Selective Removal of Microplastics from Freshwater Using Low-Voltage Electrocoagulation with Aluminum Electrodes

Abstract:

Microplastics are persistent contaminants in freshwater systems because many particles remain suspended and are difficult to remove using conventional filtration. This project investigates the use of low-voltage electrocoagulation as a method to capture and remove microplastics from water. Iron and aluminum electrodes were tested in a bench-scale reactor operated with direct current at controlled current densities. During treatment, metal ions released from the electrodes formed hydroxide flocs that physically aggregated microplastic particles. Removal efficiency was quantified through post-treatment membrane filtration and gravimetric analysis, while voltage and current were recorded to calculate energy consumption per gram of microplastics removed. Results were compared between electrode materials and operating conditions to identify the most effective and energy-efficient configuration. Findings from this study provide insight into the feasibility and scalability of electrocoagulation as a low-cost approach for reducing microplastic contamination in freshwater treatment systems.

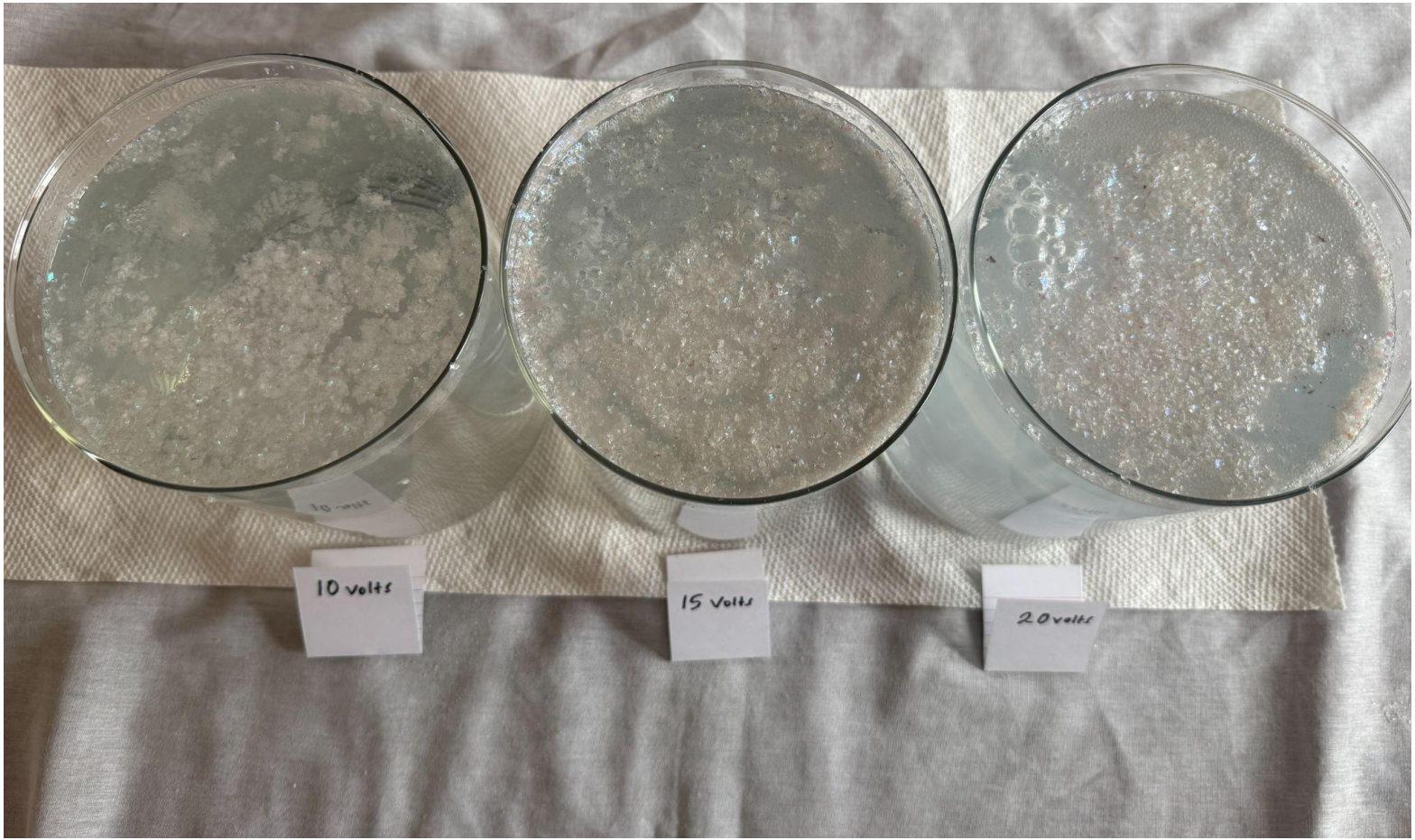
Background:

Microplastics are tiny plastic particles, smaller than 5 millimeters, that end up in freshwater systems such as rivers, lakes, and streams. They come from the breakdown of larger plastic materials or from products that we use on a daily basis. These particles often remain suspended in water, which makes them difficult to remove using traditional filtration. Microplastics can harm aquatic organisms if ingested and may even enter the human food chain through drinking water. They can also carry chemicals and microorganisms, posing risks to both ecosystems and human health (Amjad 2025).

Electrocoagulation is a water treatment method that could help remove microplastics from water. In this process, an electric current passes through metal electrodes placed in water. When aluminum electrodes are used, aluminum ions are released and form clumps called flocs. These flocs act like tiny sticky clusters that trap suspended contaminants, including microplastics. This method is low-cost, efficient, and has been tested in laboratory and wastewater treatment studies with promising results (Huang 2025).

Microplastics can be captured in two main ways during electrocoagulation. First, the flocs physically aggregate the particles, causing them to clump together and fall out of the water. Second, chemical reactions with aluminum ions help stabilize the particles in the flocs, preventing them from remaining suspended. Studies have tested electrocoagulation with different electrode materials, voltages, and treatment times to optimize removal efficiency.

For this project, I plan to test whether low-voltage electrocoagulation using aluminum electrodes can reduce microplastic concentrations in freshwater. I will prepare water samples containing known amounts of microplastic particles, treat them with aluminum electrodes at different voltages and durations. By comparing treated samples to untreated controls, I will determine how effective this method is at removing microplastics. This experiment could show whether electrocoagulation is a simple, low-cost, and scalable method for reducing microplastic pollution in freshwater systems.


10 volts
15 volts
20 volts

Introduction:

Research Question: Can low voltage electrocoagulation using aluminum electrodes effectively capture microplastics from freshwater?

Hypothesis: Low voltage electrocoagulation with aluminum electrodes will capture microplastics in freshwater by forming aluminum hydroxide flocs that trap plastic particles.

Methods:

Project Plan:

- Find ways that microplastics, a harmful contaminant can be removed from water effectively. I researched different methods for removing microplastics from freshwater and found that electrocoagulation with aluminum electrodes may be effective in trapping suspended particles.
- Learn about the electrocoagulation process and how aluminum electrodes release aluminum ions that form aluminum hydroxide flocs, which can capture microplastics in the water.
- Use aluminum electrodes and built a low-voltage electrocoagulation setup using a DC power supply, wires, and a glass beaker.
- Using my electrocoagulation system, I tested the effectiveness of removing microplastics from freshwater by applying different voltages and treatment times.

Sampling Procedure:

1. Preparing Microplastic-Contaminated Water Samples:
    - Distilled water will be prepared and a measured mass of microplastic particles added to ensure a known concentration.
    - Mix the water thoroughly so microplastics are evenly suspended.
    - Label all samples.
    -
2. Control Sample:
3. Control Sample:
4.
    - Prepare a control sample with the same microplastic concentration but without applying electrical current to compare natural settling versus electrocoagulation treatment.
5. Observation and Documentation:
    - Record initial conditions including water volume, microplastic concentration, and pH.
    - Photograph samples before treatment for comparison with post-treatment observations.

Materials:

1- Aluminum sheet metal (1x4 inch electrodes)
2- Metal Cutters
3- DC Power Supply
4- Large Glass Beaker
5- Alligator Clip Wires
6- Microplastic Particles (Fake Snow)
7- Distilled Water
8- Salt to improve electrical conductivity
9- Timer
10- Camera

Methods:

- Prepare microplastic contaminated water by adding microplastic particles to distilled water and mixing thoroughly.
- Place two aluminum electrodes vertically into a glass beaker containing the contaminated water.
    - Cut two electrodes (1x4 inch).
- Connect the electrodes to a DC power supply using alligator clip wires.
- Apply electrical current at different voltages (10 V, 15 V, and 20 V).
- Run each trial for 5 minutes and 10 minutes while observing floc formation and particle aggregation.
- Take photographs and record observations in changes in water clarity during the experiment.
- Prepare a control sample with microplastics and without electrical current for comparison.
- Compare treated samples to the control to determine the effectiveness of electrocoagulation.
- Compare results between different voltage and time conditions to evaluate the most effective treatment.

Results:

Voltage 10

5 min	10 min
	

Control



Voltage 15

5 min	10 min
	

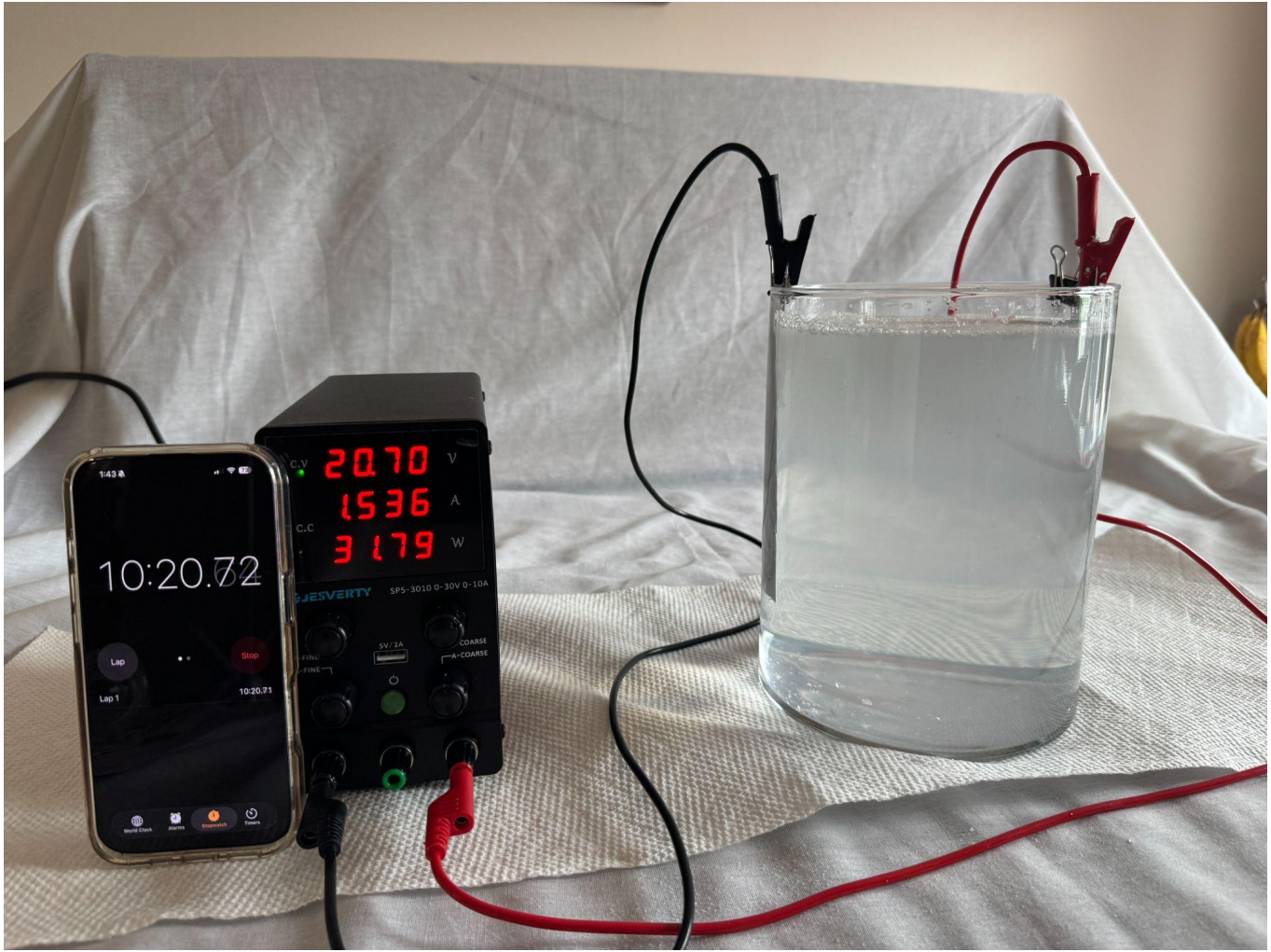
Control


Voltage 20

5 min	10 min
	

Control




20.70
15.36
3 1.79
V
A
W
C.V
C.C
SPS-3010 0-30V 0-10A
5V/2A
COARSE
A-COARSE
10:20.72
Lap
Stop
Lap 1
10:20.71

Discussion & Interpretation:

Across all voltage trials, electrocoagulation caused visible aggregation of microplastic particles. Before treatment, the particles remain evenly distributed throughout the water. Once the electrical current was applied, flocs began forming around the particles and caused them to clump together.

At 10 volts, small flocs started forming after about five minutes of treatment. These flocs slowly aggregated the microplastic particles, all microplastic had risen within the 5 minute mark. While removal was visible, the effect was slower compared to the higher voltages.

At 15 volts, floc formation occurred more rapidly. After three minutes, microplastics were already visibly clustering together, and by ten minutes larger flocs had formed.

At 20 volts, the strongest effect was observed. Flocs formed quickly and created large clusters that captured many of the suspended microplastics. After five minutes, a significant amount of aggregation and settling was visible compared to the lower voltage trials.

These observations conclude that higher voltage increases the rate of electrocoagulation reactions, allowing more aluminum ions to form hydroxide flocs.

The control sample, which did not receive electrical treatment, showed no floc formation and the microplastics remained evenly distributed in the water.

Improvements:

- Conduct a test using other materials, such as iron, to determine which produces more effective flocs.
- Use materials other than, fake snow, with common environmental microplastics like polyethylene, polystyrene, or microfibers to test removal efficiency.
- Experiment with varying concentrations of salt to identify the ideal electrical conductivity for efficient floc formation.

What Happens Chemically During Electrocoagulation?

When electricity passes through the aluminum electrodes, aluminum atoms lose electrons and form aluminum ions (Al^{3+}). These aluminum ions react with water to form aluminum hydroxide, $Al(OH)_3$, which creates sticky particles called flocs. The flocs trap and clump together microplastic particles that were floating in the water. The clumps become larger and settle or separate from the water, making the microplastics easier to remove. Electrocoagulation works because electricity creates aluminum hydroxide flocs that capture microplastics and pull them out of the water.

EC REACTOR — SURFACE SKIMMER

- Reactor Tank (open top)
- Wastewater
- Electrode Plates (Al/Fe)
- Scraper Rail + Carriage
- Scraper Blade
- Microplastic Flocs (surface)
- Collection Compartment
- Collected Floc Layer
- Inlet / Drain Pipes
- DC Power Supply

EC REACTOR

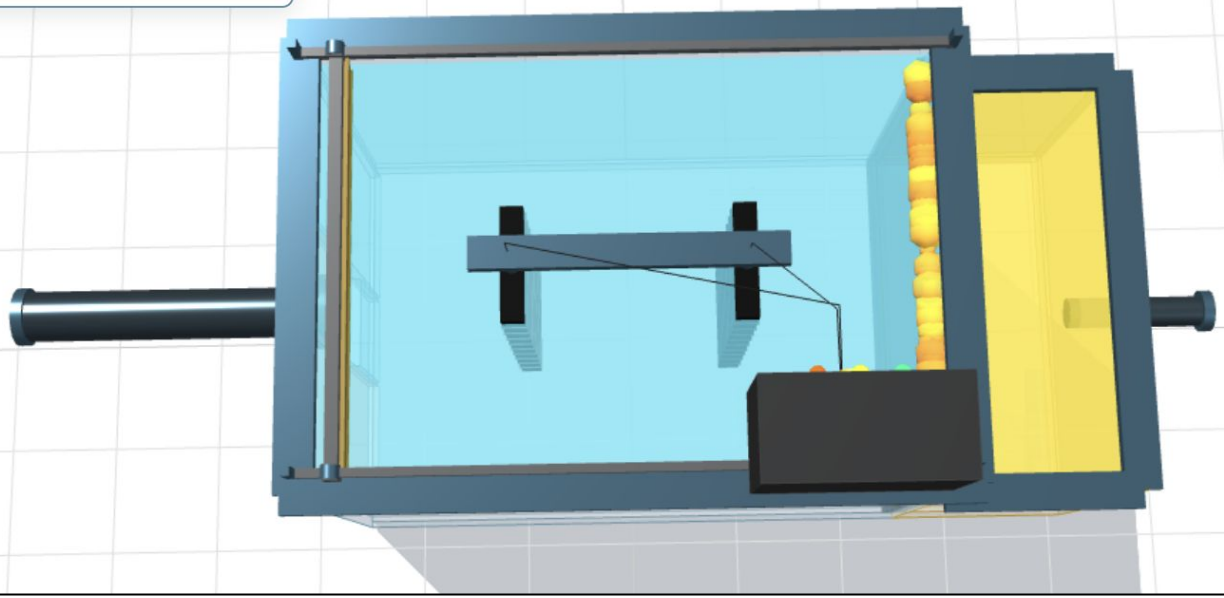
MICROPLASTIC REMOVAL SYSTEM

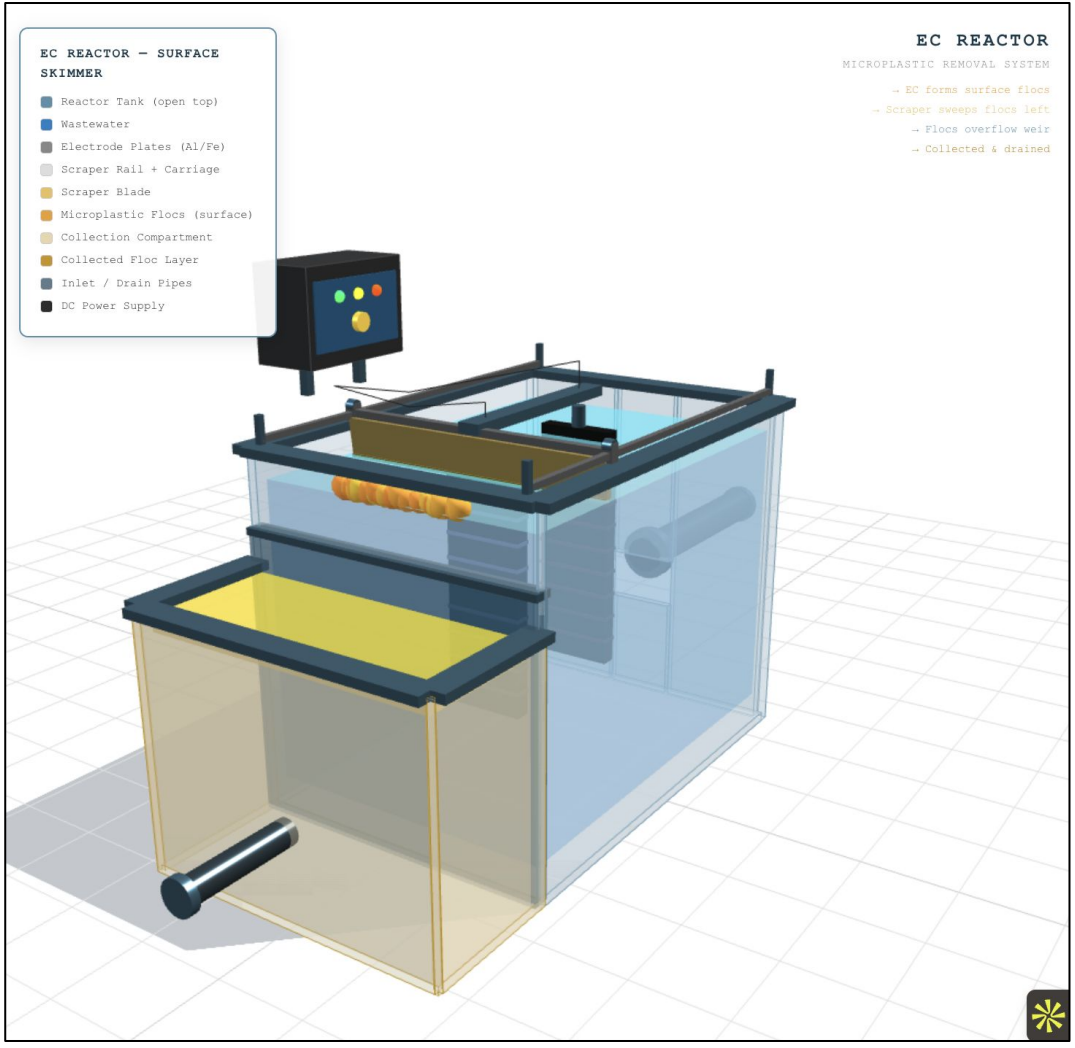
→ EC forms surface flocs

→ Scraper sweeps flocs left

→ Flocs overflow weir

→ Collected & drained




EC REACTOR — SURFACE SKIMMER
Reactor Tank (open top)
Wastewater
Electrode Plates (Al/Fe)
Scraper Rail + Carriage
Scraper Blade
Microplastic Flocs (surface)
Collection Compartment
Collected Floc Layer
Inlet / Drain Pipes
DC Power Supply
EC REACTOR
MICROPLASTIC REMOVAL SYSTEM
→ EC forms surface flocs
→ Scraper sweeps flocs left
→ Flocs overflow weir
→ Collected & drained

EC REACTOR

MICROPLASTIC REMOVAL SYSTEM

→ EC forms surface flocs

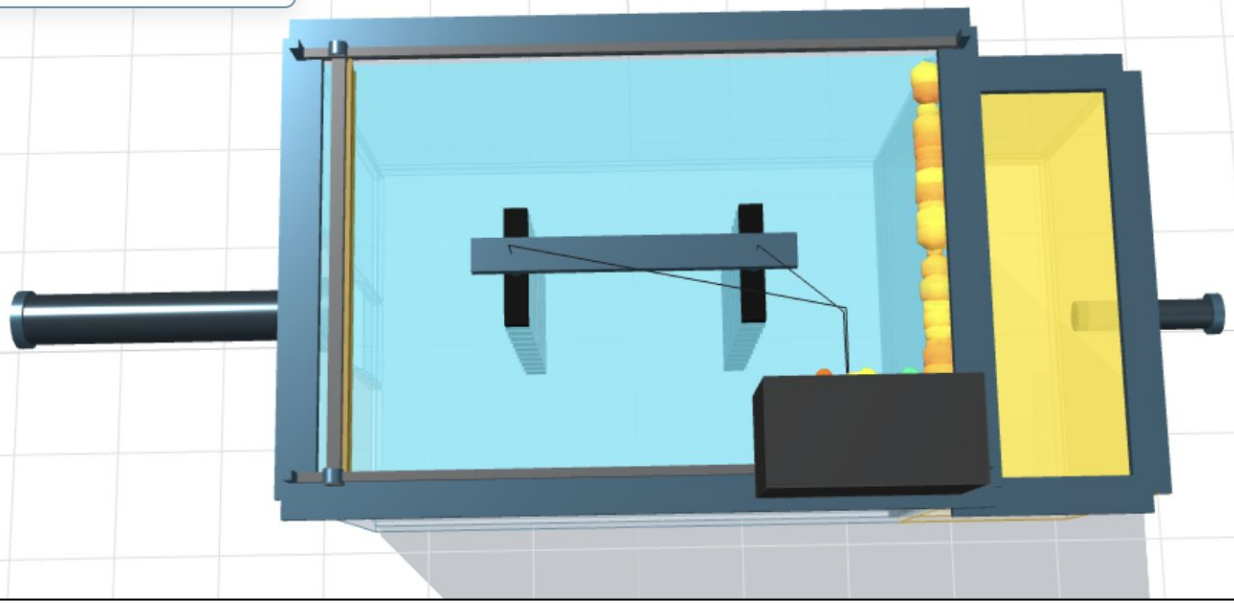
→ Scraper sweeps flocs left

→ Flocs overflow weir

→ Collected & drained

EC REACTOR — SURFACE SKIMMER

- Reactor Tank (open top)
- Wastewater
- Electrode Plates (Al/Fe)
- Scraper Rail + Carriage
- Scraper Blade
- Microplastic Flocs (surface)
- Collection Compartment
- Collected Floc Layer
- Inlet / Drain Pipes
- DC Power Supply



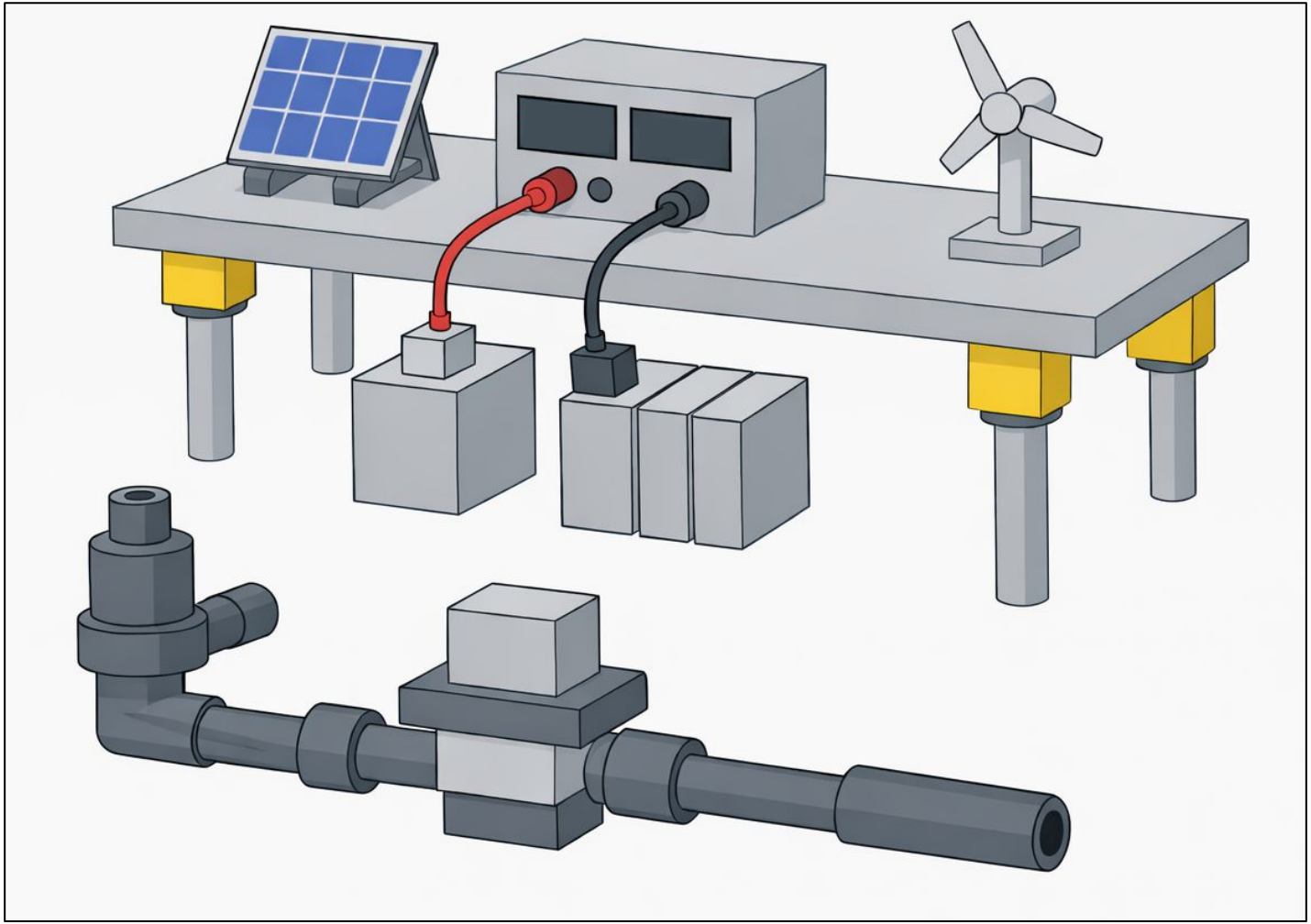
Conclusions:

In conclusion, I found that electrocoagulation is effective in aggregating and removing microplastics from freshwater. When electrical current was applied to aluminum electrodes, metal ions were released into the water and formed hydroxide flocs. These flocs acted like sticky clusters that captured suspended microplastic particles and caused them to clump together and settle out of the water. My results showed that higher voltages produced faster and more visible microplastic aggregation. While floc formation occurred at 10 volts, the strongest aggregation and settling occurred at 20 volts. We concluded that increased voltage improves the efficiency of electrocoagulation. These findings show that electrocoagulation could be a low-cost and scalable method for reducing microplastic pollution in freshwater systems. Using these results, electrocoagulation could potentially be integrated into water treatment systems to help reduce microplastic contamination.

Future Research & Application:

My proposed solution for removing microplastics from freshwater uses low-voltage electrocoagulation with aluminum electrodes. In this system, electricity generated from solar panels and a wind turbine is sent through a power supply/controller box to control the voltage and current. The current flows through aluminum electrodes submerged in the water, causing electrocoagulation reactions that produce aluminum hydroxide flocs, which trap and aggregate microplastic particles. Water flows through a pipe system, and a valve regulates the flow to ensure consistent treatment.

In future research, I plan to develop an AI model to automatically analyze images of treated water and floc formation during electrocoagulation. The AI could measure the size, density, and distribution of microplastic flocs, providing faster and more precise results than manual observation. This model could also track differences between voltage and treatment time conditions, helping identify the most efficient parameters for microplastic removal.
Applications of this research include creating a scalable water treatment monitoring system for freshwater sources and wastewater facilities. The AI-assisted system could continuously observe and optimize microplastic removal processes, reducing human error and improving efficiency. By combining electrocoagulation with AI-based monitoring, this approach could provide a low-cost, automated solution to help tackle microplastic pollution in rivers, lakes, and drinking water sources worldwide.



References:

Amjad, H., Maqbool, N., Sarwar, S., Sohail, A., & Noor, M. (2025). Assessing the Removal Efficiency of Microplastics from Water Using Electrocoagulation. *Advanced Materials Research*, *1183*, 87–94. https://doi.org/10.4028/p-n1oc78

Huang, L., Tian, J., Wang, Y., Jiang, M., & Wu, D. (2025). Efficient and cost-effective microplastic removal by electrocoagulation using upcycled aluminum anodes. *Chemical Engineering Science*, *321*, 122769. https://doi.org/10.1016/j.ces.2025.122769

Hydroleap Pte Ltd. (2023, November 30). *Learn with Hydroleap | What is Electrocoagulation?* YouTube. https://www.youtube.com/watch?v=Y8A2s0OWZkg

Javier, F., Augusto, V., Rodrigues, L., & Medici, R. (2023). Analysis of the Efficiency of the Electrocoagulation Process in the Removal of Microplastics. *RGSA*, *17*(3), e03280–e03280. https://doi.org/10.24857/rgsa.v17n3-027

Liu, F., Zhang, C., Li, H., Offiong, N.-A. O., Bi, Y., Zhou, R., & Ren, H. (2023). A systematic review of electrocoagulation technology applied for microplastics removal in aquatic environment. *Chemical Engineering Journal*, *456*, 141078. https://doi.org/10.1016/j.cej.2022.141078

Mateo, S., Zhang, A., Piedra, A., Ruiz, A., Miranda, R., & Rodríguez, F. (2024). Electrocoagulation Assessment to Remove Micropolystyrene Particles in Wastewater. *ACS ES&T Water*, *4*(7), 3049–3058. https://doi.org/10.1021/acsestwater.4c00312

Sezer, M., Eylem Topkaya, Serdar Aksan, Sevil Veli, & Arslan, A. (2024). Optimizing microplastic treatment in the effluent of biological nutrient removal processes using electrocoagulation: Taguchi experimental design. *Journal of Environmental Management*, *369*, 122413–122413. https://doi.org/10.1016/j.jenvman.2024.122413