Surface-Functionalised Hydrogels Incorporating Organoclay–Phloxine B Films

Vinny George[1], and Juraj Bujdak[1,2].

[1]Slovak Academy of Science, Institute of Inorganic Chemistry, Bratislava, Slovak Republic.

[2]Comenius University in Bratislava, Faculty of Natural Sciences, Department of Physical and Theoretical Chemistry.

The escalating problem of antimicrobial resistance has accelerated the need for novel treatment strategies. Among the most promising alternatives, photodynamic inactivation (PDI) offers an antibiotic-free method for efficiently eliminating pathogenic microorganisms. Hydrogels have gained recognition as versatile carriers for photosensitisers (PS) in PDI applications; however, their clinical translation remains limited, with ongoing research exploring a wide range of formulations and systems. On the other hand, smectites represent low-cost, environmentally sustainable inorganic hosts that can stabilise photosensitisers by preserving their fluorescence, reducing photodegradation, and enhancing photoactivity. Combining these two host systems—hydrogels and smectites—provides an opportunity to create advanced nanocomposite materials with improved stability, functionality, and therapeutic potential for antimicrobial applications.

In this study, the photosensitiser phloxine B (PhB) was intercalated into synthetic saponite (Sap) modified with surfactant, forming the primary nanostructured host. Thin films on the micrometre scale were fabricated via vacuum filtration and subsequently integrated with a poly(vinyl alcohol) (PVA) hydrogel precursor solution containing glycerol as a crosslinker. Casting the precursor onto the freshly prepared films enabled partial penetration of the polymer solution into the organoclay layer, and crosslinking led to the formation of a nanocomposite surface layer, yielding surface-functionalised hydrogels. This fabrication route allows more precise localisation of PS at the hydrogel surface compared to bulk loading, thereby maximising local photoactivity.

Spectroscopic analysis confirmed that increasing PhB incorporation enhanced absorbance, while fluorescence intensity decreased due to molecular aggregation and concentration quenching. X-ray diffraction indicated structural modifications upon PhB intercalation and composite formation, while X-ray tomography revealed significant swelling of the hydrated film, with PVA chains intercalating between clay lamellae and expanding the thickness far beyond that of the dry film. Infrared spectroscopy further confirmed the presence of all components without any significant chemical transformations. Overall, this surface-engineering strategy introduces a straightforward route for controlled photosensitiser loading and concentrating photoactive species at the interface, offering a pathway toward more efficient and therapeutically effective PDI-based antimicrobial materials.

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