Proceedings of the 11th World Congress on New Technologies (NewTech'25)
Paris, France - August, 2025
Paper No. ICEPR 105
DOI: 10.11159/icepr25.105

Removal of Arsenic from Aqueous Solutions using Natural Biochar-Based Sorbent from Fibers of Date Palm (*Phoenix dactylifera*)

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Extended Abstract

Biochar (BC) is a durable, low-cost sorbent for aqueous metal removal; manganese-oxide functionalization (via $KMnO_4$) enhances arsenic uptake by introducing redox-active MnOx domains and additional oxygenated surface sites that favor As (III) oxidation/adsorption [1], [3],[8]. This study reports an enhanced biochar (EBC) produced from $KMnO_4$-treated date-palm fiber by slow pyrolysis, benchmarked against pristine BC. Objectives were to (i) increase specific surface area and (ii) enrich oxygen-containing functionalities/MnOx domains to strengthen As (III) removal. The scope covered synthesis, physicochemical characterization, batch adsorption under environmentally relevant conditions, isotherm modeling, and regenerability.

Materials were characterized by SEM–EDS, BET N_2 physisorption, FTIR, and ICP–OES to quantify morphology, texture, functionality, and composition [2]. Relative to BC, EBC exhibited larger surface area and higher densities of oxygenated groups with detectable Mn-bearing deposits, consistent with oxidative modification and MnOx loading [1], [3], [4]. Batch tests evaluated removal efficiency (E, %) and adsorption capacity (q_e, $mg \cdot g^{-1}$) for As (III) at pH 3, 7, 9; initial concentrations 5, 50, 100 $mg \cdot L^{-1}$; and sorbent doses 0.05, 0.20, 0.40 g per 0.025 L. EBC consistently outperformed BC, reaching a maximum E of ~70% versus ~40% for BC. Observed pH, concentration, and dose effects follow trends reported for Mn-modified biochars and date-palm–derived biochars used in metal/arsenic remediation [1], [4], [9], [12].

Equilibrium data favored the Langmuir model over Freundlich (representative $R^2 = 0.97$), indicating monolayer adsorption on a finite set of relatively uniform sites—consistent with the creation of new high-affinity MnOx/oxygenated centers during $KMnO_4$ treatment [5]. Regeneration using aqueous NaOH restored EBC performance with minimal capacity loss across cycles, aligning with evidence that alkaline desorption effectively reactivates metal-loaded biochar adsorbents [6], [13]. Overall, $KMnO_4$-assisted modification of date-palm–fiber biochar improved As (III) removal by coupling textural enhancement with targeted surface chemistry, offering a practical route to valorize regional agricultural residues into regenerable sorbents for wastewater treatment [1]–[4],[12].

Keywords: biochar; date-palm fiber; $KMnO_4$ modification; MnOx; arsenite; adsorption capacity; removal efficiency; Langmuir isotherm; regeneration.

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