Membrane-Iron Oxide Nanoparticle Based Reactor for Toxic Organic Degradation

Minghui Gui¹, Lindell E. Ormsbee² and Dibakar Bhattacharyya¹

1. Department of Chemical and Materials Engineering, University of Kentucky
2. Department of Civil Engineering, University of Kentucky

Introduction

The removal of chlorinated organic contaminants from the Superfund sites has always been a critical issue. The use of reductive pathway (such as with Fe/Pd nanoparticles, NPs) to degrade trichloroethylene (TCE) and polychlorinated biphenyls (PCBs) is an attractive technology. To eliminate NP loss, agglomeration issues, and metal leaching, different supports like membranes provide significant advantages. However, the reduction product of PCBs (biphenyl) is still mildly toxic. In order to detoxify PCBs to non-chlorinated and non-toxic products, a combination of reductive and oxidative treatment (PCB→Biphenyl→Organic acids) is desirable. We developed the reactive membrane system with Fe/Pd NPs synthesized in polyacrylic acid (PAA) functionalized polyvinylidene fluoride (PVDF) microfiltration membranes. By the development of reactive membranes, we studied the detoxification of 2-chlorobiphenyl to biphenyl first by reductive dechlorination. Depending on the Fe/Pd NP loading, the complete hydrodechlorination of PCBs can be achieved in a short time. The further oxidative degradation of biphenyl by iron oxides catalyzed heterogeneous Fenton reaction (near neutral pH) led to significant reduction in toxicity by forming aromatic ring breakdown products with no chlorine.

Objectives

➢ To synthesize Fe/Pd NPs inside the membrane pores (preventing the NP agglomeration and metal leaching)
➢ To degrade the toxic pollutants (TCE, PCBs...) into non-toxic compounds in aqueous phase
➢ To eliminate the production of toxic intermediates (using combined chemical treatment)

Hydrodechlorination Reaction (reductive pathway)

Heterogeneous Fenton’s Reaction (oxidative pathway)

Combined pathway

Membrane and NP morphology

Membrane benefits

PVDF functionalization and NP synthesis

2-Chlorobiphenyl dechlorination

(1) Batch

(2) Convective flow

Laminar flow reactor model

Biphenyl oxidation and products

Intermediates and products

Acknowledgements

This research is supported by NIEHS-SRP at University of Kentucky (P42ES007380), and by the DOE-KCREEE programs (DE-FG05-03OR23032). We acknowledge the highly significant contributions of Sepro Membrane Inc. of Oceanside, CA towards the joint development of full-scale PVDF functionalized membranes.