Research Brief 131: Advances in Photocatalytic Remediation Technology

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Background

Photocatalysis, the acceleration of a photoreaction in the presence of a catalyst, is rapidly emerging as a remediation technology with the potential to provide orders of magnitude reduction in treatment costs at hazardous waste sites. This technology is especially well-suited for treatment of off-gases from air stripping of contaminated groundwater or vapor extraction of contaminated soils. Photocatalysis can occur at ambient temperatures and, because high temperature incinerator is not needed, construction and operating costs are significantly reduced. Low temperature operation also eliminates the potential for formation of combustion byproducts such as dioxins. Photocatalytic systems also destroy pollutants, so unlike many systems based on granular activated charcoal, there is no hazardous solid waste disposal issue.

Optimization of photocatalytic systems is contingent on identification of catalysts with appropriate activity, selectivity and deactivation characteristics. It is also critical to limit, or eliminate, the formation of toxic byproducts.

Scientists at KSE, Inc. of Amherst, MA developed the Adsorption-Integrated-Reaction (AIR) Process in which airborne contaminants entering the reactor are concentrated on the surface of the adsorbent/catalyst contained in the reactor. Under illumination by UV light, the adsorbed contaminants are continuously destroyed on the surface by the photocatalytic action of the promoted adsorbent, and a contaminant-free gas stream leaves the AIR reactor system.

Advances

With funding from an SBRP Small Business Innovation Research (SBIR) grant, KSE, Inc. scientists conducted research to optimize catalyst composition for the photocatalytic treatment of chlorinated hydrocarbons. A particular challenge with photocatalytic remediation of these compounds is the formation of toxic intermediates, particularly phosgene, chloroform and carbon tetrachloride. The KSE SBIR research program included synthesis and evaluation of a set of diverse catalysts; kinetic studies of destruction efficiency on representative chlorinated hydrocarbons; and comparative cost analysis to demonstrate technical and economic feasibility.

The KSE scientists prepared more than 40 catalysts containing copper, manganese, cerium, cobalt, tungsten, titanium dioxide, tin oxide, and noble metals such as platinum. These materials were embedded in high silica UV transparent gels. Each catalyst was evaluated for surface area, UV transmittance, photocatalytic oxidation performance, activity, selectivity and stability. The yield of byproducts was determined for each catalyst. The scientists also examined the impact of design characteristics including moisture and oxygen content of the air stream through the system, the wavelength of the UV light source and use of two photocatalytic reactors in series.

They designed a set-up that achieved high TCE destruction and minimal phosgene or chloroform yield. They used a two-stage design with the first stage catalyst selected for high TCE destruction activity and minimal chloroform generation. The air stream exiting the second catalyst and reactor showed > 95% TCE destruction and contained no detectable chloroform or phosgene.

Finally, the KSE team conducted an extensive competitive technology assessment to compare the new photocatalytic technology to existing technologies. KSE developed a set of nine comparison criteria, selected a common design basis, and surveyed vendors offering competitive technologies. Using TCE as a model target compound, they found that compared to Granular Activated Carbon adsorption, photocatalytic air emissions control offers a 5 fold advantage in capital cost and 40 fold advantage in operating costs. Compared to catalytic oxidation, photocatalytic air emissions control offers a 20 fold advantage in capital cost and 2 fold advantage in operating costs.

Significance

This KSE SBIR research program yielded a system design that has high selectivity and eliminated hazardous byproducts such as phosgene and chloroform. This had never been achieved via conventional titania photocatalytic oxidation of TCE.

Over the next decades, federal, state and local government agencies, and private industry, will commit billions of dollars annually to clean up sites contaminated with hazardous materials. It is critical that innovative, cost-saving technologies be developed and applied, and this work represents an important advancement toward that goal.

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To learn more about this research, please refer to:

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