Development of Sustainable Super-Sorbent Biochar-Based Fabrics

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Introduction

Biochar, a type of activated carbon, is derived from biomass. Activated charcoal, as opposed to biochar, is the current filtration standard for the majority of protective fabrics in emergency worker, farm worker, and military personnel gear.

With a potentially high turnover of protective clothing in the field, costs and raw material supplies for these garments are large. By replacing activated charcoal in protective clothing with biochar, a cheaper and greener alternative may be achieved by also maintaining individual safety. This project aims to create a sustainable, highly effective and absorbent fabric that will potentially inspire a new generation of protective clothing.

Electrospinning

Figure 1. Electrospinning Set Up.

Figure 2. Electrospun membranes with W350 biochar. The membranes were spun with a) unsieved biochar; b) <10 µm biochar, c) no biochar for a control.

Synthesis and Characterization of Biochar

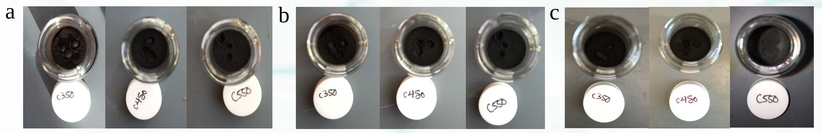

Figure 3. Water Droplet Penetration Test photos for Corn samples. a) After 1 minute; b) After 10 minutes; c) After 60 minutes. The C350 sample showed the highest degree of water repellency.

Figure 4. Settling Assay Experimental Set Up. From left to right, the solutions for the settling assay were the four electrospinning solutions, <10 µm, 10-22 µm, 22-38 µm, and unsieved biochar, followed by the two control vials with 9.22 mL of acetone, then water. The solutions for the four experimental vials were made in accordance with the electrospinning solution methods, with 9.22 mL Formic Acid (95%), 3.75 g of Nylon 6, and 20 mg biochar.

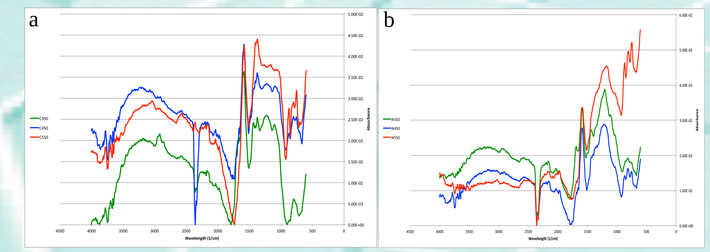

Figure 5. FTIR Analysis of Various Biochar Samples: a) Corn; b) Wood.

- The C350 sample was the most water repellent, or hydrophobic, followed by the C450 and C550 samples. The wood samples had approximately the same absorption times, but different sample characteristics after each test.

- The electrospinning solutions made with <10 µm, 10-22 µm, and 22-38 µm particle sizes remained homogeneous for the entire three-hour period. The electrospinning solutions made with unsieved biochar began to settle after approximately 45 minutes.

- Each biochar material was analyzed with FTIR analysis for two purposes: (1) to characterize the surface functional groups, and (2) to determine if exposure to formic acid will change the surface functionalization of the biochar samples. The general trends of the FTIR analysis are the absorbance will increase in the region of single carbon bonds, at around 1400 cm^{-1}, as temperatures increase. This is because the samples become more graphitic in nature as the aromatic rings are broken down in more extreme pyrolysis conditions. This trend is clearly observed in the Corn samples, and is somewhat observed in the Wood samples. Additionally, a decrease in the intensity of bands in the triple and double bond regions was expected with increased temperatures. This trend is clearly observed in the Wood samples, and somewhat in the Corn Samples. Decreases in the band at 3280 cm^{-1} were observed, which represents O-H stretching vibrations of hydrogen bonded hydroxyl groups. An unexpected peak occurs at 2360 cm^{-1}. This could represent the presence of an alkyne, which is a low intensity peak between 2200 and 2300 cm^{-1}.

Adsorption of Target Contaminant by Biochar

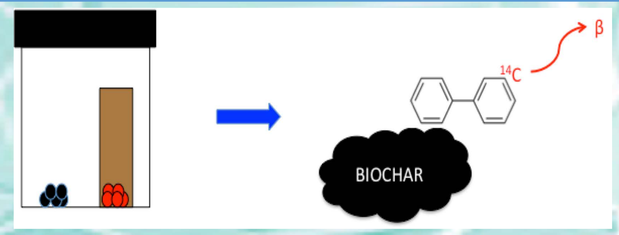

Figure 6. Schematic for sorption of biphenyl on biochar surfaces. Biphenyl containing 14C will emit beta particles. Beta particles will react with compounds in the scintillation cocktail (PPO and bis-MSB) to produce a photon. Photon activity is recorded by scintillation counter.

- The biphenyl adsorption assay was performed on the W350 biochar sample. Raw data was converted from counts per minute (CPM) to disintegrations per minute (DPM) to milliCurie (miCi) with the following equations and ratios:

$$\text{DPM} = \frac{(\text{CPM} - \text{Background})}{\text{Effeciency}} \qquad \text{Effeciency} = \frac{\text{standard CPM}}{\text{standard DPM}}$$

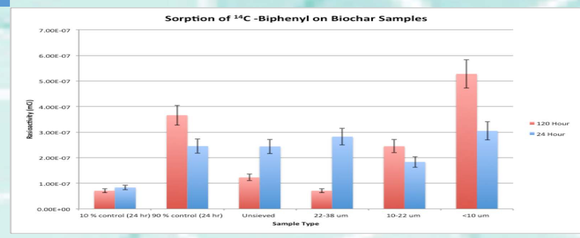

Figure 7. Biphenyl Adsorption onto Biochar Surfaces. 30 µL containing biphenyl suspended in ethyl acetate was pipetted into the 1.5 mL vials, and 10 mg of each biochar type was deposited into the 20 mL vials. The first set of experimental vials was allowed to sorb for 24 hours, and the second set was allowed to sorb for 120 hours.

- The set of experimental samples that was exposed to the biphenyl for 24 hours did not show any significant trends in adsorption behavior. The set of samples that was exposed to the biphenyl for 120 hours showed an increase in sorption with a decrease in particle size.

References

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