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# Performance Evaluation of Electrocoagulation System for Wastewater Treatment

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***Abstract*- This study aimed to evaluate the performance of an electrocoagulation reactor (EC) and investigate its efficiency in heavy-polluted industrial wastewater treatment. The electrocoagulation (EC) reactor has been experimentally evaluated using aluminium (Al) electrodes and connected to a direct current power at various applied voltage levels at room temperature in a relatively limited reaction time.**

**The treatment performance efficiency of the selected dominant EC operating parameter groups: pH, reaction time, inter-electrode distance, and applied voltage was investigated. The results demonstrate that the applied voltage to the electrocoagulation reactor was the most significant factor in pollutant removal. The maximum total suspended solids (TSS), Biochemical oxygen demand ($BOD_5$), and Chemical Oxygen demand (COD) removal efficiencies up to 87%, 88%, and 90% respectively were obtained at 20 mm inter-electrode distance with pH 7 when the applied voltage was 55V in 60 treatment minutes. Overall, the removal performance efficiencies obtained under the study's conditions show that the electrocoagulation system is significantly efficient in treating industrial wastewater effluents with high pollutant contents.**

***Keywords*- Electrocoagulation; aluminum electrodes, wastewater treatment, pollutants.**

## 1. INTRODUCTION

Industrial wastewater discharges with high pollutants have an increasingly serious impact on the sustainability of environmental life. Electrochemical methods such as electrocoagulation (EC) are promising technologies for removing organics and heavy metals contained in industrial effluents (Sharma et al., 2020). Many favorable benefits of the EC technology include a neglected harmful substance (Dolatabadi et al, 2017).

In 2020, an experimental and analytical study was conducted on the successful significant effect of electrochemistry on the improvement of the quality of highly polluted wastewater effluents (Lefebvre et al, 2020).

According to Zanjani et al., the feasibility and the own disadvantages of the electrical coagulation process were investigated. This research involved electrocoagulation usage for mine wastewater treatment as well as recovery of metals (Zanjani et al., 2023).

The main advantage of the electrocoagulation reactor can be mainly considered by many certain criteria that influence its performance such as the applied voltage, distance between the electrodes, electrode contact area, cell potential, mass transfer, pH, and reaction time, among others (Al Jaberi et al., 2023). It has been confirmed that electrocoagulation is one of the most effective green technologies that ensure a great deal of environmental sustainability.

Shaaban et al. (2021) evaluated the performance of the aluminum electrodes electrocoagulation system for restaurants wastewaters discharges. The results indicated distinctive efficiency of the system treatment in the case of high wastewater organic load (Shaban et al.,2021).

In 2023, a study implemented by Mutalip et al. proposed a distinctive model for peat water treatment with a continuous electrocoagulation reactor by utilizing aluminum electrodes (Mutalip et al., 2023).

Pasquali et al. implemented an extended experimental program to evaluate the electrocoagulation process associated with advanced oxidation as a preferable technology rather than the corresponding conventional effluent treatment systems. The removals obtained under the recommended conditions exceeded 92% in the aqueous phase, indicating that the electrocoagulation peroxidation technique has superior efficiency in treating contaminants such as drug effluents (Pasquali et al., 2023).

Consequently, the main objective of this study was to evaluate the performance of electrocoagulation in removing TSS, $BOD_5$, and COD from highly polluted industrial wastewater utilizing aluminium electrodes. Moreover, the influence of various electrocoagulation reactor operation conditions such as pH values applied electric current voltage, and inter-electrode distance on the removal efficiency was explored and discussed to determine the optimum operational conditions.

## 2. MATERIALS AND METHODS

### 2.1 MATERIALS

The wastewater used in this work was collected from the local milk factory in the 6 October City industrial zone with an average daily production capacity of 30000 kg. The main characteristics of the wastewater are illustrated in Table 1.

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Table 1 Character of raw wastewater effluents

| Parameters | Values | Discharge to sewer system according to Egyptian Standard limit (ESL) |
|---|---|---|
| Temperature (°C) | 21.70±0.24 | <43 |
| pH | 7.24 ± 0.12 | 6-9.5 |
| COD (mg/l) | 6033.17 ± 66.48 | <1100 |
| $BOD_5$ (mg/l) | 2742.81 ± 37.16 | <600 |
| TSS (mg/l) | 615.29 ± 21.23 | <800 |

To demonstrate the effect of pollutant concentration and the time required for their quantitative removal, a stock solution of 1 L containing 1000 mg for each sample was prepared. In the laboratory, experiments were conducted using a fiberglass cell of 7mm thickness, as an electro-coagulation reactor on an argentic stirrer (Falc Instruments F60 model, Italy) provided with mono-polar electrodes connected in parallel. The volume of this reactor was 0.3m3 (0.8 m length 0.5m width * 0.75m depth). Aluminum was utilized as electrode fabricated material for the experiments. The reactor has six square plate electrodes (10cm * 8cm) with a thickness of 0.5 mm. Fig.1 shows a schematic diagram of the experimental setup of the electrocoagulation unit.

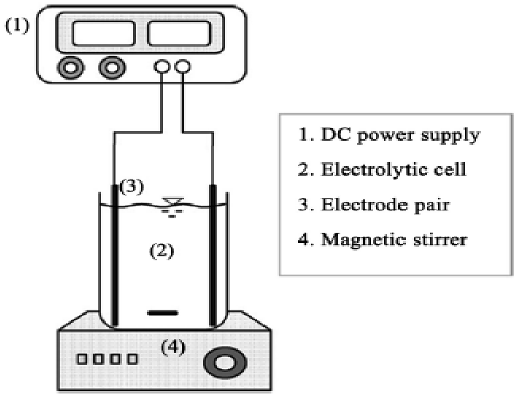


**Fig.1 Experimental set up.**

## 3. METHODS

In this study, six plates of aluminum were installed vertically with the various experiment's inter-electrode distances and immersed to a 5 cm depth. The experiment was run for 60 minutes. A digital meter, KEW SNAP model-2007 is used for the measurement of the potential between the electrodes. The temperature of each system was maintained at 25 ± 2°C. In turn, the reading of the experiment's dominant varied parameters is observed every 5 minutes as a fixed time interval. Different samples were filtered before being analyzed to determine $BOD_5$, COD, TSS, and other parameters. All the aforementioned procedures were repeated by using aluminum electrodes with differences in an electrolyte solution with varying pH values: 3, 5, 7, and 9 also in addition to different applied voltages (25V, 35V, 45V, and 55V) as well as inter-electrode distances of 10mm, 20mm, 30mm, and 40mm.

## 3. RESULTS AND DISCUSSIONS

### 3.1 INFLUENCE of INITIAL pH on ELECTROCOAGULATION EFFICIENCY

The initial pH of the wastewater is one of the most significant parameters in electrocoagulation treatment processes (Mercier et al., 2012). Fig 2, shows the total suspended solids data for various experiment reaction times and different pH operation conditions have been presented.

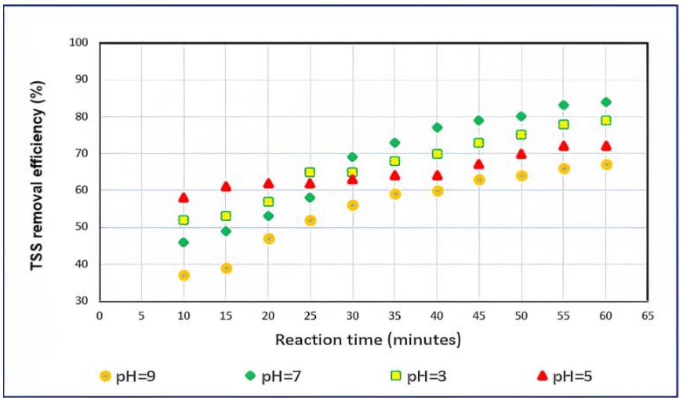


**Fig.2 Influence of initial pH on TSS reduction concerning time When applied voltage, 35V; and electrode distance, 20mm**

As a reaction time increases from 10 cm to 60 minutes, increases in the TSS removal efficiencies with various pH conditions up to 68.43%, 71.86%, 78.11%, and 85.67%, for pH equal to 9, 5, 3, and 7 respectively were noted. On the other hand, it is obvious with pH=7 that, the optimum distinctive reduction efficiency can be obtained by 87%. Meanwhile, Fig.3 investigates the influence of wastewater pH values on the electrocoagulation performance efficiency for COD reduction.

After 60 minutes of treatment, the removal efficiencies reach 69.16%, 73.97%, 81.32%, and 88.33%, for pH equal to 9, 5, 3, and 7 respectively. The obtained results agree with those appointed by Fayad, 2018 and confirm by Tezcan, 2015 that pH can be considered one of the important governing parameters in determining the efficiency of various electrocoagulation processes.

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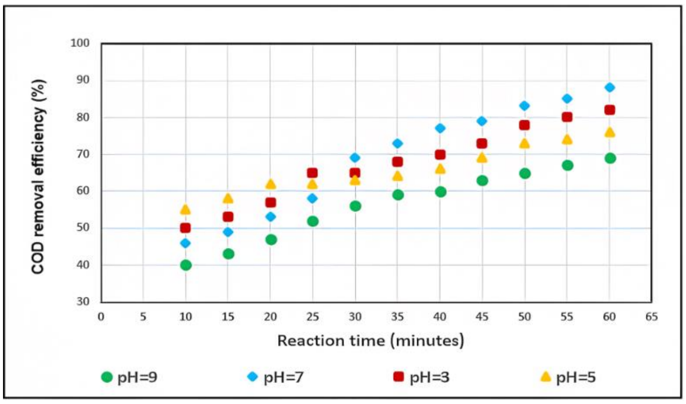


**Fig.3 Influence of initial pH on COD reduction concerning time When applied voltage, 45V; and electrode distance, 10mm.**

In addition, the experimental investigation results of the electrocoagulation pH and the reaction time effect on the $BOD_5$ removal are shown in Fig.4.

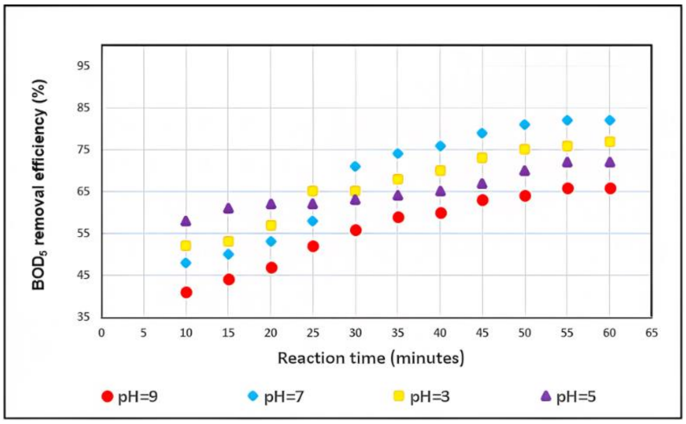


**Fig.4 Influence of initial pH on $BOD_5$ reduction concerning time When applied voltage, 55V; and electrode distance, 30mm.**

It can be noted that the minimum $BOD_5$ removal efficiency occurred with pH 9. However, when increasing the reaction time from 10 to 60 minutes, a gradual increase in the amount of $BOD_5$ removal efficiencies from 37.34% to 65.11% was achieved with the mentioned pH value. On the other hand, a noted increase in $BOD_5$ removal efficiency with pH7 from 48.66% to 84.11% was obtained due to the increase in electrocoagulation reaction time from 10 to 60 minutes.

## 3.2 INFLUENCE of APPLIED VOLTAGE on POLLUTANTS REMOVAL

As can be seen in Fig.5, the experimental reaction time was carried out at various applied voltages where pH, 5; and electrode distance, 20mm for the Al electrodes to investigate the influence of electrocoagulation on the TSS reduction efficiency.

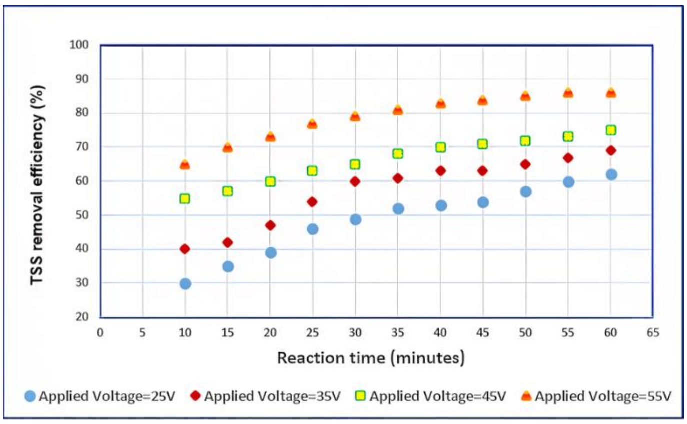


**Fig.5 Influence of applied voltage on TSS reduction concerning time When pH, 5; and electrode distance, is 20mm.**

TSS removal efficiency was directly proportional to reaction time as well as the applied voltage. Furthermore, the TSS reduction efficiency is directly proportional to the applied reactor voltages for a given time, meanwhile, after 60 minutes of reaction time, where pH, 5; and electrode distance, 20mm, good progress in TSS removal percentages such as 86.64, 75.51, 69.57, and 62.17 % removal was achieved in 55, 45, 35, and 25 applied voltages respectively. Fig.6 illustrates the reflected electrocoagulation of various applied voltage effects on the COD removal efficiency with pH, 7; and electrode distance of 40mm.

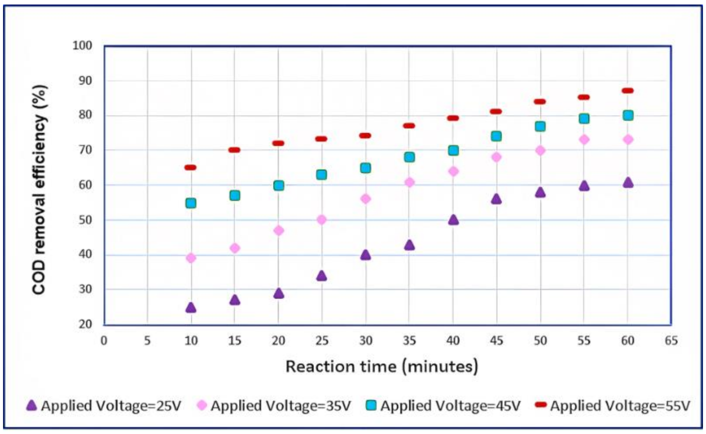


**Fig.6 Influence of applied voltage on COD reduction concerning time When pH, is 7; and electrode distance, is 40mm.**

It was observed that at a lower applied voltage of 25V, the COD removal rate reached up to 60.05%, and at a higher voltage of 55V, COD removal efficiency reached 89.38%. In turn, with a moderate voltage of 35V and 45V, the maximum COD removal achieved 73.53% and 80.43% respectively. Therefore, it is obvious that by increasing the electrical potential voltage from 25 to 55 V, the concentration of the pollutant in the effluent was reduced significantly. The results of this study

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are in agreement with the results of research done by Nasution et al., (2011). Furthermore, the experimental investigation of the applied electrocoagulation voltage effect on COD reduction is shown in Fig.7 for pH, 9; and electrode distance of 30mm.

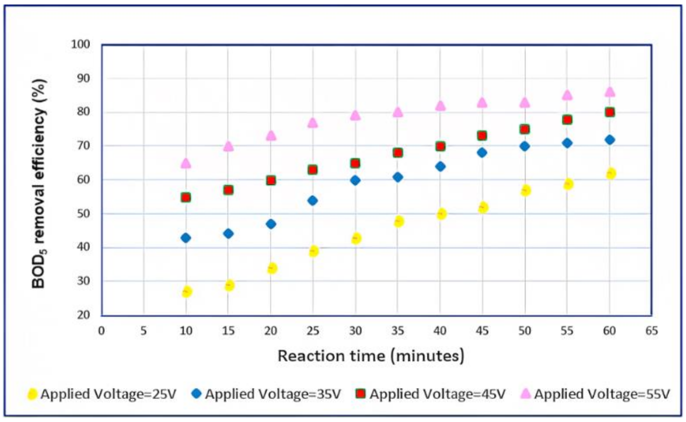


**Fig.7 Influence of applied voltage on BOD5 reduction concerning time When pH, is 9; and electrode distance, is 30mm.**

It can be noted that after 60 minutes of reaction time, the BOD5 removal efficiencies reach 62.21%, 71.15%, 80.04%, and 87.36% for the applied voltages 25V, 35V, 45V, and 55V respectively with specific experiment conditions of pH: 7 and 30 mm electrode distance. Our results are in agreement with output which appointed by Nakhaie et al., (2013).

### 3.3 INFLUENCE of INTER-ELECTRODE DISTANCE

Many previous studies have confirmed that inter-electrode distance adjustments can increase coagulants (Kumbur et al., 2018). Therefore, various inter-electrode distance experiments were conducted to investigate their effect on TSS removal efficiencies for distances of 10, 20, 30, and 40 mm. Fig. 8 shows the obtained results for pH 7 and applied voltage 45V.

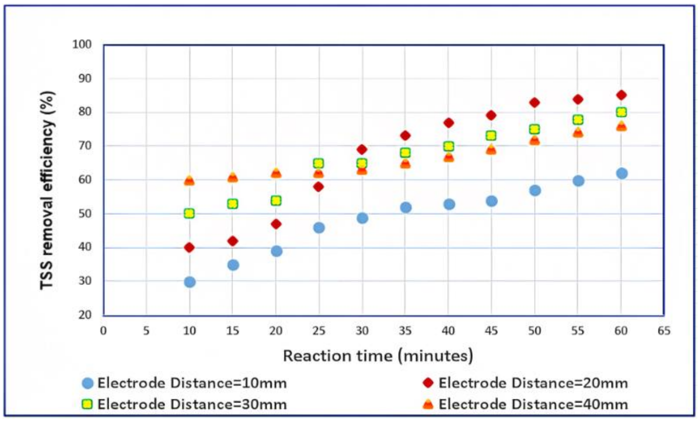


**Fig.8 Influence of inter-electrode distance on TSS reduction concerning time, when pH, is 7; and applied voltage, is 45V.**

After 60 minutes of electrocoagulation treatment reaction time, the minimum TSS removal efficiency trend from 30.05% to 61.16%, was obtained with an electrode distance equal to 10mm. In turn, the maximum TSS removal efficiency was achieved by 86.43% with an electrode distance equal to 20mm. On the other hand, after passing 30 minutes of treatment reaction time, a notable increase in the TSS removal trend of 20mm electrode distance was observed, rather than the corresponding one of 30 mm electrode distance. This can be mainly explained due to the fluctuation of direct proportion between electrode distances and ohm loss concerning the anode and cathode overvoltage which causes a significant increase in mass transfer resistance (Hanafiah et al., 2021). Additionally, Fig.9 illustrates the effect of inter-electrode distance on the COD removal efficiencies where pH, is 5; and the applied voltage is 55V.

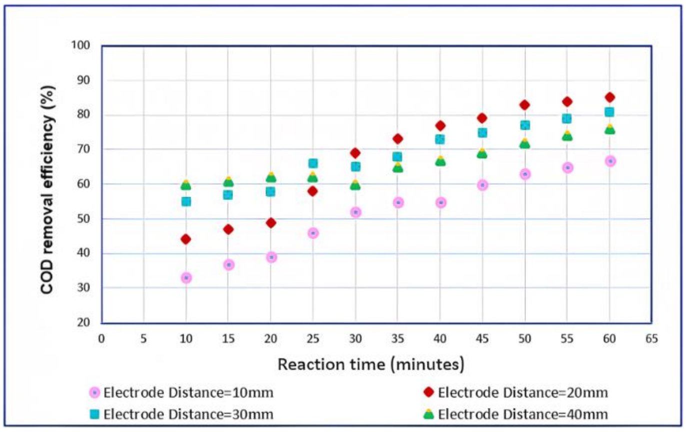


**Fig.9 Influence of inter-electrode distance on COD reduction concerning the time when pH, is 5; and applied voltage, is 55V.**

It can be noted that after 60 minutes of reaction time, where pH, is 5; and applied voltage, is 55V, the maximum archived COD removal efficiency due to applying the electrocoagulation process is 87.53%, 81, 87%, 75.33%, and 68.12% with an electrode distance of 20, 30, 40, and 10. Our results are in agreement with those reported by Iounes et al., (2022). Fig.10 illustrates the influence of inter-electrode distance on BOD5 reduction for time, when pH, is 3; and the applied voltage is 35V.

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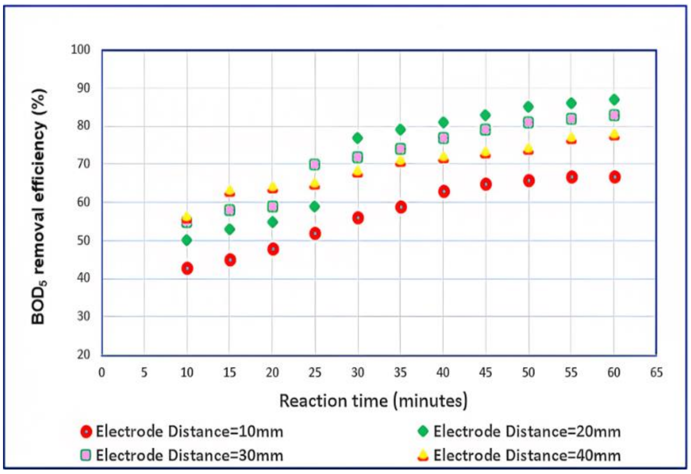


**Fig.10 Influence of inter-electrode distance on $BOD_5$ reduction concerning the time when pH, is 3; and applied voltage, is 35V.**

The 20mm electrode distance realizes the optimum $BOD_5$ removal efficiency with a minimum value of 50.08% after 10 minutes of reaction time and a maximum value of 88.54% after 60 minutes of reaction time. Also, a similar trend of $BOD_5$ removal efficiency was previously determined in the research of Kurt et al. (2016).

## 4. CONCLUSIONS

In this study, the evaluation of the electrocoagulation removal efficiency of industrial wastewater was experimentally investigated from aqueous solutions by an EC reactor. Electrode combination, pH (3–9), applied voltage (25–55 V), electrode distance (10–40 mm), and reaction time (10–60 minutes) were studied. Moreover, the EC treatment rate has a significant direct relationship with the applied voltage and reaction time. The optimum EC operation conditions were determined with pH 7.0, an applied voltage of 55V, an electrode distance of 20mm, and a reaction time of 20 minutes, the removal efficiency was achieved up to 87, 88, and 90% for TSS, BOD5, and COD respectively.

## 5. REFERENCES

[1] APHA. Standard methods for the examination of water and wastewater. 20th Ed. Washington D.C.: American Public Health Association; 1998.

[2] APHA (AMERICAN PUBLIC HEALTH ASSOCIATION). Standard methods for the examination of water and wastewater. 21.ed. Washington, DC, 2005. 1200p.

[3] Abbas A. Al- Raad and Marlia M.Hanafiah, (2021). “Removal of inorganic pollutants using electrocoagulation technology: A review of emerging applications and mechanisms”. Journal of Environmental Management, 330, https://doi.org/10.1016/j.jenvman.2021.113696.

[4] Bassam Al Aji a, Yusuf Yavuz b,and A. Savas_ Koparal, (2012). “Electrocoagulation of heavy metals containing model wastewater using monopolar iron electrodes”. Separation and Purification Technology, 86, 248–254. doi:10.1016/j.seppur.2011.11.011.

[5] Behling, L., da Luz, V.C., Pasquali, G.D.L. et al, (2023). “Ibuprofen removal from synthetic effluents using Electrocoagulation-Peroxidation (ECP)”, Environmental Monitoring Assessment 195, 271 (2023). https://doi.org/10.1007/s10661-022-10879-y.

[6] Deepak Sharma, Parmesh Kumar Chaudhari, Savita Dubey, and Abhinesh Kumar, (2020).” Electrocoagulation Treatment of Electroplating Wastewater: A Review”, Journal of Sustainable Water in The Built Environment, 146(10). https://doi.org/10.1061/(ASCE)EE.1943-7870.0001790.

[7] Deghles, A. and Kurt, U. (2016) Treatment of Tannery Wastewater by a Hybrid Electrocoagulation/Electrodialysis Process. Chemical Engineering and Processing,104, 43-50. https://doi.org/10.1016/j.cep.2016.02.009

[8] Edris Bazrafshan, Hossein Moein, Ferdos Kord Mostafapour, and Shima Nakhaie, (2013).” Application of Electrocoagulation Process for Dairy Wastewater Treatment”. http://dx.doi.org/10.1155/2013/640139.

[9] El-Ezaby, K.H., El-Gammal, M.I. & Shaaban, Y.A, (2021). “Using electro- and alum coagulation technologies for treatment of wastewater from fruit juice industry in New Damietta City, Egypt”. Environmental Monitoring Assessment 193, https://doi.org/10.1007/s10661-021-09149-0.

[10] Fayad N., (2018). “The application of electrocoagulation process for wastewater treatment and for the separation and purification of biological”. Chemical and Process Engineering. Université Clermont Auvergne. English. NNT: 2017CLFAC024 p207. archives-ouvertes 5, 6–11.

[11] Habibe Elif Gülşen Akbay, Ceyhun Akarsu, and Halil Kumbur,(2018).” Investigation of electrocoagulation process for the removal of phosphate: full-scale process optimization, operation cost and adsorption kinetics”. Desalination and Water Treatment. 155, 168–174. doi: 10.5004/dwt.2019.23729.

[12] Jasim, M.A., AlJaberi, F.Y, (2023). “Removal of COD from real oily wastewater by electrocoagulation using a new configuration of electrodes”, Environmental Monitoring and Assessment 195, https://doi.org/10.1007/s10661-023-11257-y.

[13] Khaled H. El-Ezaby, Maie I. El-Gammal and Youmna A. Shaaban, (2020). “Electrocoagulation Treatment for Wastewaters from some Restaurants in New Damietta City-Egypt”. Journal of Environmental Sciences, 49(4). http://Joese.mans.edu.eg.

[14] M. Ansori Nasution, Z. Yaakob, Ehsan Ali, S. M. Tasirin, S.R.S Abdullah, (2011).” Electrocoagulation of Palm Oil Mill Effluent as Wastewater Treatment and Hydrogen Production Using Electrode Aluminum”. https://doi.org/10.2134/jeq2011.0002.

[15] Nazeri Abdul Rahman, Allene Albania Linus, Calvin Jose Jol, Nur Syahida Abdul Jalal , Chieng Kwong Ming , Wan Wafi Shahanney Wan Borhan , Nooranisha Baharuddin , Shaleen Nur Ain Samsul , Nurshazatul’aini Abdul Mutalip, (2023).” Kinetic modelling of peat water treatment with continuous electrocoagulation using aluminium electrodes”, Journal of Environmental Chemical Engineering, 11, https://doi.org/10.1016/j.jece.2023.109559.

[16] Orlando Garcia -Roodriguez, Emmanel Mousset,Hugo Olvera- Vargas, Oliver Lefebure, (2020). “Electrochemical treatment of highly concentrated wastewater: A review of experimental and modeling approaches from lab- to full-scale”, Critical Review in Environmental Science and Technology, 52(2), https://doi.org/10.1080/10643389.2020.1820428.

[17] Ridha Lessoued, ,Lotfi Baameur,and Ahmed Tabchouche, (2021).” Modeling and Optimization of COD Removal from Leachate by Electrocoagulation: Application of Central Composite Design, Environmental Modeling & Assessment”, https://doi.org/10.1007/s10666-021-09765-7.

[18] Rimeh Daghrir, Patrik Drogui,Jean Blais ,and Guy Mercier, (2012). “Hybrid Process Combining Electrocoagulation and Electro-Oxidation Processes for the Treatment of Restaurant Wastewaters”, Journal of Environmental Engineering, https://doi.org/10.1061/(ASCE)EE.1943-7870.0000579.

[19] Saeid Ahmadzadeha,b, , Ali Asadipourc, Mostafa Pournamdaric, Behzad Behnamb, Hamid Reza Rahimid, Maryam Dolatabadie, (2017).” Removal of ciprofloxacin from hospital wastewater using electrocoagulation technique by aluminum electrode: Optimization and modelling through response surface methodology”, Process Safety and Environmental Protection, 109, http://dx.doi.org/10.1016/j.psep.2017.04.026.

Journal of Engineering Research (ERJ)
ISSN: 2356-9441 Vol. 8 – No. 3, 2024 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

[20] Shahedi, A., Darban, A.K., Jamshidi-Zanjani A. et al., (2023). "An overview of the application of electrocoagulation for mine wastewater treatment". Environmental Monitoring Assessment 195, 522 . https://doi.org/10.1007/s10661-023-11044-9.

[21] Soukaina Namoussi, Chaimaa Merbouh1, Mohamed Kabriti1, Abdelmottalib Nahli1, Ayoub Naamane, Mohamed Chlaida,and Nadia Iounes,(2022). "Treatment of Surface Treatment Effluents by Electrocoagulation Process Using Aluminium Electrodes". 23(1), 91–99. Journal of Ecological Engineering.https://doi.org/10.12911/22998993/143974.

[22] Tezcan U., Eren Ö, (2015). "A Removal of Heavy Metals (Cd, Cu, Ni) by Electrocoagulation". https://www. researchgate.net/publication/269404945.