Nanotechnology: Applications for Environmental Remediation
CLU-IN Technology Focus Area
Fact Sheet

INTRODUCTION

The U.S. Environmental Protection Agency's (EPA) Office of Superfund Remediation and Technology Innovation (OSRTI), Technology Innovation and Field Services Division (TIFSD) is interested in providing EPA remedial project managers (RPM), other federal and state personnel, and interested parties with timely information about developments in the field of hazardous waste clean-up. Through the Technology Focus Area on EPA's Hazardous Waste Clean-Up Information (CLU-IN) website (www.clu-in.org/techfocus), EPA provides information on tools and resources to assist in hazardous waste remediation, characterization, and monitoring. This fact sheet describes a new remediation technology focus area: *Nanotechnology: Applications for Environmental Remediation*. The goal of this focus area is to help site owners and other parties involved in remedial activities understand the current and potential applications of nanotechnology at their sites. Information on this website is organized into the following categories: Overview, Guidance, Application, Training, and Additional Resources. Website content is continuously updated using sources such as federal cleanup programs, state sources, universities, nonprofit organizations, peer-reviewed publications, and public-private partnerships.

Nanoscale Materials for Environmental Remediation

Full-scale applications:

- Nanoscale Iron

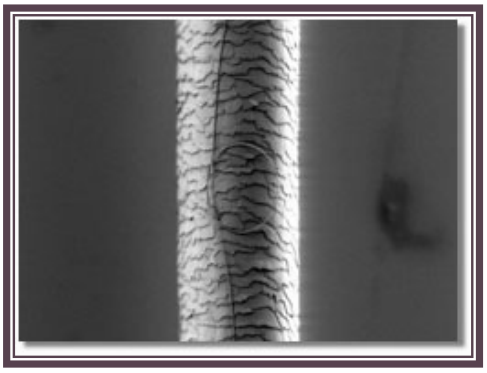
Bench- and pilot-scale studies:

- Fullerenes and carbon nanotubes
- Nanosized metal oxides
- Quantum dots
- Dendrimers
- Composite nanoscale materials
- Self-assembled monolayers on mesoporous supports (SAMMS™)
- Swellable organically modified silica (SOMS)
- Metalloporphyrinogens

OVERVIEW

The National Nanotechnology Initiative defines nanotechnology as understanding and controlling matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Nanoscale materials are being used in a variety of applications within the scientific, environmental, industrial, and medical arenas. This website focuses on the use of nanoscale materials in environmental remediation applications.

An increasing variety of nanoscale materials with environmental applications has been developed over the past several years. Nanoscale materials are of interest for environmental applications because the surface areas of the particles are large when compared with their volumes; therefore, their reactivity in chemical or biological surface mediated reactions can be greatly enhanced in comparison to the same material at much larger sizes.

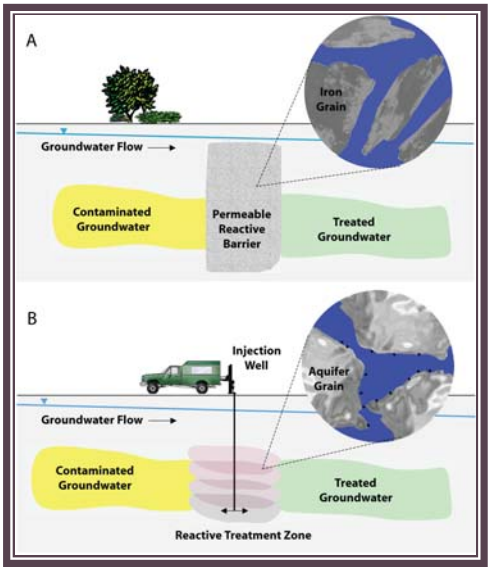


Micrograph of a looped nanowire against the backdrop of a human hair.
Mazur Group, Harvard University. 2008. Available at:
www.nsf.gov/od/lpa/news/03/pr03147.htm

APPLICATION

Some applications of nanoscale materials for environmental remediation are in the research phase, some are rapidly progressing from pilot-scale to full-scale implementation, and some have been used in full-scale environmental remediation applications. Nanoscale materials that contain iron are the most widely used nanoscale materials in full-scale applications for site remediation. For example, nanoscale zero-valent iron (nZVI) has been shown to chemically reduce contaminants such as tetrachloroethene (PCE), trichloroethene (TCE), and cis-1,2-dichloroethylene (c-DCE) effectively in both pilot and full-scale studies.

The application of nanoscale materials for *in situ* application is site specific. Conditions such as site location and layout, geologic conditions, nanoscale material surface properties, concentrations of contaminants, and types of contaminants affect nanoscale material performance. The method of injection is based on an evaluation of these factors; however, injection of nanoscale iron is typically done via direct injection through gravity feed or under pressure. Additional methods and processes to apply nanoscale material for *in situ* treatment include recirculation, pressure pulse technology, pneumatic fracturing, and hydraulic fracturing. The figure to the right illustrates the basic principles of two methods of remediating contaminated groundwater using nZVI. Detailed information on the types of nanoscale materials and their use in environmental remediation is available within the *Application* section of the website.



Schematic of two methods of groundwater remediation using nanoscale iron.
Center for Groundwater Research (CGR). 2009. Zero-Valent Iron (ZVI) Web page. Available at: http://cgr.ebs.ogi.edu/iron/#results.

Research in the field of nanotechnology is constantly expanding. Researchers are developing nanoscale materials that have the potential to adsorb or destroy contaminants as part of either *in situ* or *ex situ* processes. Studies are being performed in an effort to improve the efficiency and overall performance of current nanoscale materials. In addition, research is underway to understand the fate and transport of nanoscale materials in the environment, whether they are persistent, and whether they have toxicological effects on various biological systems.

GUIDANCE AND REGULATIONS RELATED TO NANOTECHNOLOGY

U.S. and International organizations have developed guidance documents or regulations to address the increasing presence of nanoscale materials. The majority of these provide information on the safe use and manufacturing of nanoscale materials and measures to minimize potential exposure. As more information regarding the toxicity and fate of nanoscale materials in the environment becomes available, these regulations may change. The *Guidance* section of the website summarizes available guidance and regulations and will be updated as new information is available.

TRAINING

The website includes detailed information on training opportunities including nanotechnology forums, conferences, workshops, and meetings. In addition, the website provides a list of available on-line resources or tutorials. Links to archived meetings and conference abstracts are included, where available.

Sites Using or Testing Nanoscale Materials for Environmental Remediation

As of November 2011, data were obtained for 36 sites using or testing nanoscale materials for remediation. Of these 36 sites, 15 of the sites utilized nZVI. The majority of the field studies injected the nanoscale material through gravity-feed or low pressure injection and addressed TCE, PCE, and their by products. Details on these sites are available at: www.clu-in.org/products/nanozvi.

ADDITIONAL RESOURCES

For further access to information, the website provides links to additional resources including organizations currently working with nanotechnology, publications regarding the use of nanotechnology in the environment, and several nanotechnology databases. EPA encourages interested parties to provide any suggestions or additional resources that can be added to the Nanotechnology Focus Area. Website visitors may submit a new resource for inclusion on the website or comment on existing content using the *Submit Resource* or the *Comments* links available on the website.

CONTACT INFORMATION

If you have any questions or comments on this fact sheet, please contact: John Quander, U.S. EPA Headquarters, by phone at (703) 603-7198 or by email at quander.john@epa.gov.