

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

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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 O₂/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 H₂O₂ 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/m²) 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 Physicochemical

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 ($\text{H}_2\text{O}_2 / \text{Fe}^{2+}$) (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 $T = 4\text{ }^\circ\text{C}$, 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 $6 \times 5 \times 0.1\text{ cm}$ ($L \times W \times T$) 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 ($500 - 1000\text{ A/m}^2$). 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.

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 |

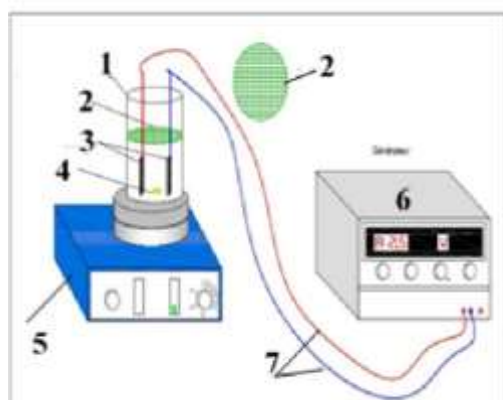


Figure 1. The electrochemical reactor in the laboratory experiments. (1) Beaker, (2) filter, (3) electrodes, (4) magnetic bar-stirrer, (5) magnetic stirrer, (6) DC power supply, (7) electric wire.

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⁻, NH₄⁺, HCO₃⁻, SO₄²⁻, Na⁺, Ca²⁺, Mg²⁺ and K⁺.

The BOD₅/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 BOD₅/COD of the present studies showed that the low BOD₅/COD (~ 0.1) values indicative of a stabilized leachate for BBA landfills. Unlike for KHELIL landfills where the BOD₅/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 BOD₅/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 O₂/l | 462499 | 2666 - 5666 | 25041.66 | 21333 - 33000 | 7666.66 | 7666.66 | 120 |
| BOD₅ mg O₂/l | 437.5 | 320 - 500 | 8300 | 7200 - 9000 | 2300 | 2300 | 35 |
| BOD₅/COD | 0.09 | 0.08 – 0.12 | 0.34 | 0.25 – 0.40 | 0.30 | 0.30 | |
| COT (mg/L) | / | / | / | / | / | / | |
| NH₄⁺ (mg/l) | 3654.80 | 2467 - 5511 | 3490.78 | 2388.40 – 5065.61 | 4566.92 | 4566.92 | |
| NO₃⁻ (mg/l) | 87.82 | 27.77 – 191.19 | 120.50 | 32.67 – 233.66 | 290.84 | 290.84 | |
| NO₂⁻ (mg/l) | 0.47 | 0.23 – 068 | 1.27 | 0.59 – 7.72 | 1.77 | 1.77 | |
| PO₄³⁻ (mg/l) | 2.07 | 0.37 – 6.94 | 3.56 | 2.51 – 3.95 | 1.97 | 1.97 | 10 |
| SO₄²⁻ (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 | |
| HCO₃⁻ (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;

BOD₅, 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/m²), 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 $[\text{Fe}(\text{H}_2\text{O})]^{2+}$ 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 Fe^{3+} 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 parameters 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).

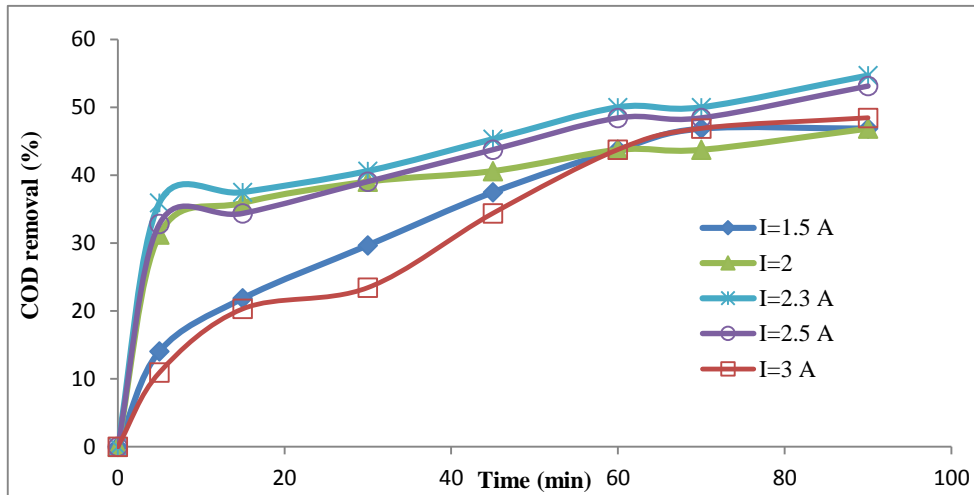


Figure 2. Effect of current intensity on the rate of COD abatement as a function of time. (Number of electrodes = 2, inter-electrode distance = 1.7 cm, Stirring speed = 150 rpm, and pH = 8)

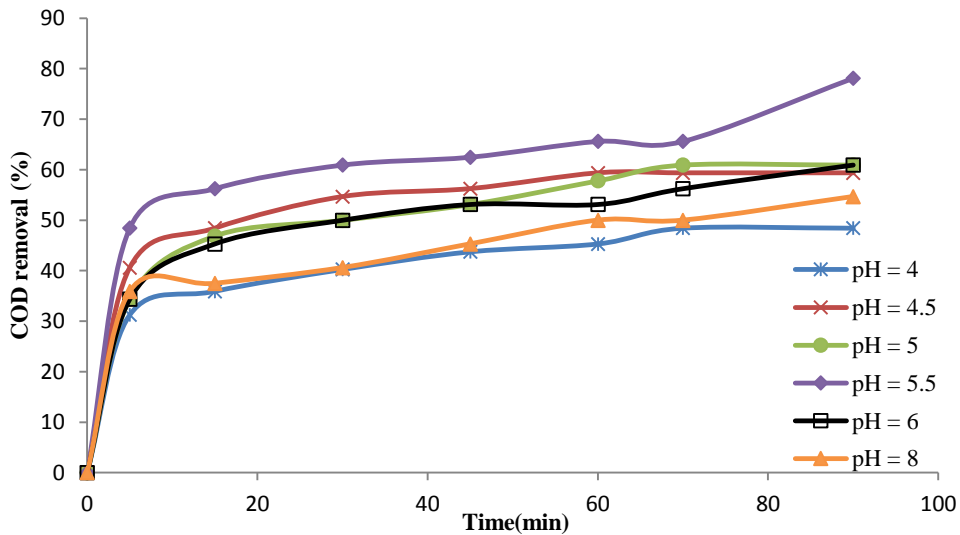


Figure 3. Effect of pH on the rate of COD abatement as a function of time (Number of electrodes = 2, $e = 1.7$ cm, $v = 150$ rpm and $I = 2.3$ A).

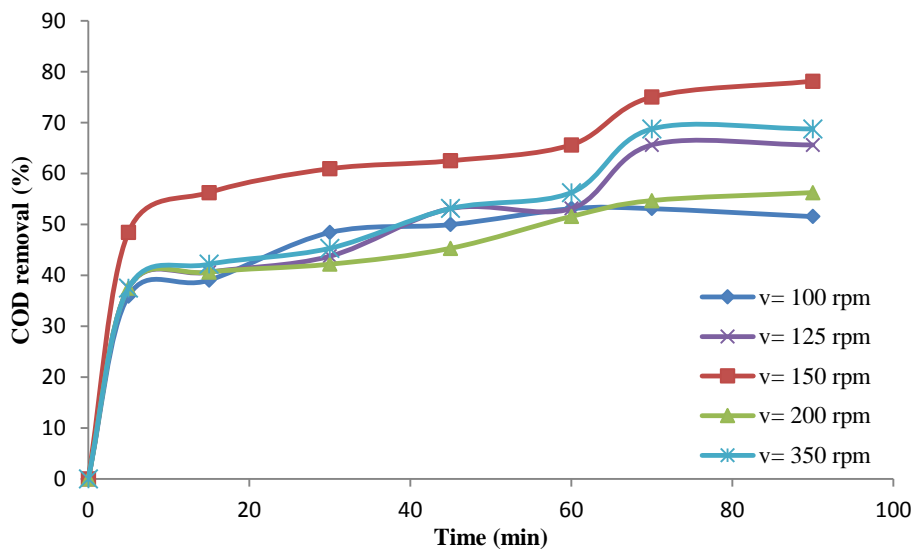


Figure 4. Effect of agitation speed on COD abatement rate (Number of electrodes = 2, $e = 1.7$ cm, pH = 5.5, and $I = 2.3$ A)

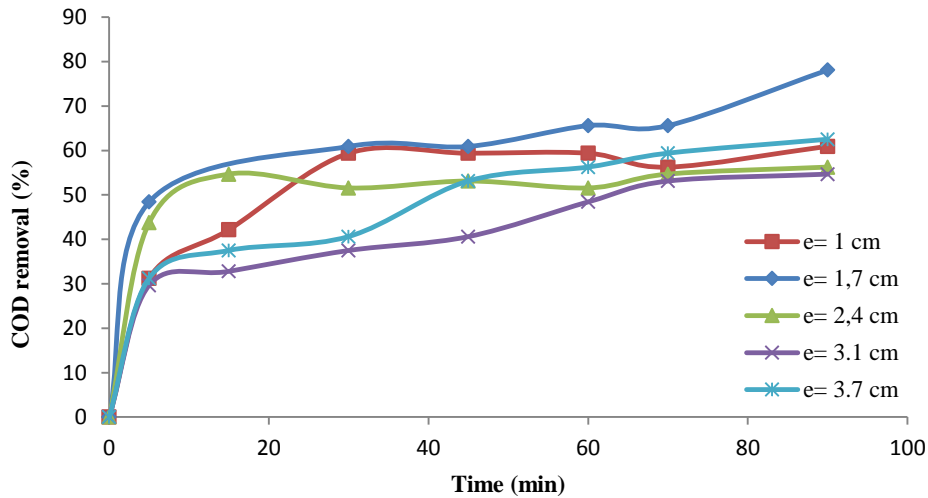


Figure 5. Effect of the inter-electrode distance on the rate of reduction of the COD as a function of time (number of electrodes = 2, pH = 5.5, V = 150 rpm and I = 2.3 A)

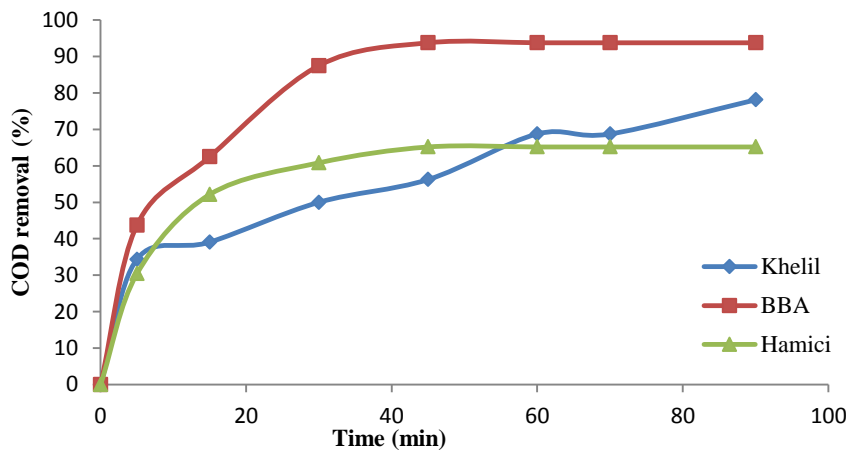


Figure 6. Evolution of COD abatement performance for each leachates of the three landfill as a function of time (number of electrodes = 2, pH = 5.5, V = 150 rpm and I = 2.3 A, e=1.7cm).

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 H₂O₂

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 H₂O₂ [H₂O₂] = 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 [H₂O₂] (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 [H₂O₂] = 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 al., 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 BOD₅ abatement of 96.5, 78.7 and 88.7% for the KHELIL, BBA and HAMICI landfill respectively. Similar results were found by (Zhang et al., 2006; Li et al., 2010; Gautam et al., 2019) were obtained.

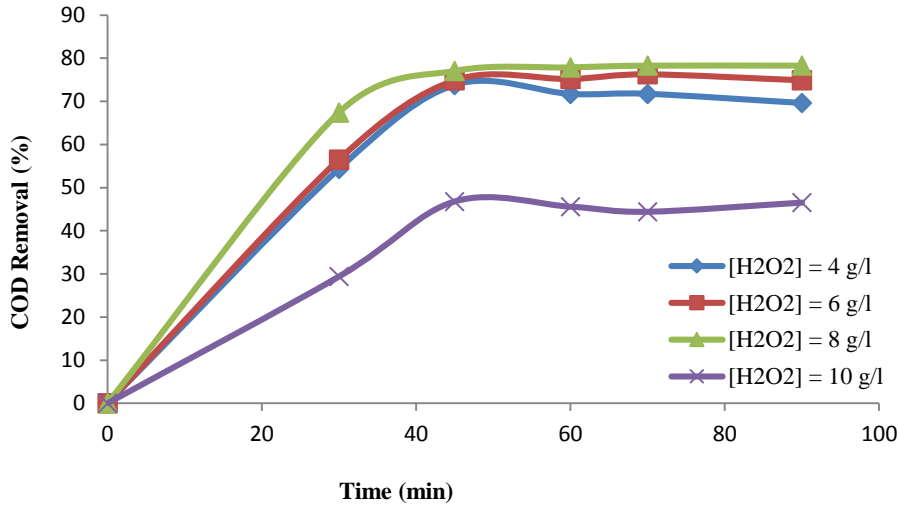


Figure 7. Evolution of COD abatement performance for each leachates of the TLC as a function of time (number of electrodes = 2, pH = 5.5, V = 150 rpm, I = 2.3 A, e=1.7 cm).

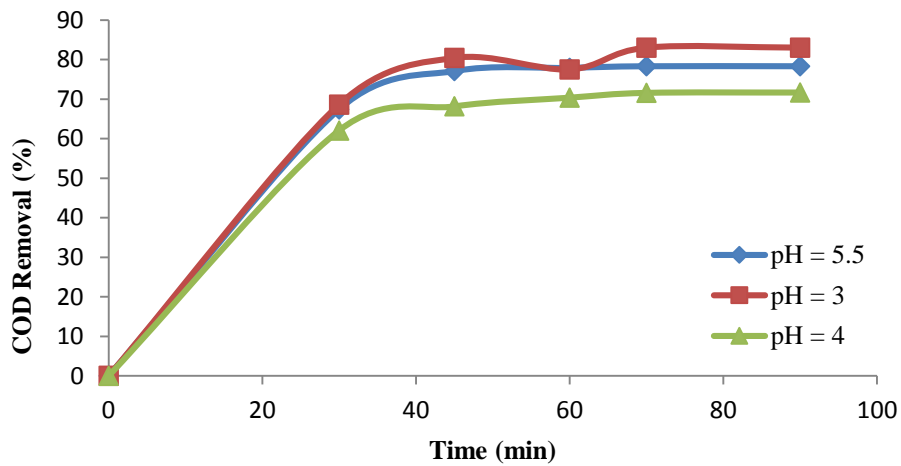


Figure 8. Evolution of COD abatement performance for each leachates of the TLC as a function of time (number of electrodes = 2, V = 150 rpm, I = 2.3 A, e=1.7 cm, [H₂O₂] = 8 g / L).

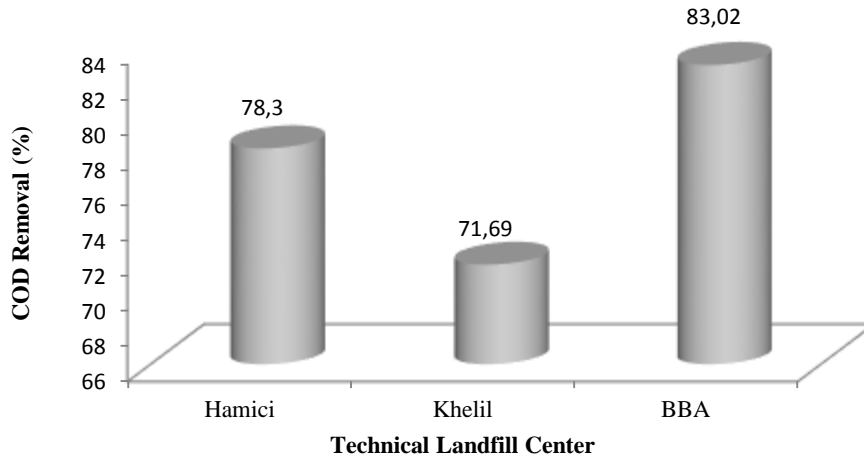


Figure 9. COD abatement performance for each leachates of the TLC as a function of time (number of electrodes = 2, pH = 3, V = 150 rpm, I = 2.3 A, e=1.7 cm, [H₂O₂] = 8 g / L).

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 SO₄²⁻ 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 (Laa et al., 2004) observed that Fe²⁺ and FeCl⁺ had the same reactivity towards hydrogen peroxide while FeSO₄ is more reactive than Fe²⁺. On the other hand, for the iron (III) / H₂O₂ system, the presence of the Cl⁻ and SO₄²⁻ 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.

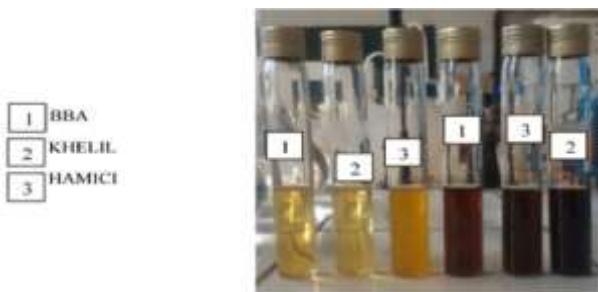


Figure 10. The result of landfill leachate before and after treatment by EC



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 BOD₅/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 O₂/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, [H₂O₂] = 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.

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