Nanotechnology-Based Membrane Systems for Detoxification for Chlorinated Organics from Water

D. Bhattacharyya, J. Xu, D. Meyer, Y. Tee, L. Bachas, Department of Chemical and Materials Engineering, University of Kentucky, USA

The development of nano-sized materials has brought important and promising techniques into the field of environmental remediation of chlorinated organics. Nanostructured metals have become an important class of materials in the field of catalysis, optical, electronic, magnetic and biological devices due to the unique physical and chemical properties. Extensive studies have been reported on the degradation of toxic chlorinated organics (such as, TCE, PCB) with nonimmobilized Fe0 based bulk/nano particles. Work involving reductive dechlorination involved the use of bimetallic (Fe/Ni, and Fe/Pd) nanoparticle systems, both membrane-supported and direct aqueous-phase synthesis. The nanosized metals precipitated from solutions are extremely reactive due to the high surface energy, and they usually form aggregates without the protection of their surface. Therefore, immobilization of metal nanoparticles in polymer membrane (such as, cellulose acetate, PVDF, polysulfone, chitosan, etc,) media is important from the point of view of reactivity, organic partitioning, preventing loss of nanoparticles, and reduction of surface passivation. Another major advantage of having a polymer domain is that nanoparticles (without causing agglomeration) can be directly synthesized in the matrix.

We report a novel in-situ synthesis method of bimetallic nanoparticles (< 40 nm) embedded in polyacrylic acid (PAA) functionalized microfiltration type membranes by chemical reduction of metal ions bound to the carboxylic acid groups. Polymer immobilization eliminates worker exposure issues relating to nanoparticles. We demonstrated complete (with product and intermediates analysis) dechlorination of trichloroethylene (TCE) and selected PCBs by nanosized metals. The 2nd dopant metal (such as, Ni, Pd) plays a very important role in terms of catalytic property (hydrodechlorination) and the significant minimization of intermediates formation. In addition to the rapid degradation (by Fe/Ni) of TCE (trichloroethylene) to ethane, we were also able to achieve complete dechlorination of selected chloro-biphenyls (PCBs) using milligram quantities immobilized Fe/Pd nanoparticles in membrane domain. In order to predict detoxification reactions at different conditions, a two-dimensional steady state model was developed to correlate and simulate mass transfer and reaction in the membrane pores under convective flow mode. The 2-D equations were solved by COMSOL (Femlab). The influence of changing parameters such as, membrane pore size and Pd coating composition were evaluated by the model and compared well with the experimental data. The role of hydrogen generation by the Fe corrosion reaction and the surface reactivity will also be discussed. This research has been supported by the NIEHS – SBRP program and by the U.S. EPA STAR Grant.