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Update on Engineered Nano Particles For Remediation at EPA Superfund Sites

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Greg Gervais, P.E.
Technology Innovation and Field Services Division
US EPA OSWER Office of Superfund Remediation & Technology Innovation

Presentation Outline

- ENPs for Site Remediation – Promise and Realities of Powerful Advancement
- Tracking usage for remediation…is hard
- Sustainable Nano-based Remediation
  - Perceptions
  - Questions
  - Careful Adoption

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ENPs for Site Remediation

- The promise of remediation performance advances
  - particle size benefits
  - can remediate many contaminants
    - flavors of ZVI reduce PCE, TCE, c-DCE, VC, 1,1,1-TCA, PCBs, halogenated aromatics, nitroaromatics, As, Cr^{+6}, nitrate, perchlorate, sulfate, and cyanide
    - TiO_2 mineralizes many pesticides via photocatalysis
  - new uses and implementation methods
    - oleophilic slurrys, emulsions
    - reactive sediment caps

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ENPs for Site Remediation

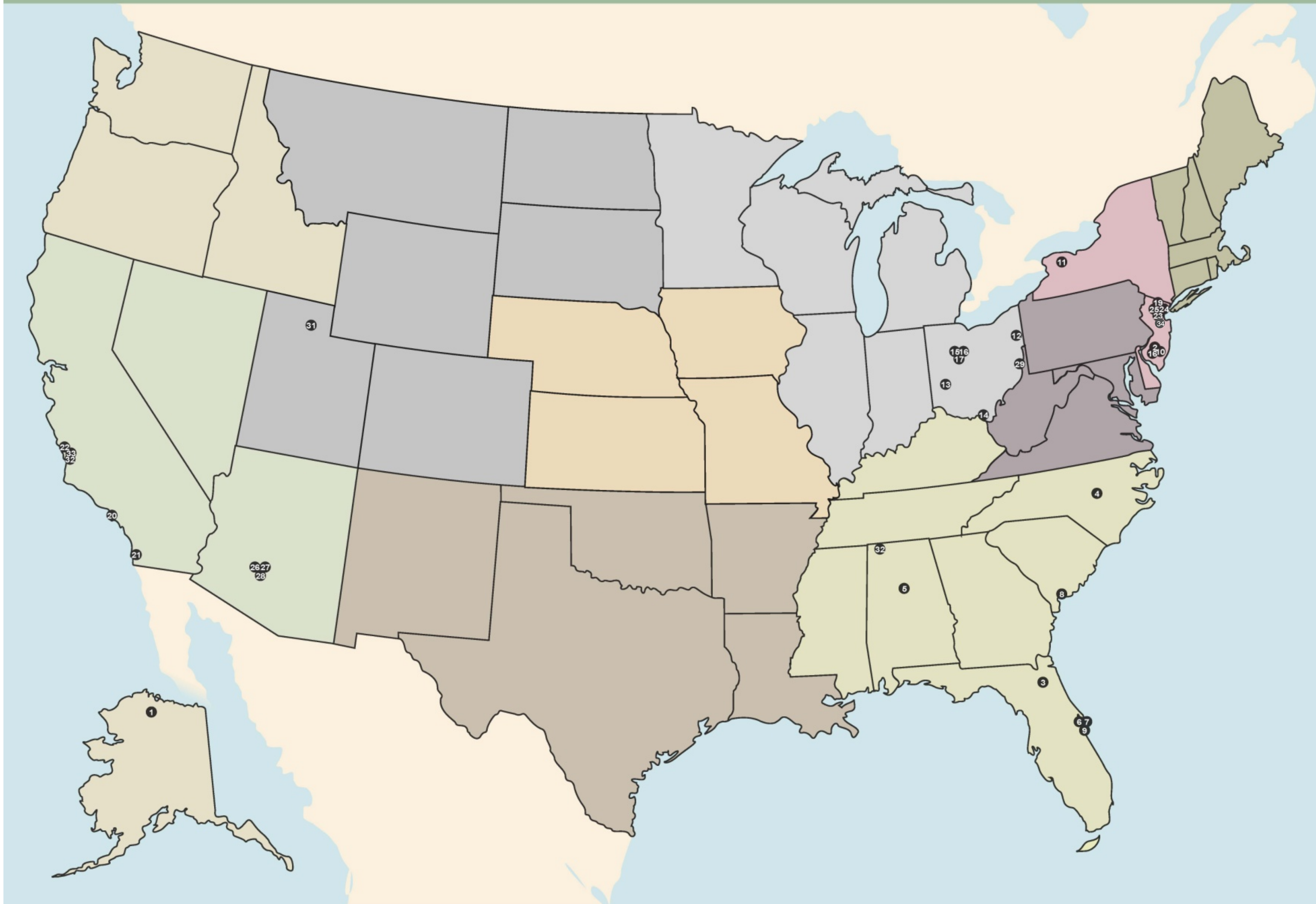
- The realities (so far)
  - ex situ easier than in situ
    - water treatment unit ops vs. ISCR
  - agglomeration (sticky situation)
  - same or bigger in situ 'delivery' challenges
    - fast kinetics & high reactivity = 'gone baby gone' ?
  - storage & handling safety
  - ENP material cost vs. alternative materials
  - emerging science, practices for safe use

We’ve been tracking ENPs for 10 years…

…and it’s hard

OSWER OSRTI TIFSD

Hazardous Waste Cleanup Sites in the U.S. Leveraging Engineered Nanoparticles for Remediation



BNP

1 BP–Prudhoe Bay Unit | North Slope, AK
2 Manufacturing Plant | Trenton, NJ (Fe/Pd) Particles
3 Naval Air Station | Jacksonville, FL
34 Naval Air Engineering Station | Lakehurst, NJ
4 Pharmaceutical Facility | Research Triangle Park, NC (produced in laboratory by Lehigh University)

CMC Stabilized Zero-Valent Iron

5 Alabama Site | Northern Alabama, AL

EZVI

6 Cape Canaveral Air Force Station Launch Complex 15 | Cape Canaveral, FL
7 Cape Canaveral Air Force Station Launch Complex 34 | Cape Canaveral, FL
8 Parris Island | Port Royal, SC
9 Patrick AFB, OT-30 | Patrick AFB, FL

Golder Associates nZVI: Produced by Golder Associates Inc. Under License from Lehigh University

10 Former Chemical Storage Facility | Winslow Township, NJ
11 Industrial Plant | Rochester, NY
12 Nease Chemical | Salem, OH

Iron-Osorb™ nZVI-silica Hybrid Nanoparticles

13 Active Business Site | Dayton, OH
14 Industrial Site | Ironton, OH
15 Penn-Michigan Manufacturing Site Phase I and Phase III (Location 1) | West Lafayette, OH
16 Penn-Michigan Manufacturing Site Phase II (Location 2) | West Lafayette, OH
17 Penn-Michigan Manufacturing Site Phase IV | West Lafayette, OH

Nanoiron slurry (NanoFe Plus™)

18 Klockner Road Site | Hamilton Township, NJ

Nanoscale Calcium Ions with Noble Metal Catalyst (Nano-Ox™)

19 Residential Site | Ringwood, NJ

Nanoscale Porous Metallic Iron

20 Vandenberg Air Force Base | Santa Maria, CA

Nanoscale Zero Valent Zinc

21 Camp Pendleton | Southern CA

nZVI

22 Hunters Point Ship Yard, Parcel E | San Francisco, CA
23 Industrial Site | Edison, NJ (Engineered Zero Valent Metal Powder (Z-Loy™) Manufactured by OnMaterials)
24 Manufacturing Site | Passaic, NJ
25 Picatinny Arsenal Superfund Site | Rockaway Township, NJ (Ferragel Particles)
26 Phoenix Goodyear Airport-North (Unidynamics) Phase I | Goodyear, AZ
27 Phoenix Goodyear Airport-North (Unidynamics) Phase II | Goodyear, AZ
28 Phoenix Goodyear Airport-North (Unidynamics) Phase III | Goodyear, AZ

Palladium-Osorb™ Palladium-silica Nanoparticles

29 Former Manufacturing Site | Bridgeport, OH

Polysaccharide Stabilized Bimetallic Nanoiron - Golder Associates, Auburn University On-Site Production of Stabilized nZVI

30 Industrial Plant | Sheffield, AL

Stabilized Fe-Pd Bimetallic Nanoparticles with Sodium Carboxymethyl Cellulose

31 Hill Air Force Base Operable Unit 2 | Utah

Starch-stabilized BNP (Fe/Pd)

32 Ford Aerospace Site | Palo Alto, CA

Surface-modified nZVI

33 OU-2B Installation Restoration Site 4 | Alameda Point, CA

Acronym List

BNP Bimetallic Nanoparticles
EZVI Emulsified Zero Valent Iron
Fe Iron
Pd Palladium
nZVI Nanoscale Zero Valent Iron

EPA TIFSD Nanotechnology for Site Remediation Database, http://clu-in.org/products/nanozvi/, EPA OSWER OSRTI, Arlington, Virginia

June 2013

ENPs at Superfund Sites

- nZVI is in situ chemical reduction, and sometimes use isn't specified until design
- Other ENPs with ongoing R&D for use in remediation, so use on Superfund sites may be down the road

→Ex. of an upcoming use: Nease Chemical (Ohio) – nZVI for PCE, other CVOCs in a bedrock aquifer

Sustainable Nano-based Remediation

- Perceptions affecting sustainability
  - nZVI reaction 100%, byproduct 'just rust'
  - ENPs fit into existing regulatory framework
  - EU approach to NanoRem (www.nanorem.eu/)
- Key questions
  - safe for remediation? site workers? people near site? environment?
  - where is 'implications' research heading?
    - Ex. EPA-led research: www.epa.gov/nanoscience/

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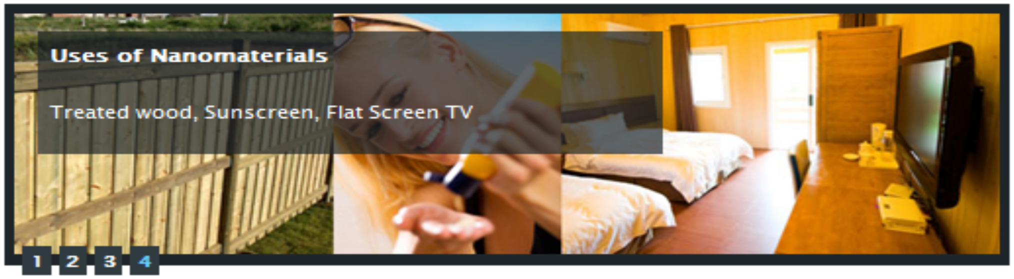
Nanotechnology & Nanomaterials Research



Key Links

- Chemical Safety Research
- Control of Nanomaterials
- Nanomaterials Research Coordination Team
- Nanomaterial Research Fact Sheet
- Risk Assessment

Commercial processes and products that use nanomaterials are growing rapidly and these tiny products are increasingly found in paint, fabrics, cosmetics, treated wood, electronics and sunscreen. Nanomaterials can be 100,000 times thinner than a strand of hair and they exhibit unique properties different than the same chemical substances in a larger size. Nanomaterials provide opportunities for the development of innovative products that provide advances in technologies and medicine. EPA is using scientific methods to research what nanomaterials are, how they act, travel and change over time. This research is used by EPA's Chemical Safety and Pollution Prevention Office and others making chemical decisions to inform policy and regulatory decisions to better protect human health and the environment.

Exposure & Nanomaterials Properties

The unique composition/properties of nanomaterials—their size, diversity and countless uses—pose challenges to assessing the risks they pose to human health and the environment. EPA is researching the properties of nanomaterials to better detect, quantify and describe them.

- Ecosystem Health Effects Research
- Human Health Effects Research
- Detecting, quantifying and characterizing nanomaterials
- Characterizing Nanomaterial Properties
- Examining Nanoparticles Impact on Fuel Emissions and Air Pollution

Learn more about Exposure/Characterizing Properties...

Risk Assessments

EPA is using the comprehensive environmental assessment (CEA) approach to identify and prioritize research to support future assessments and risk management decisions.

- CEA Approach
- Nanoscale Silver in Disinfectant Spray Case Study
- Carbon Nanotube Case Study: A comparison of multi-walled carbon nanotube and decabromodiphenyl ether flame retardant coatings applied to upholstery textiles
- Nanomaterial Case Studies: Nanoscale Titanium Dioxide in Water Treatment and in Topical Sunscreen

Learn more about Risk Assessments...

Life Cycle Assessment

EPA scientists are evaluating the life cycle of consumer products (including raw material extraction, processing, manufacturing, benefits of the product, use, recycling and ultimate disposal) containing nanomaterials to inventory the environmental and health impacts. The research findings can be used to update and create new risk assessments.

- Carbon nanotubes (used in flat panel television displays, automobile dashboard panel)
- Micronized Copper Treated Lumber (used to build decks on homes)
- Silver-based Nanomaterials (found in paint, fabrics)

Sustainability

EPA researchers have developed alternative ways to apply nanomaterials to minimize environmental and human health impacts.

- Nano Zero Valent Iron (emerging option for treatment of contaminated soil and groundwater)
- Nanoparticle useful in cleaning up "Polychlorinated Biphenyls" or PCBs
- Nanoparticles Impact of Fuel Emissions and Air Pollution

Learn more about Sustainability...

Other Research Topics

- Research homepage
- Air Research
- Human Health Research
- Water Research

Top Three Questions

1. What is nanotechnology?
2. Why is EPA studying nanotechnology?
3. Are nanomaterials safe?

More Questions

Reports & Other Resources

- Nanomaterial Case Study: Multiwalled Carbon Nanotube
- Publications
- Nanomaterial Case Study: Nanoscale Silver in Disinfectant Spray (Final Report)
- EPA Science Matters Newsletter

More Reports & Other Resources

Related Links

- 2008 Nano Technology Conference Proceedings, volumes 1 and 2 (PDF) (600 pp, 11.8MB)
- Nanotechnology Review Article
- Environmental Futures Project EXIT Disclaimer
- EPA and ILSI Research Foundation Partnership EXIT Disclaimer

More Related Links

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Sustainable Nano-based Remediation

– Screening ENP remedial technologies vs. others?
  - performance, cost, and impact of technology
  - innovative vs. baseline vs. ‘proven’ technologies
– Sharing best practices for nanoremediation
  - conferences, especially main line remediation conferences vs. ENP conferences
  - peer-reviewed science, case studies

B5. Advances in Nanotechnology

28. Combined Application of nZVI and DC Electric Field for In Situ CHC Remediation.
M. Cernik, J. Nosek, and J. Hrabal.
Miroslav Cernik (Technical University of Liberec/Czech Republic)

29. Degradation of Endosulfan by Nano- and Microsized Iron Particles: Effect of Particle Surface Area. *S.P. Singh and P. Bose.*
Swatantra P. Singh (IIT Kanpur/India)

30. Tailoring of Carboiron as Alternative to Nanoiron from Laboratory Design to the First Field Test—Part 2: Results of the Field Tests.
H. Doose, K. Mackenzie, J. Bruns, and S. Bleyl.
Heide Doose (Golder Associates GmbH/Germany)

31. In Situ Chemical Reduction with Zerovalent Nanoiron: Local Solutions for Chlorinated Hydrocarbon Remediation in Hungary. *E. Beno, L. Lonstak, G. Kozma, and C. Loftenius.*
Christer Loftenius (Golder Associates AB/Sweden)

32. Application of a New Type of nZVI—NANOFER STAR—at a Site Contaminated by Chloroethenes: Case Study. *M. Stavelova, M. Kralova, J. Slunsky, L. Lacinova, V. Brenner, P. Kvapil, and J. Jurak.*
Monika Kralova (AECOM CZ s.r.o./Czech Republic)

33. Towards Coated Nanogold Particles as Nonreactive Tracers in Coated nZVI for In Situ Remediation. *A.S. Fjordboge, B. Uthuppu, E. Caspersen, S. Vang Fischer, M.H. Jakobsen, and M.M. Broholm.*
Annika S. Fjordboge (Technical University of Denmark/Denmark)

34. Exposure of Nano Zerovalent Iron (nZVI) to Plants Leads to Enhancement of Root Elongation through Cell Wall Loosening.
J.-H. Kim, C. Lee, D. Oh, and Y.-S. Chang.
Jae-hwan Kim (POSTECH/South Korea)

35. Comparison of Nanozerovalent Iron Particles for ISCR. *T. Kabeche, C. Chene, L. Muhr, and M.-O. Simonnot.*
Marie-Odile Simonnot (Universite de Lorraine/France)

Summary

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For More Info

- www.epa.gov/nanoscience/
- www.cluin.org
  - Focus area (e.g., www.cluin.org/nano)
  - Searchable remediation database
- www.nanorem.eu/

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Thank You!

Greg Gervais
Office of Superfund Remediation and Technology Innovation
gervais.gregory@epa.gov

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