Removal of cobalt(II) ion from water by adsorption using intact and modified *Ficus carica* leaves as low-cost natural sorbent

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Received 28 May 2015; Accepted 28 September 2015

**ABSTRACT**

A series of experiments were carried out in a batch system to assess the removal of cobalt ion (Co\textsuperscript{2+}) by intact and modified *Ficus carica* leaves (FCLs) from the aqueous solutions in laboratory experiments. Adsorption kinetics and thermodynamic parameters, as well as equilibrium adsorption isotherms, were examined. The effects of pH, initial concentration of metal ions, biosorbent dose, and the treatment of biosorbent on the biosorption process were also studied. Results showed that the optimum uptake (20.2 mg/g with the removal efficiency of 31.02%) was reached at pH 4. It was also found that the FCLs treated with MgCl\textsubscript{2} caused an increase in the uptake capacity, 33.9 mg/g (q\textsubscript{exp}) at pH 6, and removal efficiency was 57.15%. The biosorption data followed the Freundlich ($R^2 = 0.974$), Langmuir ($R^2 = 0.978$), Dubinin–Radushkevich ($R^2 = 0.982$), and Temkin ($R^2 = 0.915$) isotherms. Langmuir, Freundlich, and Dubinin–Radushkevich models exhibited a higher and better fit of the data. The Freundlich constants $K_f$ and $n$ were found to be 0.75 and 1.014, respectively, and the maximum sorption capacity ($q_{max}$) was 82.64 mg/g. Dubinin–Radushkevich parameters were $K_{D-R} = 0.00142$, $X_m = 0.0067$ mol/g, and $E_{D-R}$ value was 18.782 kJ/mol. The overall biosorption process of Co\textsuperscript{2+} ion was best described by pseudo-second-order kinetic model. The negative $\Delta G^\ominus$ ($-0.124$) observed at 20°C revealed that biosorption of Co\textsuperscript{2+} ions onto FCLs was spontaneous at this temperature. Thermodynamic studies also demonstrated positive $\Delta S^\ominus$ (+0.705), showing increased disorder of the cobalt ion removal process. Ion-exchange mechanism and dominant sorption functional groups determination accomplished using Fourier transform infrared (FTIR) and X-ray fluorescence (XRF) techniques, and hence pseudo-second-order kinetic model. The results from this study showed the raw and modified FCLs are a new biomass for the removal of Co\textsuperscript{2+} from aqueous solutions.

**Keywords:** Cobalt; Removal; *Ficus carica*; Kinetics; XRF; FTIR