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Thermodynamics and kinetics of biosorption of aqueous Co(II) ions on pectin bead-based Teabag

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ABSTRACT

Contamination of water through heavy metal ions has received great attention and wide-ranging consequences for human health and living beings. Polymer@metal oxide composites are good candidates for detoxification of water contaminants. Herein, we report pectin@Fe_3O_4-La_2O_3 (PFLO) beads for the selective adsorption of aqueous Co(II) ions. The synthesized PFLO beads are eco-friendly, low-cost, easy to handle, simple, and have good adsorption selectivity. The Co(II) adsorption was well fitted by Langmuir and Pseudo-second-order kinetic models. Response surface modeling (RSM) was used to examine the adsorption process of PFLO beads for Co(II) adsorption. Different characterization techniques were used to explain the fabrication and adsorption mechanism i.e., XPS, XRD, FTIR, BET, FESEM, EDAX, and TGA. The monolayer adsorption capacity of synthesized PFLO beads at 318 K was found to be 344.82 mg/g. The thermodynamic studies demonstrate the adsorption process is spontaneous, workable, and endothermic. Teabag's experiment shows the commercial application of the adsorbent. The PFLO beads nanocomposite maintains 74% reusability for Co(II) adsorption even after five cycles. The developed PFLO nanocomposites can be used as potential adsorbents for effective, reproducible and selective adsorption of aqueous Co(II). This paper will be beneficial for researchers working towards further improving water purification technologies.

1. Introduction

The heavy metal ion concentration in wastewater is increasing due to industrial development, especially in the nonferrous metallurgy and mining industries. The industries discharge wastewaters have various types of lethal heavy metal ions (Singh et al., 2022a), battery manufacturing, tanneries industries (Imdad and Dohare, 2022), mining operations (Song et al., 2022) and nuclear power plants (Choudhury et al., 2022). Various toxic heavy metal ions, for example, Co(II), Pb(II), Hg(II), Cd(II), and Cr(VI), are associated with these activities. The accumulation of heavy metals in living organisms is hazardous to human health. It causes lung irritations, diarrhea, mutations in living cells, paralysis, low blood pressure, and bone defects (Singh et al., 2022b). Among these heavy metal ions, Co(II) metal ions occur in various forms in many salts. It is extensively used in semiconductors and enamels as a foam stabilizer in beer. It is also used as a driver for lacquers, paints and varnishes, painting on porcelain and glass, electroplating and hygrometers, in nuclear medicine, in manufacturing of vitamin B_{12}, as a catalyst for organic chemical reactions, and in grinding wheels. We are exposed to the minute amount of Co(II) ions through food, water, and air uptake. The Environmental Bureau of Investigation sets 0.05 and 1.0 mg/L as the permissible limits for irrigation water and livestock watering for Co(II) ions, respectively. Co(II), in small amounts, is vital for animal, plant, and human metabolic processes (Zhao et al., 2022). Likewise, nuclear power reactors are an essential source for releasing ^{60}Co from pressurized water. It is widely used for industrial and medical applications (Glukhoedov et al., 2022). The adsorption of Co(II) heavy metal ions from the aqueous media is vital for hazardous nuclear waste management.

A plenty of materials have been utilized as adsorbents for contaminant remediation, such as aminonaphthalenesulfonic acid modified magnetic-graphene oxide (Alsohaimi et al., 2023), activated carbon-layered double hydroxide (Aldawsari et al., 2021a), aminoterephthalic acid modified oxidized activated carbon (Aldawsari et al., 2021b),

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