Synthesis and Characterization of Biomass-Derived Functional Carbon for Electrochemical Water Treatment

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Abstract

Motivation: Water contamination is a major health concern in Puerto Rico, specifically impacting birth rates and complications during and after pregnancy. Emerging contaminants, like methylene blue, have been connected to the high rates of preterm births and adverse pregnancy outcomes. The PROTECT (Puerto Rico Testsite for Exploring Contamination Threats) Program seeks to provide cost effective and efficient water filtration to the people of Puerto Rico.

Personal Objectives: This research investigates the conversion of sargassum and bamboo, two invasive species found in Puerto Rico, into activated carbon cathodes to support the adsorption of Methylene Blue and electrochemical generation of hydrogen peroxide (H_2O_2).

Results: Results demonstrate significant MB removal and H_2O_2 generation. SAC and BB's potential for Methylene Blue removal offers a sustainable approach to drinking water remediation using low-cost, waste-derived electrode materials.

Background

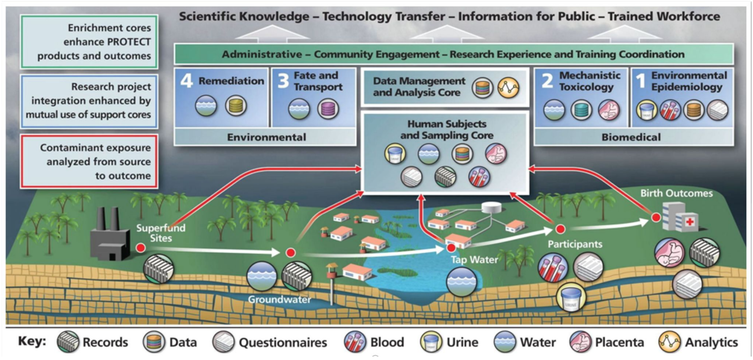


Figure 1: PROTECT Program Goals Flowchart

This research explores the efficiency of sargassum seaweed and bamboo for the filtration of Methylene Blue, an emerging contaminant, from drinking water. Electrochemical water treatment from activated carbon offers a potentially low-cost, sustainable solution for water treatment. This is especially important in Puerto Rico, where emerging contaminants (ECs) are known to cause maternal and fetal health issues. 19 Federal Superfund sites across Puerto Rico contribute to rising levels of ECs in the region, and extreme weather events spread the contaminants, worsening water quality further.

Experimental Methods

Creating Activated Sargassum

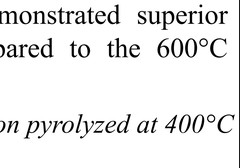
Sargassum from Puerto Rico was saturated with H_3PO_4 → The sargassum was then pyrolyzed (heated without oxygen) in a tube furnace filled with N_2 gas → Pyrolysis time was kept at 2 hours while the temperature was varied at 400°C and 600°C.

Batch Experiments

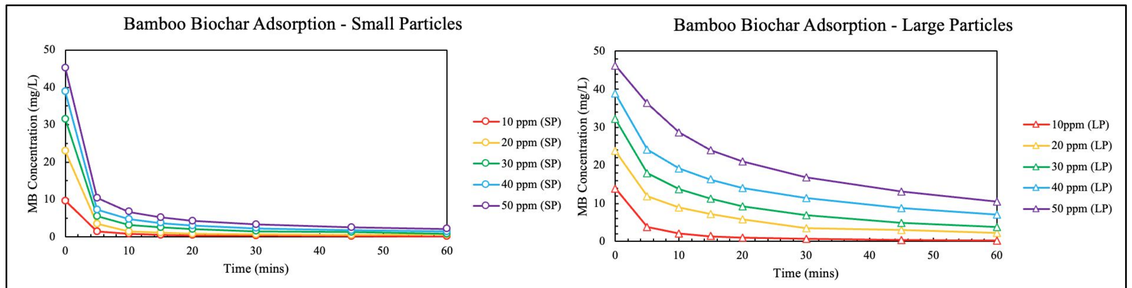
200 mL of MB solution were prepared at concentrations of 10, 20, 30, 40, and 50 ppm → 1.5 g of BB or SAC was added to each beaker and samples were taken at t = 0, 5, 10, 15, 20, 30, 45, 60, 80, 100, 120, 150, 180, and 1440 min → At each time point, an aliquot was taken using a needle and syringe and filtered into a cuvette with a 0.2um filter. → All samples were analyzed on a UV-Vis Spectrophotometer at 665 nm

Cathode Fabrication

Carbon, PTFE, and Ethanol were combined in a 1:2:4 ratio → The mixture was vortexed, sonicated for 30 minutes, and then vortexed again → The mixture was then dried at 350°C for 1 hour and stored in desiccator

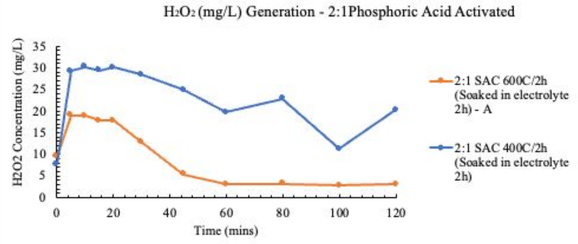


Results



Figures 2a and 2b: Bamboo small and large particle adsorption of methylene blue (10, 20, 30, 40, and 50ppm) over an hour.

Particle size significantly influenced the adsorption performance of bamboo biochar, with smaller particles exhibiting faster methylene blue removal. Adsorption kinetics were best described by the pseudo-second-order model, indicating that adsorption is guided by chemisorption.



For sargassum-derived activated carbon, phosphoric acid activation successfully introduced phosphorus-containing surface functional groups, while the 2:1 biochar produced at 400°C demonstrated superior H2O2 generation compared to the 600°C material.

Figure 3: Hydrogen peroxide production from sargassum-derived activated carbon pyrolyzed at 400°C and 600°C over 120 minutes.

Conclusion and Future Steps

Conclusion: This research demonstrated the potential of sustainably derived biochar as a multifunctional material for water treatment. By optimizing material synthesis and activation conditions, biomass waste can be transformed into high-performance carbon materials that support the development of more efficient and sustainable water treatment technologies.

Future Steps:

- Repeat MB batch experiments with Sargassum
- Repeat H_2O_2 cathode experiments with bamboo biochar
- Run electrochemical batch experiments with MB
- Eventually switch from electrochemical batch experiments to flow-through experiments.

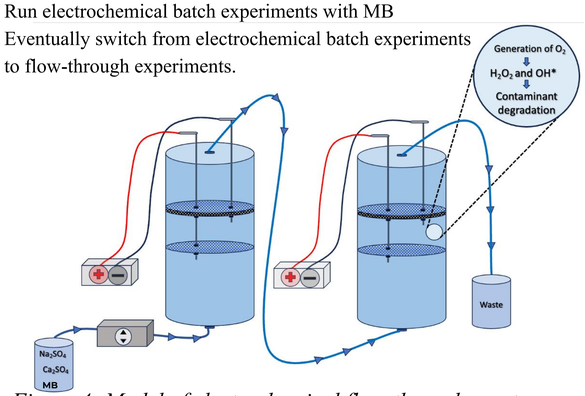


Figure 4: Model of electrochemical flow-through reactor

References

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Acknowledgements

PROTECT Project 4 Laboratory
Professor Akram Alshawabkeh, Program Director
Muhammad Fahad Ehsan, Senior Research Scientist
Amanda Thomas, Ph.D Student
Nima Sakhaee, Ph. D Student
Center for STEM Education
Claire Duggan, Executive Director
Jennifer Love, Associate Director
Ahmed Othman, Kenneth Rene Santizo Carbajal, & Frances Corcell, YSP Coordinators
Nicolas Fuchs, Program Manager
Mary Howley. Administrative Officer

This work was supported by the National Institutes of Health