Electrochemical treatment enhancement with dissolved air floatation to minimise organic pollutants of leachate in the press stations in Baghdad

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Abstract. Leachate is a complex solution of contaminants produced from municipal waste compacting stations, being primarily comprised of household waste. In this research, leachate was treated in an electrochemical batch process with a dissolved air floatation system using aluminium as the anode with cathode electrodes. Conditions such as pH, current density (i), contact time, and air flow rate were varied and tested to determine their effects on the removal efficiency in terms of Chemical Oxygen Demand (COD), Oil, and Turbidity (Turb.). Under the best conditions, the removal efficiencies for oil, COD, and turbidity were 78.7%, 77.5%, and 98.6%, respectively, suggesting that this method can be considered an efficient and effective treatment for leachate.

Keywords: electrochemical, dissolved air, leachate, COD, Oil, aluminium electrode (Al).

1. Introduction
Press stations receive huge amounts of waste, mostly from households each day. Hundreds of tons of this waste is thus compressed and reduced in size to be disposed of to sanitary landfills. The fluids produced in this process are called leachate [1], and this is a high polluted load. The pollutants can be divided into categories such as colloidal, suspended solids, organic, inorganic materials, and others, and the wastewater must be treated for all of these, as effects of this pollutant content on the sewage stream would have a significant negative impact on the natural environment and human health due to its high concentration of COD, Oil, and inorganic solids [2, 3].

There are many methods for treating leachate, though the electrochemical process is generally regarded as the most effective and economical; this technique relies on transferring electrons between electrodes and the electrolytic solution, a process triggered by applying an electric field between an anode and cathode made of specific materials appropriate for the relevant electrochemical process [4].

The electrochemical method has proven its efficiency in treating different types of wastewater and offers many advantages, the most important of which is that its products are environmentally friendly, and it can be operated at ambient temperatures and pressures [5, 6]. To produce coagulant reagent, an
aluminium electrode is generally used because of its important advantages in availability, effectiveness, relative cheapness, and non-toxicity [7].

In many works, the main mechanism of the removal of pollutants by electrolysis is the electrodissolution of sacrificial anodes, made of aluminum or iron, to form hydrolysis products (hydroxo-metal species) that are effective in the destabilisation of pollutants [8]. This electrochemical method has been used to treat many types of wastewater, including municipal wastewater [2], stabilised leachate [9], landfill leachate [10], hospital wastewater [11], carwash wastewater [12, 13], textile wastewater [14], paper mill wastewater [15], and livestock wastewater [16].

In this work, dissolved air was used with the electrochemical method to produce bubbles of oxygen gas to encourage the mixing of contaminated water with coagulation factors and to increase contact between them in order to examine its effect on the treatment of leachate. The main objective of this work was to examine the implementation of the treatment of leachate produced from municipal waste compression plants by a mixed electrochemical and dissolved air method and to determine the best rates of removal of pollutants under practical conditions by examining the effects of current density, pH, contact time, and air flowrate.

2. Materials and methods

2.1. Characteristics of leachate

The characteristics of the leachate produced by press stations varies from one batch to another, depending on the waste composition and climatic conditions. Samples were collected from the waste compression station in Baghdad, and the physical and chemical properties of the waste leachates were tested in both the Ministry of Science and Technology and in the postgraduate laboratory of the department of Chemical Engineering at the University of Baghdad. All laboratory analyses were performed according to standard methods [17]. The characteristics of the raw leachate are shown in Table 1.

| Analysis test            | Value (unit) | Device used                 |
|--------------------------|--------------|-----------------------------|
| pH                       | 4.7          | pH-meter (ATC)              |
| Turbidity                | 1850 (NTU)   | Turbi Direct Lovibond, TB   |
| Conductivity             | 0.0174 (mS/cm) | Conductivity-meter         |
| Chemical oxygen demand(COD) | 38610 (mg/l) | HACH DR5000               |
| Oil                      | 52200 (mg/l) | Horiba                     |
| TOC                      | 12870 (mg/l) | HACH DR5000-SHIMADZU       |

To treat this as a form of wastewater, it was diluted to reasonable levels, as the efficiency of pollutant removal decreases with increases in the initial concentration of pollutants when the current density is constant. This occurs because the number of metal hydroxide masses generated is insufficient for the coagulation of the higher volumes of pollutants at higher primary pollutant concentrations [18]. Each litre of leachate was thus diluted with 4 litres of tap water. The characteristics of the leachate after dilution are shown in Table 2.
Table 2. Average characteristics of diluted leachate.

| Analysis test          | Value (unit) |
|------------------------|--------------|
| PH                     | 4-6          |
| Turbidity              | 820(NTU)     |
| Conductivity           | 0.022(mS/cm) |
| Chemical oxygen demand(COD) | 4120(mg/l) |
| Oil                    | 1903(mg/l)   |

2.2. Materials and devices used

The electrochemical lab unit and lab scale used are shown in **Figures 1 and 2**. The unit consisted of a glass reactor with dimensions 60 x 13 x 13 cm. Two aluminium electrodes were positioned for coagulation of 30 x 11 x 0.1 cm, giving an area of active electrode of 156.2 cm², with 6 cm between the electrodes. A DC power supply 0 to 5 A and 0 to 30 V. An air pump was used at 1, 1.7, and 2.3 L/min and a distributer of 1.5 cm diameter and 4 cm height was also incorporated. In order to adjust the pH levels, NaOH and H₂SO₄ were used as necessary.
2.3. Procedure
After dilution, the pH value of the leachate was adjusted; it was then transferred to the electrolysis unit. Each experiment was carried out using 3 L of diluted leachate in an electrochemical reactor in batch mode at room temperature and atmospheric pressure. Aluminium electrodes were used, arranged in a monopolar-parallel mode and connected with the DC power supply by two wires, one for the anode and the other for the cathode. Each run of the experiment was timed from the DC power supply switching on and the air pump opening.

3. Results and discussion
3.1. Effect of current density ($i$)
Current density is an important factor in electrochemical treatment processes; this is the ratio of current to the area of the effective electrode ($i = \text{mA/cm}^2$). This parameter determines the amount of metal ions released from the electrodes as well as the size of the bubble and the growth of flocs [19]. To examine the effect of current density on the treatment process, experiments were conducted at 3.2, 6.4, and 19.2 mA/cm$^2$ current densities for 80 min each, with other practical conditions maintained steady. As shown in figure 3, when the current density increases, the removal efficiency for turbidity, COD, and oil increases; this is explained by the increase in the coagulant concentration (metal hydroxide) in the solution due to the higher production of metal ions at the anode, which depends mainly on passing electricity [4][20]. Maximum turbidity, COD, and oil removal efficiencies were obtained at 19.2 mA/cm$^2$ (at pH=6 and air flowrate=2.3 L/min), suggesting that this value is the best of those tested.
Figures 3. Effect of Current density on removal of (a) Turbidity, (b) COD, and (c) Oil.

3.2. Effect of contact time ($t$)
The effect of contact time is shown in Figure 4. The efficiency of removal for both turbidity and oil was shown to increase with increasing treatment time, while for COD, the highest removal rate was obtained at 60 minutes; however, comparing other ratios showed that the results were considered satisfactory, so a time of 80 minutes was taken as the best time for the operation due to the increased dissolution of the metal and the release of more ions (coagulation precursors) as the treatment time increases, in agreement with Gönder et al [13]. It Taking 80 minutes as a suitable time for the electrochemical process helps to prevent waste electrical energy in addition to offering good results.
3.3. Effect of pH
The initial value of pH is an important factor in the electrochemical process as the electrolysis of the anode electrode in the wastewater at different values of pH gives different polymers (metal hydroxides) [21]. The electrocoagulation process thus depends extensively on the solution pH as this impacts the stability of the coagulant in the solution [10]. The influence of the initial pH on the elimination competence with regard to COD, oil, and turbidity was examined with pH adjusted for 4, 6, and 8 for a current density of 19.2 mA/cm², a contact time of 80 min, and an air flowrate of 2.3 L/min with Al electrodes, as shown in Figure 5.

![Figure 4. Effects of contact time (t) at (pH= 6, i=19.2 mA/cm², and air flowrate=2.3 L/min) on turbidity, COD, and oil removal.](image)

![Figure 5. Effects of pH on turbidity, COD, and oil removal.](image)
This figure shows the relationship between the pH and the removal efficiency of the pollutants, with the highest removal efficiency obtained with a pH value of 6, indicating the stability of the coagulant (aluminum hydroxide) over a significant period. The shape of the graph suggests that the highest removal efficiency is obtained at pH-neutral and near-neutral values when using aluminum electrodes; when electrocoagulation using aluminum has an initial pH solution that is acidic, the final pH of the solution is raised, while when the initial pH of the solution is alkaline, the final pH decreases [22].

3.4. Effect of air flowrate
In this study, the air pump was calibrated to known values, and the effects of these on the treatment of leachate from municipal waste compacting stations with electrocoagulation thus studied. The effects of the air flowrate are shown figure 6 for 80 minutes processing time at pH = 6 with the best value of current density per previous tests.

As shown in figure 6, the highest removal efficiency for turbidity, COD, and oil was obtained at the highest value of air flowrate, showing the importance of regular mixing between the coagulant and the pollutants and the separation of the coagulated pollutants by the floatation process during contact with the oxygen bubbles thus formed. This is clearly a major part of the sedimentation process, consistent with Atiyah [23].

4. Conclusion
An enhanced electrochemical system using dissolved air was successfully applied to treat the leachate produced from a waste compaction plant in Baghdad using aluminum electrodes. The results showed that the maximum COD, turbidity, and oil removal efficiencies, which were 77.5%, 98.6%, and 78.7% respectively, were obtained at a pH of 6 on treatment for 80min with 19.2 mA/cm² current density and 2.3 L/min air flowrate. This is a promising method with practical applications.
Acknowledgments
Huge thanks go to the staff of the Water Research Center at the Ministry of Science and Technology in Baghdad for their efficiency and effectiveness during the examination of samples.

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