Lead removal from contaminated water: comparative study of *Sargassum spp*. biomass and synthetic Geopolymer adsorbents

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Heavy metal contamination in water sources represents a critical environmental challenge, necessitating the development of efficient and sustainable remediation technologies. Among these, adsorption has emerged as a promising method for the removal of toxic metals such as lead (Pb). This work focuses on the preparation and characterization of two distinct adsorbent materials: *Sargassum spp*., a natural marine biomass, and a laboratory-synthesized geopolymer. The aim was to evaluate their physical, chemical, and adsorption properties to determine their effectiveness in removing lead from aqueous solutions. The *Sargassum spp.* biomass underwent thorough characterization using X-ray diffraction (XRD) to assess crystallinity, Fourier-transform infrared spectroscopy (FT-IR) to identify functional groups involved in metal binding and scanning electron microscopy (SEM) to examine surface morphology. Results indicated a porous structure rich in functional sites favourable for metal ion adsorption. Adsorption experiments revealed that *Sargassum ssp.* efficiently removed lead, achieving an adsorption efficiency of 86.87% after one hour at 50 ppm, and 94.90% at 300 ppm. These findings confirm the potential of *Sargassum ssp.* as a natural and effective adsorbent for lead-contaminated water treatment. Similarly, the synthesized geopolymer demonstrated outstanding adsorption performance. At 50 ppm lead concentration, it removed over 92% of Pb within just 5 minutes, reaching over 99% removal after 60 minutes. At higher concentrations (100, 150, 200, and 300 ppm), despite a slower initial adsorption rate, lead removal rapidly increased over time, achieving approximately 99% efficiency. Remarkably, at 200 and 300 ppm, the geopolymer removed 98.77% and 97.40% of lead, respectively, underscoring its high effectiveness even under challenging conditions. These results highlight the promise of both *Sargassum ssp*. and the geopolymer as highly efficient adsorbents for lead removal. Combining natural and synthetic materials presents a sustainable and innovative approach to treating heavy metal-contaminated industrial wastewater.

Keywords: *Heavy metal contamination; Lead adsorption; Sargassum biomass; Synthetic geopolymer; Sustainable water treatment*