Nano-structuration and functionalization of cellulose acetate membrane for advanced water purification

Abdelkrim Belasri[1], Amina Boukrim[2], Omar Lakbita[3], Abdellah Bakka[1,2], Benaissa Rhouta[2], Mohammed Lahcini[2,4], Redouane Beniazza[1], Taha El Assimi[1,2]

[1] Institute of Science, Technology & Innovation (IST&I), Mohammed VI Polytechnic University (UM6P), 43150 Ben Guerir, Morocco.
[2] IMED-Lab, Faculty of Sciences and Techniques, Cadi Ayyad University, 40000 Marrakech, Morocco.
[3] Applied Chemistry & Engineering Research Centre of Excellence (ACER CoE), Mohammed VI Polytechnic University (UM6P), 43150 Ben Guerir, Morocco.
[4] Department of Chemical and Biochemical Sciences - Green Process Engineering (CBS), Mohammed VI Polytechnic University (UM6P), 43150 Ben Guerir, Morocco
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Presenting author email: **abdelkarim.belasri@um6p.ma**

Abstract

The development of sustainable nanostructured materials for water purification remains a crutial challenge in environmental remediation (Liberty et al. 2024)(Saud et al. 2024). In this study, cellulose acetate (CA) nanofibrous membranes were fabricated using an electrospinning method (Zhang et al. 2018) and subsequently functionalized for dual-purpose decontamination: (*i*) photodegradation of organic pollutants (orange G dye) and (*ii*) selective adsorption of heavy metals (Cd^{2+}, Cu^{2+}, Ni^{2+}). Sulfur-doped titanium dioxide (TiO_2-S) (Lakbita, n.d.) nanoparticles previously prepared were integrated into the CA matrix to enhance visible-light-driven degradation of Orange G dye, achieving over 85% degradation within 60 minutes under ambient light conditions. A secondary functionalization, via silanization with (3-aminopropyl) triethoxysilane (APTES), facilitated efficient heavy metal capture through amine complexation, with adsorption capacities reaching 70 mg/g. In addition, the membranes were extensively characterized using FTIR, XRD, SEM-EDX, TGA, and zeta potential analysis to confirm successful functionalization and nanofiber stability. Morphological analysis revealed uniform nanofiber structures with diameters ranging from 200 nm to 1 µm, while XRD confirmed the dominance of the anatase phase in TiO_2-S, which is essential for photocatalytic activity. TGA analysis further demonstrated enhanced thermal stability with increased TiO_2-S content. Overall, the results underscore the potential of functionalized nanomembranes for water purification. By integrating biopolymer-based nanostructures with tailored functionalities, this study opens the way for combining photodegradation with efficient heavy metal capture in a single membrane.

Graphical abstract

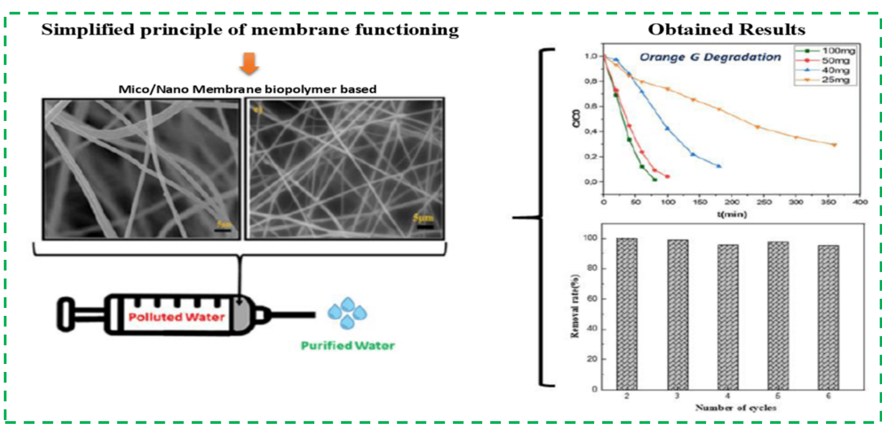

Figure 1. Simplified principle of membrane functioning.

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