Filtration of copper-contaminated water using *Crescentia cujete*'s shell based activated carbon

1 ABSTRACT

Industrialization and urban stressors have accelerated the increasing levels of the most dangerous contaminants in our water bodies, heavy metals, because of their non-biodegradability, their high toxicity, and their harmful effects in organisms' health (Reyes-Toriz, 2006). WHO (World Health Organization, 2004) and EPA (U.S. Environmental Protection Agency, 1987) consider copper as a dangerous heavy metal if long term exposed. The aim of this investigation was to contribute with an effective way to improve water pollution in developing countries demonstrating the potential filtering capacity of the shell of a fruit known in Puerto Rico as Higüera converted into activated carbon. In order to do demonstrate its efficiency, concentrated solutions of Copper(II) Sulfate 5-Hydrate were processed through four different ratios of the activated carbon. The results showed that just 0.6 grams of activated carbon retained more than the 65% of copper ions from the aqueous solutions in every sample. Based on this data, the investigator got to a conclusion that this biomaterial should be used as an effective adsorbent because of its metal removing performance, economic value, its reduction of waste disposal and will provide an inexpensive alternative to commercial activated carbons.

2 PROBLEM

Will the *Crescentia cujete*'s shell based activated carbon samples reduce the concentrations of Copper(II) Sulfate 5-Hydrate from the aqueous solutions?

3 HYPOTHESIS

The *Crescentia cujete*'s shell based activated carbon will filter these contaminants because of the types of acids the fruit is composed of which contains functional groups that includes carboxylics and hydroxyls which have high affinity to metal ions, similarly to the coconut shell, and the rice husk, which have proven to be potential absorbents.

4 METHODOLOGY

Preparation of activated carbon

- The shells were initially dried at 100°C for 24.0 h.
- The raw material was pyrolyzed in a furnace at 600°C for 2.0 h.
- The obtained char was mixed with varying amounts of NaOH at the ratios of 1:1, 2:1, 3:1, and 4:1 (NaOH:char)
- This suspension was stirred for 2.0h, and finally dried at room temperature.
- The dry solids were activated in a tube furnace under N^2 flow, at 800°C for 2.0 h.
- Obtained solids were thoroughly washed with a 0.1M solution of HCl, followed by water to a neutral pH.

Heavy metal samples preparation

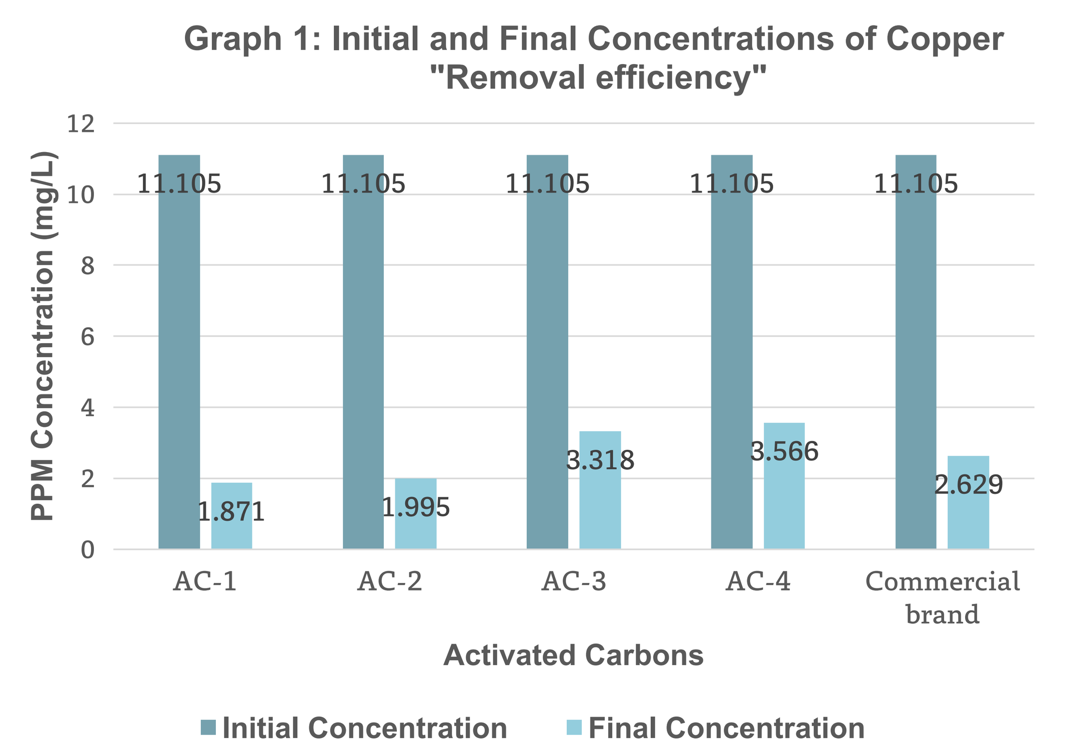
- The 20ppm heavy metals solutions were prepared by dissolving Cu^{2+} in deionized water.
- Samples were filtered trough the system created by the 3D printer.
- An AAS was used to measure copper absorbance before and after filtration.
- Based on the information and observations gathered, graphs and tables were made to analyze the results.

5 DATA AND CAD RENDER

Figure I. Absorbance rate, copper uptake, and removal percentages of activated carbons.

AC	C_i (mg/L)	C_f (mg/L)	Absorbance (mg/L)	Uptake (mg/g)	R_p (%)
AC-1	11.105	1.871	9.234	1.539	83.2
AC-2	11.105	1.995	9.110	1.518	82.0
AC-3	11.105	3.318	7.787	1.298	70.1
AC-4	11.105	3.566	7.539	1.256	67.8
Commercial brand	11.105	2.629	8.476	1.412	76.3

C_i = Initial concentration; C_f = Final concentration; R_p = Removal Percentage



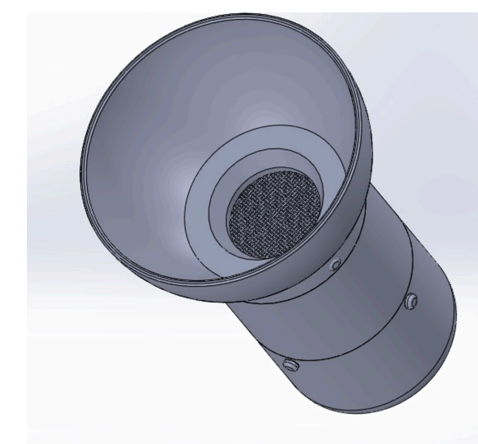


Figure II. Isometric view of filter.

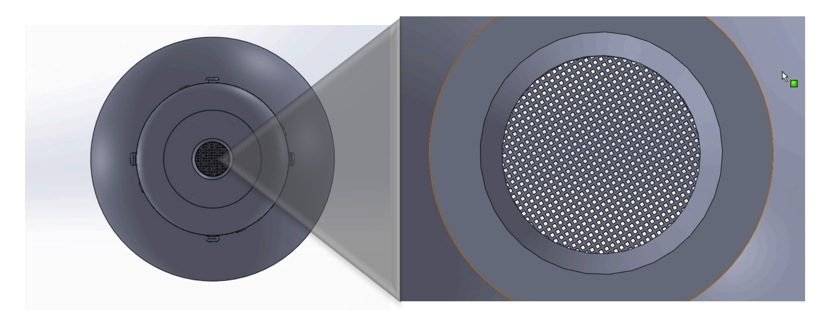


Figure III. Bottom view of filter with zoom into the strainer.

Figure IV. *Crescentia cujete*'s shell.

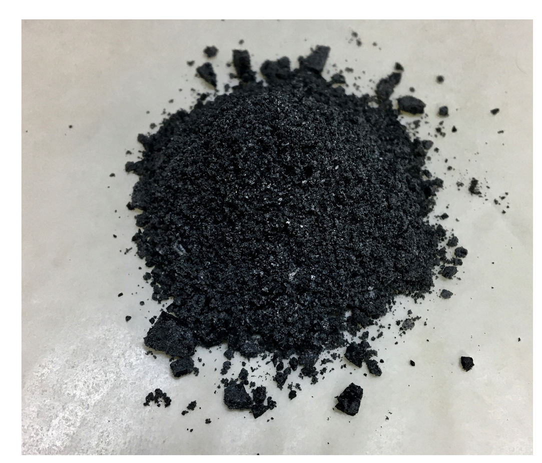


Figure V. *Crescentia cujete*'s char.

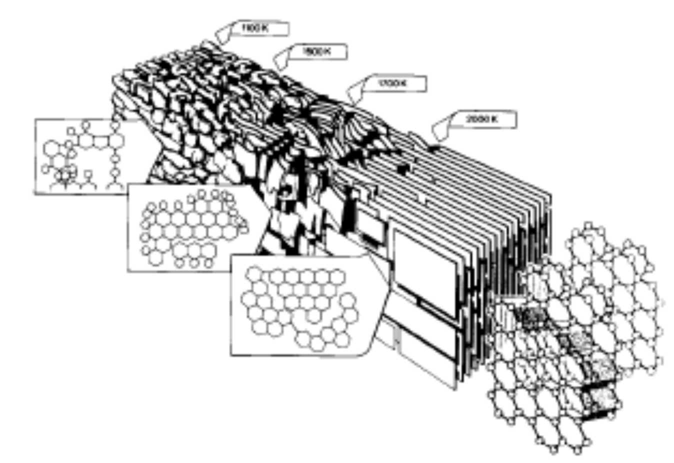


Figure VI. Conversion of carbon into graphite at high temperatures.

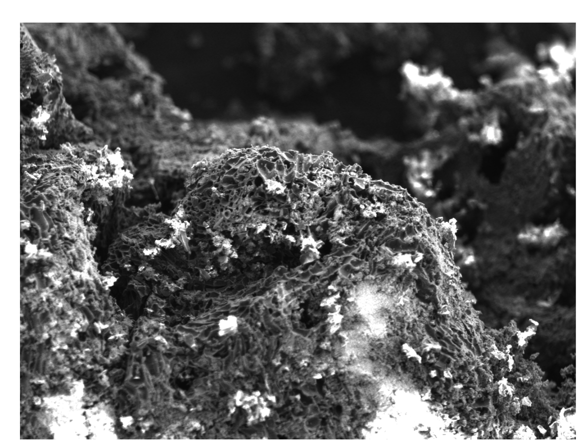


Figure VII. *Crescentia cujete*'s shell SEM.

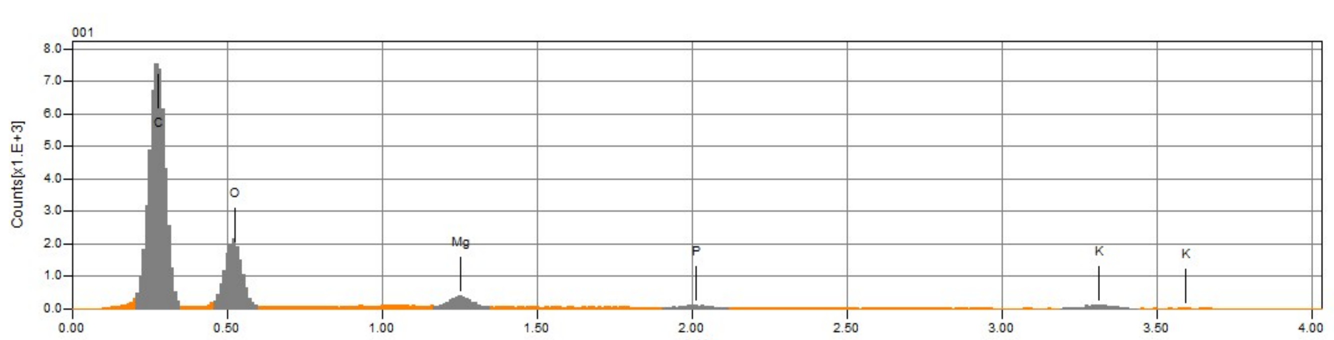


Figure VIII. Energy-dispersive X-ray spectrometry results of Crescentia cujete's shell.

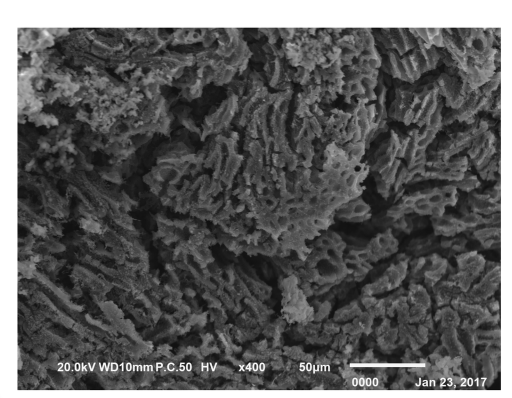


Figure IX. SEM 1:1

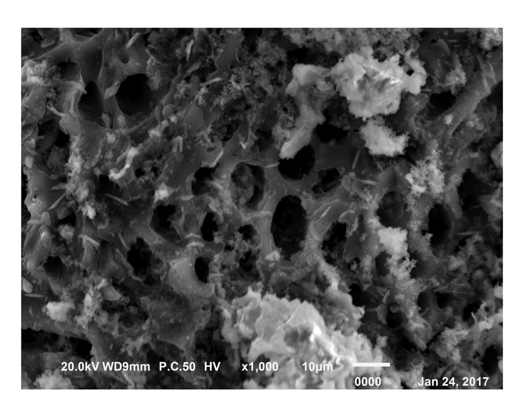


Figure X. SEM 2:1

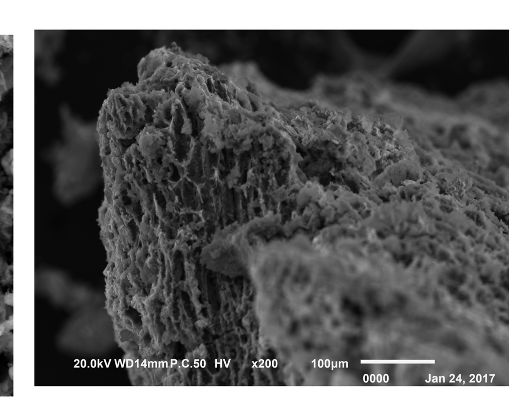


Figure XI. SEM 3:1

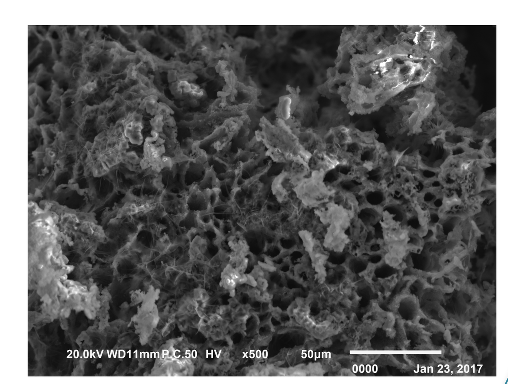


Figure XII. SEM 4:1

Photos taken by researcher.

6 DISCUSSION

Based on the data from Figure I, we can see that all the *Crescentia cujete's* shell based activated carbon samples had a removal percentage above 65%, making the *Crescentia cujete*'s shell an efficient biofilter. AC-1 [1:1 (NaOH:char)] and AC-2 [2:1 (NaOH:char)] even had a better performance than a conventional carbon brand. To analyze the aqueous solutions trough the Atomic Absoprtion Spectrometer (AAS) the samples had to be diluted to reach the standards of the calibration curve of copper, that is why the initial concentration appears to be 11.105 ppm instead of 20 ppm. The copper uptake was measured using the mass balance equation $q = \frac{V\,(C_i - Cf)}{S}$, where V is volume, and S is the mass of the sorbent (activated carbon) used. It explains how many milligrams of copper were absorbed by gram of the activated carbon, which in this case were only 0.6grams of sample per filtration.

7 CONCLUSION

The result obtained for copper adsorption indicates that *Crescentia cujete's* shell based activated carbon had higher adsorptive efficiencies than the commercial brand at two of the dosages used during the experiment. Acids containing functional groups such as hydroxyls and carboxylics were the main site for the adsorption of copper by the shell. Removal of copper ranged from 67.8-83.2% demonstrating the potential retention capacity of the shell. Do to its chemical characteristics, the *Crescentia cujete's* shell based activated carbon obtained in this investigation is a potential absorbent in water for the removal of heavy metals, which could be applied trough filtration systems and water treatment plants to benefit developing countries within the intertropical zone of the world to have access to clean water.

8 PROJECTIONS

- ✓ Measure physical and chemical properties of the activated carbon.
- ✓ Combine the raw material with a biomass to make it a lot eco-friendlier.
- ✓ Surface area and pore size characterization by applying BET equation.
- ✓ Apply Lagmuir and Freundlich isotherm models.

9 REFERENCES

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