SUSTAINABLE MAGNETIC BUCKWHEAT HULL-Fe_3O_4 NANOCOMPOSITES FOR ENHANCED BIOSORPTION OF HEAVY METALS IN BINARY AND TERNARY CONTAMINANT MATRICES

Tayyab Tahir[1], Rūta Druteikienė[1], Zita Žukauskaitė[1], Rūta Barisevičiūtė[1], Jūratė Vaičiūnienė[2]

[1]Lithuania, Center for Physical Sciences and Technology, Department of Nuclear Research, Savanorių ave. 231, LT-02300 Vilnius

[2]Lithuania, Center for Physical Sciences and Technology, Department of Catalysis, Saulėtekio av. 3, LT-10257 Vilnius

tayyab.tahir@ftmc.lt

Water has always been essential for life on Earth. However, as a result of urbanization and industrialization, numerous contaminants, including mercury (Hg), lead (Pb), arsenic (As), cadmium (Cd), chromium (Cr), and nickel (Ni), have been introduced into aquatic systems. Due to their harmful effects on aquatic and marine ecosystems, these heavy metals have become a major environmental concern in both developed and developing countries [1]. Ion exchange, redox processes, electrochemical treatment, phytoremediation, and precipitation have been employed for the removal of toxic metals from water systems. However, these techniques have several limitations, including high cost, low efficiency, lack of selectivity, and labor-intensive operation. In contrast, adsorption is a cost-effective and environmentally friendly technique for the removal of heavy metals. It offers advantages such as high selectivity and the ability to remove metals even at low concentrations [2]. Bio adsorbents offer several advantages, including biocompatibility, affordability, biodegradability, and non-toxicity, making them among the most widely studied adsorbents in recent years. Due to their superparamagnetic and photocatalytic properties, and high specific surface area, and short diffusion distance which leads to fast kinetics, Fe_3O_4 nanoparticles have been extensively applied in water treatment. Magnetic adsorbents provide the additional advantage of facile separation from treated water through the application of an external magnetic field. Therefore, the development of magnetic adsorbents, such as those derived from buckwheat hulls, can enhance treatment efficiency by simplifying operational processes and improving overall productivity [3].

The objective of this research was to develop and assess a magnetic biosorbent derived from buckwheat hulls for the efficient elimination of multiple heavy metals from complex aqueous systems.

Buckwheat hull–Fe_3O_4 nanocomposites were synthesized and applied as a sustainable magnetic biosorbent for the efficient removal of heavy metals from binary and ternary aqueous systems. The characteristics of buckwheat hull–Fe_3O_4 before and after sorption were analyzed using SEM, EDX, FTIR, XRD, BET, and point of zero charge (pHpzc) techniques. The sorption performance toward Pb(II), Cd(II), and Cr(III) ions was investigated through batch experiments by varying operational parameters including contact time (30-1440 min), solution pH (2-9), biosorbent dosage (0.1 g-0.35 g), temperature (25–50 °C), initial each metal ion concentration (5-50 mg/L) and agitation speed 150 rpm. The biosorption behavior of Pb(II)/Cd(II) in binary systems and Pb(II)/Cd(II)/Cr(III) in ternary systems was further analyzed using kinetic, isotherm, and thermodynamic models.

The findings confirm that buckwheat hull–Fe_3O_4 nanocomposite exhibit strong potential for the efficient removal of metal ions from aqueous solution.

Keywords: Heavy metals biosorption, buckwheat hull–Fe_3O_4 nanocomposites, kinetics, equilibrium, thermodynamics

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