Immobilizing catalysts on textiles- case of zerovalent iron and glucose oxidase enzyme

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Abstract

Catalytic systems are one of the most effective technologies of modern chemical processes. The system uses a molecule called 'catalysts' that is capable of catalyzing a reaction without being produced or consumed during the process. A catalytic system requires the separation of catalysts from products after each cycle, which is an expensive and resource-intensive process. The purpose of catalyst immobilization is to ensure easy separation of the catalysts from the system and provide subsequent reusability. However, in many cases, the preparation of the support material is energy-intensive and more expensive than the catalysts themselves as it requires exclusive support material involving a complex preparation process. Therefore, this doctoral thesis focuses on an innovative concept of using textile as an inexpensive support material for the immobilization of an inorganic catalyst (zerovalent iron-Fe^0) and a biocatalyst (glucose oxidase -GOx).

This thesis aims to establish the feasibility of textile as support material for immobilization of catalysts in the pursuit of fabrication of robust catalytic system (oxidative and reductive) for wastewater treatment. Polyester nonwoven fabric (PF) was chosen as textile support material for immobilization of both catalysts. A combination of eco-friendly and resource-efficient processes (such as plasma treatment, use of hyperbranched dendrimer, bio-based polymers) was used for modification of PF surface with favorable surface properties in the view of high and stable immobilization yield of Fe^0 and GOx while preserving their inherent catalytic performance. Results showed successful activation of PF through plasma treatment and realization of the modified surface with tailor-made functionality. Regarding the immobilization of Fe^0 on a PF surface, the results revealed that reduction methods (in-situ or ex-situ) of producing Fe^0 particles and surface functionality of textile support material have synergistic effects on the success of immobilization in terms of morphology, stability, particle size, and particle distribution. Resultant Fe^0-immobilized PF showed high catalytic activities in the removal of toxic water pollutants either in heterogeneous Fenton/Fenton-like, catalytic reduction systems or in pathogen inhibition systems. In the case of GOx-immobilization in textiles, tailor-made PF surface with amine functional groups has found to be more effective in securing high loading and the stability of immobilized GOx. Finally, as a proof of concept, this thesis also reveals the first successful design of a complete heterogeneous bio-Fenton system for wastewater treatment using immobilized catalysts (Fe^0 and GOx).

The novelty of the research presented in this doctoral thesis is primarily attributed to the novelty of immobilizing two types of catalysts (inorganic catalyst and biocatalysts) on polyester nonwoven fabric for wastewater treatment application. In general, this thesis contributes to general knowledge of heterogeneous catalytic system, Fenton/Fenton-like system, and the bio-Fenton system as well as opens the promising prospect of using textile as support material for immobilizing various catalysts for a wide range of application.

Keywords : Biocatalysis; Bio-Fenton; Catalysts immobilization; Environmental remediation; Fenton-like system, Glucose oxidase; Heterogeneous catalysts; Pollutants removal; Plasma eco-technology; Polyester textile; Textile surface modification; Textile catalyst; Wastewater treatment; Zerovalent iron;