

Regeneration of Activated Carbon Cathodes for Sustainable Water Treatment

Shiza Hussain, YSP Student, *Foxborough High School*

Kian Nhuch, YSP Student, *Somerville High School*

Muhammad Fahad Ehsan, Amanda Thomas, Marieh Arekhi, Nima Sakhaee, Civil and Environmental Engineering, *Northeastern University*

Akram Alshawabkeh, PROTECT Program Director, *Northeastern University*

Abstract

Motivation: Water contamination is a major global challenge, particularly affecting underprivileged communities. In these communities, such as Puerto Rico, affordable and sustainable methods of water purification are a necessity, sparking the need for research surrounding the role that activated carbon can play in more efficient water filtration.

Personal Objectives: This research aims to enhance pollutant (methylene blue) adsorption via optimizing the pore size of the Granular Activated Carbon (GAC) cathode. Additionally, the research conducted searched for optimal regeneration periods for carbon cathodes in order to refine sustainability of the product.

Results: Electrochemical regeneration of this material showed no decrease in efficiency over the course of 4 cycles.



Background

Our research, contributing to Project 4 of PROTECT (Puerto Rico Testsite for Exploring Contamination Threats), explores how GAC cathodes can be regenerated effectively for long-term water treatment. Embedding GAC into cathodes for a combined effect of adsorption and electrochemical degradation offers a potentially low-cost, sustainable solution for water treatment. First, water is oxidized at the anode, which interacts with the carbon cathode forming hydrogen peroxide. The hydrogen peroxide degrades organic pollutants while the GAC pores provides a surface for adsorption. However, pore space is finite and the GAC eventually becomes saturated with contaminants. During electrochemical regeneration, applied current enhances the electrochemical degradation of the pollutant on the cathodic surface, restoring its adsorptive capacity for future uses. Batch tests were run using 5 ppm methylene blue and adsorption tracked over time (0–240 min) with a UV-Vis spectrophotometer. In this research, we have investigated the adsorptive capacity of GAC following 3 cycles of electrochemical regeneration in batch set-up. With improved design and regeneration methods, electrochemical degradation and adsorption with GAC cathodes can improve the efficiency and sustainability of water treatment systems.

Experimental Methods

- 1) Employed the dilution equation: $C_1V_1 = C_2V_2$ to prepare a stock solution of methylene blue.
- 2) Washed -20+40 mesh GAC in deionized water and dried it for 24 hours at 60°C
- 3) Combined GAC with ethanol and PTFE for the cathode material. This mixture was vortexed, sonicated for 30 minutes, and then spread onto a stainless steel mesh substrate and baked at 350°C for 1 hour.
- 4) The cathodes were secured on the reactor tops consisting of titanium rods and a titanium mixed metal oxide anode. The reactor tops were submerged in 250mL batch experiments with a MB concentration of 5 ppm to test for adsorption. The mixture was stirred continuously and samples were taken at time intervals of 0 (minutes), 5, 10, 15, 20, 30, 45, 60, 80, 100, 120, 150, 180, 210, 240.
- 5) Samples were filtered using a 0.2 micron filter and run on the Spectrophotometer to analyze concentration.
- 6) To regenerate the cathodes, they were placed in fresh electrolyte solution and connected to a power source. Cathode A was regenerated at 50 mA and cathode B was regenerated at 100mA, each for 3 hours.
- 7) The same cathodes were subjected to 4 cycles of adsorption batch experiments and electrochemical regeneration.
- 8) Data was plotted and analyzed on Excel.

Conclusion and Future Steps

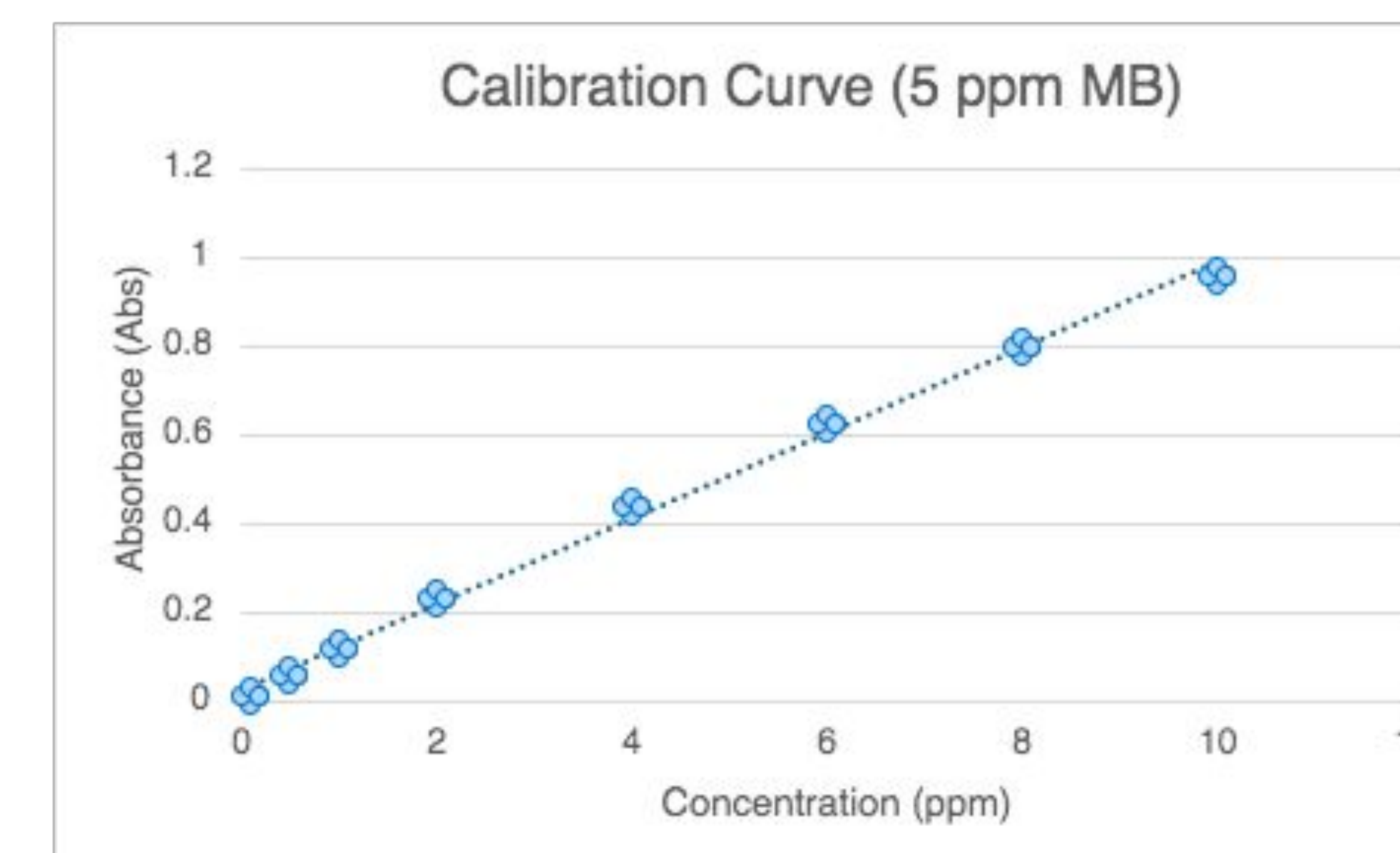
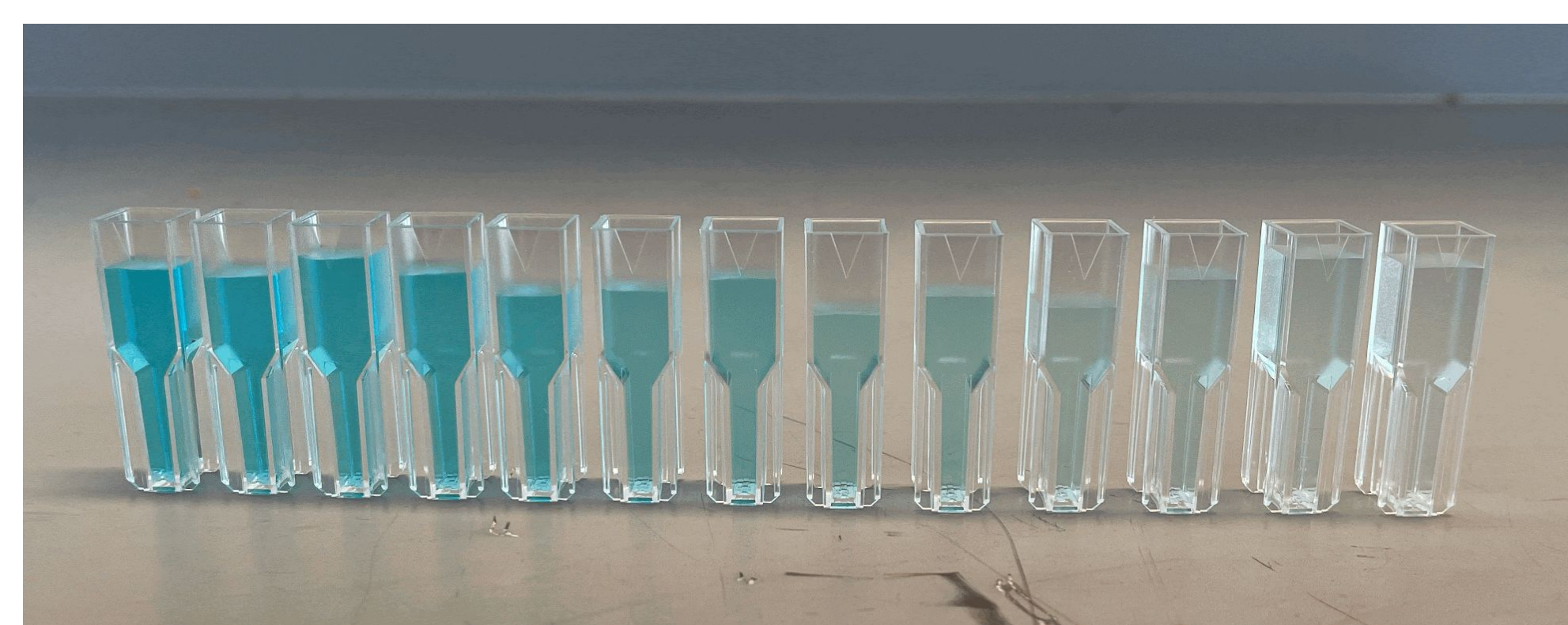
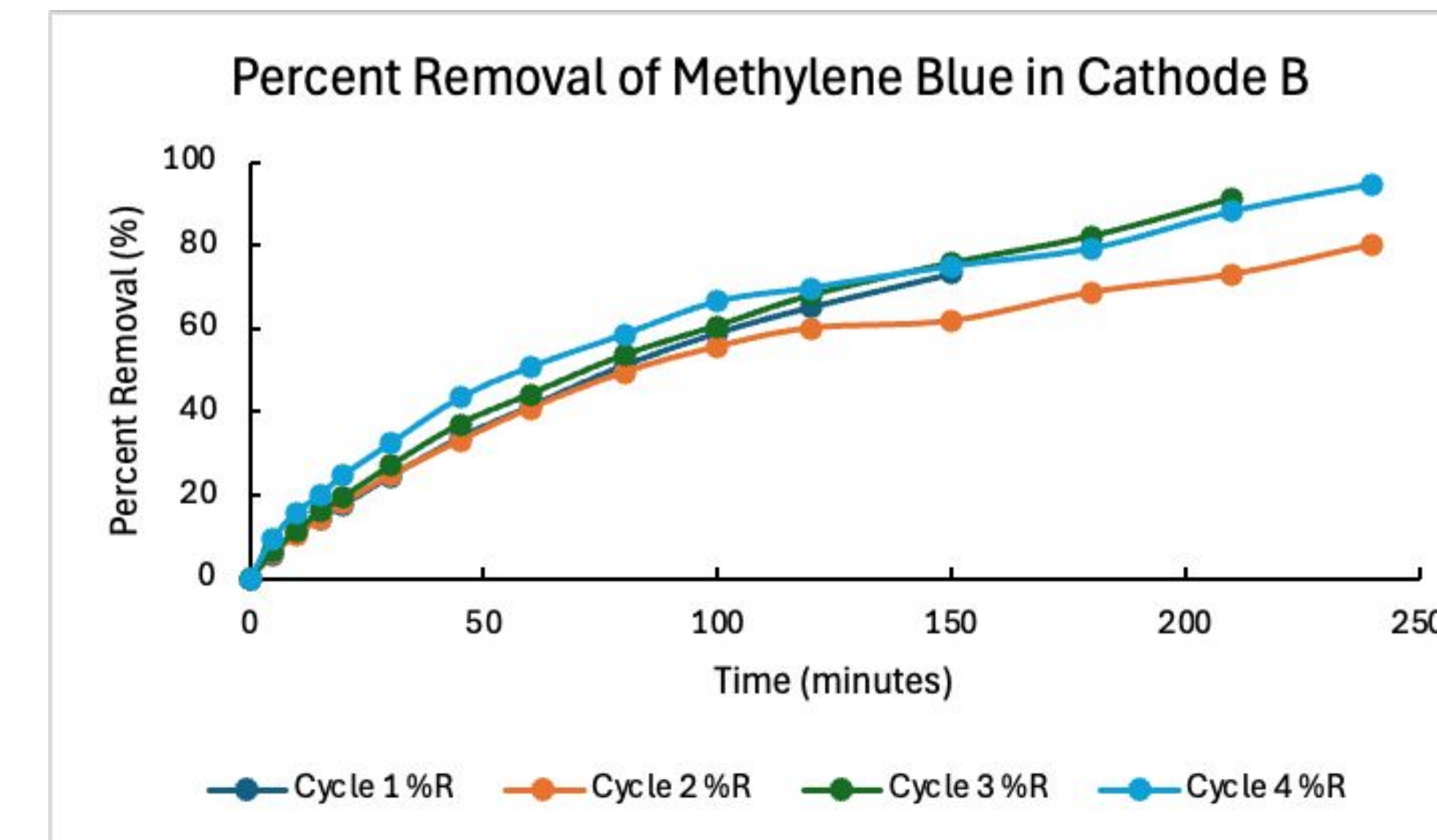
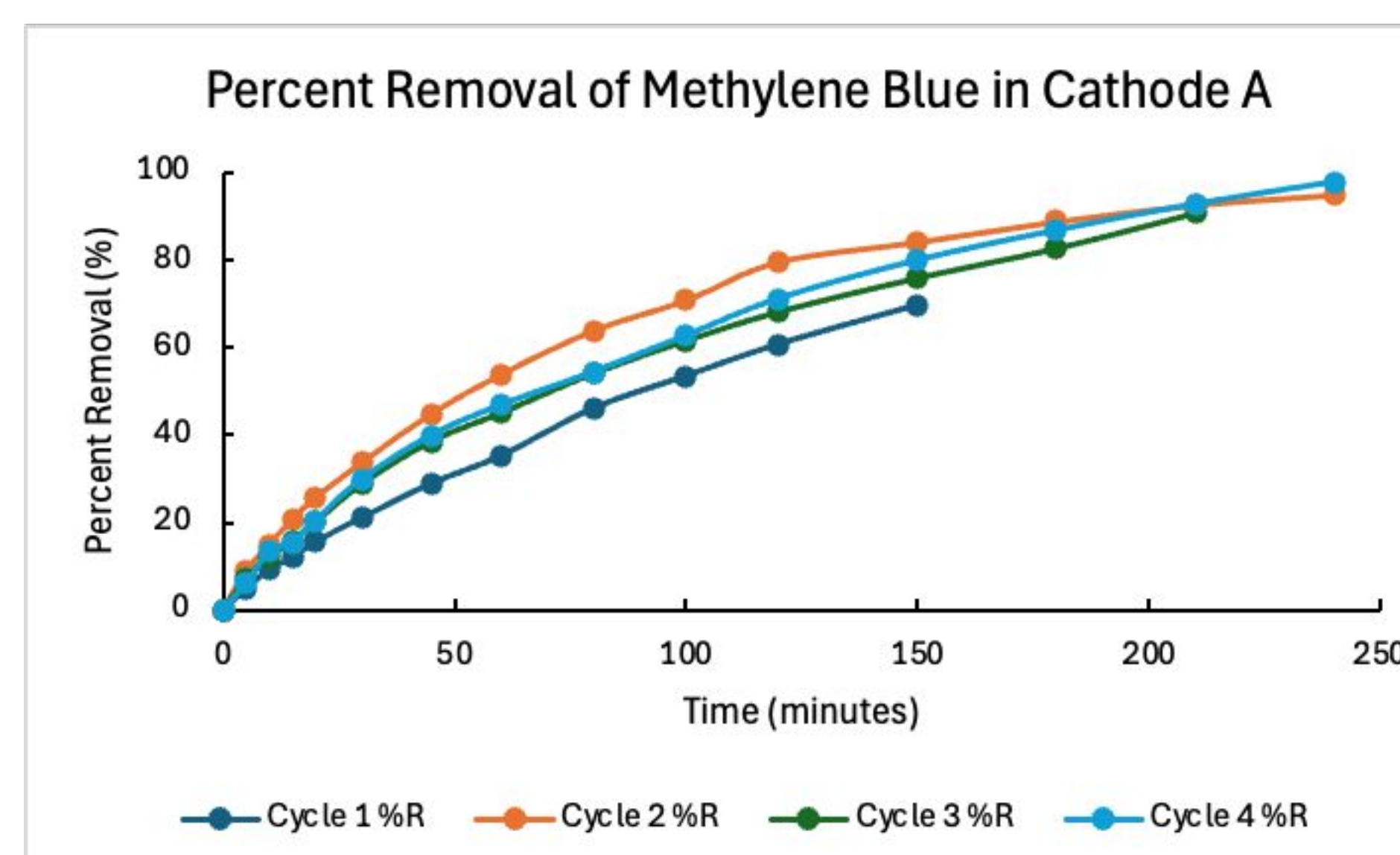
Conclusion:

Cathode A in the 50mA electrochemical regeneration solution had a 97.74% removal of MB, while cathode B (regenerated at 100mA) had a removal of 94.61% at the end of cycle 4. During electrochemical regeneration of the cathodes, no visible MB was released into the fresh electrolyte solution and spectrum analysis with UV-Vis showed absorbance around 260 nm indicating leucomethylene was present. This confirmed that MB was being electrochemically degraded.

Future Steps:

The adsorptive capacity of electrochemically regenerated cathodes was tested in this work. The next step would be to utilize current for electrochemical degradation for a combined effect. Additionally, adding different organic dyes with varying concentrations can be used to understand GAC pore-size efficiencies.

Results



References

- Compton, P., et al. (2023). In-situ electrochemical synthesis of H₂O₂ for p-nitrophenol degradation utilizing a flow-through three-dimensional activated carbon cathode with regeneration capabilities. *ScienceDirect*, 441(141798).
- Zhou, W., et al. (2019). "Self-cleaning" electrochemical regeneration of dye-loaded activated carbon. *ScienceDirect*, 100, 85-89.
- Zhou, W., et al. (2019). Hydrogen peroxide generation from O₂ electroreduction for environmental remediation: A state-of-the-art review. *ScienceDirect*, 225, 588-607.

Acknowledgements

PROTECT Project 4 Laboratory

Professor Akram Alshawabkeh, Program Director
 Muhammad Fahad Ehsan, Research Scientist
 Amanda Thomas, Ph.D Student
 Nima Sakhaee, Ph. D Student
 Marieh Arekhi, Future Faculty Fellow
Center for STEM Education
 Claire Duggan, Executive Director
 Jennifer Love, Associate Director
 Ahmed Othman, D'mitra Mukasa, & Victoria Berry, YSP Coordinators
 Nicolas Fuchs, Program Manager
 Mary Howley, Administrative Officer