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Activated carbon from *Luffa cylindrica* doped chitosan for mitigation of lead(II) from an aqueous solution

Asha H. Gedam*[a] and Rajendra S. Dongre[b]

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The present study is concerned with the batch adsorption of toxic lead(II) ions from an aqueous solution using activated carbon from a *Luffa cylindrica* fibers doped chitosan (ACLFCS) biocomposite as an adsorbent. The adsorption experiments were conducted as a function of pH, agitation time, initial lead(II) ion concentration and adsorbent dose. The synthesized biosorbent was characterized by instrumental techniques such as XRD, FTIR, SEM, BET surface area and BJH pore size distribution. XRD analysis revealed that the synthesized ACLFCS adsorbent exhibited broad diffraction peaks, reflecting an amorphous structure. FTIR study showed various functionalities, such as C=O, –OH and $-NH_2$, which were responsible for lead(II) adsorption on the ACLFCS biocomposite. The surface morphology of the ACLFCS adsorbent possesses a porous texture with round- and elliptical-shaped voids that can provide adsorption sites for the adsorbate. BJH pore size distribution analysis showed an average pore diameter >2 nm for all chitosan (CS), activated carbon of *Luffa cylindrica* (ACLF) and ACLFCS adsorbents, corresponding to the presence of a mesoporous structure. Batch adsorption of lead(II) ions was carried out at room temperature wherein the optimum conditions for the maximum adsorption of lead(II) ions were attained at pH 5 with an adsorbent dose of 0.1 g L^{-1}. The equilibrium adsorption isotherm data were fitted by the Langmuir and Freundlich models and the Langmuir isotherm exhibited the best fit with the experimental data. The maximum removal of lead(II) obtained was 98% (experimental) and 112 mg g^{-1} (from the Langmuir isotherm model). The adsorption kinetics was evaluated using pseudo-first-order, pseudo-second-order and intraparticle diffusion models. The adsorption data follows a pseudo-second-order kinetic model. The high uptake of lead(II) ions using ACLFCS indicates an effective and low cost adsorbent for the treatment of water contaminated with lead(II) ions.

1. Introduction

The presence of lead in water, air and soil environments, even as traces, has detrimental effects on plants and animals. The natural sources of lead are soil erosion, volcanic eruptions, sea sprays and bush fires. Industries engaged in lead-acid batteries, paint, oil refining, metal plating, phosphate fertilizer, electronics, wood production, combustion of fossil fuel, mining activity, automobile emissions, and sewage wastewater release lead into wastewater.[1] Lead toxicity causes serious dysfunction of the liver, kidney, reproductive system and central nervous system, reduction in hemoglobin formation, mental retardation, infertility and abnormalities in pregnant women. Due to the hazardous nature of lead(II), it can, directly or indirectly, cause anemia, headache, chills, diarrhea, encephalopathy, hepatitis, nephritic syndrome and even death.[2] The World Health Organization (WHO) in 1995 proposed a safe total lead limit of 50 ppb in drinking water, which was decreased to 10 ppb in 2010.[3] The permissible limits of lead in drinking water as set by the European Union (EU), the United States Environmental Protection Agency (USEPA)[4] and Guidelines for Canadian Drinking Water Quality[5] are 10 ppb, 15 ppb and 10 ppb, respectively. However, more recently, an EPA document recommended a zero lead value in a national primary drinking water standard.[6] Techniques that are extensively used for the abatement of lead from wastewaters are chemical precipitation, membrane filtration, reverse osmosis, electrochemical reduction, ion exchange and adsorption. Among the aforementioned technologies, adsorption has been preferred due to its cheapness and efficacy with respect to heavy metal removal, even at trace levels. Recently, bioadsorbents[7] and activated carbon obtained from agricultural by-products rich in cellulose, lignin, pectin and tannin, which can serve as adsorption sites for heavy metal ions, have been prominently used for wastewater treatment. The production of activated carbons from abundantly available agricultural waste allows the conversion of unwanted

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[a] *Department of Allied Science, Cummins College of Engineering for Women, Nagpur – 441 110, India. E-mail: agedam.ccoew@gmail.com; Fax: +91 7104 280304; Tel: +91 9730184638*

[b] *Post Graduate Teaching Department of Chemistry, Rashtrasant Tukdoji Maharaj Nagpur University, Nagpur – 440 033, India*