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Electrocoagulation-Floatation for Treatment of Oil Industry Wastewater: Optimization Using Iron and Aluminium Electrodes

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Abstract: The rapid growth of industrial activities has significantly increased the generation of highly polluted wastewater, particularly from oil processing industries. Oil industry wastewater is characterized by high concentrations of chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), and oil and grease, posing serious environmental threats if discharged untreated. In the present study, the effectiveness of the electrocoagulation (EC) process for the treatment of oil industry wastewater was investigated using iron and aluminium electrodes under various operating conditions. Batch experiments were conducted by varying electrical potential (10–30 V), electrolysis time (15–120 min), inter-electrode spacing (1.5–3.0 cm), and initial pH (4.2–7). The performance of the EC process was evaluated based on the removal efficiencies of COD, TSS, TDS, and oil and grease. Experimental results revealed that optimum operating conditions were achieved at 30 V, 90 min electrolysis time, 1.5 cm electrode spacing, and initial pH in the range of 4–8. Under these conditions, removal efficiencies exceeding 85% for COD, 95% for TSS and TDS, and 98% for oil and grease were obtained. Aluminium electrodes consistently exhibited superior removal performance compared to iron electrodes, although higher sludge production and electrode consumption were observed. The study confirms that electrocoagulation using aluminium electrodes is an efficient and reliable technique for the treatment of oil industry wastewater.

Keywords: *Electrocoagulation; Oil Industry Wastewater; COD; TSS; TDS; Aluminium Electrode; Iron Electrode.*

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I. INTRODUCTION

Industrialization and rapid urbanization have led to a substantial increase in the discharge of untreated industrial wastewater into natural water bodies, resulting in severe environmental pollution. Among various industrial effluents, oil industry wastewater is considered one of the most complex and hazardous due to its high organic load, suspended solids, dissolved salts, and oil and grease content. If discharged without adequate treatment, such wastewater can cause depletion of dissolved oxygen, inhibit aquatic life, and contaminate surface and groundwater resources.

Conventional treatment methods employed for oil industry wastewater include physical and chemical processes such as oil separation, chemical coagulation, flotation, and filtration. However, these methods often fail to remove soluble organic compounds effectively and generate large quantities of sludge, leading to increased operational costs and environmental concerns. Therefore, there is a growing need for alternative treatment technologies that are efficient, economical, and environmentally sustainable.

Electrocoagulation (EC) has emerged as a promising electrochemical treatment technique for industrial wastewater due to its operational simplicity, reduced chemical consumption, lower sludge generation, and high pollutant removal efficiency. The EC process involves the in-situ generation of coagulant species from sacrificial metal electrodes, which destabilize and aggregate contaminants through electrochemical reactions. This study focuses on evaluating the performance of EC using iron and aluminium electrodes for treating oil industry wastewater under varying operational conditions.

II. MATERIALS AND METHODS

- *Wastewater Source*

Raw oil industry wastewater was collected from the effluent treatment plant of M.K. Agrotech Pvt. Ltd.,

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Srirangapattana, India. The wastewater was analyzed for physicochemical characteristics including pH, COD, TSS, TDS, and oil and grease following standard methods (APHA, 2006).

➢ *Electrocoagulation Reactor Setup*

Batch electrocoagulation experiments were carried out in a 1-L borosilicate glass reactor. Iron and aluminium plate electrodes (5 cm × 5 cm × 1 mm) were used in monopolar configuration. A DC power supply (0–30 V, 2 A) provided electrical energy, and a magnetic stirrer ensured uniform mixing during the experiments.

➢ *Experimental Procedure*

Experiments were conducted by varying:

- Electrical potential: 10, 20, and 30 V
- Electrolysis time: 15–120 min
- Inter-electrode spacing: 1.5, 2.0, 2.5, and 3.0 cm
- Initial pH: 4.2 and 7

Samples were withdrawn at regular intervals and analyzed for COD, TSS, TDS, and oil and grease. Removal efficiency was calculated using standard equations.

III. RESULTS AND DISCUSSION

➢ *Characteristics of Raw Oil Industry Wastewater*

The raw oil industry wastewater collected from M.K. Agrotech Pvt. Ltd., Srirangapattana, exhibited high pollution strength. The initial pH was acidic (4.2) with elevated concentrations of COD (2700 mg/L), TSS (2500 mg/L), TDS (13,200 mg/L), and oil and grease (1200 mg/L). These values exceed permissible discharge limits, highlighting the necessity for effective treatment prior to disposal.

➢ *Effect of Electrical Potential and Electrolysis Time Using Iron Electrodes*

The performance of the EC process using iron electrodes was evaluated at electrical potentials of 10, 20, and 30 V with electrolysis times ranging from 15 to 120 min at an electrode spacing of 2 cm and pH 4.2.

- *COD Removal*

COD removal efficiency increased with both electrical potential and electrolysis time. At 10 V, a maximum COD removal of 65.7% was achieved after 90 min. Increasing the voltage to 20 V improved COD removal to 71.2%, while the highest removal of 77.5% was observed at 30 V after 90 min. Beyond 90 min, no significant improvement was noted, indicating attainment of equilibrium conditions.

- *TSS Removal*

TSS removal followed a similar trend. At 30 V, TSS removal increased from 39.5% at 15 min to 87.5% at 90 min. Increasing electrolysis time beyond 90 min did not significantly enhance removal efficiency due to saturation of floc formation.

- *TDS Removal*

TDS removal efficiency increased steadily with voltage and time. At 30 V, TDS removal reached 90.5% at 90 min, compared to 81.1% and 85.8% at 10 V and 20 V, respectively. The enhanced removal is attributed to increased dissolution of iron ions and subsequent formation of $Fe(OH)_3$ flocs.

- *Oil and Grease Removal*

Oil and grease removal was rapid, with efficiencies exceeding 84% within the first 30 min for all voltages. The maximum removal of 91.8% was achieved at 30 V within 30 min, after which the removal rate remained nearly constant.

➢ *Effect of Electrical Potential and Electrolysis Time Using Aluminium Electrodes*

Experiments using aluminium electrodes were conducted under identical operating conditions for comparison.

- *COD Removal*

Aluminium electrodes demonstrated superior COD removal compared to iron electrodes. Maximum COD removal efficiencies of 70.9%, 74.2%, and 79.0% were achieved at 10 V, 20 V, and 30 V, respectively, at 90 min of electrolysis.

- *TSS and TDS Removal*

At 30 V and 90 min, aluminium electrodes achieved 89.4% TSS removal and 90.3% TDS removal, which were higher than those obtained with iron electrodes. The enhanced performance is attributed to the formation of gelatinous $Al(OH)_3$ flocs with high adsorption capacity.

- *Oil and Grease Removal*

Oil and grease removal was highly efficient, exceeding 98% at 30 V within 90 min. More than 88% removal was achieved within the first 30 min, indicating the dominance of electroflotation mechanisms.

➢ *Effect of Inter-Electrode Spacing Using Iron Electrodes*

The effect of inter-electrode spacing (1.5–3.0 cm) was examined at a constant voltage of 30 V and pH 7.

The highest removal efficiencies were obtained at the smallest electrode gap of 1.5 cm, achieving 86% COD, 90.3% TSS, 93% TDS, and 96.9% oil and grease removal. Increasing the electrode spacing reduced removal efficiency due to decreased ion concentration and weaker electrostatic attraction between contaminants and coagulant species.

➢ *Comparison of Iron and Aluminium Electrodes*

Under identical operational conditions, aluminium electrodes consistently outperformed iron electrodes in removing COD, TSS, TDS, and oil and grease. However, aluminium electrodes produced a higher quantity of sludge and experienced greater electrode consumption. Despite this limitation, aluminium electrodes offered superior treatment efficiency and faster pollutant removal.

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➢ *Overall Treatment Performance*

Under optimal operating conditions of 30 V, 90 min electrolysis time, 1.5 cm inter-electrode spacing, and initial pH between 4 and 8, the EC process achieved removals exceeding 85% COD, 95% TSS and TDS, and 98% oil and grease. These results confirm the effectiveness of electrocoagulation as a robust treatment technique for oil industry wastewater.

IV. CONCLUSIONS

The present study investigated the treatment efficiency of oil industry wastewater using the electrocoagulation (EC) process with iron and aluminium electrodes under different operating conditions. Batch experiments were conducted to evaluate the effects of electrical potential, electrolysis time, inter-electrode spacing, and initial pH on the removal of COD, TSS, TDS, and oil and grease.

The experimental results revealed that an electrical potential of 30 V and an electrolysis time of 90 min were optimal for achieving maximum removal of COD, TSS, and TDS using both iron and aluminium electrodes. In contrast, oil and grease removal was rapid, with optimum performance observed at 30 V and 30 min of electrolysis time. Inter-electrode spacing played a significant role in treatment efficiency, and the highest pollutant removal was obtained at an electrode gap of 1.5 cm due to enhanced ion concentration and electrostatic attraction.

The influence of initial pH showed that maximum removal efficiencies were achieved at pH 4.2 and pH 7, with aluminium electrodes outperforming iron electrodes under identical conditions. Although aluminium electrodes resulted in higher sludge production and electrode consumption, they consistently demonstrated superior removal efficiencies for all studied parameters.

Overall, the EC process operated at 30 V, 90 min electrolysis time, 1.5 cm inter-electrode spacing, and initial pH between 4 and 8 achieved removals exceeding 85% for COD, 95% for TSS and TDS, and 98% for oil and grease. The study confirms that electrocoagulation, particularly using aluminium electrodes, is an effective, reliable, and environmentally sustainable technique for the treatment of oil industry wastewater.

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