Advancing bacterial cellulose biopolymers & hydrogels to remediate microplastic pollution

César Cunha*[1], Marisa Faria†[2,3], Ivana Mendonça[4], and Nereida Cordeiro[5,6,7]

[1]Laboratory of Bioanalysis, Biomaterials am Biotechnology - Faculty of Science and Engineering, University of Madeira – Campus Universitário da Penteada 9000-390 Funchal Portugal, Portugal

[2]Laboratory of Bioanalysis, Biomaterials am Biotechnology - Faculty of Science and Engineering, University of Madeira – 9020-105 Funchal, Portugal

[3]CIIMAR - Interdisciplinary Centre of Marine and Environmental Research, University of Porto – 4450-208 Matosinhos, Portugal

[4]Laboratory of Bioanalysis, Biomaterials am Biotechnology - Faculty of Science and Engineering, University of Madeira – Campus Universitário da Penteada 9000-390 Funchal Portugal, Portugal

[5]University of Madeira [Funchal] – Campus Universitário da Penteada 9000-390 Funchal Portugal, Portugal

[6]Oceanic Observatory of Madeira - ARDITI – 9020-105 Funchal, Portugal, Portugal

[7]CIIMAR - Interdisciplinary Centre of Marine and Environmental Research, University of Porto – 4450-208 Matosinhos, Portugal, Portugal

Abstract

Microplastics (MPs) pollution has become one of the most impactful problems of our generation, with wastewater treatment plants (WWTPs) being considered one of the central sources of the issue. Current filtration systems rely on non-biodegradable fossil-based polymeric filters whose maintenance procedures are environmentally damaging. As the focus to develop sustainable filtration solutions increases, years of R&D lead to the conception of bacterial cellulose (BC) biopolymers and hydrogels as potential bioflocculants of MPs. These naturally secreted polymers display unique features for biotechnological applications, such as straightforward production, large surface areas, biodegradability, and utilitarian circularity. To fully explore its economic and logistics potential in large-scale industrial settings, an array of semi-dried and fully dried BC biopolymers and hydrogels were studied. Also, several operational parameters influencing MPs flocculation and dispersion were evaluated. To streamline the translation to the industry, a response surface methodology (RSM) was computed to understand how these parameters influence the flocculation process. Diligently, techniques such as flow cytometry, scanning electron and fluorescence microscopy, UV-Vis, ATR-FTIR, IGC, and water uptake assays were used to characterize the BC and evaluate the remediation potential of highly concentrated MPs. Results show that BC biopolymers display removal efficiencies of MPs of up to 99%, far outperforming dispersive commercial bioflocculants like xanthan gum and alginate while maintaining high performance for several continuous cycles. The use of more economically- and logistics-favourable dried BC biopolymers preserves their physicochemical properties while maintaining high efficiency (93-96%).

*Corresponding author: cesar.cunha@staff.uma.pt

†Speaker

Short exposure times (5 min) were sufficient to drive robust particle aggregation. The RSM showed high reliability in predicting flocculation performance, unveiling that the BC:MPs ratio and grinding times of the hydrogel were the most critical variables modulating flocculation rates. In sum, this pilot study provides clear evidence that BC biopolymers are high performing, sustainable alternatives to synthetic filtration technologies.

Keywords: Bacterial Cellulose, Biopolymers, Hydrogels Microplastics, Environmental Biotechnology, Sustainability