NSF Press Release

NSF PR 03-94 - September 3, 2003

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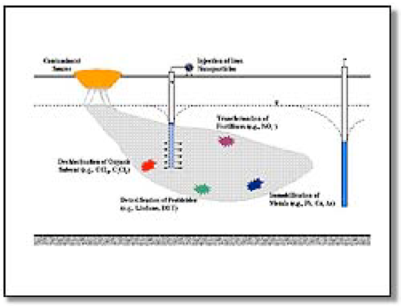
Nanoscale Iron Could Help Cleanse the Environment

The ultrafine particles will flow underground and destroy toxic compounds in place



Site remediation with iron nanoparticles.
Credit: Lehigh University
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Note About Images

ARLINGTON, Va.—An ultrafine, "nanoscale" powder made from iron, one of the most abundant metals on Earth, is turning out to be a remarkably effective tool for cleaning up contaminated soil and groundwater--a trillion-dollar problem that encompasses more than 1000 still-untreated Superfund sites in the United States, some 150,000 underground storage tank releases, and a staggering number of landfills, abandoned mines, and industrial sites.

The case for nanoscale iron is laid out in the September 3 issue of the *Journal of Nanoparticle Research*, where Lehigh University environmental engineer Wei-xian Zhang reviews his eight years of pioneering work with the material. Much of Zhang's research has been funded by the National Science Foundation as a part of the federal government's 16-agency National Nanotechnology Initiative (NNI). This issue of the Journal is dedicated to nanoparticles in the environment and it is prefaced by Mihail Roco, NNI's coordinator and NSF's Senior Advisor on Nanotechnology, with a perspective on "Broader Societal Issues of Nanotechnology".

Iron's cleansing power stems from the simple fact that it rusts, or oxidizes, explains Zhang. Ordinarily, of course, the only result is the familiar patina of brick-red iron oxide. But when metallic iron oxidizes in the presence of contaminants such as trichloroethene, carbon tetrachloride, dioxins, or PCBs, he says, these organic molecules get caught up in the reactions and broken down into simple carbon compounds that are far less toxic.

Likewise with dangerous heavy metals such as lead, nickel, mercury, or even uranium, says Zhang: The oxidizing iron will reduce these metals to an insoluble form that tends to stay locked in the soil, rather than spreading through the food chain. And, iron itself has no known toxic effect--just as well, considering the element is abundant in rocks, soil, water, and just about everything else on the planet. Indeed, says Zhang, for all those reasons, many companies now use a relatively coarse form of metallic iron powder to purify their industrial wastes before releasing them into the environment.

Unfortunately, says Zhang, these industrial reactors aren't much help with the pollutants that have already seeped into the soil and water. That's the beauty of the nanoscale iron particles. Not only are they some 10 to 1000 times more reactive than conventional iron powders, because their smaller size collectively gives them a much larger surface area, but they can be suspended in a slurry and pumped straight into the heart of a contaminated site like an industrial-scale hypodermic injection. Once there, the particles will flow along with the groundwater to work their decontamination magic in place--a vastly cheaper proposition than digging out the soil and treating it shovelful by shovelful, which is how the worst of the Superfund sites are typically handled today.

In that sense, says Zhang, nanoscale iron is similar to *in situ* biological treatments that use specialized bacteria to metabolize the toxins. But unlike bacteria, he says, the iron particles aren't affected by soil acidity, temperature, or nutrient levels. Moreover, because the nanoparticles are between 1 and 100 nanometers in diameter, which is about ten to a thousand times smaller than most bacteria, the tiny iron crystals can actually slip in between soil particles and avoid getting trapped.

Laboratory and field tests have confirmed that treatment with nanoscale iron particles can drastically lower contaminant levels around the injection well within a day or two, and will all but eliminate them within a few weeks--reducing them so far that the formerly polluted site will now meet federal groundwater quality standards. The tests also show that the nanoscale iron will remain active in the soil for 6 to 8 weeks, says Zhang, or until what's left of it dissolves in the groundwater. And after that, of course, it will be essentially undetectable against the much higher background of naturally occurring iron.

Finally, says Zhang, the cost of the nanoscale iron treatments is not nearly as big a barrier as it was in 1995, when he and his colleagues first developed a chemical route for making the particles. Then the nanoscale iron cost about $500 a kilogram; now, it's more like $40 to $50 per kilogram. (Decontaminating an area of about 100 square meters using a single injection well requires 11.2 kilograms.)

Zhang is currently forming a company to mass-produce the nanoscale iron particles. And in the meantime, he and his colleagues are consulting with multiple clients. "It used to be just the feds--agencies like the Navy and so on," he says. "But now, we're working with big pharmaceutical firms, semiconductor manufacturers, and many other companies, all of which are interested in cleaning up sites."

After nearly a decade of research, he adds, "we're entering a phase of exponential growth. There are thousands and thousands of contaminated sites out there. And hopefully, this will be a cost-effective way to deal with many of them."

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