Spring 4-27-2022

Biochar Hydrophilicity Characterization by a Smartphone-Based Apparatus: Design, Construction, and Measurement Calibration

Emma Letourneau
University of Nevada, Las Vegas, letoue2@unlv.nevada.edu

Suraj Pochampally
University of Nevada, Las Vegas

Biochar Hydrophilicity Characterization by a Smartphone-Based Apparatus: Design, Construction, and Measurement Calibration

Authors: Emma Letourneau, Suraj Pochampally, Jaeyun Moon
1) Department of Mechanical Engineering, University of Nevada, Las Vegas

Introduction

- Water contact angles are used to determine hydrophilicity, which is a material's attraction to water.
- A water contact angle of greater than 90 degrees indicates a hydrophobic material that repels water, whereas a contact angle of less than 90 degrees indicates a hydrophilic material [Fig. 1].

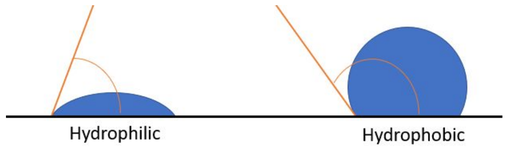

Figure 1: Water Contact Angles Diagram

- Water contact angles are measured through a goniometer, which can cost between $2000 to $10,000.
- Biochar is a porous carbon material created from biological waste products, that is pyrolyzed (i.e. burned) in a low-oxygen, high heat environment [1].
- Biochar can be used to remove contaminants from water and remediate soil while reusing waste, making it an excellent environmentally-friendly material.
- The biochar feedstock type and pyrolysis temperature impacts the resulting biochar's material properties, including hydrophilicity [2].

Objectives

- Create a low-cost apparatus to measure water contact angles with less than 5% error.
- Determine the water contact angles of pecan, poultry litter, and pine biochar at three different pyrolysis temperatures.
- Determine the relationship between hydrophilicity and pyrolysis temperatures for pecan, poultry litter, and pine biochars.

Methodology

- The apparatus [Fig. 3] includes a platform, backlight, syringe pump, and adjustable phone holder.
- Glass slides with carbon tape coated in biochar were prepared, with four samples per slide [Fig. 4].
- The image processing software ImageJ was used to determine contact angle values.
- The percent error of the results from the constructed apparatus and a traditional goniometer was used to determine the apparatus's accuracy.
- The results were plotted against pyrolysis temperatures for each biochar to determine the relationship between pyrolysis temperatures and hydrophilicity.

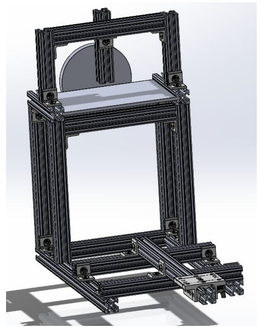

Figure 2: Solidworks Drawing of Constructed Apparatus

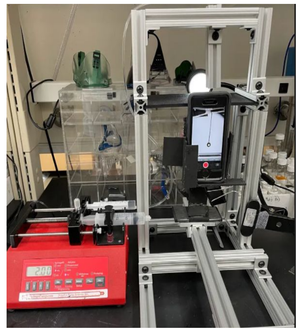

Figure 3: Picture of Constructed Apparatus

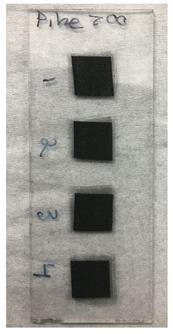

Figure 4: Prepared Slide Coated in Biochar

Results

Contact Angle Tests

A contact angle test is conducted to determine the hydrophilicity of a biochar sample. Figure 5 displays the images taken and the measured contact angles (in degrees) for each trial for the traditional goniometer and the constructed apparatus.

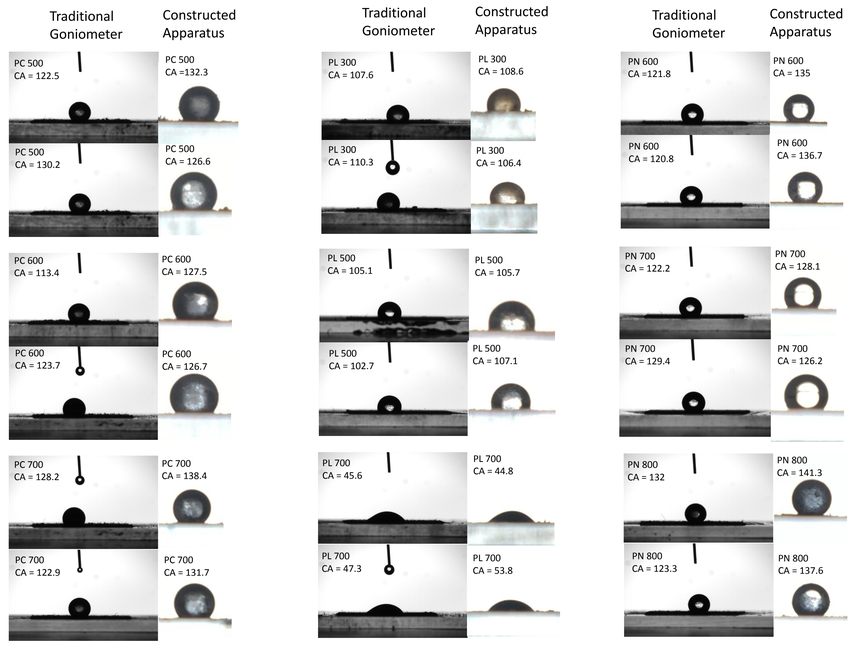

Figure 5: Pecan (PC) Contact Angle (CA) Images (Left Column), Poultry Litter (PL) Contact Angle (CA) Images (Middle Column), Pine (PN) Contact Angle (CA) Images (Right Column)

An average value for the contact angle of the trials was calculated for each biochar, and these averages were compared to determine the percent error between the traditional goniometer and the constructed apparatus [Table 1].

Table 1: Contact Angle Measurement Results

	Traditional Goniometer		Constructed Apparatus		
Biochar Type	Average Contact Angle (Degrees)	Percent Difference (%)	Average Contact Angle (Degrees)	Percent Difference (%)	Percent Error (%)
Pecan 500	126.35	6.09	129.45	4.4	2.45
Pecan 600	118.55	8.69	127.1	0.63	7.21
Pecan 700	125.55	4.22	135.05	4.96	7.57
Poultry Litter 300	108.95	2.48	107.5	2.05	1.33
Poultry Litter 500	103.9	2.31	106.4	1.32	2.41
Poultry Litter 700	46.45	3.66	49.3	18.26	6.14
Pine 600	121.3	0.82	135.85	1.25	12.00
Pine 700	125.8	5.72	127.15	1.49	1.07
Pine 800	127.65	6.82	139.45	2.65	9.24
			Average		5.49
			Standard Deviation		3.65

- Percent errors range: low (1.07 %) to medium (12.00%).
- Percent difference range: low (0.63%) to medium (18.26%).
- The average percent error was 5.49%, with a standard deviation of 3.65%.
- Error may have come from differences in drop size between the two apparatus, variations in the moment of photo capture in the video, vibrations in the constructed apparatus, and the angle of tilt of video capture.

Continued Results

Contact Angles vs Pyrolysis Temperatures

- Figure 6 examines the relationship between the average contact angle and the pyrolysis temperature for each biochar and apparatus type.

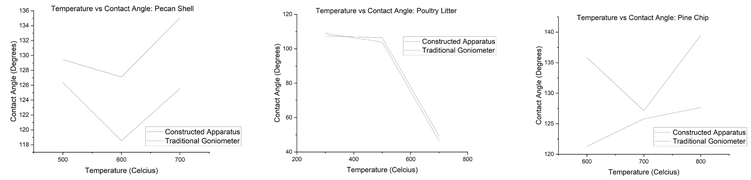

Figure 6: Contact Angles vs Pyrolysis Temperatures

- Current research indicates higher pyrolysis temperatures burn more of the hydrophobic compounds present in the biomass, increasing hydrophilicity [2].
- Poultry Litter behaved as expected and displayed an inverse relationship between contact angle and pyrolysis temperature.
- Pecan Shell and Pine Chip did not display an inverse relationship between pyrolysis temperature and contact angle.

Discussion

- The constructed apparatus did not meet the accuracy objectives, but has the potential to do so after further refinement.
- Variability between the samples hampered the determination of the accuracy of the apparatus [3]. Testing on a more consistent medium (such as carbon tape) may provide more precise results.
- The final cost was approx. $816. The syringe pump was the most expensive component ($560), and lower cost alternatives would reduce the total cost.
- Pecan Shell displayed an inverse relationship between contact angle and pyrolysis temperature from 500° to 600° C, but not from 600° to 700°C. This is likely due to the Pecan Shell 700 sample being undercoated, resulting in an inaccurate contact angle measurement. A similar error occurred for the Pine Chip biochar.

Future Work

- Test with materials of a more consistent medium to reduce variability and determine apparatus accuracy.
- Further biochar testing to increase the data sample size.
- Create a Mathematica program to automatically determine water contact angles and reduce measurement variability.
- Further develop the durable smartphone holder.
- Examine inexpensive cameras as an alternative to smartphones.

References

[1] Ahmad, M., Rajapaksha, A. U., Lim, J. E., Zhang, M., Bolan, N., Mohan, D., Vithanage, M., Lee, S. S., & Ok, Y. S. (2014). Biochar as a sorbent for contaminant management in soil and water: A review. *Chemosphere, 99*. 19-33. https://doi.org/10.1016/j.chemosphere.2013.10.071

[2] Usevičiūtė, L., & Baltrėnaitė, E. (2020). Methods for Determining Lignocellulosic Biochar Wettability. *Waste and Biomass Valorization*, *11*(8), 4457–4468. https://doi.org/10.1007/s12649-019-00713-x

[3] Chen, H., Muros-Cobos, J. L., & Amirfazli, A. (2018). Contact angle measurement with a smartphone. Review of Scientific Instruments, 89(3). Article 035117. https://doi.org/10.1063/1.5022370

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. IIA-1301726. Acknowledgements go to Suraj Pochampally for his invaluable assistance in this project.