphere* 54. 7 (2004) 1005-1010.
30. Mameri, N.; Lounici, H.; Belhocine, D.; Grib, H.; Piron, D. L. ;Yahiat, Y. Defluoridation of septentrional Sahara water of North Africa by electrocoagulation process using bipolar aluminium electrodes. *Separation and Purification Technology* 24 (2001) 113-119.
31. Malina. J. F.; F.G. Pohland. Design of anaerobic processes for the treatment of industrial and municipal wastes. *Water Quality Management* 7. 1 (1996) 169–175.
32. Millot, N. Les leachates des décharges contrôlées. Caractérisation analytique et études des filieres de traitement. *These de doctorat, INSA de Lyon* (1986).
33. Mohammed, Umar.; Aziz, H. A.; Yusoff, M. S. Trends in the use of Fenton, electro-Fenton and photo-Fenton for the treatment of landfill leachate. *Waste management* 30. 11 (2010) 2113-2121.
34. Mohammadizaroun, M.; Yusoff, M. S. Treatment of leachate by electrocoagulation technique using iron and hybrid electrodes. *International Journal of Scientific Research in Knowledge* 2. 11 (2014) 497-508.
35. Mollah, M. Y. A.; Schennach, R.;Parga, J. R.; Cocke, D. L. Electrocoagulation (EC) - science and applications. *Journal of hazardous materials* 84. 1 (2001) 29-41.
36. Oliveira, A.; Cerqueira, A.; Souza, P.; Rigo, M.; Paiva, J.; Marques, M. Evaluation of electrochemical and Fenton processes in the treatment of mature landfill leachates. *International Journal of Scientific Research in Science and Technology* 3. 1 (2017) 285-293.
37. Naveen, B. P.; Mahapatra, D. M.; Sitharam, T. G.; Sivapullaiah, P. V.;Ramachandra, T. V. Physico-chemical and biological characterization of urban municipal landfill leachate. *Environmental Pollution* 220 (2017) 1-12.
38. Pignatello, J. J. Dark and photoassisted Fe^{3+} -catalyzed degradation of chlorophenoxy herbicides by hydrogen-peroxide. *Environmental Science & Technology* 26. 5 (1992), 944-951.
39. Ramade, F. *Ediscience* (1998) 354-356.
40. Renou, S.; Givaudan, J. G.; Poulain, S.; Dirassouyan, F.; Moulin, P. Landfill leachate treatment: Review and opportunity. *Journal of hazardous materials* 150. 3(2008) 468-493.
41. Roudi Maslahati, A.; Chelliapan, S.; Wan Mohtar, W. H. M.;Kamyab, H. Prediction and optimization of the fenton process for the treatment of landfill leachate using an artificial neural network. *Water* 10. 5 (2018) 595.
42. Tezcan Un, U.; Filik Iscen, C.; Oduncu, E.; Akcal Comoglu, B.; Ilhan, S. Treatment of landfill leachate using integrated continuous electrocoagulation and the anaerobic treatment technique. *Environmental Progress & Sustainable Energy 37*. 5 (2018) 1668-1676.
43. Tuhkanen, T. A. UV/H_2O_2 processes. Advanced oxidation processes for water and wastewater treatment. (2004) 86-110.
44. Zhang, H.; Zhang, D.; Zhou, J. Removal of COD from landfill leachate by electro-Fenton method. *Journal of hazardous materials* 135. 1-3 (2006) 106-111.

Please cite this Article as:

Medkour, Y.; Kerbachi, R.; Boumechhour, F.; Khenchelaoui, S.; Djettene, R.; Teffahi, A., Characterization and treatment of leachates from three Technical Landfills Centers in Algeria by the electrocoagulation and the electro-Fenton process,***Algerian J. Env. Sc. Technology***, **8:3(2022) 2609-2620**