Study finds advantages to iron nanoparticles for environmental clean up

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A new study says some iron nanoparticles may be effective in cleaning up carbon tetrachloride in contaminated groundwater

Researchers at Oregon Health & Science University's OGI School of Science & Engineering, in collaboration with Pacific Northwest National Laboratory (PNL) and the University of Minnesota, have discovered that at least one type of nano-sized iron may be useful in cleaning up carbon tetrachloride contamination in groundwater. The new discovery was published Dec. 16, 2004, in Environmental Science & Technology, the leading environmental journal of the American Chemical Society. The study will be published in the print version of Environmental Science & Technology, March 1, 2004, in a special section on nanotechnology.

"The use of nano-sized particles of iron for cleaning up contaminants in groundwater, soil and sediments is one of the hottest new technologies to emerge in recent years," said Paul Tratnyek, Ph.D., an environmental chemist and professor of environmental and biomolecular systems at OHSU's OGI School of Science & Engineering, and a lead author of the study. "However, there are a lot of unanswered questions about the appropriate and optimal implementation of the nano-iron technology, and even some questions about its safety. We set out to answer some of the remaining questions that researchers have about the basic chemical processes that determine the fate and effects of metal nanoparticles in the environment."

The particles studies by Tratnyek and colleagues range in size from 10 to

100 nanometers. One nanometer is one-billionth of a meter. By comparison, many biomolecules are of similar size.

For the study, Tratnyek and his doctoral students James T. Nurmi and Vaishnavi Sarathy compared two leading types of nanoparticle-sized iron that are being promoted by others for groundwater remediation. They measured how fast these particles degrade carbon tetrachloride and they determined the major projects of the reaction.

Carbon tetrachloride is a manufactured chemical used mainly in cleaning fluids and degreasing agents. In a few locations, spills of these liquids infiltrated the soil and created very large areas of contaminated groundwater and soil. Carbon tetrachloride is a toxic chemical that has been shown to cause cancer in animals.

The research at OHSU was funded in part by a grant from the Department of Energy to the Pacific Northwest National Laboratory (PNL) in Richland, Wash. The interdisciplinary team includes 10 researchers from PNL, three from OHSU and two from the University of Minnesota.

The PNL researchers, led by Donald R. Baer, Ph.D., technical group leader at PNL's William R. Wiley Environmental Molecular Sciences Laboratory, first synthesized and characterized the nanoparticles using a variety of advanced microscopy and spectroscopy techniques. Once the nanoparticles were syntheisized and characterized, Tratnyek and his students studied their reactivity using electrochemical techniques they developed to help them systematically measure the microscopic particles. University of Minnesota scientists also helped with microscopy and some reactivity studies.

"Our team's study results show how the breakdown of carbon tetrachloride is influenced by some very subtle and transient differences

between the two types of nano-iron," said Tratnyek.

One of the nano-irons studied, a commercially available product of iron oxide with a magnetite shell high in sulfur, quickly and effectively degraded carbon tetrachloride to a mixture of relatively harmless products. "This was an exciting find because it may provide the basis for effective remediation of real field sites with groundwater that is contaminated with carbon tetrachloride," said Tratnyek.

"Furthermore, since it may be possible to emplace nano-sized iron deep into the subsurface by injecting it through deep wells, this approach may be suitable for remediation of very deep plumes of carbon tetrachloride contaminated groundwater, such as the one at the Hanford site in Richland, Washington."

The other nano-iron studied by the OHSU-PNL-University Of Minnesota team had a shell, or coating, high in oxidized boron. While the oxide-coated iron also rapidly degraded the carbon tetrachloride, the primary product was chloroform, a toxic and persistent environmental contaminant.

"The idea of using nanosized particles of iron for cleanup of groundwater contaminants has been around since 1997 and has gained a lot of momentum in the past four years," noted Tratnyek. "Nanotech iron has shown promise for environmental remediation, but previous work has not been particularly rigorous or thorough.

"Our report is the most comprehensive and rigorous characterization of the reaction to date between carbon tetrachloride and two leading types of nano-sized iron. We have taken a careful, second look at the chemistry of nano-iron for environmental cleanup in hopes of providing better science on which to found this promising technology."

Tratnyek's nano iron research may also someday have medical applications, for instance, in the diagnosis of brain tumors.

Source: Oregon Health & Science University