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Brown Seaweed as a potential contender for Green Energy and Sustainable Chemical Processes.

The extended emphasis on environmental sustainability and green chemistry principles has driven noteworthy interest in biopolymer-based materials as a substitute for conventional synthetic polymers. Sodium alginate, a naturally derived anionic polysaccharide extracted from brown seaweed, has positioned itself as an excellent specimen of sustainable material design, encompassing the core ideals of green chemistry through its renewable origin, biodegradability, non-toxicity, and versatile functionality. This all-inclusive review examines the role of sodium alginate in progressing green chemistry and sustainable chemical processes, with special focus on its implementations in environmental remediation, materials science, and energy storage. This review critically analyzes the synthesis strategies for sodium alginate-based materials, highlighting low-toxicity and cost-effective preparation methods that align with green chemistry principles. We assess the efficacy of sodium alginate composites in water treatment applications, including heavy metal ion removal, organic pollutant adsorption, and oil-water separation, demonstrating their potential to replace current non-biodegradable separation materials. Furthermore, the review explores the incorporation of sodium alginate in energy storage systems as electrodes, electrolytes, separators, and binders, displaying a promising potential in sustainable energy technologies. Special attention is given to regeneration and recyclability strategies, waste valorization approaches, and life cycle considerations that support circular economy principles. The challenges and opportunities for scaling up sodium alginate-based technologies are discussed, along with future directions for enhancing material performance while maintaining environmentalcompatibility. This review offers valuable insights for researchers, scientists,
and engineers looking to implement sustainable chemical processes and materials, placing sodium alginate as an ideal material for the transition toward a more sustainable chemical industry.

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