Modifying Biochar for Improved Dissolved Metal Adsorption and Recovery

Danna A. Soriano, Suhyun Lee, Adeyemi S. Adeleye*
Department of Earth and Environmental Engineering, Columbia University

Background & Motivation

Biochar, a charcoal-like solid, is made by the partial combustion of biomass in the presence of limited oxygen. Its large specific surface area and porous structure gives it the properties of an ideal material for the sustainable removal of pollutants from the environment. Due to its varying affinity for different substances, biochar may not be effective for every toxin. Our goal is to modify biochar to enhance its performance for cadmium ion removal from water, and determine the influence of pH and treatment time on cadmium adsorption.

Biochar Characteristics

The properties of biochar are heavily dependent on the source of biomass and the pyrolysis temperature. It's surface is rich in functional groups, making it easy to induce chemical and physical modifications to the material, and simultaneously alter its adsorption efficacy.

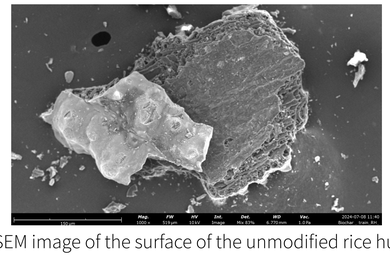


Fig. 1: SEM image of the surface of the unmodified rice husk biochar

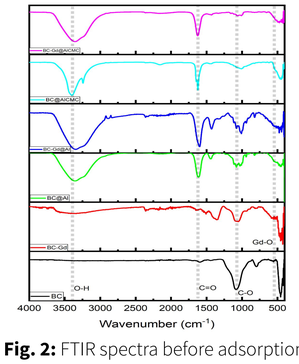


Fig. 2: FTIR spectra before adsorption

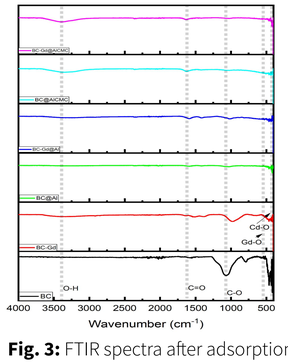


Fig. 3: FTIR spectra after adsorption

Experimental Conditions

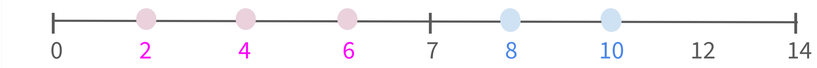
Biochar Source:
Rice husk

Heavy Metal/Pollutant:
Cadmium (Cd^{+2})

Biochar Modifications:

1. Biochar
2. Gadolinium (Gd) Doped Biochar
3. Alginate (Al)@Biochar
4. Al@Gd-Biochar
5. Al-Carboxymethyl Cellulose (CMC)@Biochar
6. Al-CMC@Gd-Biochar

Solution pH Variation:



Kinetic Analysis: Aliquots taken at 5, 10, 15, 20, 30, 60 min and at 2, 3, 4, 5, 6, 7, 8 hrs

Isotherms: Concentration of 5, 10, 25, and 50 ppm

Experimental Methodology

Part I: Sample Preparation

1. Prepare all Cd^{+2} solutions
   - pH altering - dilutions
2. Prepare samples in centrifuge tubes (See Fig. 4)
3. Shake samples for 24 hours (except kinetic samples)

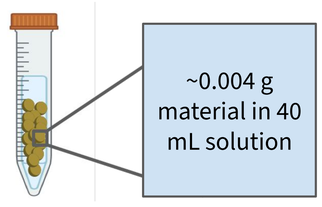


Fig. 4: Sample centrifuge tube

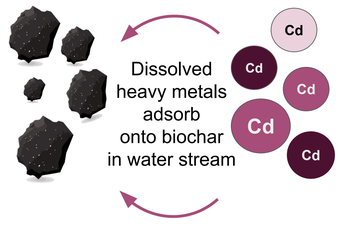


Fig. 5: Biochar and heavy metal interactions

Part II: Eqm. concentrations

4. Collect ~10 mL of final solution with a syringe filter & store in vial
5. Add one drop of pure HNO_3 solution to each sample
6. Run via ICP and conduct data analysis

References

Chen, Yanshan; Li, Hongbo (2017) Mechanisms of metal sorption by biochars: Biochar characteristics and modifications. *Science Direct, Chemosphere.*
Lee, Suhyun (2022) Biopolymer-mixture entrapped modified graphene oxide for sustainable treatment of heavy metal contaminated real surface water. *Journal of Water Process Engineering.*
Wang, Yuyao (2024) Research status, trends, and mechanisms of biochar adsorption for wastewater treatment: a scientometric review. *Environmental Sciences Europe.*

Data Analysis

Effect of pH

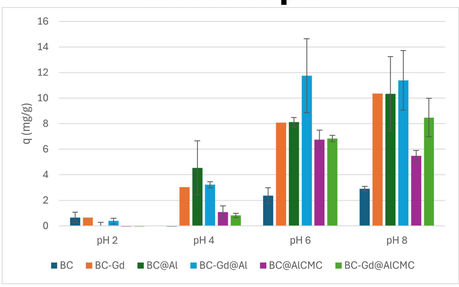
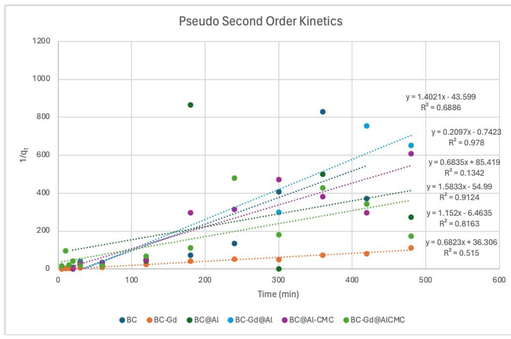


Fig. 6: pH v. Adsorption capacity for all biochar adsorbents

Adsorption kinetics



	q_e (mg/g)	K_2 (g/mg/min)
BC	0.0713	-4.509
BC-Gd	4.769	-0.05924
BC @Al	1.463	0.00547
BC-Gd @Al	0.632	-0.04559
BC @AlCMC	0.868	-0.20532
BC-Gd@Al CMC	1.466	0.01282

Fig. 7: Pseudo second-order kinetics analysis

Adsorption isotherm

	Langmuir			Freundlich		
	R^2	q_{max}	K_{Lang}	R^2	B	K_{Fre}
BC	0.0248	40.3225	0.0114	**0.7851**	0.1909	2.9829
BC-Gd	0.7381	1.1028	1.9769	**0.7795**	0.3341	7.3331
BC@Al	0.7671	1.3036	1.6694	**0.8449**	0.2731	3.0975
BC-Gd@Al	**0.7381**	1.3548	1.6290	0.4372	0.5342	0.1988
BC@Al-CMC	**0.9226**	2.1815	1.4821	0.8034	0.178	2.7997
BC-Gd@Al-CMC	**0.9068**	1.0838	3.5553	0.8199	0.5396	4.7105

Fig. 8: Adsorption isotherm parameters derived from this study

Conclusion

- Biochar surface modifications enhance adsorption
- Alginate encapsulated biochars demonstrated the highest cadmium removal rates