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Impact of Physicochemical Parameters on the Electro-Oxidation Efficiency of Saline Wastewater

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ABSTRACT

Using a batch reactor configuration, this research examines how important physicochemical factors affect the efficiency of electro-oxidation of saltwater wastewater. For controlled tests, a rectangular Plexiglas reactor with a 1 L capacity was developed. It was powered by a DC source and had parallel graphite electrodes. To replicate circumstances of high COD and salinity, synthetic saline wastewater was created using hydrochloric acid and bovine serum albumin. The research examined the impact of four main elements on COD removal efficiency: pH, salt content, current intensity (voltage), and response time. A systematic approach was used in testing each component. Methods for water analysis are commonplace in the field, and statistical power analysis guided the design of the experiment. The findings showed that pH had a significant impact on COD removal ($P < 0.001$), with 11 pH being the optimal removal level. The highest rate of COD removal (~91%) was seen at a salinity of 30 g/L and a treatment period of 90 minutes. Both the response time and salt concentration had significant influences ($P < 0.001$ and $P < 0.05$, respectively). Similarly, voltage variation affected performance, with the best results obtained at 15 V. Optimizing physicochemical parameters is crucial for successful treatment of saltwater wastewater, as the research shows that electro-oxidation effectiveness is very condition dependent.

Keywords: Wastewater, Salinity, Oxidation, Acidity, Conductivity.

I.INTRODUCTION

A growing number of industrial processes are adding salt to wastewater, which is having a devastating effect on aquatic ecosystems and water supplies. Sediment and organic pollutant concentrations are common in the effluents released by many industries, including those dealing with textiles, petroleum, chemical production, tanneries, and desalination plants. In addition to contaminating natural water sources on an ongoing basis, the osmotic stress that these salty effluents cause makes traditional biological treatment methods more difficult. One promising new approach to treating salty wastewater is electrochemical oxidation (EO), and more specifically electro-oxidation, which has the potential to degrade complex organic contaminants. The procedure may be adjusted to meet the specific treatment requirements of different kinds of effluent since it is very flexible. The kinetics and mechanism of pollutant degradation are governed by a variety of physicochemical characteristics, which in turn greatly impact its efficiency.

By passing an electric current through electrodes submerged in wastewater, electro-oxidation may produce strong oxidizing species either on the surface of the electrodes or in the larger solution. When saline effluents include high chloride concentrations, active chlorine species such hypochlorous acid (HOCl), chlorine gas (Cl), and hypochlorite ions (ClO{) are produced. Mineralization of organic molecules is greatly facilitated by these reactive species. A number of physicochemical factors, such as temperature, salinity, pH, electrolyte composition, current density, electrode material, and hydraulic retention duration, dynamically affect the process's performance and selectivity.

One of the most important factors influencing oxidant speciation and oxidation reaction characteristics is pH. At acidic to slightly basic pH, hypochlorous acid and hypochlorite ions predominate, but molecular chlorine (Cl) is more abundant at lower pH levels. The oxidative potential and reactivity of these species to various kinds of organic contaminants are distinct. Degradation efficiency and the generation of chlorinated organics and other hazardous by-products may be greatly improved by adjusting the pH.

Important operational factors also include current density, which affects oxidant formation and, by extension, pollutant oxidation rates. The synthesis of active species is often enhanced by increasing the current density, although this approach may be less cost-effective and sustainable due to increased energy consumption and electrode wear. In addition, side reactions like oxygen evolution may be induced by very high current densities, which in turn reduces the efficiency of the current and the efficacy of the therapy.

The amount of indirect oxidation by active chlorine species is greatly affected by salinity, which is the overall concentration of dissolved salts, especially chlorides. The generation of Cl, HOCl, and ClO} is aided by electro-oxidation in chloride-rich wastewaters; these compounds may subsequently oxidize organic contaminants in the bulk phase. Nevertheless, it is crucial to exercise caution and use electrode materials that are resistant to deterioration caused by very high salinity to avoid electrode passivation, increased scaling, and corrosion.

Electrode material is one of the other variables that affect electro-oxidation efficiency. Platinum, MMO, and BDD are employed for their stability and catalytic activity. Not only does the kind of oxidizing species produced depend on the electrode choice, but the system's endurance and energy consumption are also affected.

In order to develop, optimize, and scale electro-oxidation systems for practical uses, it is crucial to comprehend the interaction of various physicochemical factors. The kinetics and thermodynamics of the degradation processes are affected by each parameter, which interacts with others in complicated ways. For this reason, in order to lessen the negative effects of saline wastewater management on the environment, enhance treatment efficiency, and decrease operating costs, thorough research of these interactions are essential.

II.REVIEW OF LITERATURE

Najafinejad, Mohammad Saleh et al., (2023) the introduction of new chemicals, colors, and contaminants into water and wastewater has been a major issue for humans in recent times. Because of the close relationship between water pollution and human health, the presence of new, highly resistant chemicals in water sources is a major concern. Consequently, the proliferation of several companies has resulted in a dramatic worsening of water contamination, which is already a serious issue. As a result, it is critical to use cutting-edge wastewater treatment systems that effectively eliminate impurities. Electrochemical oxidation (EO) stands out among advanced oxidation processes as the go-to technique for effectively purging industrial and municipal wastewater of persistent contaminants. In addition, we have covered the need for energy consumption needs and a cost analysis review. At last, we have taken a quick look at photoelectrocatalysis (PEC), a method that combines EO with photocatalysis (PC). This article demonstrates that crucial operational factors are directly related to the total cost and the ultimate efficiency of emerging pollutant removal. Careful consideration of reactor design may result in optimal operating conditions, which in turn can improve treatment efficiency and efficiency overall. More effective ways to address the urgent problem of water pollution may emerge from the quick development of EO for the removal of new contaminants from affected water, in conjunction with other environmentally friendly technologies. PEC has shown great promise as a technique for degrading pollutants; it uses renewable energy sources as a foundation for eco-friendly water treatment.

Srivastava, Ashish et al., (2021) Aquatic ecosystems have been profoundly impacted by the alarming rise in saltwater effluent discharge. In addition, several wastewater treatment procedures are significantly limited in their efficacy when salt is present in the effluent. This review article has covered the causes and effects of saline wastewater in this setting. The salt level is rather high in wastewater that comes from farms and other businesses including tanneries, pharmaceuticals, aquaculture, and petrochemicals. Researchers have looked at how well various physicochemical, biological, and hybrid methods remediate saltwater effluent. Both biological treatment procedures (25 ± 31%) and physicochemical processes (9 ± 41%) were discovered to be adversely affected by high salt levels. Nonetheless, biological processes that include salt-tolerant bacteria and electrochemical oxidation performed very well in environments with high salinity. Hybrid systems, specifically developed for treating saltwater wastewater, shown no performance degradation when exposed to high salinity. Additionally, this review clarifies how increasing salinity impacts the governing factors of different processes.

Sundaramoorthy, Sundarapandiyan et al., (2010) this study investigated the electrochemical treatment of saltwater wastewater that had an organic (protein) load. Using graphite electrodes, researchers investigated how pH, time, salt content, and current density—all crucial electro-oxidation parameters—impacted the decrease of organic load. Pickling, a salty byproduct of the leather industry's production process, was continually treated and reused three times. It is possible to reuse saltwater streams by intermittently electrochemically treating them, according to the waste stream's properties and the leathers' quality.

Masid, Smita et al., (2010) Specialized treatment methods are required for industrial effluents with high organic content, especially those that are difficult to remove. This usually combines many procedures. A chemical industry-segregated wastewater system was used to test three combined treatment methods: coagulation/flocculation (C/F), electrooxidation (EO), and membrane. The effluent is brightly colored, high in salt, COD, and TKN. UF-RO (CP-I), C/F-EO-UF-RO (CP-II), and C/F-EO1-EO2-UF-RO were examined. CP-I, CP-II, and CP-III removed 73%, 82%, 84%, and 93% of COD and TDS, respectively, in order of decreasing efficiency. We studied how the EO process affected process scheme performance and COD and TDS elimination at each phase of the combined process. It was found that the organic load in the effluent is significantly reduced by the intermediate level EO process, while a considerable portion of the TDS removal is due to the ultimate RO treatment. Therefore, it seems that the combined treatment procedures have good potential for achieving more effective removal of organic and salinity loads.

III.METHODS

This descriptive-analytical study used a Plexiglas cubic-rectangular batch reactor with dimensions of 14 cm × 7 cm × 15 cm and an ideal capacity of 1/L. In the reactor, two sets of parallel electrodes were formed by interconnecting 2.5-by-15-centimeter graphite columns that were embedded with wires. An AC/DC converter (PAYANIK, RN-3003D) provided the direct current for each set of graphite electrodes. In Figure 1 we can see the electrooxidation experiments' experimental setup.

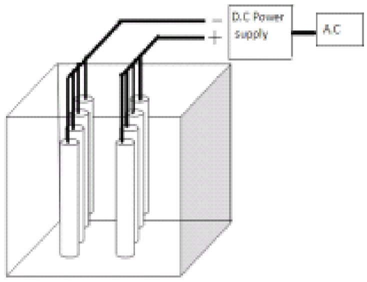

Figure 1. Schematic of the reactor setup used in this study

In order to create synthetic wastewater, 2.5 g of bovine albumin serum and hydrochloric acid were used. The method also included adding the necessary salt and adjusting the concentration of COD to the desired amount for saline wastewater. Hydrochloric acid and caustic 1 N solutions manufactured by Merck Company were used to maintain a stable pH level. The conventional procedures for water and wastewater analysis were followed in all trials. A guidebook for experimental design used as the basis for the design of the experiments. We found the sweet spot for pH, main salt content, current intensity, and duration independently. The present study examined the mean percent of COD removal at different factors, hence graphs were used to calculate sample size. With a 95% confidence interval and 80% power of test, we set our test frequencies. A mean difference of 20% or more for COD removal between experimental levels of each component was statistically significant.

Each test's frequency and component level were established by analyzing the predicted 10% standard deviation using the following formula:

$$Q = \frac{1}{\sigma}\sqrt{\frac{\Sigma T_j^2}{r}} = \frac{1}{10} \times \sqrt{\frac{5\times15^2}{5}} = 1.5$$

Where:

r = Number of groups

ó= Equal to Q

T^2 = the average concentration difference between samples. To calculate the &! coefficient at 80% power of test and 0.5 error levels, divide the number of pH factor levels in sample graphs by their ratio. Each level underwent three repetitions of the experiments as outlined in the aforementioned book. The computations led to an anticipated total of 60 samples for the investigations.

After the tests and laboratory parameter data were collected, Excel and SPSS version 16 were used to construct graphs. We utilized ANOVA and the Scheffe test to find the sweet spot for each variable.

IV.RESULTS

Effects of pH

Figure 2, tables 1 and 2, and a salt content of 10 g/L were used to measure the changes in primary COD (790 mg/L) in wastewater under various pH conditions, reaction times of 1 hour, potential differences of 15 V, and other variables.

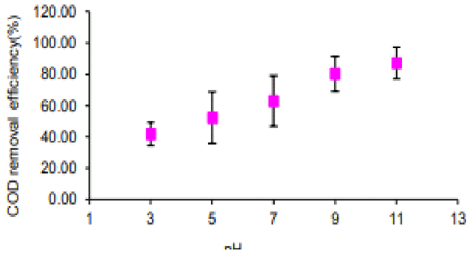

Figure 2. COD Removal Efficiency and pH (10 g/L Salt, 1 hour, 15 V).

Table 1. COD Reduction at Varying pH Levels

pH	No. of experiments	Mean	SD	SE	95% CI
3	3	42	3	1.7	34.54-49.45
5	3	52.3	6.6	3.8	35.79-68.87
7	3	63	6.5	3.7	46.71-79.28
9	3	80.33	4.5	2.6	69.13-91.53
11	3	87.33		2.3	77.29-97.37

Table 2. COD Reduction at Different pH Levels (10 g/L Salt, 1 hr, 15 V, 95% CI)

pH level compared	Other pH levels	Mean difference	SD	*P*
	3	38.33 (SE)	4.2	<0.001
9	5	28 (SE)	4.2	<0.001
	7	17.33 (SE)	4.2	<0.029
	11	-7	4.2	<0.615

ANOVA study revealed that pH significantly affected COD elimination at 10 g/L salt concentration, 1 hour reaction time, and 15 V potential difference ($F=44.24$, $P< 0.001$).

Effect of reaction time

Figure 3, tables 3 and 4, and the findings of the study's COD variations in wastewater at various reaction times with a salt content of 10 g/L, pH=9, and a potential difference of 15 V are shown.

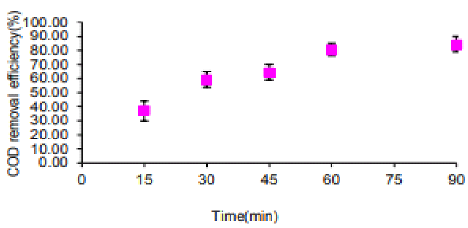

Figure 3. COD Removal at Different Reaction Times (10 g/L Salt, pH 9, 15 V).

Table 3. COD Reduction (%) by Reaction Time (10 g/L Salt, pH 9, 15 V).

Time	No. of experiments	Mean	SD	SE	95% CI
15	3	37.23	2	1.2	30-44
30	3	59.33	5.5	3.17	54-65
45	3	64.33	5.5	3.17	59-70
60	3	80.33	4.5	2.6	76-85
90	3	84	1	0.57	79-90

Table 4. Optimal Level Determination COD Reduction at Different Reaction Times (95% CI)

pH level compared	Other pH levels	Mean difference	SD	*P*
	15	43(SE)	3.39	<0.001
16	30	21 (SE)	3.39	<0.002
	45	16 (SE)	3.39	<0.013
	90	-3.66	3.39	<0.877

The ANOVA revealed that response time substantially impacted COD elimination at 10 g/L salt concentration, pH=9, and 15 V potential difference (F=60.55, P<0.001).

Effect of salt concentration

Results of increases in COD in wastewater at 1 hour reaction time, pH=9, and 15 V potential difference time at varied salt concentrations are shown in Tables 5 and 6, as well as in Figure 4.

Table 5. COD Reduction (%) at Different Salt Concentrations (1 hour, pH 9, 15 V)

Saline concentration (g/L)	No. of experiments	Mean	SD	SE	CI %95
10	3	80.33	4.5	2.6	69.13-91.53
15	3	83.66	3.2	1.8	75.68-91.65
20	3	84.66	3.7	2.18	75.26-94.07
25	3	88	3	1.73	80.54-95.45
30	3	91	1.5	0.88	87.53-95.12

Table 6. COD Reduction at Varying Voltages and Salt Concentrations (1 hr, pH 9)

Saline concentration level compared	Other time levels	Mean difference	SD	*P*
	15	-3.33	2.7	0.82
10	20	-4.33	2.7	0.65
	25	-7.66	2.7	0.17
	30	-11 (SE)	2.7	0.03

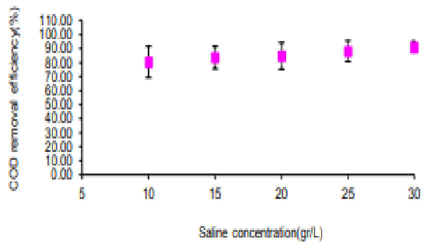

Figure 4. COD Removal at Varying Salt Concentrations (1 hr, pH 9, 15 V)

ANOVA results indicate that salt concentration substantially impacts COD elimination at pH 9, reaction duration of 1 hour, and potential difference of 15 V (F=0.4.72, P<0.05).

Influence of applied voltage

Results of variations in COD in wastewater at various potential differences, pH=9, and 10 g/L salt content are shown in Tables 7 and 8, as well as in Figure 5.

Table 7. COD Reduction (%) at Different Voltages (1 hr, pH 9, 10 g/L Salt)

Voltage	No. of experiments	Mean	SD	SE	CI 95%
2	3	64.66	4.5	2.6	53.46-75.8
5	3	70.66	3	1.7	63.7-78.25
8	3	73.66	3.21	1.8	65.68-81.65
10	3	77	1.7	1	72.69-81.3
15	3	80.33	4.5	2.6	69.13-91.53

Table 8. COD Reduction at Varying Voltages (1 hr, pH 9, 10 g/L Salt, 95% CI)

Voltage level compared	Other voltage levels	Mean difference	SD	*P*
	2	15.66 (SE)	2.9	0.005
15	5	6.66	2.9	0087
	8	3.33	2.9	0.329
	10	-11 (SE)	2.9	0.852

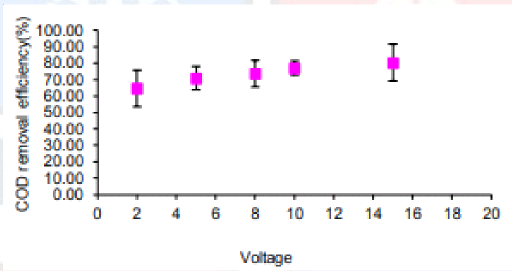

Figure 5. COD Removal at Varying Voltages (1 hr, pH 9, 15 V).

ANOVA test at pH=9, one-hour reaction length, and 10 gr/L salt level revealed significant impacts on COD elimination ($F=8.75$, $P<0.05$).

V.CONCLUSION

The results showed that important physicochemical factors including pH, reaction duration, salt content, and applied voltage greatly affect electro-oxidation's efficacy in treating saltwater effluent. Alkaline circumstances (pH 11) showed the most efficacies in removing chemical oxygen demand (COD), although pH had a significant impact on all of these processes. Another critical factor was reaction time, with longer periods resulting in a higher decrease in COD, especially up to 90 minutes. Enhancing the concentration of salt also improved the oxidation process by enhancing the generation of active oxidants such hypochlorite ions. Researchers determined that 30 g/L of salt was the sweet spot. Further investigation revealed that the rate of electrochemical reactions was voltage dependent; a voltage of 15 V provided the best compromise between energy use and pollution clearance. The findings show that, under ideal circumstances, electro-oxidation may effectively treat high-salinity wastewater. No chemical additions are needed for oxidation, and the process may be adjusted to suit various wastewater compositions; it is also eco-friendly. Electrode performance over the long term, energy efficiency, and system scalability for industrial use should all be the subject of future studies. When operating settings are fine-tuned, electro-oxidation may be a dependable method for treating saltwater effluent.

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REFERENCES

[1] M. S. Najafinejad, S. Chianese, A. Fenti, P. Iovino, and D. Musmarra, "Application of Electrochemical Oxidation for Water and Wastewater Treatment: An Overview," Molecules, vol. 28, no. 10, p. 4208, 2023, doi: 10.3390/molecules28104208.

[2] A. Srivastava, V. K. Parida, A. Majumder, B. Gupta, and A. Gupta, "Treatment of saline wastewater using physicochemical, biological, and hybrid processes: Insights into inhibition mechanisms, treatment efficiencies and performance enhancement," J. Environ. Chem. Eng., vol. 9, no. 1, p. 105775, 2021, doi: 10.1016/j.jece.2021.105775.

[3] R. Li, B. Wang, O. Owete, J. Dertien, C. Lin, H. Ahmad, and G. Chen, "Landfill leachate treatment by electrocoagulation and fiber filtration," Water Environ. Res., vol. 89, pp. 2015–2020, 2017, doi: 10.2175/106143017X15051465918976.

[4] S. Mazloomi, M. Yousefi, H. Nourmoradi, and M. Shams, "Evaluation of phosphate removal from aqueous solution using metal organic framework; isotherm, kinetic and thermodynamic study," J. Environ. Health Sci. Eng., pp. 1–10, 2019, doi: 10.1007/s40201-019-00341-6.

[5] S. Ayub, A. A. M. Mohammadi Yousefi, and F. Changani, "Performance evaluation of agro-based adsorbents for the removal of cadmium from wastewater," Desalin. Water Treat., vol. 142, pp. 293–299, 2019.

[6] M. H. Dehghani, A. Zarei, and M. Yousefi, "Efficiency of ultrasound for degradation of an anionic surfactant from water: surfactant determination using methylene blue active substances method," MethodsX, vol. 6, pp. 805–814, 2019, doi: 10.1016/j.mex.2019.03.028.

[7] R. Khosravi, H. Eslami, A. Zarei, M. Heidari, and A. Nourouzian, "Comparative evaluation of nitrate adsorption from aqueous solutions using green and red local montmorillonite adsorbents," Desalin. Water Treat., vol. 116, pp. 119–128, 2018.

[8] H. A. Jamali and M. Moradnia, "Optimizing functions of coagulants in treatment of wastewater from metalworking fluids: prediction by RSM method," Environ. Health Eng. Manag. J., vol. 5, pp. 15–21, 2018.

[9] M. H. Dehghani, E. Nikfar, A. Zarei, and N. M. Esfahani, "The effects of US/HO processes on bisphenol-A toxicity in aqueous solutions using Daphnia magna," Desalin. Water Treat., vol. 68, pp. 183–189, 2017.

[10] M. Moradnia, M. Panahifard, K. Dindarlo, and H. A. Jamali, "Optimizing potassium ferrate for textile wastewater treatment by RSM," Environ. Health Eng. Manag. J., vol. 3, pp. 137–142, 2016.

[11] M. Motevalli, D. Naghan, N. Mirzaei, S. Haghighi, Z. Hosseini, H. Sharafi, and K. Sharafi, "The reusing feasibility of wastewater treatment plant (conventional activated sludge) effluent of tomato paste factory for agricultural irrigation—a case study," Int. J. Pharm. Technol., vol. 7, pp. 9672–9679, 2015.

[12] M. Malakootian, N. Yousefi, A. Fatehizadeh, S. W. Van Ginkel, M. Ghorbani, S. Rahimi, and M. Ahmadian, "Nickel (II) removal from industrial plating effluent by Fenton process," Environ. Eng. Manage. J., vol. 14, pp. 837–842, 2015.

[13] S. Sundaramoorthy, R. Chandrasekar, B. Ramanaiah, S. Krishnan, and P. Saravanan, "Electrochemical Oxidation and Reuse of Tannery Saline Wastewater," J. Hazard. Mater., vol. 180, pp. 197–203, 2010, doi: 10.1016/j.jhazmat.2010.04.013.

[14] S. Masid, S. Waghmare, N. Gedam, R. Misra, R. Dhodapkar, T. Nandy, and N. Neti, “Impact of electrooxidation on combined physicochemical and membrane treatment processes: Treatment of high strength chemical industry wastewater,” Desalination, vol. 259, no. 1–3, pp. 192–196, 2010, doi: 10.1016/j.desal.2010.04.007.

[15] O. Lefebvre and R. Moletta, “Treatment of organic pollution in industrial saline wastewater: a literature review,” Water Res., vol. 40, pp. 3671–3682, 2006, doi: 10.1016/j.watres.2006.08.027.

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