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Comparative Study of Chemical Coagulation and Elecrical Coagulation for Wastewater Treatment

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Abstract: *The increasing discharge of industrial wastewater containing high levels of organic, inorganic, and suspended impurities poses a serious threat to the environment and public health. This project presents a comparative study of Chemical Coagulation (CC) and Electrocoagulation (EC) as two effective physicochemical methods for wastewater treatment. In the Chemical Coagulation process, Ferrous Sulphate ($FeSO_4 \cdot 7H_2O$) was used as a coagulant at varying dosages and pH conditions, while the Electrocoagulation process utilized iron electrodes under controlled electrical conditions. The performance of both methods was evaluated based on pH, BOD, COD, turbidity, and sludge formation. Results indicated that EC achieved greater removal efficiency (≈60 – 65% COD and 65% BOD reduction) with less sludge generation compared to CC (≈40 – 45% COD reduction). Although the initial cost of EC setup was higher, its operational efficiency, lower sludge handling cost, and eco-friendly nature make it a more sustainable choice for industrial wastewater treatment. This study highlights the potential of EC as a superior alternative to conventional chemical coagulation methods*

Keywords: Wastewater treatment, Chemical coagulation, Electrocoagulation, Ferrous sulphate, Iron electrodes, BOD, COD, pH, Sludge reduction, Cost analysis, Industrial effluent.

I. INTRODUCTION

BACKGROUND ON WASTEWATER:

In today's modern world, rapid industrialization, urban expansion, and technological advancement have significantly increased water consumption and wastewater generation. Every sector — domestic, commercial, and industrial — contributes to wastewater production through activities like manufacturing, cleaning, cooling, and sanitation. Wastewater is no longer just a by-product; it has become one of the most critical environmental challenges of the 21st century.

Modern wastewater contains a complex mix of pollutants including suspended solids, heavy metals, synthetic chemicals, nutrients, oils, and microorganisms. Industrial wastewater often contains toxic or non-biodegradable compounds that are difficult to treat using conventional biological processes. If this wastewater is released into the environment without adequate treatment, it can contaminate surface and groundwater sources, disrupt aquatic ecosystems, and pose serious health risks to humans and animals.

With increasing global awareness about sustainability and resource conservation, wastewater is now being viewed not as waste but as a potential resource. Treated wastewater can be reused for agricultural irrigation, industrial processes, and even groundwater recharge, reducing the demand for fresh water. This shift has driven the development of modern and efficient treatment technologies, including advanced chemical, electrochemical, and membrane-based methods.

INTRODUCTION OF WASTEWATER: -

Water is used in almost every human activity — from domestic chores and agriculture to manufacturing and industrial processes. Once water has been used, it becomes contaminated with physical, chemical, and biological impurities, and this used water is known as wastewater.

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Wastewater typically contains a mixture of suspended solids, dissolved organic matter, nutrients (such as nitrogen and phosphorus), oils, greases, pathogens, and sometimes toxic chemicals or heavy metals. The composition of wastewater depends on its source — domestic wastewater comes from households and includes sewage and greywater; industrial wastewater originates from factories and manufacturing units; and commercial wastewater comes from institutions like hospitals, hotels, and offices.

If untreated wastewater is discharged directly into the environment, it leads to severe problems such as water pollution, oxygen depletion in water bodies, and the spread of waterborne diseases. It also degrades aquatic habitats and affects human health. Therefore, wastewater treatment is essential to remove contaminants before the water is reused or released back into nature.

Modern wastewater treatment systems use a combination of physical, chemical, and biological processes to achieve high purification efficiency. These processes not only protect public health and the environment but also help conserve water resources through recycling and reuse.

Hence, understanding wastewater and its treatment is a crucial step toward achieving sustainable water management and environmental protection in the modern world.

WASTEWATER ORIGINS: -

Wastewater originates wherever water is used and becomes contaminated through human, industrial, or natural activities. As societies and industries have developed, the volume and complexity of wastewater have increased significantly. It is now produced from multiple sources, each contributing different types of pollutants depending on the process or activity involved.

The major sources of wastewater generation include

- Domestic Source: Water used in households for bathing, cooking, cleaning, and sanitation becomes domestic wastewater. It mainly contains organic matter, food residues, soaps, oils, greases, and microorganisms. This wastewater is commonly referred to as sewage and forms a large portion of municipal wastewater.
- Industrail Source: Industries are among the largest contributors to wastewater generation. During manufacturing, washing, cooling, or processing operations, water becomes contaminated with various pollutants. The composition of industrial wastewater depends on the industry type — for example, textile industries discharge dyes and suspended solids, food industries release organic waste, and chemical or pharmaceutical industries generate effluents containing heavy metals, solvents, and toxic chemicals.
- Commercial and Institutional Sources: This wastewater comes from places such as offices, hospitals, hotels, educational institutions, and laboratories. It contains cleaning agents, detergents, and sometimes chemical or biological contaminants.
- Agricultural Sources: Wastewater is also generated from agricultural activities such as irrigation runoff and livestock farming. It carries fertilizers, pesticides, and organic matter, contributing to nutrient and chemical pollution in nearby water bodies.

In modern times, urbanization and industrial growth have led to the continuous increase in wastewater generation. Each source produces wastewater with unique characteristics, making treatment and proper management essential to protect public health, preserve ecosystems, and ensure sustainable use of water resources.

PROBLEM STATEMENT:-

The pharmaceutical industry generates large volumes of wastewater containing complex and potentially hazardous substances. This includes residual drugs, solvents, chemical reagents, and organic compounds that are often non-biodegradable, toxic, and difficult to treat using conventional methods.

Pharmaceutical wastewater presents several challenges:

High Chemical Load:

Contains high concentrations of organic and inorganic chemicals that increase Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD).

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Toxicity:
Residual drugs, active pharmaceutical ingredients (APIs), and chemical additives can be toxic to aquatic life and may cause long-term environmental effects.
Treatment Difficulty:
Many pharmaceutical compounds are resistant to biological degradation, making conventional biological treatment methods ineffective.
Health and Environmental Risks:
Untreated discharge can contaminate surface water and groundwater, posing risks to human health and disrupting aquatic ecosystems.
Regulatory Compliance:
Strict environmental standards exist for pharmaceutical effluents. Industries must ensure proper treatment to avoid penalties and legal consequences.
In summary: Pharmaceutical wastewater is a highly complex and hazardous effluent, and managing it requires advanced chemical engineering solutions to protect the environment, human health, and comply with environmental regulations.

NEED FOR THE STUDY:-
Pharmaceutical wastewater contains complex, toxic, and non-biodegradable substances that, if left untreated, pose serious risks to the environment, human health, and industrial sustainability. Addressing this problem is essential for the following reasons:
Environmental Protection:
Toxic chemicals, active pharmaceutical ingredients (APIs), and residual drugs can contaminate rivers, lakes, and groundwater, harming aquatic life and reducing biodiversity.
Public Health Safety:
Pharmaceutical pollutants can enter drinking water sources, potentially causing long-term health effects, including antibiotic resistance and toxicity.
Regulatory Compliance:
Environmental laws strictly regulate pharmaceutical effluent discharge. Proper treatment is necessary to meet legal standards and avoid penalties.
Resource Conservation and Sustainability:
Effective treatment can allow reuse of treated water in industrial processes or irrigation, reducing freshwater demand and promoting sustainable water management.
Industrial Efficiency:
Untreated effluents can corrode equipment, create sludge, or interfere with recycling systems in pharmaceutical plants. Proper treatment ensures smooth industrial operations.
In essence: Solving the problem of pharmaceutical wastewater is crucial to protect ecosystems, safeguard human health, comply with regulations, and promote sustainable industrial practices.

II. METHODOLOGY (GENERAL WASTEWATER TREATMENT)

The treatment of wastewater involves a series of systematic steps designed to remove physical, chemical, and biological contaminants, making the water safe for discharge or reuse. From a chemical engineering perspective, the methodology focuses on understanding wastewater characteristics, applying suitable treatment processes, and optimizing efficiency.
1. Characterization of Wastewater: Before treatment, wastewater must be analyzed to determine its composition and pollutant load. Key parameters include:

- Physical: Turbidity, color, temperature, and Total Suspended Solids (TSS).
- Chemical: pH, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), nutrients, heavy metals, and chemical contaminants.

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- Biological: Presence of microorganisms, pathogens, and organic pollutants.

This analysis helps in selecting appropriate treatment methods and designing the process efficiently.

2. Preliminary Treatment: The first stage involves removing large solids and debris to prevent clogging and damage to equipment. Techniques may include:

- Screening
- Grit removal
- Sedimentation

3. Primary Treatment: Primary treatment focuses on removing settleable solids and floating materials. Methods often involve:

- Sedimentation tanks or clarifiers
- Flotation techniques

This reduces the pollutant load and prepares the wastewater for secondary treatment.

4. Secondary (Biological/Chemical) Treatment: At this stage, dissolved organic matter and remaining pollutants are removed. Depending on the wastewater type, chemical engineers may apply:

- Chemical processes: Coagulation, flocculation, neutralization, and oxidation
- Biological processes: Aerobic or anaerobic digestion to degrade organic matter

5. Tertiary Treatment (Advanced Treatment): Tertiary treatment removes remaining contaminants, including nutrients, heavy metals, and pathogens. Techniques include:

- Filtration and membrane processes
- Disinfection (chlorination, UV)
- Adsorption or ion exchange for heavy metal removal

6. Sludge Handling and Disposal: Treatment generates sludge, which must be properly managed. Sludge treatment includes:

- Thickening and dewatering
- Stabilization (chemical or biological)
- Safe disposal or reuse as fertilizer/energy source

7. Quality Monitoring and Reuse: Finally, treated wastewater is analyzed to ensure compliance with regulatory standards before discharge or reuse in industrial, agricultural, or municipal applications.

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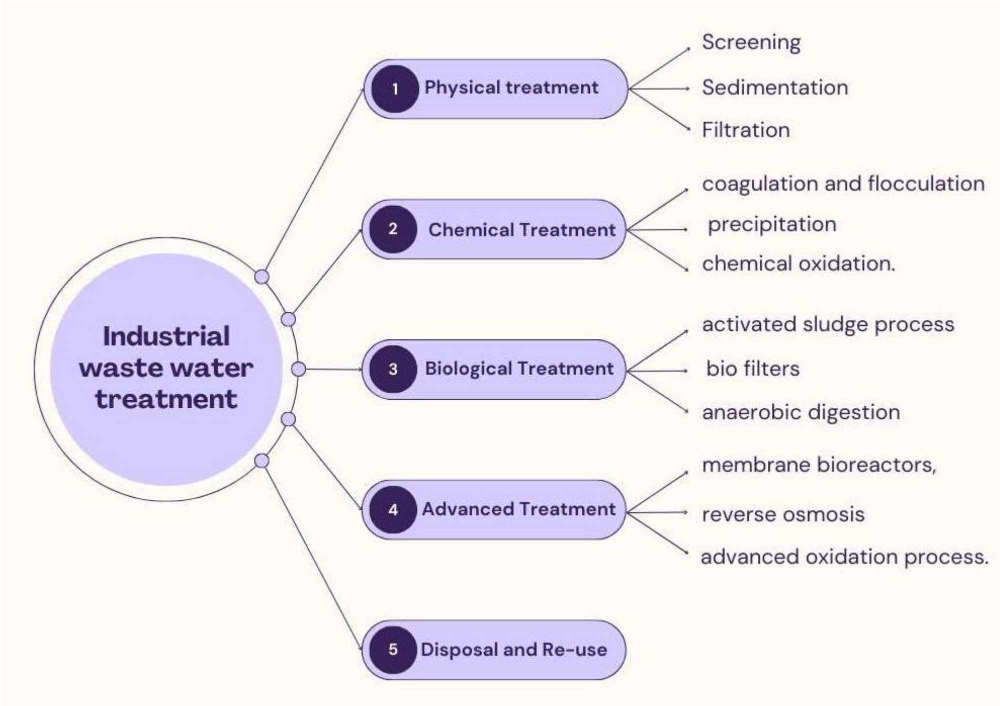

III. INTRODUCTION TO CHEMICAL COAGULATION

Chemical Coagulation is a widely used water and wastewater treatment process that removes suspended solids, turbidity, and colloidal particles from water by adding chemical coagulants. It is a physical-chemical process that destabilizes fine particles, allowing them to aggregate into larger particles (flocs) that can be easily removed by sedimentation or filtration.

HOW IT WORKS:

- Addition of Coagulants: Chemicals such as alum ($Al_2(SO_4)_3$), ferric chloride ($FeCl_3$), or polyaluminum chloride (PAC) are added to wastewater.
- Charge Neutralization: Most suspended particles carry negative surface charges, which prevent them from aggregating. Coagulants neutralize these charges, destabilizing the particles.
- Floc Formation (Flocculation): After charge neutralization, particles stick together to form larger aggregates called flocs. Gentle mixing (flocculation) enhances the growth of these flocs.
- Removal of Flocs: The formed flocs are removed by sedimentation, filtration, or flotation, resulting in clearer water with reduced turbidity and suspended solids.

ADVANTAGES OF CHEMICAL COAGULATION:

- Effectively removes turbidity, suspended solids, and colloidal particles.
- Reduces organic load (BOD & COD) in water.
- Can remove phosphates, heavy metals, and some dyes.
- Relatively simple and cost-effective for large-scale water treatment.

LIMITATIONS:

- Generates chemical sludge that requires proper disposal.
- Effectiveness depends on pH, temperature, and coagulant dosage.

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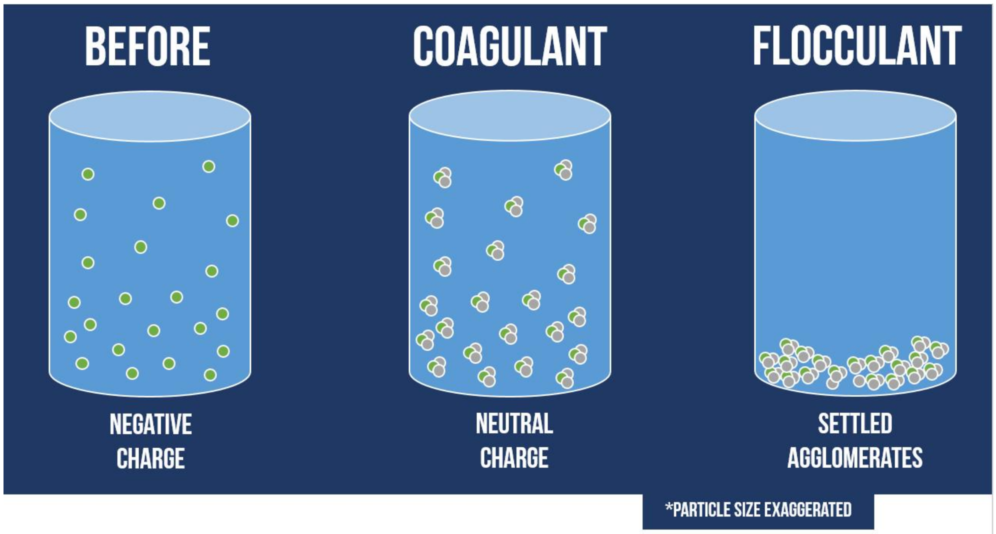
- May not completely remove dissolved organic or toxic compounds.



IV. EXPERIMENTAL SETUP

The experimental setup for the chemical coagulation of wastewater involved the use of Ferrous Sulphate ($FeSO_4 \cdot 7H_2O$) as a coagulant to study the removal of suspended solids and organic pollutants. The experiment was conducted using a jar test apparatus, which consisted of six beakers with adjustable stirring paddles to simulate coagulation and flocculation under controlled conditions. Wastewater samples were collected from industry and measured for initial parameters such as pH and total suspended solids (TSS).

Different dosages of coagulant, 1:1 (37.85 g of Ferrous Sulphate) and 1:2 (75.7 g of Ferrous Sulphate), were added to each 2-liter beaker to determine the optimum dose for maximum pollutant removal. Initially, the samples underwent rapid mixing at 100–120 rpm for 30 minutes to ensure proper dispersion of the coagulant and charge neutralization of colloidal particles. This was followed by slow mixing at 30–40 rpm for several minutes to promote floc formation, allowing destabilized particles to aggregate into larger flocs.

During chemical coagulation, the following reactions occur:

Hydrolysis of Ferrous Sulphate:

$$FeSO_4 + 2H_2O \rightarrow Fe(OH)_2\ (s) + H_2SO_4$$

Oxidation to Ferric Hydroxide (Floc Formation):

$$4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3\ (flocs)$$

Removal of Suspended Particles:

$$Fe(OH)_3 + Suspended\ particles \rightarrow Aggregated\ flocs \rightarrow Settling$$

After flocculation, the samples were left undisturbed for 30–60 minutes to allow the settling of flocs through sedimentation. The supernatant was carefully collected and analyzed for TSS. Observations such as floc formation and clarity of water were recorded to determine the effectiveness of Ferrous Sulphate as a coagulant. This setup allowed the study of optimum coagulant dosage and treatment efficiency under controlled laboratory conditions.

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ELECTROCOAGULATION (EC)

Electrocoagulation (EC) is an advanced water and wastewater treatment process that uses electric current to remove suspended solids, turbidity, heavy metals, oils, and other pollutants. Unlike chemical coagulation, EC generates coagulants in situ by dissolving sacrificial metal electrodes (usually iron or aluminum) into the wastewater.

HOW IT WORKS:

Electrode Setup:

Wastewater is placed between anode and cathode plates (commonly iron or aluminum).

Electric Current Application:

A direct current (DC) is applied, causing metal ions to be released from the anode.
These ions act as coagulants, neutralizing charges on suspended particles.

Floc Formation:

The metal ions react with pollutants to form insoluble hydroxides, which aggregate into flocs.
Flocs grow in size during gentle mixing, enhancing particle removal.

Pollutant Removal:

The formed flocs settle by sedimentation or are removed by flotation.
Pollutants such as turbidity, suspended solids, heavy metals, and oils are effectively reduced.

ADVANTAGES OF ELECTROCOAGULATION:

- Generates coagulants on-site, avoiding chemical storage and handling.
- Effective in removing turbidity, oils, heavy metals, and dyes.
- Can treat complex industrial wastewater resistant to conventional methods.
- Produces less chemical sludge compared to traditional chemical coagulation.

LIMITATIONS:

- Requires electricity and proper electrode maintenance.
- Initial setup cost can be higher than conventional chemical coagulation.
- Efficiency depends on current density, pH, and conductivity of wastewater.
- EC is generally more efficient and sustainable for complex wastewater than CC.

Parameter	Chemical Coagulation (CC)	Electrocoagulation (EC)
Coagulant Source	Added externally as chemicals (e.g., Alum, Ferrous Sulphate)	Generated in situ from sacrificial electrodes (Iron/Aluminum)
Sludge Production	High, requires proper disposal	Lower compared to CC
Pollutants Removed	Suspended solids, turbidity, some organics, phosphates, heavy metals	Suspended solids, turbidity, heavy metals, oils, dyes, complex organics
Efficiency	Effective but may require optimization of coagulant dosage	Higher removal efficiency, effective for complex wastewater
Chemical Handling	Requires storage, handling, and dosing of chemicals	Minimal chemical handling
Process Mechanism	Charge neutralization and flocculation	Charge neutralization + flocculation + electrochemical oxidation
Operational Cost	Generally low cost	Higher initial setup cost, but less chemical cost
Environmental Impact	More chemical sludge, disposal required	Less sludge, environmentally friendly
Flexibility / Control	Limited control; depends on coagulant type and dosage	Adjustable via current density, electrode material, and treatment time
Suitability	Domestic and industrial wastewater with moderate pollution	Complex industrial and pharmaceutical wastewater

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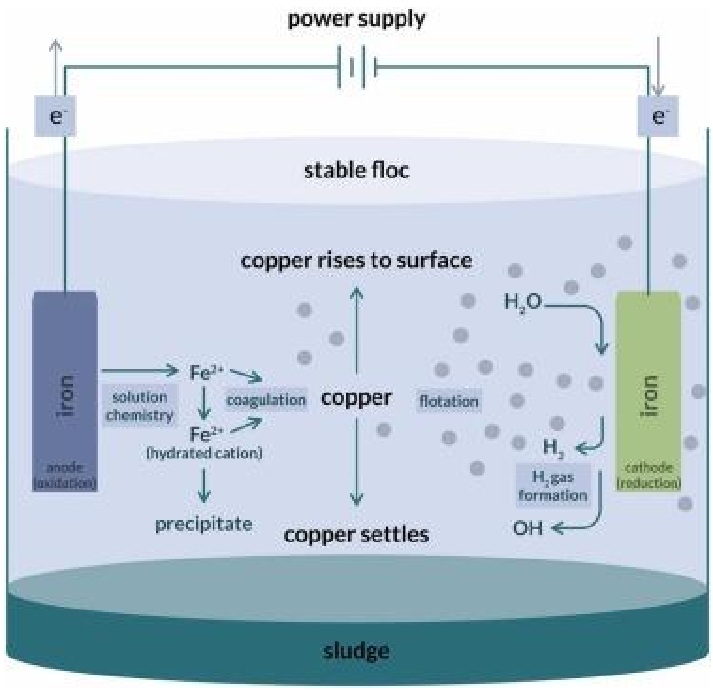

EXPERIMENTAL SETUP:-

The experimental setup for Electrocoagulation (EC) involved using sacrificial metal electrodes, typically iron, to treat wastewater and study the removal of suspended solids, heavy metals, and organic pollutants. Wastewater samples were collected from industry, and initial parameters such as pH and total suspended solids (TSS) were measured. The samples were poured into a rectangular EC reactor equipped with an anode and cathode connected to a DC power supply.

When the electric current was applied, metal ions were released from the anode into the wastewater, acting as coagulants. For iron electrodes, the main reactions occurring during electrocoagulation are:

Anode reaction (oxidation):

$$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^{-}$$

Cathode reaction (reduction of water):

$$2H_2O + 2e^{-} \rightarrow H_2(g) + 2OH^{-}$$

The ferrous ions (Fe^{2+}) further react with oxygen and hydroxyl ions in water to form ferric hydroxide flocs:

$$Fe^{2+} + 2OH^{-} \rightarrow Fe(OH)_2$$
$$4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3\ (flocs)$$

These insoluble flocs aggregate suspended particles, oils, and other contaminants, which then settle by sedimentation or can be removed by flotation. Gentle stirring was applied during the process to promote floc formation. After treatment, the supernatant was collected and analyzed for TSS, pH, and BOD/COD reduction. Observations such as floc formation, clarity improvement, and pollutant removal efficiency were recorded. This setup allowed the study of optimum current density, electrode material, and treatment time to achieve maximum pollutant removal using the Electrocoagulation process.

BIOLOGICAL OXIDATION

Biological oxidation is a wastewater treatment process in which microorganisms (bacteria, fungi, or algae) break down organic pollutants into simpler substances like carbon dioxide, water, and biomass. It is primarily used to reduce Biochemical Oxygen Demand (BOD) and treat organic contaminants efficiently.

PROCESS

Microbial Action: Microorganisms consume organic matter as food and energy, converting it into harmless byproducts.

Aerobic Oxidation: Occurs in the presence of oxygen. Organic matter is oxidized to:

$$\text{Organic Matter} + \boldsymbol{O_2} \rightarrow \boldsymbol{CO_2} + \boldsymbol{H_2O} + \boldsymbol{Biomass}$$

Anaerobic Oxidation: Occurs in absence of oxygen, producing methane, carbon dioxide, and biomass:

$$\text{Organic Matter} \rightarrow \boldsymbol{CH_4} + \boldsymbol{CO_2} + \boldsymbol{Biomass}$$

TYPES

- Aerobic Processes: Require oxygen. Examples: Activated sludge, Trickling filters, Aerated lagoons. Efficient in rapid BOD removal.
- Anaerobic Processes: No oxygen required. Examples: Anaerobic digesters, UASB reactors. Produce biogas (methane).

ADVANTAGES

- Cost-effective and environmentally friendly.
- Converts harmful organics into harmless products.
- Anaerobic processes allow energy recovery as methane.
- Reduces BOD and COD significantly.
- Applicable to both municipal and industrial wastewater.

EXPERIMENTAL SETUP:-

The experimental setup for biological oxidation was designed to study the removal of organic pollutants and reduction of BOD in wastewater using microorganisms. Wastewater samples were collected from industry and initial parameters such as pH and BOD were measured.

For aerobic oxidation, the samples were placed in beakers or aeration tanks and kept in an incubator to maintain a controlled temperature suitable for microbial growth. Continuous aeration or gentle stirring was provided to supply oxygen to the microorganisms and ensure uniform contact with organic matter. The microorganisms metabolized the organic pollutants, producing carbon dioxide, water, and biomass over the incubation period.

For anaerobic oxidation, wastewater samples were placed in sealed containers or anaerobic digesters inside the incubator to maintain the desired temperature while preventing oxygen entry. Anaerobic bacteria decomposed the organic matter into methane, carbon dioxide, and biomass over a longer reaction time.

After biological treatment, the supernatant was collected and analyzed for BOD, COD, TSS, and pH to evaluate treatment efficiency. Observations such as sludge formation, reduction in BOD, and clarity of water were recorded to study the effectiveness of biological oxidation under controlled laboratory conditions.

COD VARIO METHOD

PRINCIPLE

The COD Vario Method is a closed reflux colorimetric method used to determine the Chemical Oxygen Demand (COD) of wastewater. It measures the amount of oxygen required to oxidize organic and inorganic matter using a strong oxidizing agent (Potassium Dichromate, $K_2Cr_2O_7$) under acidic and high-temperature conditions.

In this method, the sample is digested in a COD Vario Tube containing a precise amount of reagents. The digestion is performed at 148°C for 2 hours in a Thermoreactor. During digestion, dichromate ions oxidize the organic matter present in the sample. The change in color, which corresponds to the amount of dichromate reduced, is measured using a COD Vario Photometer.

The intensity of color developed is directly proportional to the COD value of the sample.

MAIN REACTION:

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

$$\text{Organic Matter} + O \rightarrow CO_2 + H_2O$$

ADVANTAGES OF THE COD VARIO METHOD

- Fast and Efficient: Results within 2 hours.
- Closed System: Prevents sample contamination and reagent loss.
- Safe and User-Friendly: Sealed tubes minimize acid handling and exposure.
- Accurate and Repeatable: Digital photometer ensures high precision.
- Portable and Compact: Ideal for laboratory and field testing.
- Environmentally Safer: Requires smaller reagent volumes compared to classical reflux method.

EXPERIMENTAL SETUP:-

The COD analysis was performed using the COD Vario closed-tube method. Clean COD Vario tubes of 0-15000 mg/l pre-filled with reagents were used. Filter wastewater samples were collected in clean glass bottles. Using a injection, 2.0 mL of each sample was carefully dispensed into a COD Vario tube. A reagent blank (distilled water) and a standard reference (known COD standard) were prepared in the same way. All tubes were sealed with their caps and placed vertically into the Thermoreactor and digested at 150°C for 2 hours. After digestion the tubes were removed and cooled to room temperature (≈15–20 min). Each tube was inserted into the COD Vario Photometer; direct COD reading was recorded. The instrument automatically converted the measured absorbance to COD (mg/L) using its calibration. Results for sample, blank and standard were recorded. All observations were noted and appropriate safety precautions were followed.

ORIGINAL EFFLUENT

The original effluent sample was collected from an industrial wastewater source before any treatment was applied. This raw effluent represented the actual characteristics of the wastewater generated during production and cleaning operations in the industry. The sample was dark in color, with a noticeable odor and high levels of suspended and dissolved solids.

Before beginning any treatment, the original effluent was analyzed for its physico-chemical parameters to determine the pollution load and to serve as a baseline for comparison after each treatment process. The parameters measured included pH, Chemical Oxygen Demand (COD), and Biochemical Oxygen Demand (BOD).

Initial pH of effluent – 10

Biochemical Oxygen Demand (BOD) – 110 mg/L or ppm

Chemical Oxygen Demand (COD) = $\frac{(BLANK - SAMPLE) \times 8000 \times 0.03 \times DF}{25}$

$$= \frac{(757) \times 8000 \times 0.03 \times 50}{25} = 363360 \text{ mg/L or ppm}$$

EFFECTS ON PARAMETERS AFTER CHEMICAL COAGULATION:

After the treatment of industrial wastewater by chemical coagulation using *Ferrous Sulphate* ($FeSO_4 \cdot 7H_2O$) as the coagulant, a significant improvement was observed in the quality of the effluent. The process effectively reduced turbidity, total suspended solids (TSS), and organic load measured as COD and BOD. The addition of ferrous ions helped in charge neutralization of colloidal particles, leading to their aggregation and settling. The treated effluent showed clearer appearance, reduced odor, and near-neutral pH.

Chemical coagulation of the wastewater was carried out using Ferrous Sulphate ($FeSO_4 \cdot 7H_2O$) at a 1:0.5 ratio, while maintaining the pH at 7 for optimum floc formation. Under these conditions, ferrous ions hydrolyzed to form $Fe(OH)_3$ flocs, which effectively trapped and settled suspended and colloidal impurities. The treated sample showed a clear reduction in COD. The effluent became visibly clearer, colorless, and odor-free, indicating that the process was efficient at neutral pH and this dosage provided good treatment efficiency without excess chemical use.

$$\text{COD} = \frac{(BLANK-SAMPLE)\times 8000\times 0.03\times DF}{25}$$
$$= \frac{572\times 8000\times 0.03\times 50}{25} = 274560 \text{ mg/l or ppm}$$

Sludge obtained: 10.3grams

Chemical coagulation of the wastewater was carried out using Ferrous Sulphate ($FeSO_4 \cdot 7H_2O$) at a 1:1 ratio, while maintaining the pH at 7 for optimum floc formation. Under these conditions, ferrous ions hydrolyzed to form $Fe(OH)_3$ flocs, which effectively trapped and settled suspended and colloidal impurities. The treated sample showed a clear reduction in COD. The effluent became visibly clearer, colorless, and odor-free, indicating that the process was efficient at neutral pH and this dosage provided good treatment efficiency without excess chemical use.

$$\text{COD} = \frac{(BLANK-SAMPLE)\times 8000\times 0.03\times DF}{25}$$
$$= \frac{575\times 8000\times 0.03\times 50}{25} = 276000 \text{ mg/l or ppm}$$

Sludge obtained: 16.14grams

Chemical coagulation of the wastewater was carried out using Ferrous Sulphate ($FeSO_4 \cdot 7H_2O$) at a 1:2 ratio, while maintaining the pH at 7 for optimum floc formation. Under these conditions, ferrous ions hydrolyzed to form $Fe(OH)_3$ flocs, which effectively trapped and settled suspended and colloidal impurities. The treated sample showed a clear reduction in COD. The effluent became visibly clearer, colorless, and odor-free, indicating that the process was efficient at neutral pH and this dosage provided good treatment efficiency without excess chemical use.

$$\text{COD} = \frac{(BLANK-SAMPLE)\times 8000\times 0.03\times DF}{25}$$
$$= \frac{693\times 8000\times 0.03\times 50}{25} = 332640 \text{ mg/l or ppm}$$

Sludge obtained: 20.89grams

EFFECTS ON PARAMETERS AFTER ELECTRICAL COAGULATION:

The wastewater sample was treated using the Electrocoagulation (EC) process with iron electrodes under controlled voltage and time conditions. During electrolysis, Fe^{2+} and Fe^{3+} ions were generated at the anode, which hydrolyzed to form $Fe(OH)_2$ and $Fe(OH)_3$ flocs. These freshly formed hydroxides acted as strong coagulants, destabilizing and adsorbing suspended, colloidal, and organic impurities. The treated effluent showed a substantial reduction in BOD (110 → 73 mg/L) and COD (363,360 → 244,320 mg/L), The final pH remained close to neutral, and minimal sludge was produced compared to chemical coagulation. Thus, electrocoagulation using iron electrodes proved highly efficient due to the combined effects of electrochemical oxidation, coagulation, and flotation, leading to enhanced pollutant removal and better effluent quality.

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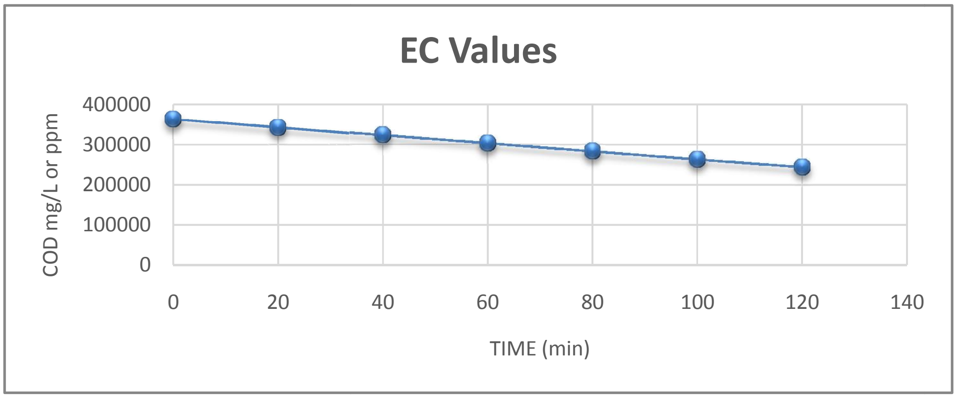
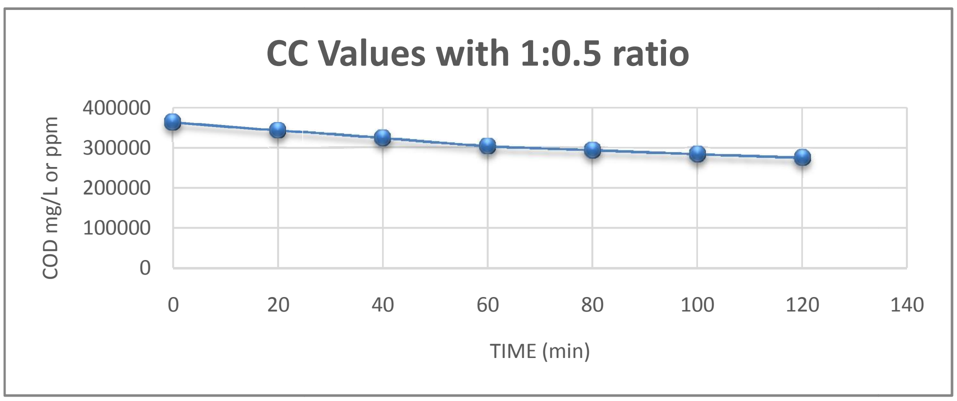
pH of EC wastewater sample = 7
Biochemical Oxygen Demand (BOD) – 73 mg/L or ppm

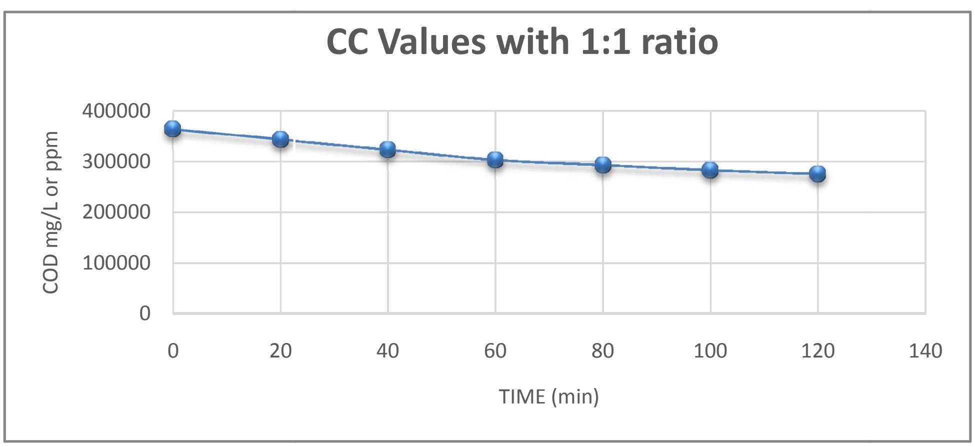
Chemical Oxygen Demand (COD) = $\frac{(BLANK-SAMPLE)\times 8000\times 0.03\times DF}{25}$

$$=\frac{(509)\times 8000\times 0.03\times 50}{25} = 244320 \text{ mg/L or ppm}$$

Sludge obtained : 1.83 grams







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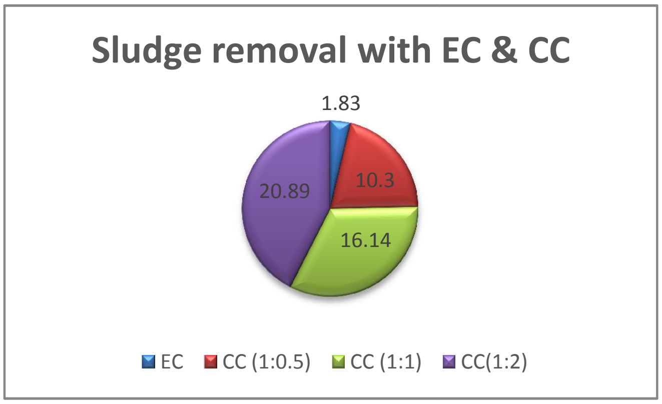
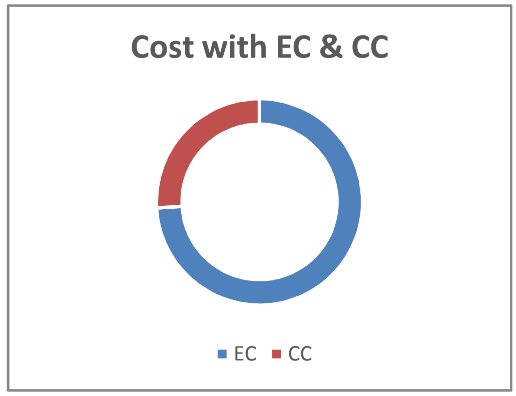
COMPARISON BETWEEN CHEMICAL COAGULATION AND ELECTROCOAGULATION

On comparing the performance of Chemical Coagulation (CC) and Electrocoagulation (EC) for wastewater treatment, it was observed that EC provided better results in terms of pollutant removal and sludge management. While CC using Ferrous Sulphate achieved moderate COD reduction (≈40–45%), EC using iron electrodes showed a higher COD removal efficiency (≈60–65%) due to simultaneous electrochemical oxidation and coagulation. The sludge formed in CC was higher in volume and required additional handling, whereas EC produced less, denser, and more easily settleable sludge. Although EC involves higher initial setup costs, its operational and chemical costs are lower in the long run, and it causes minimal secondary pollution. Hence, EC is considered more efficient, sustainable, and environmentally friendly compared to traditional chemical coagulation.





OBSERVATION TABLE:

Sr. No.	Parameter	Original Effluent	After Chemical Coagulation (CC)	After Electrocoagulation (EC)	Remarks
1	pH	10.0	7.0 (Initially)	7.2 (Initially)	pH reduced to near neutral after both treatments.
2	BOD (mg/L)	110	-	73	EC achieved greater organic load reduction.
3	COD (mg/L)	363360	276000	244320	EC showed higher COD removal efficiency.
4	Sludge Formation	—	High (chemical sludge)	Low (compact iron hydroxide sludge)	CC produced more sludge due to added coagulant.
6	Odor	Strong	Mild	Odorless	Significant odor reduction after EC.
7	Cost of Setup (₹)	—	7,000	20,000	EC setup cost is higher but more efficient long-term.

IV. CONCLUSION

The comparative study of Chemical Coagulation (CC) and Electrocoagulation (EC) for wastewater treatment demonstrated significant differences in efficiency, operational simplicity, and overall performance. Both methods effectively reduced pollutants such as turbidity, total suspended solids (TSS), biochemical oxygen demand (BOD), and chemical oxygen demand (COD); however, the extent of removal and quality of treated water varied.

In Chemical Coagulation, using Ferrous Sulphate ($FeSO_4 \cdot 7H_2O$) as a coagulant achieved considerable reductions in turbidity and suspended solids through charge neutralization and floc formation. This method proved cost-effective and simple, but it generated a higher quantity of sludge and required pH adjustment and chemical handling, which can increase operational cost and disposal concerns.

In contrast, Electrocoagulation showed superior performance due to in-situ generation of coagulants through electrolytic oxidation of metal electrodes. It achieved higher removal efficiencies for turbidity, TSS, BOD, and COD, and produced less sludge compared to chemical coagulation. EC also minimized the use of external chemicals and improved the biodegradability of the wastewater, making it suitable for subsequent biological treatment.

The Biological Oxidation process, carried out after EC treatment, further reduced BOD and COD values significantly, indicating efficient microbial degradation of the remaining organic matter. This secondary step enhanced the overall treatment quality, producing water that meets discharge or reuse standards.

Overall, the study concludes that:

- Electrocoagulation is more efficient, environmentally sustainable, and produces less chemical residue than chemical coagulation.
- Combined EC followed by Biological Oxidation provides the best results for complete wastewater purification.
- From a chemical engineering perspective, EC offers better process control, scalability, and integration potential with modern wastewater treatment systems.
- Thus, Electrocoagulation coupled with Biological Oxidation can be considered a promising alternative for advanced wastewater treatment in various industrial applications.

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