Tiny particles could solve billion-dollar problem

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New research from Rice University's Center for Biological and Environmental Nanotechnology finds that nanoparticles of gold and palladium are the most effective catalysts yet identified for remediation of one of the nation's most pervasive and troublesome groundwater pollutants, trichloroethene or TCE.

The research, conducted by engineers at Rice and the Georgia Institute of Technology, will appear next month in the journal Environmental Science and Technology, a publication of the American Chemical Society.

"The advantages of palladium-based TCE remediation are well-documented, but so is the cost," said lead researcher Michael Wong, assistant professor of chemical engineering and chemistry at Rice. "Using nanotechnology, we were able to maximize the number of palladium atoms that come in contact with TCE molecules and improve efficiency by several orders of magnitude over bulk palladium catalysts."

TCE, which is commonly used as a solvent to degrease metals and electronic parts, is one of the most common and poisonous organic pollutants in U.S. groundwater. It is found at 60 percent of the contaminated waste sites on the Superfund National Priorities List, and it is considered one of the most hazardous chemicals at these sites because of its prevalence and its toxicity. Human exposure to TCE has been linked to liver damage, impaired pregnancies and cancer.

Cleanup costs for TCE nationwide are estimated in the billions of dollars. The Department of Defense alone estimates the cost of bringing its 1,400 TCE-contaminated sites into EPA compliance at more than $5 billion.

The typical approach to getting rid of TCE involves pumping polluted groundwater to the surface, where it can be exposed to chemical catalysts or microorganisms that break the TCE down into less toxic or non-toxic constituents. In general, chemical catalysis offers faster reactions times than bioremediation schemes but also tends to be more expensive.

One of the major advantages of using palladium catalysts to break down TCE is that palladium converts TCE directly into non-toxic ethane. By contrast, breaking down TCE with more common catalysts, like iron, produces intermediate chemicals, like vinyl chloride, that are more toxic than TCE.

In the CBEN experiments, Wong and collaborators compared the effectiveness of four varieties of palladium catalysts: bulk palladium, palladium powder on an aluminum oxide support base, pure palladium nanoparticles and a hybrid nanoparticle developed by Wong that consists of a gold nanoparticle covered with a thin coat of palladium atoms.

As metal particles get progressively smaller, a higher percentage of the atoms in the particle are found on the surface of the particle instead of being locked away inside the metal where they cannot interact with other chemicals. For example, in the bulk palladium, less than 4 percent of the palladium atoms were on surface of the particle. Pure palladium nanoparticles had 24 percent of the metal on the surface. In the gold-palladium nanoparticles, 100 percent of the palladium atoms are accessible for reaction.

“We've documented the efficiency of these catalysts in breaking down TCE, and the next step is engineering a system that will allow us to get at the polluted groundwater,” said Joe Hughes, professor of civil and environmental engineering at Georgia Institute of Technology and a co-leader of CBEN's environmental research programs. “The scale of TCE contamination is enormous, so any new scheme for TCE remediation has got to clean large volumes of water very quickly for a just a few pennies.”

Hughes, Wong and their collaborators hope to develop a device that would include a cylindrical pump containing a catalytic membrane of the gold-palladium nanoparticles. The device would be placed down existing wells where it would pump water through continuously, breaking TCE into non-toxic components.

Cost is the primary hurdle to cleaning up TCE-polluted groundwater. CBEN's team hopes to drive down costs by using every ounce of palladium to maximum efficiency, and by eliminating drilling costs for new wells, construction costs for surface treatment facilities and energy costs of lifting water to the surface.

Nanotechnology is critical to the scheme because only a nanoscale catalyst will be efficient enough to provide the throughput needed to make the whole approach effective. Tests in Wong's lab have found that the gold-palladium nano-catalysts break TCE down about 100 times faster than bulk palladium catalysts.

Source: Rice University

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