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Bioinspired catalytic support for greener water treatment processes

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PURPOSE OF THE ABSTRACT

Introduction:

Due to an intensive phase of worldwide urbanisation, an accumulation of populations and activities, microbiological and chemical pollutants increase in water. In this context, the main objective of this work is to develop a simple solution for pollutants removal from water based on ?green? materials. We propose a photo-reactor filled with bioinspired catalytic foams combined with visible light and/or UV LEDs for the elimination of pathogenic microorganisms, such as bacteria, mushrooms and viruses, and the degradation of pollutants like pharmaceuticals, pesticides, endocrine disruptors, and dyes.

Material and method:

Based on the adhesive properties of marine mussels' (Mytilus edulis) foot proteins, Lee et al.[1] proposed to use a naturally abundant molecule with similar redox groups, named dopamine, which can polymerise spontaneously in a slightly alkaline aqueous solution thanks to dissolved dioxygen (named polydopamine, PDA), with equivalent adhesive and redox properties. Inspired by our previous works [2-3], we propose an original PDA coating on commercial open-cell polyurethane foams (OCPUF) with specific catalytic properties for water treatment processes. OCPUF is an ideal structured catalytic support because it allows a good light permeation and a low pressure drop, making it a pertinent choice for applications in photo-reactor.

An original route of OCPUF functionalisation is proposed for the first time in this work (Fig. 1): This approach is referred to as ?direct route?, which is a one-step synthesis of pre-functionalised PDA by dip-coating, carried out by adding a chemical oxidant containing a metal of interest (e.g. Ag, Cu?). Once in solution, the metal ions are incorporated into the PDA polymer film during its formation. The resulting tool is an active pre-functionalised PDA foam. This original route is inspired by a two-step approach (PDA coating followed by functionalisation of the PDA film) referred to as the direct route and described by Lefebvre et al. [3].
Polyurethane foams are easily cleaned after usage by dipping into an alkaline aqueous solution [5], which depolymerises PDA, making it a sustainable solution.

Results:

Fig. 2 (A, B, C, D, E) shows that resulting foams have PDA films with different structure and roughness. EDX

analyses demonstrate the presence of the metals of interest incorporated into the PDA polymer, which validates the efficacy of this original synthesis route.

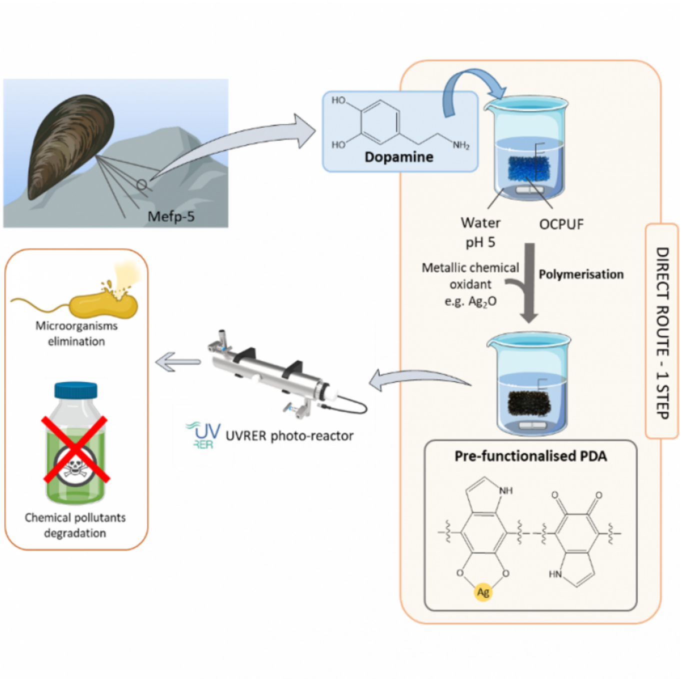
The impact of the functionalised and pre-functionalised OCPUF on the growth of pathogenic microorganisms found in wastewaters are presented for the first time in this work. Fig. 2 (F) shows the evolution of a bacterial culture of S. aureus in presence of PDA coated OCPUF (OCPUF@PDA(O2)) and pre-functionalised OCPUF@PDA(NaI, Cu, Ag). It can be clearly seen that OCPUF@PDA(NaIO4) induces a slower growth rate with 99% less colonies at 7h compared to the control or OCPUF@PDA(O2). OCPUF@PDA(Ag2O) has a bactericidal effect on the culture as the initial population decreases of more than 99% after 7h of contact with the foam, and OCPUF@PDA(CuSO4) also has a bactericidal effect with a drop of 90% of the bacterial population between 7h and 24h.

Based on these exciting results, the photocatalytic activity of the functionalised OCPUF@PDA foams are also tested on a cocktail of pollutants found in significant amount in wastewaters. The results will be presented in this communication.

Conclusion:

A simple and easy route for cheap commercial OCPUF functionalisation by dip coating was successfully developed and allow to propose an eco-friendly water treatment device. It was demonstrated that OCPUF@PDA pre-functionalised with silver nanoparticles has a bactericidal effect and it was shown that OCPUF@PDA(NaIO4) can considerably reduce bacterial growth rate. The adhesive properties of this catalytic support are crucial to prevent nanoparticles leaking in the environment.

FIGURES



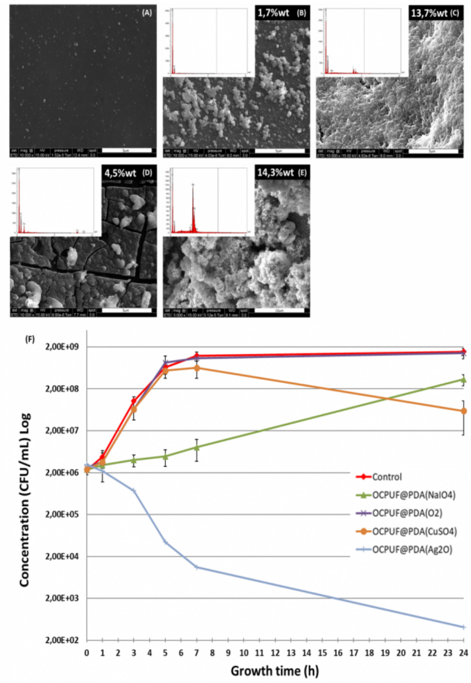


FIGURE 1

One step original approach for OCPUF functionalisation

FIGURE 2

SEM images of bare and functionalised OCPUF@PDA with corresponding EDX, PDA masses (%wt), and antibacterial activity: (A)OCPUF, (B)OCPUF@PDA(O2), (C)OCPUF@PDA(NaIO4), (D)OCPUF@PDA(CuSO4), (E)OCPUF@PDA(Ag2O) and (F) S. aureus 24h activity tests

KEYWORDS

Water treatment | Polydopamine | Photocatalysis | Antibacterial

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