Layer-by-layer Assembled Polyelectrolyte-based Bead Bio-composites: Advanced Materials for Enhanced Adsorption

Dr. Sougat Das[a] *, Dr. Martina Salzano de Luna*[a]

[a]*Department of Chemical, Materials and Industrial Production Engineering, University of Naples Federico II,*

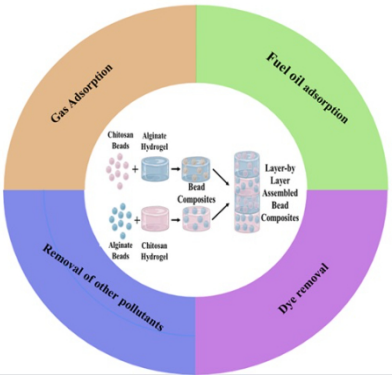
sougat.das@unina.it

While traditional wastewater treatments like ion exchange and chemical precipitation are effective, they are often costly and risk secondary pollution. Biopolymeric hydrogels offer a greener alternative but lack the necessary porosity and mechanical strength. [1] These limitations can be overcome by utilizing **polyelectrolyte-based composites** . [2] These charged polymer structures leverage specific intermolecular forces to significantly enhance pollutant adsorption. Beyond water treatment, their high porosity makes them versatile for applications like **fuel-oil recovery** and **gas adsorption** .

In this study, two different polyelectrolytes, chitosan and alginate, were used to prepare composites to increase the suitability of the materials for a broad range of applications. As positively and negatively charged polyelectrolytes, chitosan and alginate can be used for the adsorption of negatively and positively charged pollutants based on electrostatic attractions. Furthermore, hydrogen bonding also plays a vital role in adsorption. Chitosan, which is hydrophobic (depending on its acetylation degree), also contributes to the adsorption of hydrophobic pollutants. Polymeric beads were introduced into the system to induce porosity in the hydrogel. The composites were prepared using a combination of two types of materials: polymeric beads and hydrogels. Chitosan-based polymeric beads were prepared by cross-linking chitosan with sodium tripolyphosphate, and alginate-based beads were prepared by cross-linking alginate with calcium chloride. The chitosan beads were then added to the alginate solution and then frozen followed by cross-linking with calcium chloride to prepare the composite A. In a similar way, the alginate beads were added to the chitosan solution and then frozen followed by cross-linking with sodium tripolyphosphate to prepare the composite B. The layer-by-layer assembled composite was prepared by first preparing composite A then, adding the solution of composite B followed by freezing and cross-linking it to prepare the final material. Furthermore, this material showed promising results for gas adsorption and fuel oil adsorption.

With 98% efficiency for both anionic and cationic dyes, these multilayered composites leverage diverse intermolecular forces for superior performance. Their extended lifespan stems from **reversible ionic cross-linking** : bonds break during desorption and reform during adsorption. Ultimately, this high-porosity "universal material" offers a robust, reusable solution for broad pollutant removal.

Keywords:
Adsorption, Alginate, Chitosan, hydrogel



Composite for diverse pollutant removal

References:

[1] Hansima, M. A. C. K. *et al.* Fouling of ion exchange membranes used in the electrodialysis reversal advanced water treatment: A review. *Chemosphere* **263** , 127951 (2021).

[2] Gyles, D. A., Castro, L. D., Silva, J. O. C. & Ribeiro-Costa, R. M. A review of the designs and prominent biomedical advances of natural and synthetic hydrogel formulations. *Eur. Polym. J.* **88** , 373–392 (2017).

Acknowledgements:
This work has been founded by the Italian Ministry of University and Research D.D. N. 23314 11/12/2024 – CALL FIS 2 (PROJECT N. FIS-2023-01757 – POLYNEW).