Modifying Biochar for Improved Dissolved Metal Adsorption and Recovery

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Introduction: Biochar is a versatile, charcoal-like substance that is made through the partial combustion of biomass in the presence of limited oxygen. The material has a large specific surface area and a porous structure, rich in amino acids. These chemical and physical properties have made biochar an appealing candidate for a novel tool that sustainably removes environmental toxins. Our goal is to modify biochar to enhance its performance for cadmium ion removal from water, and determine the influence of solution concentration, pH, and treatment time on cadmium adsorption.

Methods: Various modifications were made to a rice husk-biochar in order to assess the strength of the material as an adsorbent under distinct chemical conditions:

1. Raw, unmodified biochar ([BC])
2. Doped biochar (Gadolinium [Gd-BC])
3. Encapsulated biochar (Alginate [Al] and Alginate-Carboxymethyl Cellulose [Al-CMC] encapsulation of BC & Gd-BC)

Additionally, pH, isotherm, and kinetic adsorption tests were conducted in order to target the optimal conditions for the highest removal rates of Cd^{+2}:

pH Test: Targets the required water pH
Isotherm Test: Targets the influence of adsorption on distinct pollutant concentrations (i.e., is the effect negligible?)
Kinetic Test: Targets reaction time required to reach a certain adsorption capacity

Results:

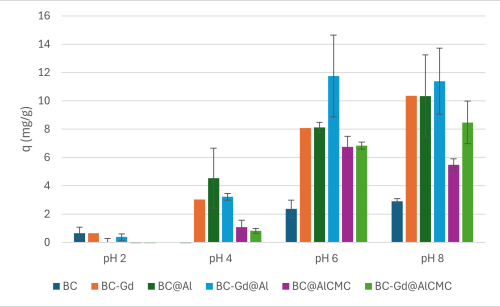

Figure 1: pH v. adsorption capacity for all biochar adsorbents

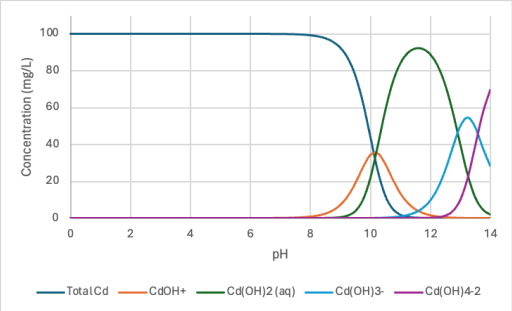

Figure 2: Cd^{+2} species concentration at varying pH levels

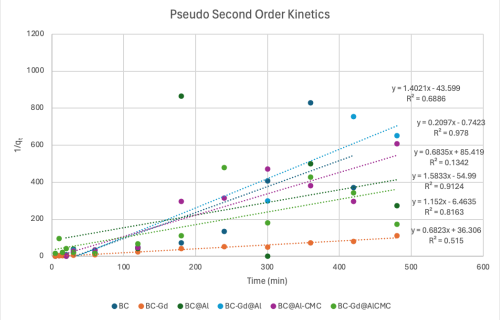

Figure 3: Pseudo second-order kinetics analysis

	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

Figure 4: Adsorption isotherm parameters derived from this study

Conclusion: Biochar surface modifications do indeed have a direct influence on the enhancement of adsorption efficacy. From assessing the isotherm parameters, we can see that the alginate encapsulated biochar (BC@Al) fits the langmuir isotherm model best, demonstrating its fixed affinity for the heavy metal. This implies that adsorption is occurring in ideal, monolayer conditions. Additionally, the pseudo second-order kinetic model shows that BC@Al has the best fit with an R^2 value of 0.978. This suggests a faster removal rate per unit time. Finally, we see that at a solution pH of 6, adsorption capacity is at its highest with no risk of solute precipitation. This indicates that cadmium removal rates are at their highest in a solution with pH 6 and a BC@Al adsorbate.

References:

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