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Mechanism of Hexavalent Chromium Adsorption-Desorption by Blue-Green Algae and Its Potential Application to Wastewater

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Cr(VI) is a toxic and mobile oxyanion in many industrial wastewaters, yet conventional treatments often require chemical reagents and generate secondary wastes. In this study, Blue-green algae (Leptolyngbya sp.) sheets were evaluated as a low-cost biosorbent, and the uptake mechanism was examined by integrating macroscopic adsorption behavior with surface chemical analyses. Dried and formed algal sheets were cut into 1–2 mm pieces and tested in batch systems at 25 °C with ionic strength adjusted to 0.05 M (NaCl).

The effects of initial pH (2, 6, 11), contact time (up to 24 h), and initial Cr(VI) concentration (5–1500 mg/L as Na_2CrO_4) were investigated to cover both environmentally relevant and higher-concentration regimes. Adsorption was markedly enhanced at pH 2, consistent with electrostatic attraction between protonated surface functional groups and dominant Cr(VI) oxyanions under acidic conditions. Time-dependent uptake exhibited a sigmoidal profile, and the Avrami equation models provided the best fit, suggesting time-evolving accessibility of sorption sites, associated with diffusion within the sheet matrix. Equilibrium data were described by heterogeneous isotherm models, indicating the presence of surface sites with different apparent affinities.

Spectroscopic analyses provided supporting evidence for surface interactions and chromium retention. FT-IR showed reproducible changes in hydroxyl- and carboxylate-related bands after adsorption, while XPS Cr 2p spectra indicated Cr(III) as the dominant surface species. These results suggest possible surface-mediated reduction of Cr(VI) in association with the biosorbent, even under conditions where aqueous Cr(VI) is thermodynamically stable. Alkaline desorption recovered nearly all adsorbed chromium (≈99% with 1 M NaOH), whereas acidic desorption remained limited, supporting a pH-switchable adsorption–desorption scheme.

Overall, the results indicate that Blue-green algae sheets can effectively remove Cr(VI) under acidic conditions and enable high-yield recovery, providing mechanistic insight into recyclable biosorption processes for chromium-bearing wastewaters.