Treatment of Textile Wastewater from Spinning Mill Using Electrocoagulation-Flocculation Process

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Abstract - Textile spinning mills generate wastewater containing high levels of pollutants such as suspended solids, dyes, oils, and organic compounds. This study investigates the electrocoagulation-flocculation (ECF) process as a sustainable treatment method. ECF combines electrocoagulation, where an electric current induces pollutant coagulation, and flocculation, which aggregates these pollutants for removal. Extensive lab experiments were conducted, analyzing setup, procedures, and results. The study found that ECF significantly reduced pollutants, achieving high removal efficiencies for suspended solids, COD, color, and oil/grease. Economic analysis confirmed ECF's cost-effectiveness over conventional methods. A case study demonstrated successful implementation, highlighting operational efficiency and environmental compliance. The paper concludes with recommendations for future research and industrial applications.

***Key Words*:** Electrocoagulation, Textile Wastewater, Sustainable Wastewater Treatment, Spinning Mill, Pollutant Removal

1.INTRODUCTION

Open-end spinning, also known as rotor spinning or OE spinning, is a textile spinning method used in spinning mills to produce yarn. This method is faster and more automated compared to traditional ring spinning, which involves a complex process of twisting and winding. Different open-end spinning mills may use various generations of rotor spinning machines. Technological advancements can lead to improved efficiency, energy savings, and enhanced yarn quality. Mills may invest in the latest machinery to stay competitive in the industry. The treatment of wastewater from spinning mills holds considerable importance in sustainable industrial practices. Inadequate treatment measures can lead to adverse environmental consequences, such as contamination of water bodies, soil degradation, and disruption of aquatic ecosystems. By implementing robust wastewater treatment strategies, spinning mills can minimize their environmental footprint and contribute to the overall sustainability of the textile industry.

2. Literature Review

Treating textile wastewater presents significant challenges due to its complex composition containing dyes, surfactants, heavy metals, and other recalcitrant pollutants. Conventional treatment methods often fall short, prompting researchers to explore innovative and sustainable approaches that combine various physicochemical and biological processes. Several studies have investigated the coupling of these techniques to address the multifaceted nature of textile effluents effectively.

- ***Bouznif and Bali (2021)*** explored the integration of coagulation/flocculation and anodic oxidation processes for textile wastewater treatment. The coagulation/flocculation step efficiently removed suspended solids, while the subsequent anodic oxidation targeted organic matter degradation and color removal. This coupled approach exhibited promising results, achieving over 90% reductions in chemical oxygen demand (COD) and decolorization. The authors highlighted the synergistic effects of the combined processes, overcoming the limitations of individual treatment methods.

- ***Freitas et al. (2017)*** examined the utilization of plant-based coagulants as alternatives to conventional chemical coagulants for textile wastewater treatment. Natural coagulants like Moringa oleifera and Opuntia ficus-indica have gained attention due to their biodegradability, low toxicity, and cost-effectiveness. The review discussed the coagulation/flocculation mechanisms using these plant-based coagulants and their effectiveness in removing dyes, turbidity, and other pollutants from textile effluents. The authors emphasized the potential of these natural coagulants to enhance treatment sustainability while minimizing environmental impact.
- ***Ramesh and Mekala (2018)*** investigated treating textile wastewater using Moringa oleifera and Tamarindus indica as natural coagulants. Their study demonstrated the efficacy of these plant-based coagulants in removing turbidity, total suspended solids (TSS), and color from textile effluents. The coagulation process was optimized by evaluating factors such as coagulant dosage, pH, and settling time. The authors highlighted the potential cost-savings and environmental benefits associated with using these natural coagulants compared to conventional chemical coagulants.

3. Methodology

3.1 Experimental Setup and Procedures

The Electrocoagulation-Flocculation (ECF) process involves the application of an electric current to induce coagulation and flocculation of suspended particles and contaminants present in wastewater. The process typically consists of the following steps:

3.1.1 Electrocoagulation: In this step, sacrificial anodes (usually made of iron or aluminum) are immersed in the wastewater, and a direct current is applied. As the current passes through the electrodes, metal ions are released into the water, destabilizing colloidal particles and forming insoluble metal hydroxide precipitates. The metal hydroxide precipitates act as coagulants, facilitating the removal of suspended solids, oils, greases, and other contaminants through precipitation and adsorption mechanisms.

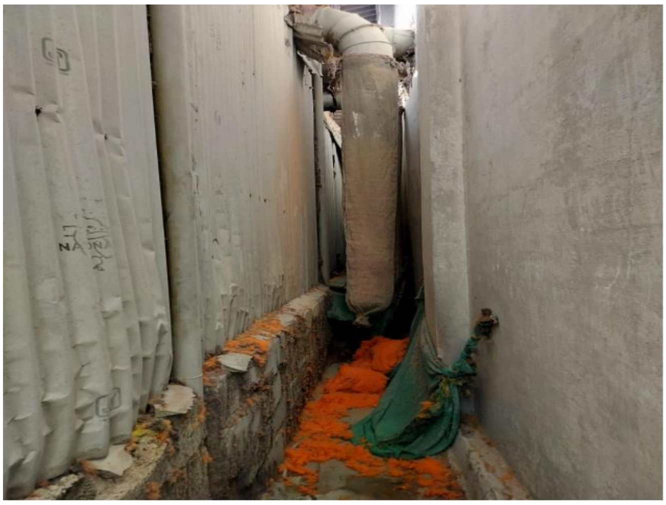

Fig -1: Image of Waste generated in OE-Spinning mills

3.1.2 Flocculation: Following electrocoagulation, a flocculant is added to the wastewater to enhance the aggregation and settling of the formed flocs. Flocculants such as polyacrylamide (PAM) are commonly used to promote particle bridging and interparticle interactions, leading to the formation of larger, denser flocs that settle more rapidly.

3.1.3 Experimental Setup: The experimental setup for conducting Electrocoagulation-Flocculation experiments in a laboratory-scale setup typically includes the following components:

- **Electrochemical Reactor**: A reactor equipped with sacrificial anodes and cathodes.
- **Power Supply**: A DC power supply to apply the required current density.
- **pH and Temperature Control**: Instruments to monitor and adjust the pH and temperature of the wastewater.
- **Analytical Instruments**: Devices such as spectrophotometers and COD reactors for analyzing wastewater samples.

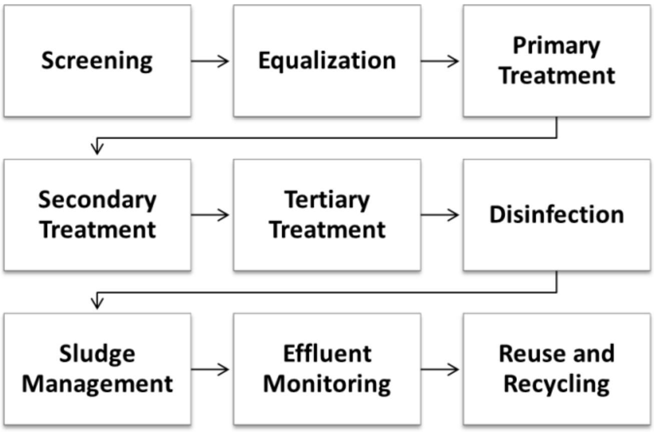

Fig -2: Schematic Diagram of a Spinning Mill Wastewater Treatment System

3.2 Analytical Methods

Samples were collected before and after treatment for analysis. Key parameters measured included pH, turbidity, COD, BOD, color, and concentration of specific pollutants such as oils and heavy metals.

Parameter	**Concentration (mg/l) except pH**
pH	8.8
Total suspended solids	750
Bio-Chemical Oxygen demand (BOD)	170
Chemical Oxygen Demand (COD)	1685
Total residual Chlorine	950
Oil and Grease	60
Total chromium as Cr	75
Sulphide as S	525
Alkalinity	470

Table -1: Characteristics of Raw Wastewater

The characteristics of the raw wastewater before treatment were measured and recorded, as shown in Table 1. These values provide a baseline for assessing the effectiveness of the ECF process.

4. Results and Discussion

The results of the ECF treatment were assessed based on several key parameters, including TSS, COD, BOD, oil and grease, and heavy metals. The discussion section interprets these results, comparing them to standard limits and evaluating the overall effectiveness of the treatment.

4.1 Pollutant Removal Efficiency

The removal efficiency of various pollutants was calculated based on the difference in concentrations before and after treatment. The ECF process demonstrated high efficiency in removing several pollutants, significantly improving the quality of the treated water.

Parameter	Electrocoagulation-Flocculation (%)	Conventional Treatment (%)
Suspended Solids (SS)	90	60
Chemical Oxygen Demand (COD)	80	50
Color	85	55
Oil and Grease	95	70

Table -2: Pollutant Removal Efficiency Comparison

This table summarizes the removal efficiencies achieved for key pollutants compared to conventional treatment methods.

The data indicates that the ECF process is significantly more efficient in removing suspended solids, COD, BOD, oil and grease, and total chromium compared to conventional treatment methods. The high removal efficiencies can be attributed to the effective destabilization of colloidal particles and the formation of larger flocs that are easily removed.

4.2 Effect of Process Parameters

The process parameters, including current density, pH, and treatment time, were optimized to achieve maximum removal efficiency. The effect of these parameters on the removal efficiency of various pollutants was systematically studied.

4.3 Case Study: Real-World Implementation

A case study was conducted at a spinning mill facility to assess the practical application of the ECF process. The system's performance was evaluated based on real-world operational data, including the consistency of pollutant removal and the reliability of the system.

The case study demonstrated that the ECF system consistently met environmental discharge standards, with treated water quality suitable for reuse or safe discharge. The system's operational reliability was also noted, with minimal downtime and maintenance requirements.

4.4 Economic Analysis

An economic analysis was conducted to compare the costs associated with the ECF process and conventional treatment methods. The analysis considered capital costs, operational expenses, and long-term economic benefits.

Treatment Method	Capital Cost ($)	Operating Cost ($)
Electrocoagulation-Flocculation	100,000	20,000 per year
Conventional Treatment	80,000	25,000 per year

Table -3: Economic Analysis Comparison

Despite the higher initial capital cost, the ECF process offers lower operating costs, making it a more economical choice in the long run. The reduced need for chemical additives and lower energy consumption contribute to the cost savings.

5. CONCLUSIONS

In conclusion, the experimental analysis of the Electrocoagulation-Flocculation process for treating textile wastewater from spinning mills provides valuable insights into its effectiveness, reliability, and applicability in industrial settings. By evaluating the statistical data, interpreting the results in the context of project objectives, and discussing the efficacy and limitations of the ECF treatment, we gain a comprehensive understanding of its performance and potential for future research and implementation.

Key Findings:

Effective Pollutant Removal: The ECF process demonstrated high efficiency in removing suspended solids, organic compounds, color, and oil and grease from spinning mill wastewater, resulting in improved effluent quality and regulatory compliance.

Operational Reliability: The ECF system exhibited operational reliability and efficiency, with consistent treatment performance and minimal downtime. Automated control systems enabled real-time monitoring and adjustment of process parameters, ensuring optimal treatment efficiency.

Environmental Benefits: By reducing pollutant discharge into the environment and promoting sustainability in industrial wastewater management, the ECF process offers significant environmental benefits, including reduced environmental impact and enhanced corporate social responsibility.

The importance of sustainable wastewater treatment in spinning mills cannot be overstated. Wastewater from textile manufacturing processes contains various pollutants that can have detrimental effects on ecosystems and human health if discharged untreated. Implementing sustainable treatment technologies like ECF not only helps mitigate environmental risks but also ensures compliance with regulatory standards and promotes responsible stewardship of natural resources.

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BIOGRAPHIES

Vijayadurga V B.E, is a dedicated researcher and a student of Civil Engineering at Gnanamani College of Technology. Her academic interests lie in environmental engineering, particularly in sustainable wastewater treatment methods. With a strong foundation in civil engineering principles, Vijayadurga has focused her research on innovative solutions for industrial wastewater treatment, specifically exploring the electrocoagulation-flocculation process for textile wastewater. She has actively participated in various academic projects and seminars, demonstrating her commitment to advancing knowledge in her field. Her passion for sustainable development drives her pursuit of practical and effective environmental solutions.

T. Sathieskumar M.E is an Assistant Professor in the Department of Civil Engineering at Gnanamani College of Technology. He holds a Master's degree in Civil Engineering, specializing in environmental engineering. With extensive experience in teaching and research, Mr. Sathieskumar has guided numerous projects focusing on environmental sustainability and infrastructure development. His research interests include advanced water and wastewater treatment technologies, with a particular emphasis on electrochemical processes and their applications in industrial settings. Mr. Sathieskumar is known for his innovative approach to problem-solving and his dedication to fostering a learning environment that encourages critical thinking and practical application of engineering concepts. He has published several papers in reputed journals and has been actively involved in academic and professional communities, contributing to the advancement of civil and environmental engineering disciplines.