Use of Biochar in Emergent Contaminant Removal

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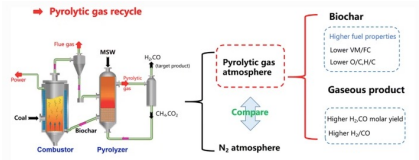
Abstract

Biochar is a carbon-based material made by pyrolysis, a process that uses low oxygen and high temperature to degrade organic matter. Adsorbent materials like biochar are used for many different purposes, such as soil remediation or water treatment. Research suggests that biochar's surface characteristics play a significant role in their ability to adsorb contaminants or release nutrients. Additional heat and chemical treatments have also been shown to change the characteristics of biochar, thus changing their performance in certain tasks. This study aims to characterize the effects of a variety of acid and base treatments at different molarities on the surface characteristics of hemp biochar. This was done through FTIR analysis and contact angle measurement tests. Currently, there are no standard protocols for measuring the contact angle for powders and granules made of organic materials like biochar. As such, we plan to introduce a protocol that may be used for carbon-based materials.

Keywords: Biochar, Contact Angle, Absorption, Charcoal

Introduction

As new products are introduced into the market, many end up in the water supply through the sewage systems or run off among other things, breeding a unique problem. These products make themselves known as emerging contaminants. Emerging contaminants (ECs) are unregulated, harmful chemicals that are increasingly detected in drinking water (Barcelo et al., 2005). ECs are becoming increasingly common as they are redistributed across the Earth in the Hydrologic cycle; they reduce water quality, disrupt human and animal health, and damage ecosystems.



Due to its absorbent properties, an effective way to remove these contaminants is biochar. Biochar is a carbon-based material made by pyrolysis, a process that uses low oxygen and high temperature to degrade organic matter (Legan et al., 2022). Furthermore, these compounds may be useful for adsorbing certain classes of contaminants due to chemical reactions. Biochar can be modified or unmodified. Modified biochar has undergone some sort of secondary heat or chemical treatment while unmodified biochar has not. This study aims to characterize the effects of a variety of acid and base treatments at different molarities on the surface characteristics of hemp biochar.

Materials

We used the following acids and bases as treatment in our experiment: HCl, HNO_3, H_3PO_4, KOH, NaOH, and NH_4OH. Additionally, as our control we also had an unmodified sample of biochar.

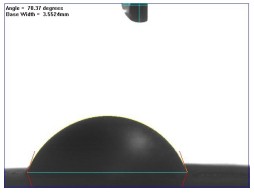
Methodology

We created 5 molar concentrations—0.05M, 0.10M, 0.2M, 0.5M, and 1M—for each of the acid and bases. We added 10 grams of biochar and 200 milliliters to an Erlenmeyer flask for each of the solutions. We utilize orbital shakers to incorporate the acid and base treatments into the biochar for 1 hour. We decanted the liquid from the treated biochar.

We transferred the biochar into a heat proof container and then baked the acid and base-treated biochar in an oven at 105℃ for 24 hours to ensure it was completely dry and any excess liquid had evaporated. After the biochar finished in the oven it was left to cool uncovered and then transferred to metal tins.

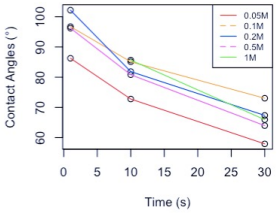
We then began preparing the biochar to be used in testing of contact angles. We manually ground up the biochar with a mortar and pestle. We prepared a slide by attaching a single piece of double-side tape to it from edge to edge. We pack the grounded char onto the slide, lightly tapping away the excess. We hold the slide to the light, looking for about 75% opacity: we can see light through the slide but not much more than that.

The slide is placed in the machine used to perform our static contact angles, raised to a standardized height of about 5 mm above the first line of sight for the light projecting behind it. For each of the biochar we measured the contact angle of the sample at 1 second, 10 second, 30 second, and 60 second time intervals from the time of the drop onto the slide.



Results

HCl Contact Angles

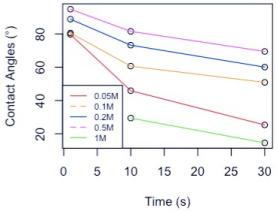


Standard Deviation

Overall = 13.4111

0.05M = 14.17036
0.1M = 11.85565
0.2M = 17.49613
0.5M = 16.13551
1M = 13.93707

H_3PO_4 Contact Angles

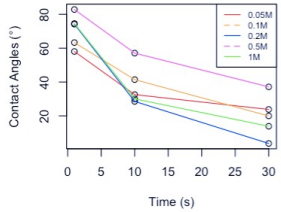


Standard Deviation

Overall = 24.90273

0.05M = 27.47552
0.1M = 15.12383
0.2M = 14.41722
0.5M = 12.70013
1M = 10.53589

NH_4OH Contact Angles

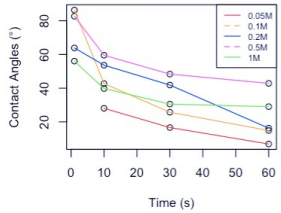


Standard Deviation

Overall = 24.21324

0.05M = 17.79141
0.1M = 21.68031
0.2M = 35.73608
0.5M = 22.91168
1M = 31.44038

HNO_3 Contact Angles



Standard Deviation

Overall = 22.12711

0.05M = 10.59571
0.1M = 31.45275
0.2M = 20.50437
0.5M = 17.64078
1M = 12.39841

Conclusion and Discussion

The contact angles for the unmodified biochar and the NaOH and KOH treated biochars dissipated within 3 to 5 seconds of the time of drop. The biochars had high wettability indicating that the biochars were hydrophilic.

The biochars treated with NH_4OH, H_3PO_4, HCl, and HNO_3 had greater longevity before dissipation. The biochars had lower wettability, indicating varying degrees of hydrophobic properties. Of the biochar treated with hydrophobic characteristics, the HCl treated biochar was the most hydrophobic. It had the lowest overall standard deviation out of all of the sample sets. It also had the lowest standard deviation for the events of molarities 0.05M, 0.10M, 0.2M, and 0.5M solutions, but not the 1M solution.

Future Works

In the future we plan to
(1) identify the most effective type of unmodified hemp biochar for removing each class of contaminants,
(2) explore how different production methods and treatments affect biochar's adsorptivity, and
(3) find effective and low-cost secondary modifications or treatments for biochar to increase contaminant removal in column and batch tests.

References

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