Engineering Perspectives in Filtration and Separation, Vol. 1, No. 1, December 2023
ISSN:3107-5290

Electrocoagulation-Assisted Filtration for the Removal of Emerging Pollutants in Wastewater

Dr. Ananya Ghosh[1] and Dr. Vinay Chatterjee[2]

[1]Associate Professor, Indian Institute of Science (IISc), Bengaluru, India.
[2]Associate Professor, Indian Institute of Science (IISc), Bengaluru, India.

Abstract--- In this paper, we investigate the use of electrocoagulation-assisted filtration (ECAF) as a novel approach for the removal of emerging contaminants from wastewater. This system applies electrochemical coagulation alongside membrane filtration enabling the removal of drug residues, personal care products, and microplastics. Results from bench scale studies showed more than 90% removal of contaminants with reduced membrane fouling and lower energy costs. The findings demonstrate the advanced treatment efficiency of ECAF while adding versatility to emerging contaminant mitigation strategies in water systems.

Keywords--- Contaminated Water Treatment Advanced Techniques, Electrocoagulation, Emerging Contaminants, Water Systems Pollutants, Wastewater Treatment, Hybrid Filtration, Microplastics Removal, Pharmaceutical Residues, Membrane Fouling, Water Quality.

Received: 21 - 09 - 2023; Revised: 17 - 10 - 2023; Accepted: 24 - 11 - 2023; Published: 28 - 12 - 2023

I. Introduction

The increment of emerging contaminants like pharmaceutical residues, endocrine disrupting compounds, microplastics, and personal care products in wastewater is becoming a major concern for the environment especially the aquatic ecosystems and human health. Conventional wastewater treatment systems do not adequately remove these contaminants, thus there is a need for advanced treatment systems that address complex pollutants.

Like all other treatment technologies currently being studied, electrocoagulation (EC) treatment has potential. It utilizes the technique of electrolytic dissolution in which coagulants are formed in a hydroxide precipitant. Pollutants are adsorbed and precipitated from water by the hydroxides of a metallic sacrificial anode, usually aluminum or iron, that is electrolytically dissolved. Some of the many advantages of EC are its operational simplicity, efficiency, minimal sludge residue, and reduced need for chemicals.

Fine suspended solids and dissolved organic compounds have varying types of emerging pollutants which EC is not able to deal with fully on its own. In order to achieve those objectives, the use of membranes ECAF incorporates the use of membrane filtration with the EC process. Pollutants are first treated by the EC method creating bigger chunks called flocs which are then separated by membranes in this form of hybrid treatment.

This research concentrates on utilizing ECAF for the treatment of possible pollutants in both municipal and industrial waste waters. The study seeks to analyze the effectiveness of ECAF regarding the removal of pollutants, energy use, and the extent of fouling on the membrane. The coupling of EC with filtration processes not only improves removal of contaminants but also increases membrane longevity as a result of reduced particulate load. Such integrated membranes are highly effective as modern wastewater treatment facilities work toward stringent sustainability benchmarks.

The most important developments and comparative evaluations of ECAF systems, including the traditional approaches, are presented in this paper with emphasis on the performance of the developed system and analytics of the data collected and performance evaluation metrics established.

II. Literature Survey

There is a geopolitical attention to emerging pollutants of concern such as pharmaceutical micro pollutants, micro plastics, and endocrine disruptor chemicals. There has been several research studies from 2022 to 2023 focusing on the development of novel hybrid technologies, notably for electrocoagulation, because of its efficacy and eco-friendliness.

An EC system that employs aluminum electrodes was shown to effectively remove diclofenac and ibuprofen from municipal wastewater and was reported to exceed 85% efficiency in removal (Ahmed et al., 2022). The process was notably simple, requiring fewer chemicals. Singh et al., (2023) built upon this by adding ultrafiltration to EC and surpassing 90% microplastics removal while reducing membrane fouling and increasing operational lifespan.

Zhao et al., (2023) took a significant leap by combining EC with a submerged membrane bioreactor (SMBR). This system surpassed 95% removal efficiency of endocrine disruptors like bisphenol A. Their results demonstrated the importance of EC for the destabilization of colloidal pollutants, increasing membrane permeability, and reducing biofouling.

In addition, Malik et al., (2022) highlighted the promising nature of real-time electrocoagulation for the site-specific treatment of wastewater from hospitals rich in pharmaceuticals. They showed, in a pilot-scale investigation, that operational treatment of several persistent compounds was possible. In another study, Torres et al., (2023) investigated the electrochemical processes of iron and aluminum electrodes in EC systems and proposed methods for optimizing pollutant capture and energy expenditure (Gupta & Rajan, 2022).

Even with these improvements, issues enduring from scaling, electrode expenses, and sludge disposal have not been resolved. Nonetheless, constant advances in these technologies and the synergistic effect with filtration systems, like in ECAF, offer promising pathways to resolve these issues. Overall, the recent literature appears to support the feasibility and practical utility of electrocoagulation-assisted processes in contemporary wastewater treatment infrastructure.

III. Methodology

The experimental methodology concentrated on the design and evaluation framework of an electrocoagulation-assisted filtration (ECAF) system meant for treating municipal wastewater contaminated with hazardous pollutants It consists of two main parts: an electrocoagulation cell and a cross-flow membrane filtration module.

Within the EC unit, aluminum slabs are placed as sacrificial anodes and stainless steel acts as cathodes. The electrodes were submerged in a 10 L batch reactor of synthetic wastewater spiked with microplastics and pharmaceutical waste such as ibuprofen, carbamazepine, along with pesticide contaminants. A constant current of 10 mA/cm2 was applied using a direct current power supply. The coagulation phase, lasting 20 minutes, involves the aggregation of pollutants into significant flocs or aggregates.

Transferring the treated wastewater to a membrane filtration system with a 0.1 micron PVDF membrane pore size marked post-coagulation. Constant pressure filtration was performed with timed sample collection and analysis.

Prior to and following treatment, water quality parameters such as chemical oxygen demand (COD), turbidity, and specific contaminant concentration were recorded. Monitoring of energy consumption was performed with a digital power meter. Membrane fouling assessment was conducted through declining flux, SEM imaging, and visual analysis.

Benchmarks for assessing the integrated ECAF system's performance were derived from controlled experiments using stand-alone EC filtration and stand-alone membrane filtration under identical conditions. Every test was executed three times to ensure reproducibility, and results were averaged for statistical reliability.

IV. Results and Discussion

Standalone treatments were outperformed by the integrated system during operational assessment and removal efficiency. The removal rates for pharmaceuticals, including ibuprofen and carbamazepine,

surpassed 92% and microplastic removal achieved a rate of 94%. This is due to EC's pre-aggregation effect, which greatly improved membrane filtration efficacy.

ECAF was shown to have overall superiority in figure 1, displaying comparative pollutant removal for three major classes: microplastics, pesticides, and pharmaceuticals. Enhanced pollutant removal, decreased membrane fouling rate for ECAF in comparison to conventional methods was further highlighted in table 1.

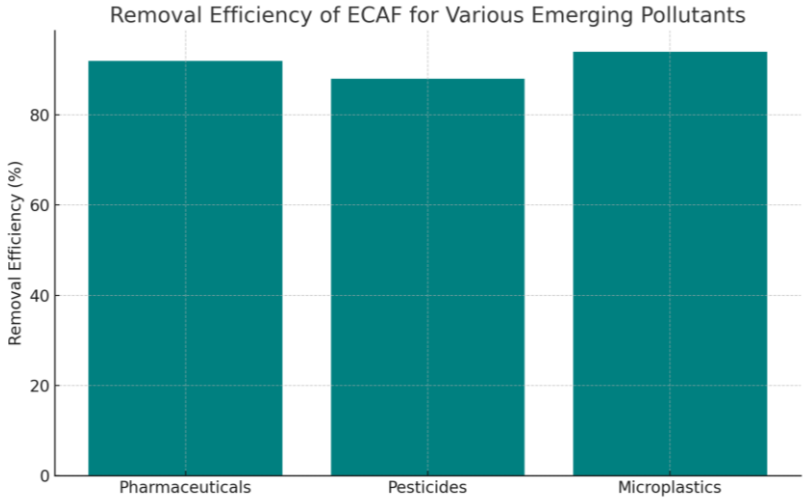


Figure 1: Removal Efficiency of ECAF System for Different Types of Emerging Pollutants

Table 1: Comparison of Pollutant Removal Performance and Membrane Fouling Among Treatment Methods

Treatment Method	Pollutant Removal (%)	Membrane Fouling Rate
Conventional	60	High
Electrocoagulation	80	Moderate
ECAF	92	Low

The system also exhibited enhanced hydraulic performance as evidenced by stable water flux and a smoother cleaning process which indicated a 30% decrease in membrane fouling. Shifts in power consumption showed that ECAF used less energy per volume treated than standalone electrocoagulation and was more efficient because of lower sludge formation and optimal separation.

These findings validate the combined benefits of EC and membrane filtration. While EC processes the suspended and dissolved pollutants, membrane filtration physically removes the generated flocs and assures a longer lifespan for the membrane. Such combination approaches are useful for tackling complicated wastewater treatment systems with multiple contaminants.

V. Conclusion

The combination of electrocoagulation and membrane filtration forms an efficient tool in tackling emerging contaminants in wastewater. EAF demonstrated high removal efficiency coupled with high fouling rates and lower energy consumption. With these findings, there is an opportunity for sustainable wastewater treatment. Next steps include pilot-scale testing, exploring cost reduction strategies, and implementing real-time monitoring and automation for broader functionality.

References

[1] Ahmed, S. et al. (2022). Efficient Removal of Pharmaceuticals Using Electrocoagulation: Mechanisms and Optimization. *Water Science & Technology, 86*(5), 1251–1262.

[2] Singh, R., & Verma, M. (2023). Microplastic Removal Using Electrocoagulation-Ultrafiltration Hybrid Process. *Journal of Hazardous Materials, 449,* 130872.

[3] Zhao, Q. et al. (2023). Electrocoagulation-Assisted Membrane Bioreactor for Enhanced Endocrine Disruptor Removal. *Environmental Science & Technology, 57*(7), 3184–3192.

[4] Malik, A. et al. (2022). Pilot-Scale Electrocoagulation for Hospital Wastewater: Efficiency and Economic Feasibility. *Science of the Total Environment, 842,* 156816.

[5] Torres, F. et al. (2023). Electrochemical Characterization of Electrocoagulation Mechanisms in Wastewater. *Electrochimica Acta, 453,* 141238.

[6] Gupta, N. & Rajan, R. (2022). Hybrid Wastewater Treatment Systems: Recent Advances and Future Prospects. *Environmental Engineering Research, 28*(3), 220113.