Using Of Different Electrocoagulation Cell Configuration Parameters for Treating of Abu-Ghraib Dairy Products Wastewater

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ABSTRACT: One of the most significant issues that people throughout the world will confront in the future years is a lack of clean and safe water. Anthropogenic activities, in particular, are polluting water systems. With rising population, urbanization, and climate change, water reuse has become a requirement in some areas of the globe, putting pressure on the development of effective water treatment methods for a range of contaminants. High biological oxygen demand (BOD), chemical oxygen demand (COD), oil-grease, and other pollutant loads define dairy sector effluent. Improved technology is required to address these issues. Electrocoagulation is a new type of therapy. It's simple to use, ecologically friendly, and removes a wide range of contaminants from a variety of water types. The goal of this study was to see how operational factors such applied voltage, number of electrodes, distance between electrodes, electrode shape, and reaction time affect the electrocoagulation of actual dairy effluent. Aluminum and iron electrodes are used for this purpose. It was discovered that raising the applied voltage, reaction time, and decreasing the distance between electrodes improved COD, BOD, EC, TDS, color, and oil-grease removal efficiency. Moreover, switch between square, triangular electrodes and perforated cylindrical. The data show that electrocoagulation is effective at the maximum COD, BOD removal efficiency of first electrode at 20 holes of cylindrical shape is (88.03) %, (87.97) %, respectively. Second triangle shape is (100) %, (100) % respectively. Third square shape is (99.38) %, (99.42) % respectively. The maximum removal of TDS, EC efficiency of first electrode at 20 holes of cylindrical shape is (67.57) %, (62.34) %, respectively. Second triangle shape is (77.45) %, (67.68) % respectively. Third square shape is (81.96) %, (71.25) % respectively. The maximum color and oil-grease removal efficiency of first electrode at 20 holes of cylindrical shape is (100) %, (100) %, respectively. Second triangle shape is (100) %, (100) % respectively. Third square shape is (100) %, (100) % respectively. Electrocoagulation methods for the treatment of dairy wastewaters were shown to be successful in the research. Finally, the findings indicated that electrocoagulation is a technically feasible method for removing contaminants from dairy wastewaters.

1. INTRODUCTION

Water is our most important resource, and appropriate quality and quantity are required for all areas of life and sustainable development. Although the majority of the planet is covered with water, humans only have access to a tiny amount of fresh water [1]. We risk contaminating our freshwater sources every time we remove water. Before being released back into freshwater sources, wastewater from agriculture, industry, and homes must be appropriately treat [2]. Releasing untreated wastewater has a negative impact on water
quality and ecosystems, resulting in a global loss in freshwater supply [3]. Ensure universal access to water and sanitation is one of the UN’s 17 sustainable development objectives for 2030 [4]. To meet these difficulties, a more integrated strategy to water resource allocation and management is required. Ecosystem protection is one of these approaches, as civilizations and economies rely on them[5]. Improving wastewater treatment and ensuring safe water reuse is an important element of this. To attain these objectives, new and improved technologies must be adopted internationally in order to improve treatment efficiency and expand therapy options.

Electrocoagulation is one future technique that might be used [6]. The production of strong wastewater with a high biological oxygen demand (BOD5) and chemical oxygen demand (COD) causes serious environmental concerns in the food processing industry [7]. The dairy sector is the most polluting of the food industries, both in terms of volume of wastewater produced and in terms of its characteristics [8]. In many countries, the dairy sector is often regarded as the most significant producer of food processing effluent [9]. Other biological techniques are often used to treat dairy wastewaters such as Activated sludge, aerated lagoons, aerobic bioreactors, trickling filters, sequencing batch reactors (SBR), anaerobic sludge blanket (UASB) reactors, anaerobic filters, bio coagulation, and others [10]. In general, wastes from the dairy processing sector contain significant levels of organic material such as proteins, carbohydrates, and lipids, as well as high levels of BOD5 and COD, suspended particles, and suspended oil-grease [11]. The dairy wastewater is generated at receiving stations, sanitization, boiling plant, cheese plant, cleaning, heating, cooling, butter and dried milk plant as well as floorwashing [12].

2. ELECTROCOAGULATION FUNDAMENTALS

Because of the increased environmental limitations on effluent wastewater, research has recently concentrated on the treatment of wastewaters utilizing electrocoagulation (EC) [13]. One anode and one cathode make form a basic electrocoagulating reactor. The anode material undergoes oxidation when a potential is provided from an external power source, while the cathode is exposed to reduction or reductive deposition of elemental metals [14].

Electrocoagulation as you shown in figure (1) occurs most commonly when electrochemical reactions occur on the anode and cathode, although solution reactions can play a part in the process, as indicated in reactions (1)-(3). Anodic response is a reaction that occurs when an object is exposed [15].

$$\text{Al}^3+ \rightarrow \text{Al}^3+ + 3e^- \quad (1)$$

Cathodic reaction

$$2\text{H}_2\text{O} + 2e^- \rightarrow 2\text{OH}^- + \text{H}_2\uparrow \quad (2)$$

Solution reaction

$$\text{Al}^{3+} + 3\text{OH}^- \rightarrow \text{Al(OH)}_3 \quad (3)$$

It is possible to identify the following steps: (1) anode oxidation, which results in the formation of metal cations (Al or Fe); (2) in the cathode, water is electrolyzed, resulting in tiny hydrogen bubbles and hydroxide; (3) solution reactions, in which metal ions react with hydroxide to create hydroxy complexes, which adsorb contaminants, form coagulants, and may subsequently be separated by coagulation/flocculation techniques [16][17]. Because it is the only operational parameter that can be adjusted directly, current density is a critical element in electrocoagulation. The anodic and cathodic reactions, as well as the chemical rate, are all controlled by current density. In electrocoagulation, the Faraday law is important because it defines the
connection between current density and the quantity of metallic electrodes dissolved [18].

**Figure (1):** Schematic diagram of Electrocoagulation

![Schematic diagram of Electrocoagulation](image)

**Table (1)** Advantages and disadvantages of electrocoagulation [19]

| Advantages                                                                 | Disadvantages                                                                 |
|---------------------------------------------------------------------------|------------------------------------------------------------------------------|
| 1. Easy to use and maintain equipment.                                     | 1. The phenomenon of passivation.                                             |
| 2. It is a green technology since it does not generate secondary pollutants because it does not require chemical additives. | 2. The phenomenon of recombination                                             |
| 3. The wastewater is pleasant, clear, colorless, and odorless after treatment. | 3. In certain situations, the close proximity of two electrodes creates distortion and hence reduces the electric field's effectiveness. |
| 4. The pH neutralizing effect is extended to a considerably wider range of pH values (4-9). | 4. Require the use of a pre-treatment technology to improve the effectiveness of pollutant removal when wastewater is fed continuously. |
| 5. Efficient technique for recovering and recycling precious metals (E); novel method for recovering gold and silver from rinse baths. | 5. Require the use of some electrolytic materials to improve the process' conductivity. |
| 6. Adaptation to a variety of pollution loads and flow rates.              |                                                                               |
| 7. More effective and faster organic matter separation than conventional coagulation; pH control is not required; coagulants are generated in situ; cost-efficient and effective in removing suspended particles, dissolved metals, tannins, COD, BOD, TSS, TOC, and dyes (effluents from textile, catering, petroleum, municipal sewage, oil-water emulsion, dyestuff, clay suspension, etc.) 8. Effective in the treatment of small- and medium-sized communities' drinking water supplies | If the donor and receptor electrodes are made of different metals, employ the switching Relatively method as a second stage to prevent complexions from being eliminated during the first round of therapy. |
| EC 9. Copper reduction, coagulation, and separation are all very successful treatments. |                                                                               |
10. Sludge that has been floating by gas bubbles can be easily removed by skimming or sedimentation.

11. Electrolysis is a good way to generate clean energy. Hydrogen gas that may be utilized as a green fuel, therefore lowering:

- Emissions of greenhouse gases (GHGs)
- The environmental impact

3. APPLICATION OF ELECTROCOAGULATION

The review was divided into the following focus areas: [20]

Water containing heavy metals
- Paper industry wastewater
- Tannery and textile industry wastewater
- Refinery wastewater
- Food industry wastewater
- Produced water

4. PROCEDURE FOR BATCH EXPERIMENTS

A 1L size glass beaker was used for batch tests. The shape (cylindrical, triangle, square) shown in figure (3) of Iron and Aluminum electrodes has 8mm in diameter and length is 6.5 cm the effective surface area is 13.816 cm². In the EC cell. Aluminum was used as an anode and iron as a cathode, and they were weighted before and after the experiment to ensure that the aluminum electrode lost weight while supporting as a donor electrode and the iron electrode gained weight while supporting as a receptor electrode.

and to calculate the experimental amount using Faraday's Second Law Eq (1) [18]

\[ G = \frac{(i*t*M.wt)}{(n*F)} \]  

(1)

Where:

- \( G \): means the amount of Fe³⁺ dissolved (g/cm²):
- \( t \): electrolysis time (second)
- \( M.wt \): molecular weight (g/mole) (56 for Fe):
- \( n \): number of electrons (3 for Fe)
- \( i \): current density (A/cm²)
- \( F \): Faraday’s constant (96,485 C/mole).

Different parameters show in figure (2). pH, TDS, electrical conductivity, and temperature were measured before and after each experiment using a pH and TDS probe, while temperature was monitored using a Mercury thermometer (0-100) C. During Anodic dissolution happened in the experiment, and hydrogen gas was released cathode. Each sample was obtained at a fixed distance from a distance between two electrodes. After the experiment was completed, all of the samples were filtered to obtain color and COD.
removal efficiency tests.

Figure (2): the experimental work with different parameters.

Figure (3): shape of electrode (a) triangle (b) cylinder of 20 holes (c) square.
Fig (4) {Removal of ((a)EC, (b)TDS, (c)COD, (d)BOD, (e)Oil, (f)Color) at different electrodes (cathode Fe- anode Al), at (20holes of cylindrical, triangle, square) shape. Operation conditions (applied voltage =25V, time=30min, dis=0.5cm)}
As you shown in figure (4) With applied voltage ranging from (0-25V) and a constant spacing between electrodes of 0.5 cm, the impact of different time electrolyzation ranging from (0-30min) on removal of 
((a)EC, (b)TDS, (c)COD, (d)BOD, (e)Oil, (f)Color) efficiency was studied. The first shape at 20 holes of cylindrical electrode shape, the second triangle electrodeshape and the third square shape electrode shape.an experimental done at 25v and 30min. Except for the perforated electrode, the difference voltage between anode and cathode increased in all geometries. This supports the hypothesis that allowing air to flow through the cathode holes reduces passivation and hence enhances process performance. that there might be a difference This demonstrates that allowing air to flow via electrode holes removes passivation/sinfluence on system performance. At the same time, air bubbles were serving as a cleaning mechanism and a mixing tool [21] The electrical conductivity is inversely proportional to the distance between two electrodes. Thesolution gets more resistant as the distance between electrodes grows, and the solubility of metalin the solution diminishes. As a result, increasing the electrode spacing causes a decrease in removal efficiency [22] Increasing the applied voltage (or current intensity) led in an increase in the quantity of metal hydroxide flocs for the removal of colloidal particles, according to Faraday's law[23]. It was also discovered that when the current strength grew, the rate of bubble formation increased and the bubble size dropped; both of these facts were advantageous in terms of H₂ flotation's high pollutant removal effectiveness[24] [25]To promote the flotation of hydroxide flocs, a certain current density is necessary to induce adequate electrode dissolution and hydrogen release [26] When tringle and squire electrodes were utilized, there was a significant rise in potential difference [25] A large amount of evidence suggests that the distance between electrodes affects the effectiveness of EC units (ID). The latter influences the cell's ohmic resistance as an equation (4-1), which in turn determines coagulant synthesis and energy demand [27][28-30]

\[ R = \frac{d}{A} \left( \frac{1}{k} \right) \]

Where "d" represents the distance between two electrodes, "A" denotes the electrodes' surfacearea, and "k" denotes the solution's conductivity.

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5. CONCLUSION

The dairy industry's wastewater discharges large amounts of water with an excess of organic matter, which would be a byproduct of the washing, cleaning, and disinfection processes. Because of its high organic content, most dairy factories lack treatment systems for whey's final disposal, and its discharge has a significant environmental impact. This problem has led to the investigation of various technologies to reduce the organic load present in the wastewater of the dairy industry, with electrocoagulation being one of the best options, owing to its clean and efficient nature. Therefore, electrocoagulation is an effective process for the removal of pollutants, being a viable alternative for its application in the country. The tests carried out in the laboratory allow us to conclude that the best conditions to obtain high efficiency in the removal of the COD, BOD, color, oil, and grease. Different configuration parameters have an effect on electrocoagulation: Perforating increases surface area, which improves efficiency (the perforated cylindrical shape gave higher efficiency than the non-perforated cylindrical). One of the new features that have an influence on increasing efficiency is changing the form of the electrode (the triangular shape gave higher efficiency than the cylindrical).

ACKNOWLEDGE

The authors acknowledge the support received from the University of Baghdad/College of Engineering/Environmental Engineering Department, Iraq.

REFERENCES

[1] J. Bebbington and J. Unerman, “Achieving the United Nations Sustainable Development Goals: an enabling role for accounting research,” Accounting, Audit. Account. J., 2018.
[2] J. P. Muldoon Jr, Multilateral diplomacy and the United Nations today. Routledge, 2018.
[3] K. A. Mingst, M. P. Karns, and A. J. Lyon, The United Nations in the 21st century. Routledge, 2018.
[4] J. Butler, Bodies that matter: On the discursive limits of sex. Routledge, 2011.
[5] M. Sillanpää and M. Shestakova, Electrochemical water treatment methods: Fundamentals, methods and full scale applications. Butterworth-Heinemann, 2017.
[6] A. Nehrii and R. Kuzhel, “Effects of electrochemical treatment of mixed liquor in submerged ceramic membrane bioreactor.” Norwegian University of Life Sciences, Ås, 2019.
[7] D. Orhon, E. Görgün, F. Germirli, and N. Artan, “Biological treatability of dairy wastewaters,” Water Res., vol. 27, no. 4, pp. 625–633, 1993.
[8] M. Vourch, B. Balannec, B. Chauffer, and G. Dorange, “Treatment of dairy industry wastewater by reverse osmosis for water reuse,” Desalination, vol. 219, no. 1–3, pp. 190–202, 2008.
[9] M. K. Hasan, A. Shahriar, and K. U. Jim, “Water pollution in Bangladesh and its impact on public health,” Heliyon, vol. 5, no. 8, p. e02145, 2019.
[10] V. Kuokkanen and T. Kuokkanen, “Recent applications of electrocoagulation in treatment of water and wastewater—a review,” 2013.
[11] S. Tchamango, C. P. Nanseu-Njiki, E. Ngameni, D. Hadjieva, and A. Darchen, “Treatment of dairy effluents by electrocoagulation using aluminium electrodes,” Sci. Total Environ., vol. 408, no. 4, pp. 947–952, 2010.
[12] R. K. Mulla, A. S. Sutar, and A. C. Ranveer, “Study of Various Technologies Available For
Treatment of Dairy Wastewater - A Review,” Int. J. Res. Appl. Sci. Eng. Technol., vol. 3, no. 11, pp. 432–435, 2015.

[13] E. Bazrafshan, A. H. Mahvi, and M. A. Zazouli, “Removal of zinc and copper from aqueous solutions by electrocoagulation technology using iron electrodes,” Asian J. Chem., vol. 23, no. 12, p. 5506, 2011.

[14] M. Y. A. Mollah, P. Morkovsky, J. A. G. Gomes, M. Kesmez, J. Parga, and D. L. Cocke, “Fundamentals, present and future perspectives of electrocoagulation,” J. Hazard. Mater., vol. 114, no. 1–3, pp. 199–210, 2004.

[15] C. B. Jagadal, M. N. Hiremath, and C. B. Shivayogimath, “Study of Dairy Wastewater Treatment Using Monopolar Series System of Electrocoagulation Process with Aluminium Electrodes,” Int. Res. J. Eng. Technol., vol. 4, pp. 1188–1192, 2017.

[16] S. Koparal and Ü. B. Öğütveren, “Removal of nitrate from water by electroreduction and electrocoagulation,” J. Hazard. Mater., vol. 89, no. 1, pp. 83–94, 2002.

[17] V. S. Kumar et al., “Highly efficient Ag/C catalyst prepared by electro-chemical deposition method in controlling microorganisms in water,” J. Mol. Catal. A Chem., vol. 223, no. 1–2, pp. 313–319, 2004.

[18] R. Aguilar, S. A. Martinez, M. G. Rodriguez, and G. Soto, “Process analysis for treatment of industrial plating wastewater: simulation and control approach,” Chem. Eng. J., vol. 105, no. 3, pp. 139–145, 2005.

[19] G. Crini and E. Lichtfouse, “Advantages and disadvantages of techniques used for wastewater treatment,” Environ. Chem. Lett., vol. 17, no. 1, pp. 145–155, 2019.

[20] D. T. Moussa, M. H. El-Naas, M. Nasser, and M. J. Al-Marri, “A comprehensive review of electrocoagulation for water treatment: Potentials and challenges,” J. Environ. Manage., vol. 186, pp. 24–41, 2017.

[21] L. Barelli, G. Bidini, P. A. Ottaviano, and D. Pelosi, “Vanadium redox flow batteries application to electric buses propulsion: Performance analysis of hybrid energy storage system,” J. Energy Storage, vol. 24, p. 100770, 2019.

[22] A. Attour, M. Touati, M. Tili, M. Ben Amor, F. Lapicque, and J.-P. Leclerc, “Influence of operating parameters on phosphate removal from water by electrocoagulation using aluminum electrodes,” Sep. Purif. Technol., vol. 123, pp. 124–129, 2014.

[23] A. Srirangsan, M. Ongwanee, and O. Chavalparit, “Treatment of biodiesel wastewater by electrocoagulation process,” Environ. Asia, vol. 2, no. 2, pp. 15–19, 2009.

[24] Y. O. Fouad, “Separation of cottonseed oil from oil–water emulsions using electrocoagulation technique,” Alexandria Eng. J., vol. 53, no. 1, pp. 199–204, 2014.

[25] S. M. A. B. D. Al-hamza, “Using of different electrocoagulation cell configuration parameters for treating Abu- Ghaib dairy products wastewater,” no. 100.

[26] S. Rönkä, “Investigation of potential benefits of vibration and turbulence on the capacity and availability of an electrocoagulation process with paperboard coating wastewater,” 2021.

[27] E. Mohora et al., “Removal of natural organic matter and arsenic from water by electrocoagulation/flotation continuous flow reactor,” J. Hazard. Mater., vol. 235, pp. 257–264, 2012.

[28] E. Hashim, A. Shaw, R. Al Khaddar, M. O. Pedrola, and D. Phipps, “Defluoridation of drinking water using a new flow column-electrocoagulation reactor (FCER)-Experimental, statistical, and economic approach,” J. Environ. Manage., vol. 197, pp. 80–88, 2017.

[29] Lavanya, K., Obaid, A., Sumaiya Thaseen, I., Abhishek, K., Saboo, K., Paturkar, R. (2020). Terrain Mapping of LandSat8 Images using MNF and Classifying Soil Properties using Ensemble Modelling. International Journal of Nonlinear Analysis and Applications, 11(Special Issue), 527-541. doi: 10.22075/ijnaa.2020.4750.
[30] M. Küçük and T. T. Karadayi, “An ecological settlement design for refugees in Kocaeli”, Heritage and Sustainable Development, vol. 2, no. 2, pp. 69-88, Jul. 2020.