DOI: http://doi.org/10.21698/simi.2026.ab05

DEVELOPMENT AND CHARACTERIZATION OF AN ALGINATE-BASED BIOSORBENT FROM RESIDUAL MICROALGAL–BACTERIAL BIOMASS

Tatiana Dragomir (Buse)[1,2,*], Olga Tiron[1], Mihai Nita-Lazar[1,3]

[1]National Research and Development Institute for Industrial Ecology-ECOIND, 57-73 Drumul Podu Dambovitei, district 6, 060652, Bucharest, tatiana.buse@ecoind.ro, Romania
[2]Faculty of Biotechnical Systems Engineering, National University of Science and Technology Politehnica Bucharest, tatiana.buse@ecoind.ro, Romania
[3]National University of Science and Technology Politehnica Bucharest, Splaiul Independentei 313, 060042, Bucharest, Romania

**corresponding author: tatiana.buse@ecoind.ro*

Keywords: *biosorbent, heavy metals, microalgal–bacterial biomass, residual biomass, sodium alginate*

Introduction

The residual microalgal-bacterial biomass generated during wastewater treatment represents a biological resource with considerable potential for further valorization. Although this biomass has fulfilled its primary role in the removal of nutrients and organic matter, its complex biochemical composition and the presence of various functional groups make it a promising raw material for biosorbent development. However, its direct application in suspended form may be limited by the difficulty of separation and recovery after metal removal. Immobilization in natural polymer matrices provides a practical approach for converting dispersed biomass into an easily recoverable form. Sodium alginate is a biodegradable and non-toxic polysaccharide widely used for biomass immobilization due to its ability to form hydrogels under mild conditions, particularly in the presence of Ca^{2+} ions, which promote the formation of three-dimensional matrices containing the biological material.

In this context, the present study focused on the development of a sodium alginate-based biosorbent using residual microalgal-bacterial biomass recovered from wastewater treatment processes in order to remove heavy metals (Zn(II) and Ni(II)) under different experimental conditions.

Materials and methods

Residual microalgal-bacterial biomass recovered after wastewater treatment was dried at 80 °C and ground. Particle size analysis using a Mastersizer indicated that 65.29% of the particles were within the 2.884–5.012 µm range. A 2% (w/v) sodium alginate solution was prepared and mixed with the dried residual biomass until a homogeneous suspension was obtained. The resulting mixture was introduced dropwise using a syringe into a $CaCl_2$ solution. Contact with Ca^{2+} ions induced ionic crosslinking of the alginate, resulting in the formation of spherical polymer-biomass granules. After immobilization, the granules were maintained in the $CaCl_2$ solution for stabilization and subsequently washed with ultrapure water before use.

The morphology of the obtained alginate-biomass granules was examined by scanning electron microscopy (SEM), with particular attention to the incorporation of the biological material within the polymer matrix. The total protein concentration of the residual microalgal–bacterial biomass was determined using the Lowry method with the Bio-Rad DC Protein Assay.

The developed material was evaluated in batch biosorption experiments using Zn(II) and Ni(II) solutionsThe effect of pH on metal removal was evaluated over the range of 3–10. Equilibrium experiments were subsequently performed using initial metal concentrations ranging from 5 to 60 mg L^{-1} for Zn(II) and from 5 to 30 mg L^{-1} for Ni(II). The experimental equilibrium data were evaluated using the Langmuir and Freundlich adsorption isotherm models.

Results and conclusions

Biosorbent Characterization

Optical microscopy revealed the presence of diverse microalgal and microbial morphologies, including *Chlorella sp., Lobochlamys segnis, Phormidium sp*., and *Klebsormidium sp*., as well as diatoms and associated bacterial biomass. SEM analysis showed that the obtained granules exhibited a rough and porous external morphology. The examination of the material also revealed biological structures associated with the original consortium, including filamentous microorganisms and diatom structures, indicating the incorporation of heterogeneous residual biomass into the alginate matrix. The protein content of the residual biomass was approximately 31%, indicating that a considerable fraction of proteinaceous material remained present after its previous use in wastewater treatment. The proteins contain several functional groups that may contribute to interactions with metal ions.

Biosorption Performance

Batch biosorption experiments were conducted to evaluate the applicability of the developed granular material for heavy metal removal. The influence of pH showed an optimum value of 4 for both Zn(II) and Ni(II). The remaining experimental results are presented in Table 1.

Table 1– Isotherm parameters of the Langmuir and Freundlich models for Zn(II) and Ni(II) biosorption onto immobilized and suspended microalgal–bacterial biomass

Heavy metals	Langmuir isotherm constants				Freundlich isotherm constants			
	q_{max} (mg g^{-1})	K_L (L mg^{-1})	R^2	*RMSE*	K_F (L g^{-1})	*n*	R^2	*RMSE*
Zn^{2+}								
Immobilized	16.20	0.52	0.97	0.67	6.33	3.85	0.73	2.13
Suspended	9.17	0.36	0.92	0.65	3.35	3.51	0.79	1.10
Ni^{2+}								
Immobilized	12.07	0.41	0.95	0.47	4.03	2.44	0.95	0.49
Suspended	5.46	0.10	0.77	0.44	0.82	1.97	0.70	0.50

The residual microalgal-bacterial biomass was successfully immobilized in a sodium alginate matrix, forming spherical granules with a rough and porous surface. The developed biosorbent showed potential for Zn(II) and Ni(II) removal, with maximum adsorption capacities of 16.20 and 12.07 mg g^{-1}, respectively. These results demonstrate the potential of immobilized residual biomass as an easily recoverable biosorbent and support its valorization within circular approaches for water treatment.