Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 10, October - 2025

Comparative Study on Treatment of Sewage using Electro-Coagulation and Chemical-Coagulation

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***Abstract*— Prior to being released into water bodies and for further recycling in agriculture and recreation, municipal wastewater must be treated because it may contain numerous pollutants that have an adverse effect on the environment. Therefore, the current study compares the two methods of treating municipal wastewater: chemical coagulation (CC) and electrocoagulation (EC). Iron and aluminum electrodes were used for EC at varying voltages and times. Ferric chloride and aluminum sulphate were utilized for the CC, along with the dosage of the coagulant and the duration of contact. The maximum removal efficiencies of COD, TOC, TDS, and BOD for the aluminum electrode after treating municipal wastewater for electrocoagulation are 85%, 87%, 82%, and 81%, respectively. For the iron electrode, the corresponding percentages were 92%, 92%, 84%, and 88%. The maximum removal efficiency of COD, TOC, TDS, and BOD for chemical coagulation is 81.66%, 80.09%, 84.67%, and 77.08% when aluminum sulphate is used as the coagulant, and 86%, 83.90%, 87.73%, and 81.8% when ferric chloride is used. The results of this study showed that electrocoagulation outperformed chemical coagulation. In addition, Fe is a much more promising electrode than Al.**

***Keywords*— Electro-coagulation, Chemical-coagulation, Chemical Oxygen Demand, Total Organic Solids, Total Dissolved Solids, Biological Oxygen Demand.**

I INTRODUCTION

Securing sustainable water resources for the expanding global population is the central challenge of twenty first century. As a result, humankind must maintain and manage its water resources, focus on water discharge into the environment, and recycle. Water resource management is looking into advanced treatment technology because treatment plants must remove pollutants from inadequately treated effluent. Municipal wastewater, which includes liquid wastes from residential, commercial, or institutional buildings such as restrooms, kitchen sinks, washbasins, urinals, and latrines, is the most significant environmental pollutants. It contains contaminants such as TSS, COD, BOD, and heavy metals.

Chemical coagulants are substances, usually positively charged, that are added to water to cause suspended particles to clump together into larger, heavier masses known as flocs by neutralising their negative charges. By using subsequent processes like sedimentation and filtration, this flocculation process facilitates the removal of flocs from water. Aluminium sulphate and ferric chloride are common chemical coagulants that are essential for filtering drinking water and wastewater for a variety of contaminants, such as particles, colour, metals, and organic materials.

In contrast to chemical coagulation, which adds external chemicals such as iron or aluminium salts to accomplish the same goal, electrocoagulation (EC) is an electrochemical process that uses electricity to create metal ions from electrodes that subsequently form flocs to remove contaminants. EC is an eco-friendly alternative to traditional chemical coagulation, which necessitates precise chemical dosing and can lead to more sludge and higher operating costs. Its benefits include in-situ coagulant formation, ease of use, and reduced sludge production.

In this research work, electrocoagulation outperformed chemical coagulation in terms of performance. $FeCl_3$ and $Al_2(SO_4)_3{\bullet}3H_2O$ were utilised for chemical coagulation, while iron and aluminium electrodes were used for Electrocoagulation.

A. Objective Of The Study

To investigate batch of Electrocoagulation for the removal of contaminants like COD, TOC, TDS, and BOD using iron and aluminium electrodes.

To investigate batch chemical coagulation for the efficient removal of COD, Aluminium sulphate and ferric chloride are used as coagulants for TOC, TDS, and BOD.

To evaluate the effectiveness of chemical coagulation and Electrocoagulation in terms of pollutant removal.

II LITERATURE REVIEW

A. General

This research is on several researchers who used chemical coagulation (CC) and Electrocoagulation (EC) to treat municipal wastewater in various ways. Properly treating wastewater is essential for preventing harmful environmental impacts caused by pollutants. These pollutants are often found in higher concentrations in municipal wastewater. Moreover, treating wastewater offers other benefits, such as minimizing pollution and enhancing groundwater recharge, which provides vital nutrients for agricultural irrigation.

Literature Studies

Ahmed Hassoon Ali et al., (2020) focused on the effectiveness of chemical coagulation and electrocoagulation in eliminating COD and the reactive black dye RB-5. In the chemical coagulation process, various coagulants were tested, including ferrous sulphate, ferric sulphate, ferric chloride, and alum.

Ali Assadi and Amrita Soudavari et al., (2016) To eliminate reactive red 196 dye from a water solution, the author analyzed the impact of EC and CC treatments. Four iron electrodes, each measuring 10 cm by 10 cm by 1 cm, were utilised for the electrocoagulation.

Feryal Akbal and Selva Cam (2012) This study looked at how to remove heavy metals like nickel, copper, and chromium from metal plating. effluent by comparing EC and CC. Fe and Al electrodes measuring 45 mm by 75 mm by 3 mm were used as the anode and cathode for Electrocoagulation.The removal efficiency of copper, chromium, and nickel was 99.9%, 99.9%, and 98%. To effectively eliminate heavy metals, 99% aluminium sulphate was used, along with ferric chloride at concentrations ranging from 500 to 2500 mg/L as coagulants for the chemical coagulation process.

Mostafa M Emara et al., (2018)The author in this paper investigates the use of electrocoagulation in the treatment of municipal wastewater. The DC power supply used was 0-60v and 0-0.6A, and a magnetic stirrer was employed. for rapid mixing up to 200 rpm to ensure that wastewater was mixed uniformly. After 99% of the COD was removed through this process, it was found that the treatment of municipal wastewater required 60 minutes of retention time and 0.30A of applied current for results of BOD, COD, Oils

Tchamango and Kamdoum O (2017) This study involved the treatment of textile waste using both electrocoagulation and chemical coagulation methods. An aluminium electrode measuring 10 cm by 4 cm by 5 cm has been used for the electrocoagulation process. A current of 0.4 A was applied, and the Time ranged from 0 to 40 minutes. The turbidity, phosphorus, and COD removal efficiencies were 97.8%, 94.4%, and 58.86%, respectively. For the chemical coagulation, 200 mg/L of aluminium sulphate was used as a coagulant. Phosphorus and COD had removal efficiencies of 63.64% and 56.08%, respectively. The author made sure that electrocoagulation was superior to chemical coagulation.

C. Research Gap and Relevance The literature highlights that:

- Based on the literature reviewed above, electrocoagulation and chemical coagulation are compared and used in various industries and municipal wastewater treatment plants.
- Sewage must be processed before being released into any nearby water bodies because it contains numerous contaminants and heavy metals that have an adverse effect on the environment. Therefore, Comparing EC and CC proved to be the most effective way to treat municipal wastewater.
- According to the literature mentioned above, electrocoagulation is superior to chemical coagulation in terms of removing the greatest number of pollutants from wastewater after that its treated with EC and CC.

III METHODOLOGY

Fig.1. Methodology flowchart

A. Materials Used

Municipal wastewater is collected from sewerage near BIET Polytechnique college at Davangere. The reactor made of acrylic glass measures 15cm on each side and includes four electrodes made from aluminium and iron, each measuring 10cm x 10cm x 0.1cm, arranged in a monopolar parallel configuration with a spacing of 10cm between them. A DC power supply was used to apply a voltage ranging from 5V to 20V for various time intervals between 15 and 60 minutes, while a magnetic stirrer operated at 200 RPM.

For the chemical coagulation process, an alum jar test apparatus was set up featuring six beakers and a stirring paddle, also operating at 200 RPM, using aluminium sulphate ($Al_2(SO_4)^3$) and ferric chloride ($FeCl_3$) with a coagulant dosage varying from 3ml/L to 15ml/L, along with a weighing balance. Acrylic glass sheet reactor has

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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dimension of 15cm×15cm×15cm, four aluminium and iron electrode with monopolar parallel connection has dimension of 10cm×10cm×0.1cm and distance between each electrode are 10cm, DC power supply of applied current was 5v to 20v with different time interval of 15min to 60min, magnetic stirrer with 200rpm.

For Chemical coagulation: Alum jar test apparatus with 6 beakers, stirring paddle of 200 rpm aluminium sulphate $Al_2 (SO_4)^3$, and Ferric chloride ($FeCl_3$) with coagulant dosage of 3ml/L to 15ml/L, weighing balance.

B. Electrocoagulation process

A batch electrocoagulation reactor was designed and fabricated using acrylic glass sheets of 5 mm thickness, having internal dimensions of 15 × 15 × 15 cm and a working capacity of 2 L. The reactor was equipped with a magnetic stirrer operating at 200 rpm to ensure uniform mixing.

Four aluminium electrodes of 10 × 10 × 0.1 cm were connected in a monopolar parallel arrangement and immersed in the wastewater. The reactor was powered by a DC supply with applied voltages of 5, 10, 15, and 20 V, and treatment durations of 15, 30, 45, and 60 minutes.

After each experiment, samples were analysed for COD, BOD, TDS, and TOC to assess removal efficiency. The same procedure was repeated using iron electrodes of identical dimensions for performance comparison.

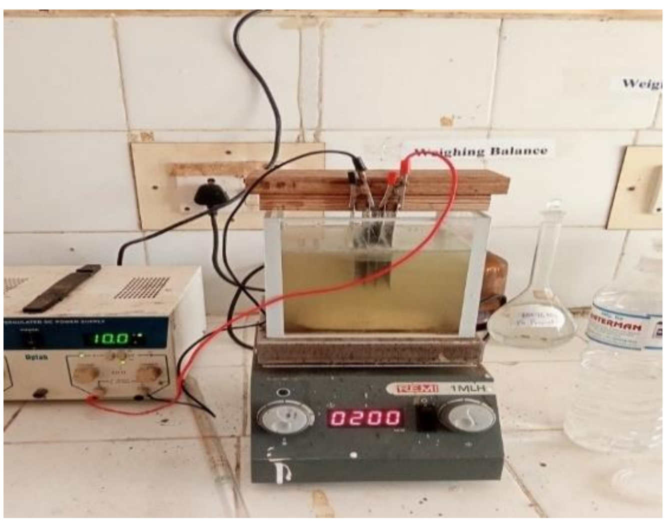


Fig 2: Electrocoagulation Setup

During electrolysis, the primary chemical reactions occurring at the electrodes involve the dissolution of metal cations at the anode and the formation of hydroxyl ions and hydrogen gas at the cathode, as represented below.

At anode: $M_s \rightarrow M_{(aq)}^{n+} + ne^-$

$2H_2O_{(l)} \rightarrow 4H_{(aq)}^{+} + O_{2\,(g)} + 4e^-$

At cathode: $M_{(aq)}^{n+} + ne^- \rightarrow M_s$

$2H_2O_{(l)} + 2e^- \rightarrow H_{2\,(g)} + 2OH^-$

When aluminium or iron electrodes are used during electrocoagulation, the generated Al^{3+} or Fe^{3+} ions in the aqueous phase undergo further reactions to form various hydroxide species. For instance, aluminium ions (Al^{3+}) undergo hydrolysis to produce several monomeric and polymeric hydroxides such as $Al(H_2O)_6^{3+}$, $Al(H_2O)_5OH^{2+}$, $Al(H_2O)_4(OH)_2^{+}$, $Al(OH)_2^{+}$, $Al_2(OH)_2^{4+}$, $Al(OH)_4^{-}$, and complex polymeric forms including $Al_6(OH)_{15}^{3+}$, $Al_7(OH)_{17}^{4+}$, $Al_8(OH)_{20}^{4+}$, $Al_{13}O_4(OH)_{24}^{7+}$, and $Al_{13}(OH)_{34}^{5+}$, which exist over a wide pH range.

Similarly, ferric ions generated through the electrochemical dissolution of iron form a variety of monomeric and polymeric hydroxide species such as $Fe(OH)_3$, $Fe(H_2O)_6^{3+}$, $Fe(H_2O)_5(OH)^{2+}$, $Fe(H_2O)_4(OH)_2^{+}$, $Fe_2(H_2O)_8(OH)_2^{4+}$, and $Fe_2(H_2O)_6(OH)_4^{4+}$. The formation and stability of these hydroxide complexes are strongly influenced by the solution pH, which governs the speciation and coagulation behaviour during the treatment process.

C. Chemical-Coagulation

In the first stage (coagulation), wastewater is treated by adding chemical coagulants such as ferric chloride ($FeCl_3$) and aluminium sulphate ($Al_2(SO_4)_3$) under rapid mixing conditions. This rapid agitation promotes the neutralization of negatively charged particles, converting them into positively charged species and enabling the formation of micro-aggregates. The second stage (flocculation) involves slow mixing, during which the previously destabilized particles collide and aggregate to form larger flocs. The addition of polyelectrolytes enhances this process by bridging between particles through ionized polymeric chains, resulting in the formation of dense, settleable flocs.

In the final stage (sedimentation), the formed flocs are allowed to settle in a settling unit, where they separate from the clarified water. The settled solids constitute the sludge, which is then collected and further processed for disposal or treatment.

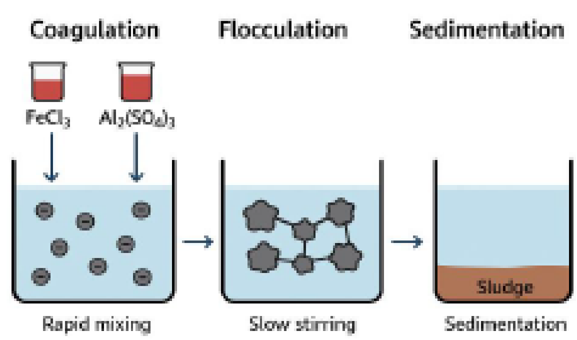


Fig 3: Step by step of coagulation

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 10, October - 2025

A chemical coagulation experiment was conducted using a jar test apparatus consisting of five beakers, each with a 1-liter capacity, equipped with a mechanical stirring device to ensure uniform mixing. One liter of municipal wastewater was poured into each beaker and secured under the stirrer with the paddles positioned uniformly at the same height and rotated upward. Alum was added as the coagulant in varying dosages of 3 mL, 6 mL, 9 mL, 12 mL, and 15 mL, with treatment times ranging from 15 to 60 minutes at a constant stirring speed of 200 rpm.

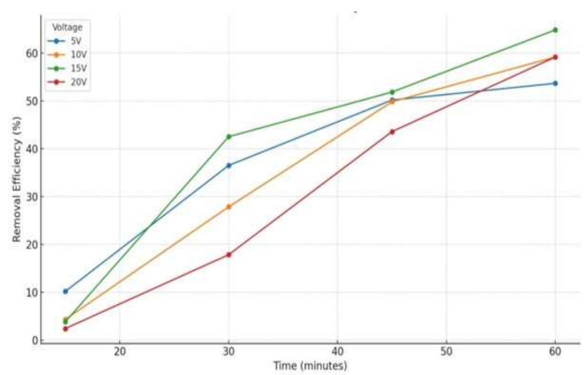
After the mixing process, the jars were removed and allowed to stand for 30 minutes to facilitate floc formation and settling. The supernatant was then carefully collected without disturbing the sediment, and parameters such as COD, BOD, TDS, and TOC were analyzed. The same experimental procedure was repeated using ferric chloride ($FeCl_3$) as the coagulant. Finally, the performance of electrocoagulation and chemical coagulation processes was compared based on the removal efficiency of the measured parameters.

Fig 4: Chemical-coagulation Setup

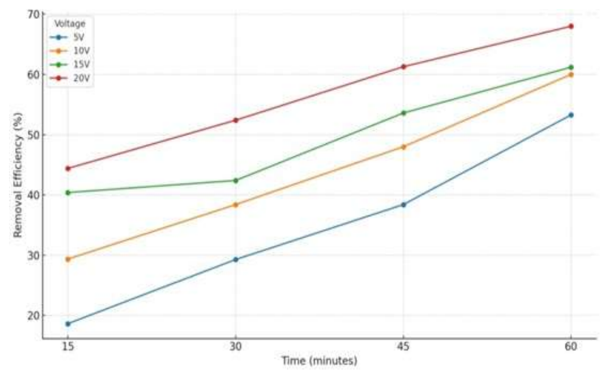
IV RESULTS

A. Wastewater collected by aluminium electrode

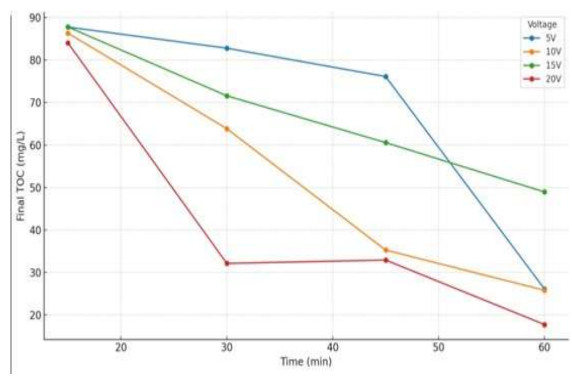
Electrocoagulation of municipal wastewater was carried out using electrode in a batch reactor with monopolar parallel connection.



(a) COD



(b) TOC



(c) TDS

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ISSN: 2278-0181
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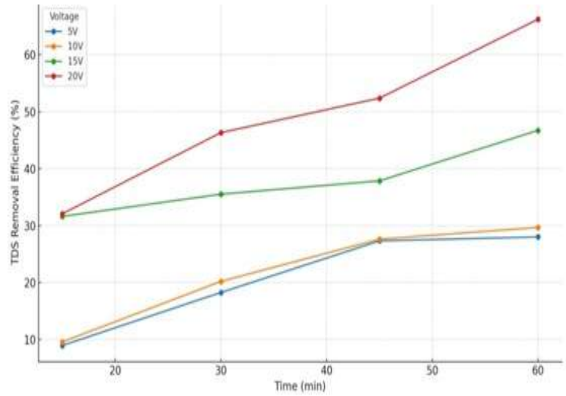
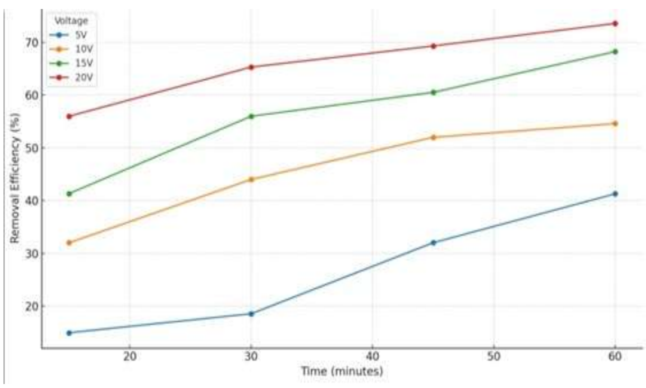


(d) BOD

Fig. 5. A, b, c, d shows that COD, TOC, TDS, and BOD removal efficiency with different voltages and contact time

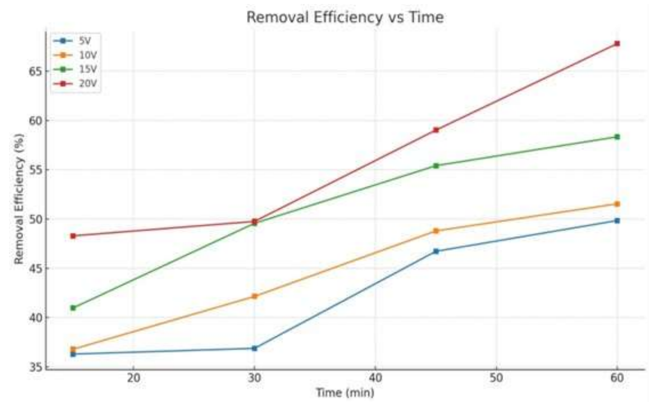
B. Wastewater treated by aluminium electrodes

Municipal wastewater treatment through electrocoagulation was performed using a batch reactor equipped with four iron electrodes arranged in a monopolar parallel configuration. Multiple experiments were conducted by varying the applied voltage and contact time to evaluate the treatment performance.

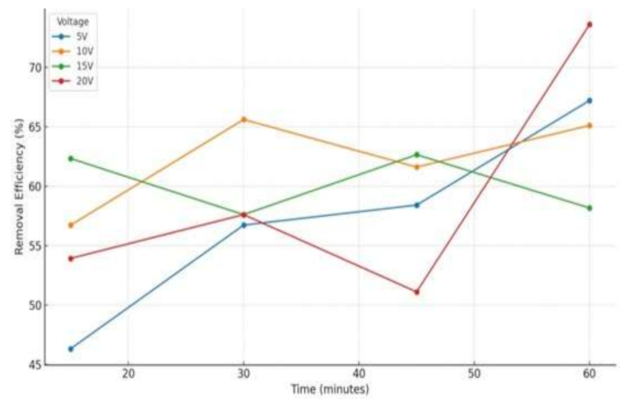


(a) COD

(b) TOC



(c) TDS



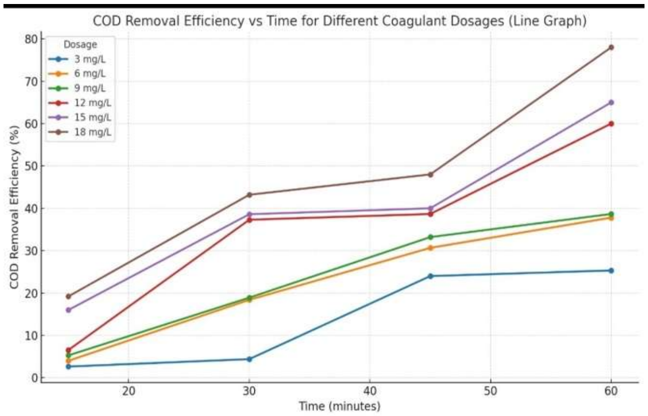
(d) BOD

Fig. 6 a, b, c, d shows that COD, TOC, TDS, and BOD removal efficiency with different voltages and contact time

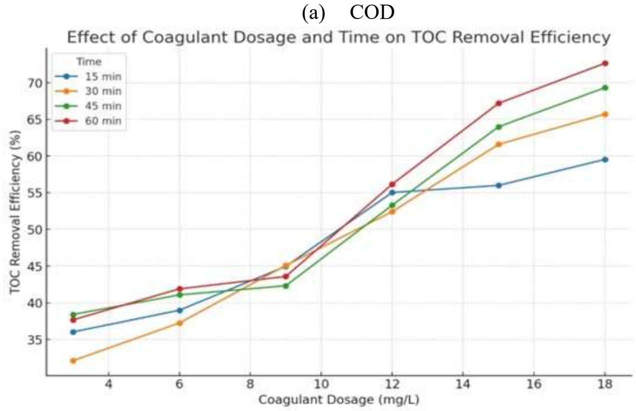
C. Wastewater treated by chemical coagulation with aluminium sulphate as coagulant

Municipal wastewater treatment using chemical coagulation was carried out with a jar test setup, employing aluminium sulphate ($Al_2(SO_4)_3$) as the coagulant. The process was evaluated under varying dosages and contact times to determine its effectiveness Wastewater treated by chemical coagulation with Ferric Chloride as coagulant

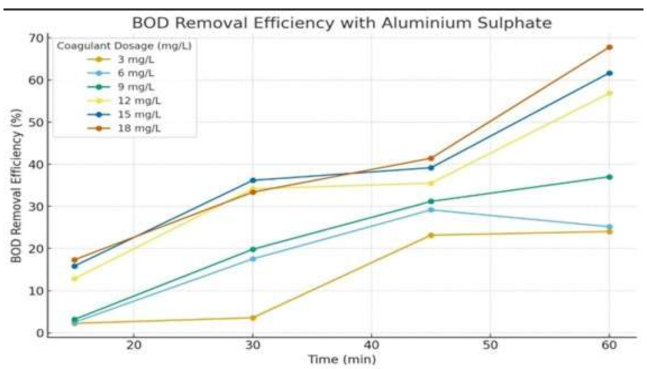
Municipal wastewater treatment through chemical coagulation was performed using a jar test apparatus, employing ferric chloride ($FeCl_3$) as the coagulant.



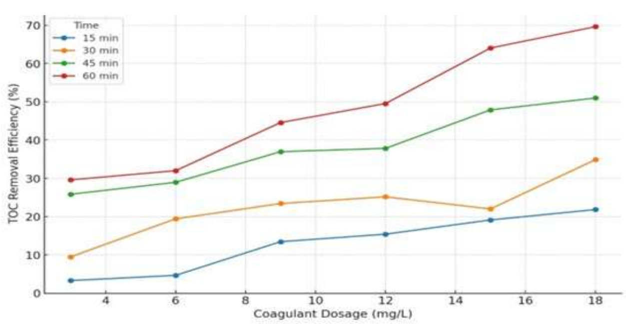
(a) COD



(b) TOC



(c) TDS

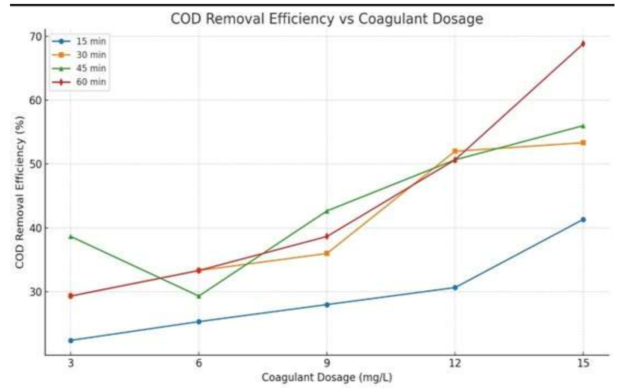


(d) BOD

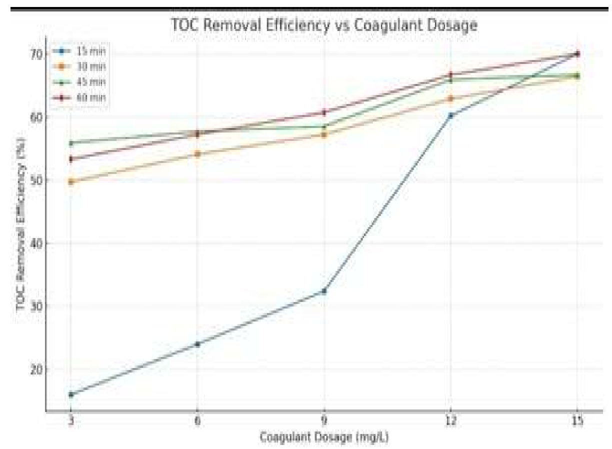
Fig. 7. a, b, c, d shows that COD, TOC, TDS, BOD removal efficiency with different coagulant dosage and contact time

D. Wastewater treated by chemical coagulation with Ferric Chloride as coagulant

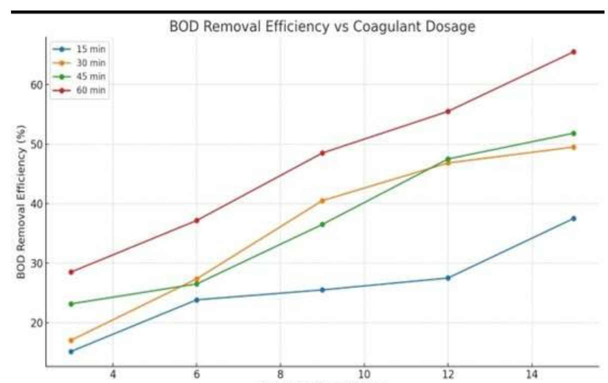
Municipal wastewater treatment through chemical coagulation was performed using a jar test apparatus, employing ferric chloride ($FeCl_3$) as the coagulant. The experiments were conducted at varying dosages and contact times to evaluate the treatment performance.



(a) COD



(b) TOC



(c) TDS

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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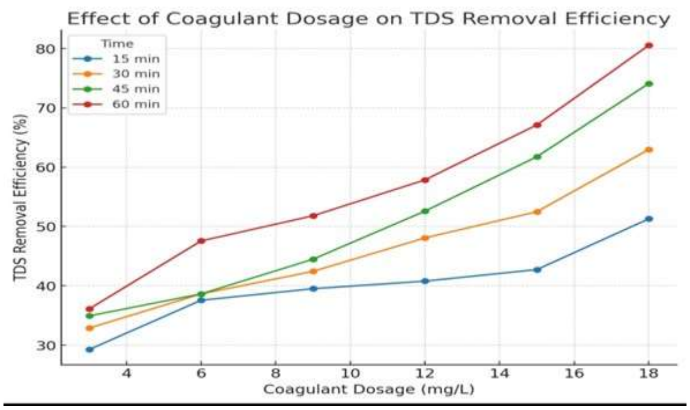
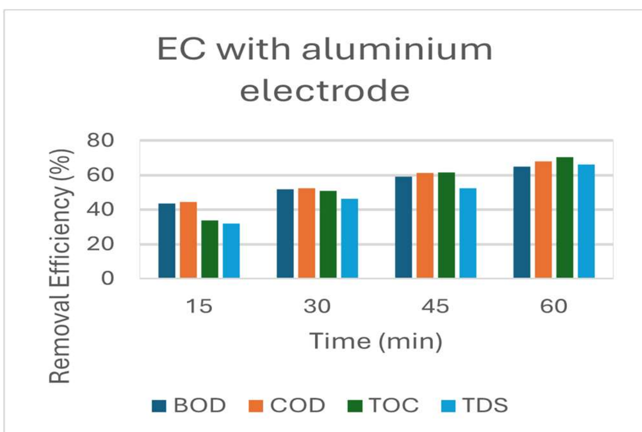


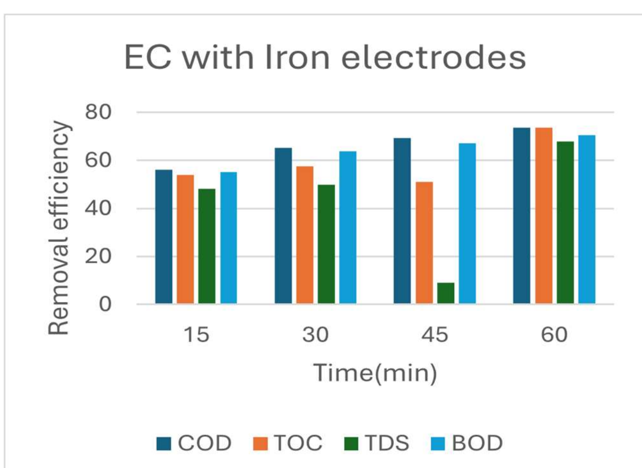
(d) BOD

Fig.8. a, b, c, d shows that COD, TOC, TDS, BOD removal efficiency with different coagulant dosages and contact time.

E. Comparison between electrocoagulation and chemical coagulation



(a)



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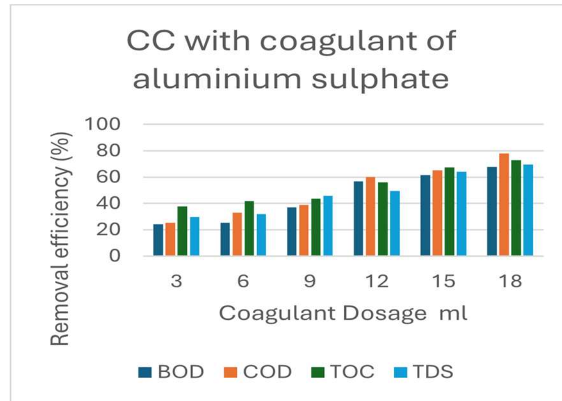
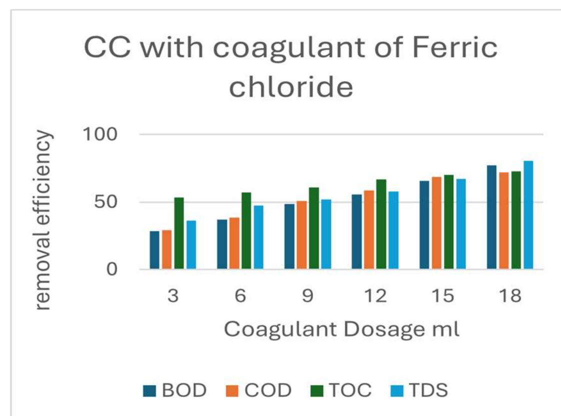


(c)



(d)

Fig.9. a and b show comparison of Electrocoagulation where c, d, shows the comparison between Chemical Coagulation of
COD, TOC, TDS, BOD removal efficiency

VI SUMMARY AND CONCLUSION

The results of the study showed that increasing both the applied current and the dosage of coagulant led to a significant improvement in the removal performance of COD, TOC, TDS, and BOD. In the electrocoagulation process, aluminium electrodes achieved maximum removal efficiencies of 85% for COD, 87% for TOC, 82% for TDS, and 81% for BOD. In contrast, the use of iron electrodes produced higher efficiencies—92% for COD, 92% for TOC, 84% for TDS, and 88% for BOD—at an applied voltage of 20 V, which represented the highest current condition during the experiments. For the chemical coagulation process, the maximum removal efficiencies recorded with aluminium sulfate as the coagulant were 81.66% for COD, 80.09% for TOC, 84.67% for TDS, and 77.08% for BOD. When ferric chloride was used at its highest dosage level of 18 mg, the removal efficiencies increased to 86% for COD, 83.90% for TOC, 87.73% for TDS, and 81.8% for BOD. Comparative evaluation between aluminium and iron electrodes under both electrocoagulation (EC) and chemical coagulation (CC) processes revealed that iron consistently provided better removal performance than aluminium. Overall, electrocoagulation exhibited greater pollutant removal efficiency than chemical coagulation, confirming it as a more effective technique for municipal wastewater treatment.

A. Scope for Future Work

- Comparative evaluation of iron and aluminium electrodes with different electrode connections for chemical coagulation and electrocoagulation techniques for treating municipal wastewater
- Municipal wastewater treatment through chemical coagulation employing various coagulant types

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