BIOCHAR DERIVED FROM COTTON FIBER FEEDSTOCK: CHARACTERIZATION OF MATERIAL AND POTENTIAL FOR ADSORPTIVE CAPACITY

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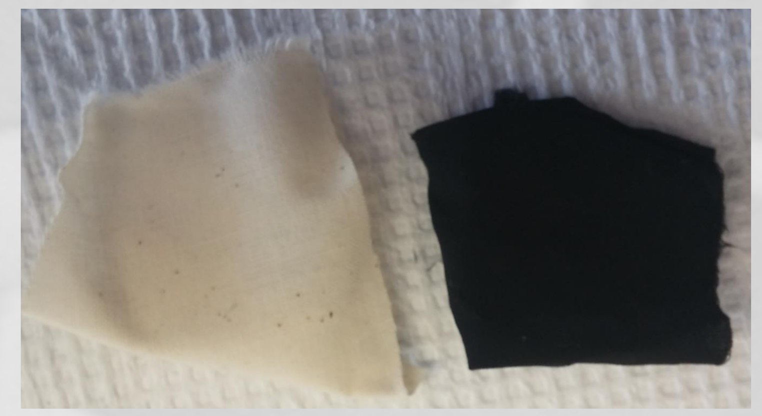
Introduction

Anthropogenic contaminants in surface waters have increased in complexity as the use of chemicals in all sectors of society has grown [1]. Water scarcity and quality issues will require robust, low-cost, and sustainable solutions.

Biochars are particularly compelling as adsorptive solids because they repurpose wastes [2, 3] from other industries and are often carbon neutral, if not carbon negative. Cotton is the most common cellulosic fiber on the global fiber market, and as such, a significant contributor to municipal waste streams [4]. This research investigates the use of undyed, unbleached, 100% cotton muslin fabric as the fuel for making biochar to determine the feasibility of sourcing cotton fabric waste as biochar feedstock.

A



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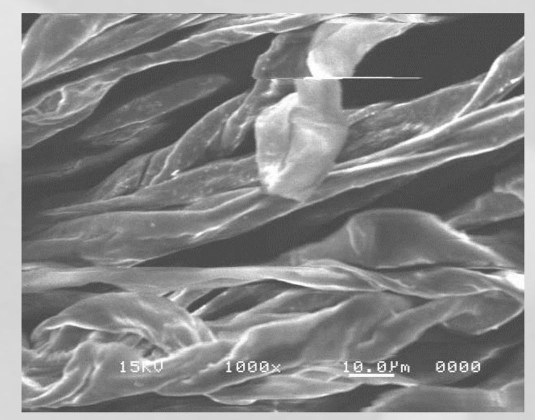

Fig. 1 **A.** Original source material of waste muslin cotton (left) and pyrolyzed cotton produced from heating at 5ºC/min to 400ºC. **B.** Scanning electron microscope image of uncoated biochar at x1000 magnification.

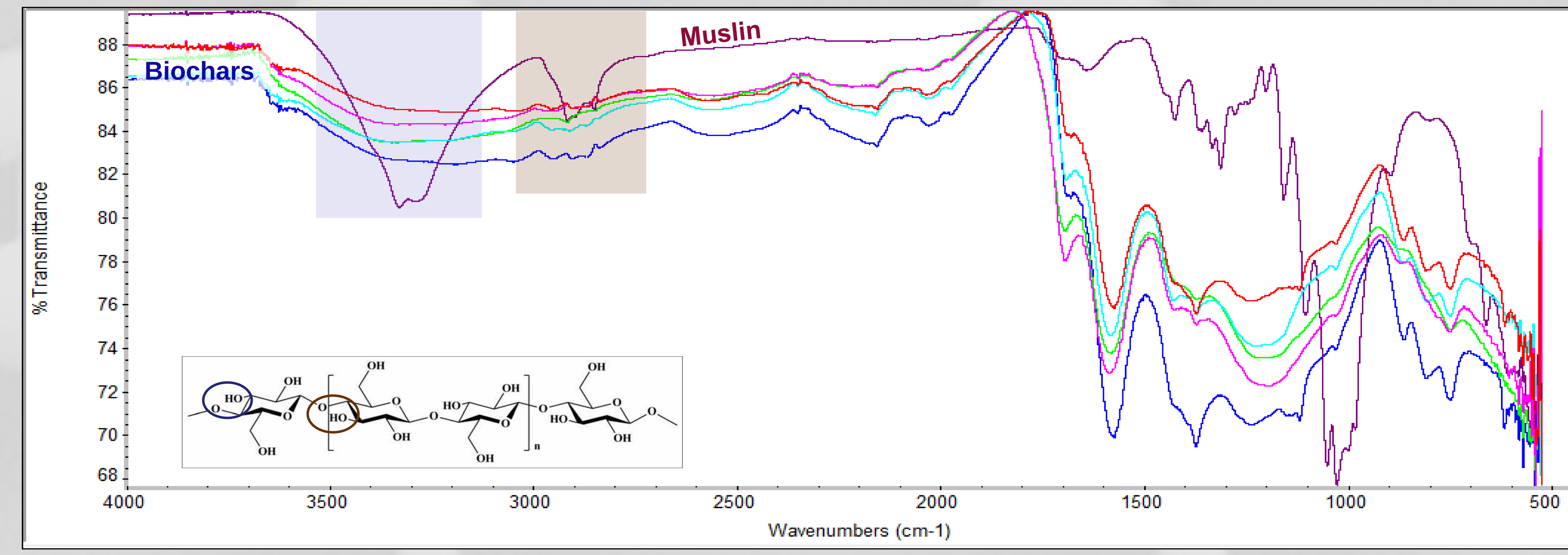

Fig. 2 FT-IR analysis of original cotton muslin and multiple samples of cotton biochar prepared at 400ºC and 500ºC. The breadth of the peak at 3480 is indicative of the complex hydrogen bonding interactions both within the cellulose molecule and between the molecules. The increase in absorbance in the 1750 to 1400 cm^{-1} range indicate the development of C=O and C=C bonds, in addition to the increase of aromaticity of the carbonized material [8].

Procedure

Pyrolysis of samples

- The pyrolysis of cotton fabric waste samples were conducted using a tube oven, Thermoscientific Lindberg Blue M, in a nitrogen rich atmosphere.
- Samples were prepared at two different maximum temperatures (400ºC or 500ºC) using the same ramp of 5ºC per minute.
- Initial and final masses were obtained for each trial to measure mass sequestration.

Thermogravimetric Analysis

- The thermogravimetric analysis was completed using a TA Instrument TGA Q50 model.
- Small samples of the cotton waste were evaluated at the same temperature ranges used during the tube oven pyrolysis.

Surface imaging/analysis: FT-IR and SEM

- Both FT-IR and SEM analyses were completed. Pyrolyzed samples were analyzed using FT-IR on a Thermoscientific Nicolet iS10. Both pyrolyzed and nonpyrolyzed samples were analyzed.

Heavy Metal Equilibrium Adsorption Isotherms: Zinc

- Equilibrium adsorption isotherms were run for both 400ºC and 500ºC pyrolyzed cotton samples.
- Carbonized samples were cut into approximately 2cm squares and samples from multiple runs were homogenized.
- Each reaction vessel in the isotherm contained 0.15 grams of the pyrolyzed cotton material.
- Ten milliliter dilutions of a 1000ppm Zinc stock solution ranging from 4ppm to 20ppm were placed into 6 reactions vessels.
- The samples were analyzed using a Perkin Elmer AAnalyst 100 flame atomic absorption spectrophotometer

Adsorption isotherms for Zn2+

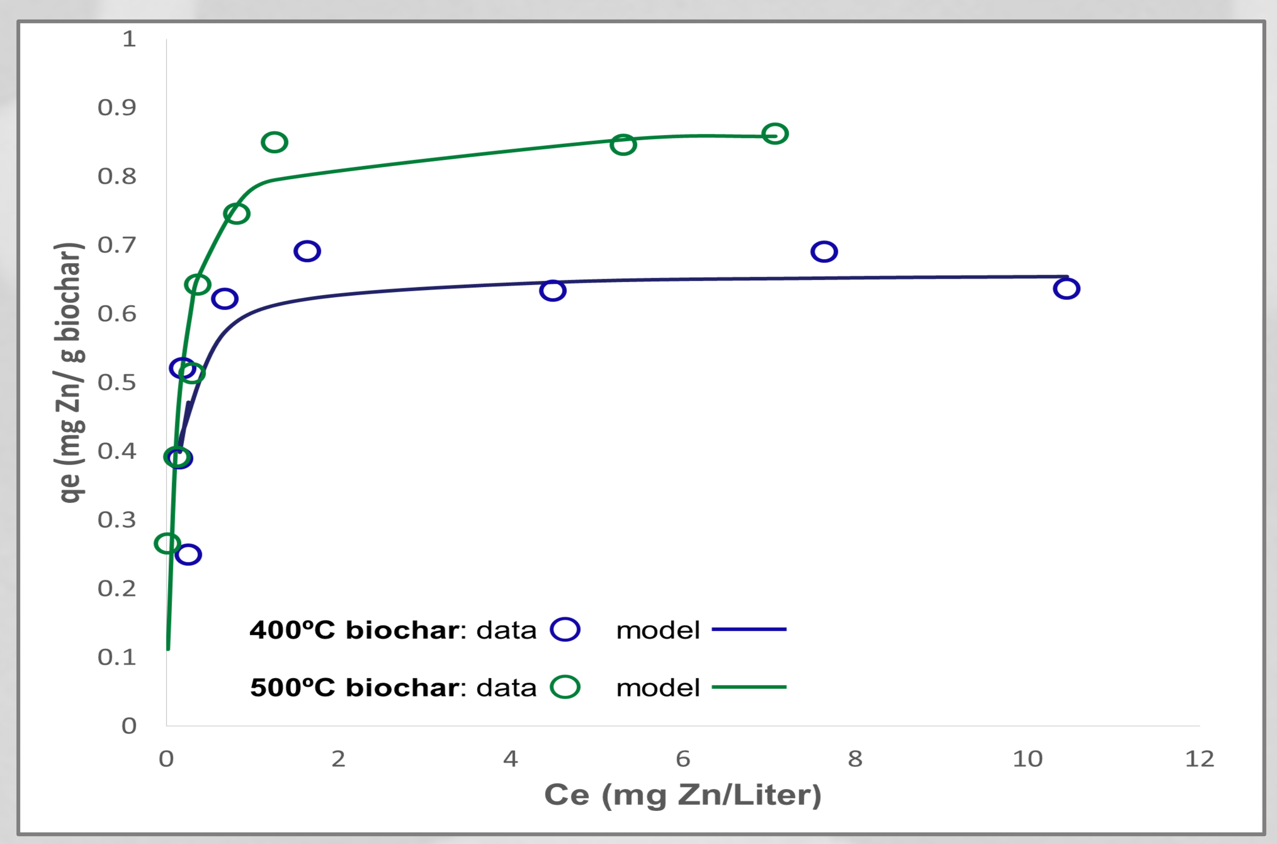

Fig. 3 Equilibrium adsorption isotherms of Zn^{2+} onto both 400ºC and 500ºC cotton biochars. The Langmuir fitting parameters are shown in Table 1. Zinc was chosen as a test metal because of its use and presence in textile finishing fluids.

Sample	K	q_m
400ºC	9.67	0.66
500ºC	8.02	0.87

Table 1 Langmuir fitting parameters resulted in a comparable fit to the Freundlich model. The model maximum adsorption capacities are on the low end of published values.

Results

Heavy metal contaminants were successfully removed from samples using cotton biochar

Pyrolysis and thermogravimetric analysis

- Bulk pyrolysis performed in the tube furnace showed that cotton heated to 400ºC experienced 78% mass loss while cotton heated to 500ºC experienced 82% mass loss.
- The TGA analysis under similar temperature and inert atmosphere conditions showed mass losses of 72.86 and 81.65% respectively.

Surface imaging and analysis

- Samples of both unprocessed and pyrolyzed cotton muslin were analyzed using FTIR, the loss of the –OH functional group, seen in the wavenumber region around 3480cm^{-1} is the prominent change between the unprocessed and pyrolyzed cotton samples. Increase in absorbance in the 1450 to 1750cm^{-1} region shows the development of C = C and C=O structures.

Heavy metal equilibrium adsorption isotherms

- Equilibrium adsorption isotherms of the two pyrolyzed cotton samples showed measurable adsorption of Zn^{2+} ions.
- The 500ºC samples showed maximum adsorption of 0.90mg Zn^{2+}/g of biochar. The 400ºC sample showed maximum adsorption of 0.70mg Zn^{2+}/g of biochar
- Using the Langmuir model, a fit was generated for both 400ºC and 500˚ C Biochar

$$\frac{C_e}{q_e} = \frac{C_e}{q_m} + \frac{1}{K_L q_m}$$

- For the 400ºC the model K and q_m were 9.67 and 0.66 respectively. For the 500ºC the model K and q_m were 8.02 and 0.87 respectively.

Discussion

This preliminary study shows that textile wastes, specifically cotton, is a possible feedstock for the production of biochar for the purpose of removing heavy metal contaminants. There seems to be a trade off between adsorptive capacity of the biochar, and carbon sequestration during pyrolysis. Although the biochar created at 500ºC had a greater adsorption rate of 0.9mg Zn/g compared to 0.7mg Zn/g at 400ºC, it also had a greater percent mass loss of 82% compared to 78% for 400ºC. Comparatively current research reports a range of adsorption capabilities of biochars. Biochars differing in feedstock, activation levels, and pH of solution produce significantly different adsorption rates ranging from 0.53mg/g to 45.62mg/g [5, 6]. The activation of these chars would confer additional adsorptive potential. The activation of these biochars will be investigated in the future.

Future Work:

- Investigate activation processes that are as green and sustainable as possible to increase the adsorptive capacity of carbonized cotton
- Begin surface area quantification on samples, both activated and non-activated
- Design a novel binding process to maximize surface area in pellets of carbonized material

Acknowledgements:

This work was made possible by a Provost's Office grant at Philadelphia University. Additional funding was provided through an American Society of Chemical Engineering grant for Environmental Engineering.

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