U.S. EPA OSWER
Selected Sites Using or Testing Nanoparticles for Remediation.

The list of sites includes information on current or planned applications of nanotechnology at pilot and full scale sites.

Site Information							Media		Contaminants			Technology Information		
Site Name	**Site location (city, state)**	**EPA Region**	**Site type**	**Cleanup program**	**Scale**	**Geology**	**Media treated**	**Volume of media treated**	**Contaminants treated**	**Initial contaminant concentrations**	**Final contaminant concentrations**	**Type of nanoparticle**	**Technology design**	**Vendor Information**
Naval Air Engineering Station	Lakehurst, NJ	2	Aircraft Launch Facility	CERCLA	Full	This site is characterized as a Coastal Plain Aquifer consisting of mostly sand and gravel. Both the northern and the southern areas are underlain by approximately 75 ft of unconsolidated sediments characterized as fairly uniform, brown-yellow, fine to coarse sand. Grain-size analyses characterized the sediments as 0.5 to 5.9% gravel, 86 to 94% sand, and 5 to 9% clay.	Soil and groundwater	Not available	PCE, TCE, TCA, c-DCE, VC	Max VOC concentration: 900 µg/L	The two primary contaminants of concern, TCE and DCE, showed an average decrease of 79% and 83%, respectively. The average decrease in total VOCs concentrations was 74%.	BNP	A total of 300 lbs of BNP was made into 2 g/L slurry. The BNP iron slurry was injected using DPT (i.e., Geoprobe®) at 10 locations within the northern plume and 5 locations within the southern plume over a periods of 13 days. At each injection point, 20 lb of BNP were mixed with 1,200 gallons of water. A total of 300 lbs of BNP were mixed with 18,000 gallons of water. The injections were conducted in a grid pattern for one portion of the plume and in a linear pattern for the second portion in order to form a treatment wall along the facility boundary. A Geoprobe® distributed the mixture over a 20-ft depth interval to reach a total treatment depth of 70 ft bgs. This process continued until BNP had been injected into the entire 20-ft treatment zone.	• PARS Environmental, Inc., • Environmental Chemical Corporation, Inc.
Naval Air Station	Jacksonville, FL	4	Former UST Site	CERCLA and RCRA	Full	Geologic borings indicate that the unsaturated zone at the site appears to be fairly uniform fine to medium grained sand and sandy fill. A thin layer of silty sand is located at and just below the water table between 6 and 12 ft bgs underlain by a fine to medium silty sand encountered from 10 to 17 ft bgs. The horizontal extent of contamination is approximately 1,450 ft^2 with a thickness of 18 ft (saturated zone), resulting in a total volume of 967 yd^3 of soil.	Groundwater	Not available	PCE, TCE, DCE, VC, TCA	Max soil concentrations: • PCE: 4,360 µg/kg • TCE: 60,100 µg/kg • 1,1,1-TCA: 25,300 µg/kg Max groundwater concentrations (baseline): • PCE: 210 µg/L • TCE: 26,000 µg/L • 1,1,1-TCA: 8,400 µg/L • cis-1,2-DCE: 6,700 µg/L	Rapid reductions by 65% to 99%	BNP	300 lbs of BNP was made into 4.5 to 10 g/L iron slurry with water from an extraction well and injected into the subsurface by a combination of DPT and closed-loop recirculation. Direct, gravity feed, injection of the nanoparticles using DPT was employed first at 10 "hot spot" locations. For injection via DPT, the iron suspension was diluted to 10 g/L and injected directly into the DPT boreholes using pumps from 7.5 to 23.0 ft bgs, equating to approximately 4.2 lb of iron injected in each borehole. A recirculation system was used to distribute the BNP particles in the rest of the suspected source zone. The design of the recirculation system consisted of 4 injection and 3 extraction wells. For the recirculation system, the applied iron concentration was initiated at 2 g/L and later increased to 4.5 g/L based upon field observations indicating the iron was being accepted by the aquifer without clogging or backing up in the wells. The recirculation system was operated continuously for approximately 23 hours using these wells. During the second recirculation event, water was only recirculated into the 4 new injection wells for approximately 21.5 hours. The applied iron concentration remained at 4.5 g/L.	PARS Environmental, Inc.
Patrick AFB, OT-30	Patrick AFB, FL	4	Industrial Area	RCRA	Full	Groundwater is encountered at 4 to 5 ft bgs. The upper surficial aquifer consists of mostly fine to medium grained sands with occasional silt/clay. The silty region, around 35 to 42 ft bgs, holds DNAPL migration.	Soil and groundwater	600,000 ft^3 (groundwater) ; 22,222 cy (soil)	TCE and corresponding daughter products	TCE: 150,000 µg/L (max concentration detected)	TCE post treatment: 260 µg/L (max concentration detected based on April 2009 monitoring data)	EZVI	High pressure pneumatic injection	Jacobs Engineering Group (Prime)

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		Performance Information											
Site Name	**Site location (city, state)**	**Cleanup/ remedial objectives and goals**	**Were cleanup goals and objectives met? (Yes/No)**	**Performance data available (Yes/No)**	**Maintenance (O&M) activities/ monitoring system**	**Start date/date installed**	**Anticipated end date of current phase**	**Length of operation**	**Comments**	**Cost Information**	**Future Work/ Current Plans**	**Contact Information**	**Information Sources**
Naval Air Engineering Station (continued)	Lakehurst, NJ	Achieve decreasing trends in contaminant concentrations	Yes	Yes	Groundwater samples were collected from each of 13 monitoring wells for analysis of chlorinated VOCs, chloride, iron, and dissolved iron. 7 sampling events, including one baseline pre-injection event and 6 post-injection events, were conducted to assess the effectiveness of the BNP treatment. The 6 post-injection sampling events were conducted 1 week, 2 weeks, 4 weeks, 8 weeks, 12 weeks, and 6 months after BNP injection.	Phase I - November 2005 Phase II - January 2006	Not available	Not available	TCE, cis-DCE, and VC levels gradually decreased in the monitoring wells over several weeks of monitoring. An apparent increase in VOC concentrations was observed in approximately 50% of the monitoring wells in the sampling round performed 1 week after the BNP injections; however, in subsequent sampling rounds, a decrease was observed for virtually all VOCs (and total VOCs), in all of the monitoring wells. The initial increase was likely caused by desorption of VOCs from the soil particles to the aqueous phase as a result of the BNP treatment. The ORP levels decreased slightly in 3 of the 13 wells 6 months after the injection. ORP levels increased in the majority of the wells or remained relatively the same after injection. This may indicate that not enough BNP was injected to create the strongly reducing conditions necessary for abiotic reduction of VOCs. In general, the groundwater pH values remained below 6 throughout the monitoring period. ORP data: Pre-Injection: 170 to 311 mV Post-Injection: -100 to -400 mV	The total costs for the field nanoscale iron demonstration was reported to be approximately $255,500. This cost included monitoring well installation, baseline sampling, nanoscale iron injection, 6 month post-injection sampling, and reporting results.	Nanotechnology application at the site has been stopped for now.	Paul Ingrisano, RPM EPA, Region 2 212-637-4337 Ingrisano.Paul@epamail.epa.gov	*Remedial Action Report for Nanoscale Particle Treatment of Groundwater at Areas I and J Naval Air Engineering Station Lakehurst, NJ.* June, 2006. Gavaskar, A., Tatar, L. and Condit, W. *NAVFAC Cost and Performance Report. Nanoscale Zero-Valent Iron Technologies For Source Remediation*. September 2005. www.clu-in.org/download/remed/cr-05-007-env.pdf EPA. *Bimetallic ZVI Technology Implementation Expands to Remediate VOC Hot Spots in Ground Water. Technology News and Trends*. September 2005. http://cluin.org/products/newsltrs/tnandt/view.cfm?issue=0905.cfm EPA Region 2. NPL Listing History. www.epa.gov/region02/superfund/npl/0201174c.pdf
Naval Air Station (continued)	Jacksonville, FL	Reduce the total site contaminant mass by 40 to 50%.	Yes	Yes	Short-term performance monitoring was conducted with groundwater samples collected within 6 weeks after BNP injection from a select number of wells. Longer-term performance monitoring was conducted between 2 months and 1 year after injection. This phase of monitoring evaluated the longer-term performance of the remedial system in the source area and within the dissolved-phase plume.	January 2004	Through 2007	The first monitoring event took place 5 weeks after initial injection.	Results of the remedial process varied widely from well to well. The recirculation process appeared to enhance desorption of contaminants into the dissolved phase. Many wells achieved over a 65% decrease in concentrations of parent VOCs within a short period of 5 weeks. Some source zone wells however, experienced a rise in both TCE and DCE concentrations after injection. This likely stems from poor distribution of the BNP slurry and possible displacement of dissolved TCE. After injection, groundwater ORP levels decreased to well below -200 mV, but pH remained relatively constant (-400 to -750 mV common in iron barriers).	The total costs for the field nanoscale iron demonstration was reported to be approximately $259,000, with an additional $153,000 for administrative tasks such as project management, work plan development, and bench-scale study.	Establish institutional controls to prevent human exposure to contaminated groundwater until natural attenuation takes place.	Keith Henn Tetra Tech NUS 412-921-8146 Keith.Henn@ttnus.com	Henn, Keith W. Henn; Widell, Dan. *Utilization of nanoscale zero-valent iron for source remediation - A case stud*y. Remediation, Spring 2006. NAVFAC. *Cost and Performance Report. Nanoscale Zero-Valent Iron Technologies For Source Remediation* www.clu-in.org/download/remed/cr-05-007-env.pdf Email from Keith Henn to Marti Otto dated 11/24/2004; Henn and Waddell. 2005. U.S. EPA Nanotechnology Workshop Watlington, K. 2005. *Emerging Nanotechnologies for Site Remediation and Wastewater Treatmen*t. www.clu-in.org/download/studentpapers/K_Watlington_Nanotech.pdf Ruiz, Nancy. NAVFAC. *Use of Nano- and Micro-Scale Zero Valent Iron at Navy Sites: A Case Study.* US EPA Workshop on Nanotechnology for Site Remediation Washington, DC, October, 2005. www.frtr.gov/nano/pdf/day1/ruiz_nancy.pdf
Patrick AFB, OT-30 (continued)	Patrick AFB, FL	• Interim Goal: Reduction of significant source mass. • Final Goal: Meet Florida groundwater target levels.	TBD	Yes	Semi-annual monitoring	November 2005	November 2010	On-going, minimum 5 years	ORP and DO decreasing	• Unit cost: $180/cy • Monitoring: ~$39,000/year • Capital costs: $1 million, EZVI, $1 million pneumatic injection contractor • Total remedial cost: $4 million	Site is currently in long term performance monitoring to evaluate impacts to the plume post source reduction.	Mark Kershner Mark.Kershner@patrick.af.mil	Naval Facilities Engineering Command (NAVFAC). *Emulsified Zero-Valent Iron (EZVI) Treatment of Chlorinated Solvents*. 2009. https://portal.navfac.navy.mil/portal/page/portal/navfac/navfac_ww_pp/navfac_nfesc_pp/environmental/erb/resourceerb/ezvi.pdf EPA. *Nanotechnology for Site Remediation Fact Sheet.* EPA 542-F-08-009. October 2008. www.epa.gov/tio/download/remed/542-f-08-009.pdf OT-30 Corrective Measure Implementation (CMI) Report

The list of sites includes information on current or planned applications of nanotechnology at pilot and full scale sites.

Site Information							Media		Contaminants			Technology Information		
Site Name	Site location (city, state)	EPA Region	Site type	Cleanup program	Scale	Geology	Media treated	Volume of media treated	Contaminants treated	Initial contaminant concentrations	Final contaminant concentrations	Type of nanoparticle	Technology design	Vendor Information
Cape Canaveral Air Force Station Launch Complex 15	Cape Canaveral, FL	4	Former Rocket Launch Site	RCRA	Full	Groundwater is encountered 4 to 5 ft bgs. The upper portion of surficial aquifer known as Upper Sand Unit, is underlain by Middle Fine-Grained Unit which makes up a hydraulic barrier to Lower Sand Unit Upper. The soils at the site are characterized as mostly fine to medium grained sands with occasional silt/clay. Silty region at about 45 ft bgs holding DNAPL migration.	Soil and groundwater	7,500 ft^3 (groundwater); 280 cubic yards (soil)	TCE and corresponding daughter products	TCE: 439,000 µg/L (max concentration detected)	In the EZVI zone, the max detected TCE concentration is approximately 109,000 µg/L (April 2007 sampling event)	EZVI	EZVI was injected through Drop Tip injection	Jacobs Engineering Group (Prime)
Cape Canaveral Air Force Station Launch Complex 34	Cape Canaveral, FL	4	Former Rocket Launch Site	RCRA	Pilot	Groundwater is encountered 4 to 5 ft bgs. The upper portion of surficial aquifer, known as Upper Sand Unit, is underlain by Middle Fine-Grained Unit, which creates a hydraulic barrier to Lower Sand Unit Upper. The soils at the site are characterized as mostly fine to medium grained sands with occasional silt/clay. The silty region exists 45 ft bgs and holds DNAPL migration.	Groundwater	1200 ft^3 (groundwater)	TCE and corresponding daughter products	TCE: 1,180,000 µg/L (max concentration detected)	The dissolved TCE level in the treatment plot groundwater declined considerably, from 1,180,000 µg/L (close to saturation) before the EZVI treatment to 8,800 µg/L afterward. Significant reductions in TCE soil concentrations (>80%) were observed at 4 of the 6 soil sampling locations within 90 days of EZVI injection. Somewhat lower reductions were observed at the other 2 soil sampling locations where visual observations suggest that most of the EZVI migrated up above the target treatment depth. Significant reductions in TCE groundwater concentrations (57 to 100%) were observed at all depths targeted with EZVI.	EZVI	EZVI was injected at the site using the following techniques: high pressure injection, pneumatic injection, and pressure pulse enhanced injection. • Injections were made at depths ranging from 16 to 24 ft bgs. • The EZVI mixture used in the demonstration consisted of: 44.3% water, 37.2% oil, 1.5% surfactant, and 17.0% iron by weight. • The EZVI was injected into eight separate 3-inch diameter wells in the demonstration test area at two injection intervals per well (16-20.5 ft bgs and 20.5-24 ft bgs). • Approximately 670 gallons of EZVI were injected into an area 15 ft by 9.5 ft over a 10 ft depth interval. During the injection of the EZVI, additional water was added to the injection points to enhance the distribution of EZVI into the formation.	Geosyntec Consultants

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		Cleanup/ remedial objectives and goals	Were cleanup goals and objectives met? (Yes/No)	Performance data available (Yes/No)	Maintenance (O&M) activities/ monitoring system	Start date/date installed	Anticipated end date of current phase	Length of operation	Comments				
Cape Canaveral Air Force Station Launch Complex 15 (continued)	Cape Canaveral, FL	• Interim Goal: Reduction of significant source mass • Final Goal: Meet Florida groundwater target levels	TBD	No	Semi-annual monitoring	February 2006	February 2011	On-going, minimum 5 years	ORP and DO decreased slightly after the EZVI injection.	Monitoring: $40,000 per year	Site is currently in long term performance monitoring to evaluate the impacts to plume post source reduction. Site is awaiting funding for an additional injection of EZVI.	Mark Kershner Mark.Kershner@patrick.af.mil	*Space Launch Complex 15 Groundwater Remediation Report*
Cape Canaveral Air Force Station Launch Complex 34 (continued)	Cape Canaveral, FL	• Achieve 50% removal of total TCE, • Evaluate change in aquifer quality due to EZVI treatment, • Evaluate fate of TCE due to injection, and • Verify EZVI operating requirements and costs	Yes	Yes	Soil sampling was conducted (from groundwater table down to lower sand unit) prior to injection, directly after injection, and 6 weeks after injection. Groundwater samples were taken by the vendor from multilevel samplers within plot area.	July 2002	January 2003	6 months	18 months after injection, groundwater concentrations indicated that long term degradation due to bioremediation was ongoing. ORP and DO decreased slightly after the EZVI injection. The groundwater pH remained stable.	• Site characterization cost: $352,000 • Performance assessment cost: $275,000 • Vendor total: $327,000	Ongoing work includes a field evaluation of different injection methods for EZVI funded by NASA, and another pilot-scale demonstration of EZVI funded by the Department of Defense Environmental Security Technology Certification Program (ESTCP ER-0431).	Suzanne O'Hara Geosyntec Consultants 519-822-2230 ext.234 SOHara@Geosyntec.com Jacqueline Quinn NASA 321-867-8410 Jacqueline.Quinn-1@ksc.nasa.gov	S. Chan Remillard*, Ph.D., FICN and J.S. Goudey. Golder Associates. *NANOTECHNOLOGY: The Next Remediation Magic Bullet?. REMTEC 2008* . www.remtech2008.com/remtech/2009/pdf/09-ChanRemillard.pdf EPA. Innovative Technology Evaluation Report. *Demonstration of in-situ Dehalogenation of DNAPL Through Injection of Emulsified Zero-Valent Iron at Launch Complex 34 in Cape Canaveral Air Force Station, FL* . EPA/540/R-07/006. September 10, 2004. www.epa.gov/nrmrl/pubs/540r07006/540r07006.pdf Geosyntec Consultants. *Pilot Test Evaluation of Emulsified Zero-Valent Iron for Chlorinated Solvent Source Zone Remediation at NASA KSC LC 34* . 2010. www.geosyntec.com/ui/Default.aspx?m=ViewProject&p=53 Quinn, Jacqueline.NASA "F*ield Demonstration of DNAPL Dehalogenation Using Emulsified Zero-Valent Iron* ". Environ. Sci. Technol. 2005, 39, 1309-1318. March 2005. http://pubs.acs.org/doi/abs/10.1021/es0490018 Wilson, Greg. *Nanotechnology Applications for Remediation: Cost-Effective and Rapid Technologies Removal of Contaminants From Soil, Groundwater and Aqueous Environments.* 2004. www.epa.gov/ncer/publications/workshop/8-18-04/ppt/greg_wilson.ppt Watlington, K. „ *Emerging Nanotechnologies for Site Remediation and Wastewater Treatment* .” 2005 www.clu-in.org/download/studentpapers/K_Watlington_Nanotech.pdf

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Parris Island	Port Royal, SC	4	Marine Corps Recruit Depot Former Dry Cleaner	CERCLA/ Private	Pilot	The site is characterized as a small, relatively flat, sandy island with minimal topographic relief. The highest elevation on the site is approximately 9 ft above msl. Soil present is from the Seabrook, Capers, and Bohicket series. The pneumatic injection test plot consists primarily of grayish/brown, fine to medium grained silty sand with intermittent clay lenses to a depth of approximately 18 ft bgs. The direct injection test plot consists primarily of light to dark grey, fine grained sand with traces of silt and clay to depth of approximately 17 ft bgs.	Soil and Groundwater	Not available	PCE, TCE, c-DCE, VC	Groundwater: • Max PCE: 32,000 µg/L • Max TCE: 10,000 µg/L • Max c-DCE: 3,400 µg/L • Max VC: 710 µg/L	• At least an 85% reduction in PCE and TCE. • Reductions in c-DCE of 71% to 75% were observed. • VC concentrations showed increases in mass flux of 71% up to 240%.	EZVI	For this demonstration, the site was instrumented to create 2 hydraulically independent pilot test plots (pneumatic injection and direct injection test plots) in the existing site DNAPL source area by installing a network of monitoring wells. Approximately 17 barrels of EZVI (55 gallons/barrel) were injected at the 2 injection plots: Pneumatic Injection Plot • Pneumatic fracturing involves the injection of gas at high pressure and flow in order to create fractures or fissures in soil or rock matrix. • For the pneumatic injections, a 2 step injection procedure was used. First, the formation was fluidized by the injection of nitrogen alone, followed by injection of the EZVI with nitrogen as the carrier. • A total of 576 gallons of EZVI injected into 8 locations between 7 and 19 ft bgs. • During injections, injection pressure, pressure distribution in subsurface, ground heave, and EZVI at ground surface was monitored. Direct Injection • Using a direct push rig, EZVI and water (at a ratio of 1:3) were injected into the formation at max pressures of 50 lbs psi. • A total of 151 gallons of EZVI was injected into 4 locations between 6 and 12 ft bgs. • During injections, injection pressure and the presence of EZVI at ground surface were monitored. EZVI combination used in both test plots consisted of 10% nanosized iron, 38% corn oil, 1% surfactant (sorbitan trioleate), and 51% tap water.	Geosyntec Consultants
Vandenberg Air Force Base	Santa Maria, CA	9	Missile Launch Pad	CERCLA	Pilot	Site soils are characterized as interbedded sands, silts, and clays referred to as the Orcutt Formation. Bedrock is encountered below the alluvium at depths of approximately 40 to 50 ft bgs.	Groundwater	Not available	TCE, DCE	TCE: 2.5 mg/L	Not available	Nanoscale porous metallic iron	BOS100® is activated carbon impregnated with nano-scale porous metallic iron. 2 BOS100® injection events, referred to as Phase I and Phase II, were peformed in 2008 and 2009. In January 2008, a Phase I pilot study was performed near the edge of the Site 15 groundwater plume using the Trap & Treat® technology with the BOS100® product. In January 2009, a Phase II injection using a modified injection approach was performed. In this injection event, 2 BOS100® injection points were completed. A slurry consisting of 400 lbs of BOS100®, groundwater, and 1,000 mg/L of bromide was injected in Injection Hole #1 between 28 and 42 ft bgs. A direct push EC probe was evaluated as a method for tracking BOS100® slurry distribution in the subsurface. To optimize the injection method, 8 shallow test injection holes were also performed followed by collection of soil cores to evaluate BOS100® distribution. In Injection Hole #2, 330 lbs of BOS100® and 1,920 gallons of groundwater were injected between 26 and 40 ft bgs.	Not available
Phoenix Goodyear Airport - North (Unidynamics) Phase I	Goodyear, AZ	9	Former Missile development R&D facility	CERCLA	Pilot	Deposits at the site consist of an upper alluvial unit, middle fine-grained unit, and lower conglomerate unit. Groundwater is present at 85 ft bgs. The target injection interval was 110 to 120 ft bgs.	Groundwater	Not available	TCE, PCE, Perchlorate	Total VOCs concentrations up to 39,000 µg/L.	Not available	nZVI	Phase I of this project included reactivity and kinetics testing, column studies, groundwater geochemical analyses, an injection tracer test, and a field injection test. The field injection test consisted of the injection of 30 g/L nZVI slurry in water through 1 injection well.	Polyflon Company PolyMetallix™

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		Cleanup/ remedial objectives and goals	Were cleanup goals and objectives met? (Yes/No)	Performance data available (Yes/No)	Maintenance (O&M) activities/ monitoring system	Start date/date installed	Anticipated end date of current phase	Length of operation	Comments				
Parris Island (continued)	Port Royal, SC	Performance objectives: • Evaluate 2 injection technologies (pneumatic and direct injections) within a DNAPL source zone for EZVI delivery. • Evaluate the effectiveness of EZVI to decrease mass flux of dissolved VOCs from a DNAPL source zone. Regulatory drivers: • The USEPA MCL for PCE and TCE in drinking waters is 5 µg/L. • The MCLs for VC and cDCE are 2 µg/L and 70 µg/L, respectively.	Yes	Yes	June 2006: Installed 6 fully screened and 7 multi level monitoring wells to identify the source areas. Groundwater baseline sampling was conducted June, August, and October 2006. Post-injection groundwater monitoring was conducted Nov 2006, Jan 2007, March 2007, July 2007, Jan 2008, July 2008; and March 2009 (2 to 3 week sampling events).	October 2006	May 2009	Not available	There were significant reductions in the downgradient groundwater mass flux values (the rate at which mass moves through a cross-sectional area perpendicular to the direction of groundwater flow) for parent compounds PCE (> 85%) and TCE (> 85%) and a significant increase in the mass flux of ethene. The cleanup achieved total VOC mass reduction of 81% and 91% reduction in the DNAPL mass. The radius of influence was as much as 7 ft with pneumatic injection and 2.5 ft with direct injection. Upgradient wells show continued presence of DNAPL although significant production of ethene indicates that degradation is ongoing in the area. There were some difficulties providing uniform distribution of the EZVI within the plot and the amount of EZVI that was injected into the plot was roughly 275 gallons short of the target amount.	Actual Costs (includes labor and equipment): • Design and Planning: $39,200 • Well Installation: $41,700 • EZVI Injections (pneumatic injection): $105,600 • EZVI Injection (direct injection): $32,400 • Baseline Characterization: $61,800 • Performance Monitoring: $279,000	Performance monitoring will continue. Soil cores will be collected at the last field sampling to examine the transformation of nanoscale iron over time at the site.	**U.S. Navy** Nancy Ruiz 805-982-1155 nancy.ruiz@navy.mil **EPA** Chunming Su 580-436-8638 Su.Chunming@epamail.epa.gov Bob Puls, EPA puls.Robert@epa.gov **Geosyntec Consultants** Suzanne O'Hara 519-822-2230 ext.234 sohara@geosyntec.com Thomas Krug tkrug@geosyntec.com Mark Watling **NASA** Jackie Quinn 321-867-8410 Jacqueline.Quinn-1@ksc.nasa.gov	Krug, T., O'Hara, S., Watling, M., and Quinn, J. *Emulsified Zero-Valent Nano-Scale Iron Treatment of Chlorinated Solvent DNAPL Source Area. FInal Repor* t. ESTCP Project ER-0431. April 2010. EPA. NRMRL. *Field Test on the Treatment of Source Zone Chloroethenes Using Nanoscale Emulsified Zero-Valent Iron.* Jacqueline Quinn. NASA. *Emulsified Zero-Valent Iron, Laboratory and Field Testing* . www.frtr.gov/pdf/meetings/may07/quinn_presentation.pdf
Vandenberg Air Force Base (continued)	Santa Maria, CA	Not available	No	No	The collection of soil cores from locations surrounding each injection point or test injection point was found to be the most useful method for evaluating distribution of BOS100® in the subsurface during Phase II. Post-injection groundwater samples were collected from the same monitoring wells as baseline samples 3 weeks after the injection on February 19 - 20, 2009 and 8 weeks after injection on March 27, 2009.	Phase I: January 2008 Phase II: January 2009	Phase I: Not available Phase II: January 25, 2009	Phase II: 12 days	The Phase I injection of the pilot study had limited success due to incomplete distribution of the BOS100®. Phase II groundwater sampling results showed that there was no change in contaminant concentrations from the pre-injection baseline. In addition, EC probe results were inconsistent with core results and use of the EC probe and bromide tracer was discontinued.	Not available	During the pilot, it was concluded that there was too much uncertainty associated with injection of BOS100® and physical emplacement methods should be considered. Based on the results of these 2 studies and evaluation of site conditions, direct soil mixing technology utilizing biopolymer slurry as both drilling fluid and the vehicle for delivery of BOS100® was recommended. The new delivery method is currently under evaluation. As of March 2011, there were no plans to do any additional injections at the sire.	Andrea Leeson Department of Defense 703-696-2118 Andrea.Leeson@osd.mil	EPA. Technology News and Trends. "ESTCP Evaluates Bimetallic Nanoscale Particles in Treating CVOCs." March 2004 www.clu-in.org/products/newsltrs/tnandt/view.cfm?issue=0304.cfm AECOM. Site 15 ABRES-B Launch Complex Distal Plume Treatability Study Field Modification Report.Vandenberg Air Force Base, California Site 15. September 2009.
Phoenix Goodyear Airport - North (Unidynamics) Phase I (continued)	Goodyear, AZ	• Achieve target compound concentration decreases in source area • Collect information for the design of full scale system	No	Yes	Sampling at variable time intervals.	January 2006	March 2008	Injection was for 3 days. Post injection monitoring was conducted for 2 months.	Some significant challenges were identified as a result of Phase I testing, including the lithology and aqueous geochemistry of the site; the poor predictive value of column studies for the success of field injections; agglomeration of aged nZVI particles that resulted in clogging; and limited distribution of nZVI in the aquifer. There was a limited ORP decrease at the injection well.	Not available	The first test was unsuccessful due to problems with the delivery of nanoparticles. Further injections will be conducted using new wells and different solutions, including sodium hydroxide and hexametaphosphate. Injections were proposed for Spring 2008.	Glenn Bruck, EPA 415-972-3060 bruck.glenn@epa.gov Robert J. Ellis, L.G. ARCADIS-US 248-994-2252 rellis@arcadis-us.com	Preliminary & final report for Phase I testing. Ellis, Robert J., Harry S. Brenton, David S. Liles; Michael A. Hansen. 2007. *Nanoscale Zero Valent Iron Bench Scale Kinetic and Phase II Injection Testing, Phoenix-Goodyear Airport North Superfund Site, Goodyear, Arizoma* . U.S. EPA Desert Remedial Action Technologies Conference Proceedings. www.epa.gov/osp/presentations/drat/D-RAT_Workshop_Proceedings_(Oct_2-4,_07).pdf

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Site Information							Media		Contaminants			Technology Information		
Site Name	Site location (city, state)	EPA Region	Site type	Cleanup program	Scale	Geology	Media treated	Volume of media treated	Contaminants treated	Initial contaminant concentrations	Final contaminant concentrations	Type of nanoparticle	Technology design	Vendor Information
Phoenix Goodyear Airport - North (Unidynamics) Phase II	Goodyear, AZ	9	Former Missile Development R&D Facility	CERCLA	Pilot	Deposits at the site consist of an upper alluvial unit, middle fine-grained unit, and lower conglomerate unit. Groundwater is present at 85 ft bgs. The target injection interval was 110 to 120 ft bgs.	Groundwater	Not available	TCE, PCE, Perchlorate	Total contaminant concentration ranged from 3,500 to 11,000 µg/L	Not available	nZVI	Phase II testing was intended to understand and overcome some of the challenges that occured during Phase I testing. It included additional groundwater testing; shelf life/longevity of nZVI in terms of reactivity; and kinetics studies to better understand TCE reduction once nZVI is introduced into the ground. • During this phase, 10,400 liters (2,750 gallons) nZVI, at a concentration of 2.1 g/L, was gravity fed at a pressure of 26 psi through an injection well with 10 ft long 6 inch diameter stainless steel wire and 0.03 slot screen. • The average injection rate was 1.6 gpm. • To address potential agglomeration issues that occured during Phase I of the demonstration, deoxygenated site water, SHMP dispersing agent, and onsite colloid mill was used.	Polyflon Company PolyMetallix™
Phoenix Goodyear Airport - North (Unidynamics) - Phase III	Goodyear, AZ	9	Former Missile Development R&D Facility	CERCLA	Pilot	Deposits at the site consist of an upper alluvial unit, middle fine-grained unit, and lower conglomerate unit. Groundwater is present at 85 ft bgs. The pilot test will target the same depth interval as the existing monitoring well screens (108–118 ft bgs) to ensure representative downgradient performance monitoring.	Groundwater	Not available	TCE, PCE, Perchlorate	Max baseline concentrations detected (µg/L): PCE: 3 TCE: 6,300 cis-1,2-DCE: 2	Not available	nZVI	In order to maximize nZVI distribution and effectiveness for removing TCE and perchlorate from groundwater, a high pressure injection method was proposed for Phase III testing. • The nZVI injection was conducted using combination of a jet lance injection tool with pressurized packer isolation of the target injection zone. • A total of volume of 8,000 gallons of 21 g/L of Polyflon Company's PolyMetallix was injected through two injection intervals: 108 to 113 ft bgs, and 113 to 118 ft bgs (2,000 gallons containing 350 lbs of PolyMetallix™ per injection interval). •The nZVI delivered to the site contained 5% polyacrylate and 5% SHMP by weight. The nZVI also contained a 0.5% by weight guar gum, a biopolymer, and cross linker (sodium borate decahydrate), that was used to assist with maintaining suspension of the nZVI particles during shipment and improve cohesion of the injectate during the injection process.	Polyflon Company PolyMetallix™
Industrial Site	Edison, NJ	2	Former Adhesives Manufacturer	Private	Pilot and Full Scale	The industrial site consists of mostly fractured bedrock, specifically Brunswick Shale. Surface elevation at the site ranges from approximately 95 ft above msl to approximately 85 ft msl. Surface water generally drains to the southeast-southerly direction and collects in an undeveloped portion of the property that occasionally floods. Over the bedrock, there is 4 to 6 ft of soil comprised of silt and clay	Groundwater	Not available	TCA, TCE, DCA, DCE, chloroethane, VC	Pilot Scale: Max TCA concentration: 37,000 mg/L; TCA at injection well 1: 10,000 µg/L ; presence of DNAPL possible Full Scale: Within the Shallow Target Zone a TCA concentration range of 170,000 - 1,200,000 ppb was detected and within the Deeper Zone a TCA concentration range of 13,000 ppb - 190,000 ppb was detected.	Pilot: TCA concentrations decreased to below detection limits within 7 months and continue to be below detection limits more than 1 year after the pilot study. DCA concentrations experienced an initial increase due to the degradation of TCA, however levels quickly began to decline. Full Scale: TCA concentrations decreased within the Shallow Target Zone to a range of 710 ppb to 730,000 ppb. TCA concentrations decreased within the Deeper Target Zone to a range of non detect to 21,000 ppb.	nZVI (engineered zero valent metal powder (Z-loy) manufactured by OnMaterials)	The remedial injection included a combination of remedial products which were co-injected: nZVI (OnMaterial's Zloy), emulsified vegetable oil (NewmanZone) and filtered potable water. Due to the primary source being located beneath a building, a series of pilot studes were designed to evaluate injection well design, geophysical data collection and evaluate pneumatic injection technology to enhance injection delivery to reduce the number of injection wells and to target specific vertical zones. Based upon field pilot tests, a series of shallow (3 to 12 ft bgs) and deeper injection wells (15 to 30 ft bgs) were designed to optimize injection delivery. The deeper injection wells were deigned to incorporate alternative injection techniques in order to target specfic vertical zones and fractures that were identified from the borehole geophysics. A total of 3,000 gallons was injected within the Shallow Target Zone and 7,013 gallons was injected within the Deeper Zone.	Delta Environmental Consultants, Inc.

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		Cleanup/ remedial objectives and goals	Were cleanup goals and objectives met? (Yes/No)	Performance data available (Yes/No)	Maintenance (O&M) activities/ monitoring system	Start date/date installed	Anticipated end date of current phase	Length of operation	Comments				
Phoenix Goodyear Airport - North (Unidynamics) Phase II (continued)	Goodyear, AZ	• Achieve target compound concentration decreases in source area • Collect information for design of full scale	Not available	Post- injection monitoring ongoing	Ongoing periodic monitoring at 3 wells (5 ft, 10 ft, and 14 ft from injection well) for 3 to 6 months.	April 2008	December 2008	The injection occured over a period of 3 days. Post injection monitoring was conducted for 3 to 6 months.	It was observed that the dispersing agent SHMP could be used to overcome the agglomeration issues and aid in dispersal of the subsurface, and that nZVI remained reactive for 30 days after production. Evidence of nZVI was noted 5 ft downgradient of the injection point, indicating a radius of influence of at least 5 ft, and an estimated mobile porosity of 0.31. The injection also showed a 2 order of magnitude decrease in permeability based on slug testing completed before and after injection. There was a decrease in the injection rate over the duration of the test, indicating an apparent decrease in permeability within the aquifer. The apparent loss of permeability may be temporary due to geochemical reactions, such as hydrogen gas production and amorphous mineral precipitation, or semi-permanent, due to emplacement of nZVI particles within the aquifer.	Not available	Work is ongoing on testing and enhancing nZVI technology, which remains a viable option for remediation of TCE in the source area at the site.	Robert J. Ellis, L.G. ARCADIS-US 248-994-2252 rellis@arcadis-us.com	Abstract: "Nanoscale Zero Valent Iron Phase II Injection Field Pilot Study, Phoenix-Goodyear Airport North Superfund Site, Goodyear, Arizona" Authors: R.J. Ellis, H.S. Brenton, D.S. Liles, C. McLaughlin, N. Wood in U.S. EPA International Nanotechnology Conference October 5-7, 2008 Proceedings. Ellis, Robert J., Harry S. Brenton, David S. Liles; Michael A. Hansen. 2007. *Nanoscale Zero Valent Iron Bench Scale Kinetic and Phase II Injection Testing, Phoenix-Goodyear Airport North Superfund Site, Goodyear, Arizona.* U.S. EPA Desert Remedial Action Technologies Conference Proceedings. www.epa.gov/osp/presentations/drat/D-RAT_Workshop_Proceedings_(Oct_2-4,_07).pdf
Phoenix Goodyear Airport - North (Unidynamics) - Phase III (continued)	Goodyear, AZ	• Demonstrate that a pressurized injection method (jet-assisted injection) can increase the nZVI mass applied at each point and increase the radius of influence of injected nZVI as compared to the Phase I and II results • Reduce TCE and perchlorate concentrations within the treatment area • Evaluate the persistence of the nZVI in the treatment are area	No	Yes	A baseline monitoring round would be performed prior to injection of the nZVI. After injection, groundwater samples will be collected using the EPA approved low flow sampling method at 2 weeks, 1 month, 2 months, 3 months, and 6 months post-injection.	February 2010	February 2010	The injection occured over a period of 3 days. Post injection monitoring was conducted for 3 to 6 months.	The data suggests that despite the already low ORP conditions from previous nZVI injections at this location, significant TCE degradation is not occurring.	Not available	The Month 6 post-injection monitoring event is presently scheduled for August 4 through 6, 2010.	Paula Chang Phone: 480-455 -6075	Environmental Resources Management, Inc. *Technical Memorandum: Nano-scale Zero-Valent Iron Pilot Test Conceptual Design Approach Phoenix-Goodyear Airport-North Superfund Site Goodyear, Arizona.* July 21, 2009. Environmental Resources Management, Inc. *Draft Technical Memorandum #6 Pilot Test Work Plan Phase III Nano-scale Zero-valent Iron Injection Field Testing Program Phoenix-Goodyear Airport-North Superfund Site Goodyear, Arizona*. August 2009
Industrial Site (continued)	Edison, NJ	Not available	Not available	No	Groundwater monitoring was performed 1 month prior to and 13 months subsequent to the pilot study injection.	Not available	Not available	13 months	The TCA concentrations in the majority of monitoring wells containing TCA appear to be highly biodegradable by reductive dechlorination. The evidence from accumulated groundwater data and chemical data trends are consistent with the expected biochemical degradation pathway for TCA to its breakdown products of 1,1-DCA and chloroethane; where Dehalobacter bacterium was demonstrated to be present in groundwater at this site. The accumulated groundwater data also indicates 1,1-DCE is being converted by reductive dechlorination to VC; where evidence suggests that VC is being converted to ethene slowly. The degradation process has been slow where lower than optimum pH for D.ethenogenes has been monitored. The abiotic processes are more prominent in the shallow zone where the levels of TCA may still be too high to promote a more active and healthy biological environment requiring sufficient electron donor within an optimum pH range.	Not available	Not available	Peylina Chu Delta Environmental Consultants, Inc. pchu@deltaenv.com Joshua A. Orris Delta Environmental Consultants, Inc. jorris@deltaenv.com	Chu, Peylina, John Mateo, Sam Fogel, John Freim, Clint Bickmore, William Newman, David Crisman. 2005. *Rapid In-situ Dechlorination of Solvents by Abiotic and Biotic Mechanisms.* Effective Pilot Studies for Combination of Remedial Technologies; Josh Orris & John Mateo – Delta Consultants, Deborah Schnell-Pneumatic Fracturing, Inc. and Clint Bickmore-OnMaterials, LLC; The 5th International Conference proceedings, September 2007, Oxidation & Reduction Technologies for In-Situ Treatment for Soil and Groundwater Combination of Technologies for Full Scale Enhanced Dechlorination Remediation; Josh Orris & John Mateo – Delta Consultants, Deborah Schnell-Pneumatic Fracturing, Inc. and Clint Bickmore-OnMaterials, LLC; The 1st International Conference proceedings, Contaminated Fractured Rock: Characterization & Remediation, September 2007 Schnell, Deborah; Bickmore, Clint; Mateo, John; Orris, Josh. *Pneumatic Fracturing / Injection Delivery Evaluation for Enhanced Dechlorination.* May 2006. Battelle proceedings, May 2006, Remediation of Chlorinated and Recalcitrant Compounds

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The list of sites includes information on current or planned applications of nanotechnology at pilot and full scale sites.

Site Information							Media		Contaminants			Technology Information		
Site Name	Site location (city, state)	EPA Region	Site type	Cleanup program	Scale	Geology	Media treated	Volume of media treated	Contaminants treated	Initial contaminant concentrations	Final contaminant concentrations	Type of nanoparticle	Technology design	Vendor Information
Hunters Point Ship Yard, Parcel E	San Francisco, CA	9	Naval Shipyard	Not available	Pilot	2 aquifers and 1 bedrock water-bearing zone have been identified at Hunters Point. Groundwater flow patterns are complex due to heterogeneous hydraulic properties of the fill materials and weathered bedrock, tidal influences, effects of storm drains and sanitary sewers, and variations in topography and drainage. Site soils are characterized as silty sand, sand, and gravel.	Groundwater	Not available	TCE, DCE, VC	Total concentrations of VOCs ranged from 2,600 µg/l to 10,000 µg/l.	Total concentrations of VOC 1,530 µg/l to 21,100 µg/l	nZVI	nZVI was injected into the subsurface of the site.	ARS
Manufacturing Site	Passaic, NJ	2	Former Manufacturer	Not available	Pilot	Soils are composed of high permeability sands from 0 to 20 ft bgs. The silt unit exists from 20 to 26 ft bgs. Most of the contaminant mass is bound within a low permeability silt unit situated at a depth of approximately 20 ft. Prior to the injection of the amendments ORP and DO levels indicated aerobic conditions, there was little to no evidence that biodegradation was occurring and low pH levels were likely inhibiting microbial activity.	Groundwater	Not available	TCE	Total concentrations of VOCs range 450 to 1,400 µg/L.	Post-injection VOC data showed a significant drop in TCE concentrations in the injection area deep well (MW-17D) from 241 mg/L to 13 mg/L by month 6. There was a 90 to 100% reduction in average TCE concentrations.	nZVI	The nZVI and emulsified oil injections targeted a low permeability silt unit where most of the contaminant mass was bound. 108 lbs of nZVI slurry and 1,200 lbs of emulsified oil was injected into 3 points within the silt unit. Pneumatic fracturing injections were used at 2 of the injection points and hydraulic injection was used at the third injection point to enhance the distribution of the amendments.	Not available
Pharmaceutical Facility	Research Triangle Park, NC	4	Former Waste Disposal Area	RCRA	Pilot	The site is located in the west-central portion of the Durham subbasin. The site consists of sandstone interbedded with siltstone grading downward into mudstones. In general, groundwater flow at the site is radial with a hydraulic divide along the topographic ridge.	Groundwater in fractured bedrock	Not available	PCE, TCE, DCE, VC	The max concentration of VOCs was around 14,000 µg/L.	There was over a 90% reduction of pre-injection baseline concentrations at the injection well and observation well. PCE, TCE, and DCE concentrations were reduced to levels near or below groundwater quality standards with no accompanying increases in VC concentrations.	BNP (produced in laboratory by Lehigh University)	The iron nanoparticles were injected as a slurry suspension that was prepared onsite using potable water. The total slurry volume injected was 6,056 liters (1,600 gallons) at a nanoparticle concentration of 1.9 g/L in the slurry. The total nanoparticle mass injected was 11.2 kg. The injection rate was 0.6 gpm. During the injection, the slurry in the tank was mixed continuously to prevent settlement of the larger size particle aggregates.	Pilot test designed and implemented by Golder Associates Inc.

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		Cleanup/ remedial objectives and goals	Were cleanup goals and objectives met? (Yes/No)	Performance data available (Yes/No)	Maintenance (O&M) activities/ monitoring system	Start date/date installed	Anticipated end date of current phase	Length of operation	Comments				
Hunters Point Ship Yard, Parcel E (continued)	San Francisco, CA	Not available	No	No	None	Not available	Not available	Not available	Microscale ZVI was also injected in areas surrounding location of nZVI injections.	Not available	Not available	Steve Pierce Shaw Environmental & Infrastructure 4005 Port Chicago Highway Concord, California 94520 Phone: (925) 288-2139	Email from Steve Pierce and Steve Hall on August 17, 2010
Manufacturing Site (continued)	Passaic, NJ	Not available	Not available	Yes	Monitoring occured weekly during the first month and monthly thereafter. A comparison of pre and post-injection electrical imaging surveys and groundwater microscopy samples were used to evaluate the distribution of the nZVI particles achieved by the fracturing techniques.	September 2005	Not Available	6 months	Pre-Injection ORP levels were 375 to 550 mV with a pH between 3 to 4.5. Within days after the injections, ORP and DO levels dropped significantly to levels as low as -500 mV and indicated anoxic conditions and resulting sulfate reduction to methanogenesis had been achieved. In addition, pH levels had increased to near neutral. 6 months after the injection ORP levels were still below -100 mV and continue to decrease downgradient of the pilot study area, and DO levels are still anoxic. nZVI particles were detected in samples collected from monitoring wells in the silt unit and the overlying sand unit at distances up to 25 ft from the injection points. In addition, post-injection TCE concentrations increased significantly in the sand unit (from 1.4 mg/L to 220 mg/L by month 2). This indicates that both of the fracturing techniques were successful in distributing the nZVI a significant distance from the injection points.	Not available	Not available	David Liles ARCADIS 919-544-4535 dliles@arcadis-us.com	Zhang, W.X., N. Durant and D. Elliott. *"In-situ remediation using nanoscale zero-valent iron: fundamentals and field applications."* Battelle Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey California. May 22-25, 2006 Sullivan, Edward. . University of Massachusetts - Amherst. *Combined Abiotic and Biotic Dechlorination of TCE in a Low Permeability Aerobic Aquifer.* 2006. The 22nd Annual International Conference on Soils, Sediments and Water
Pharmaceutical Facility (continued)	Research Triangle Park, NC	Source mass reduction	Yes	Yes	3 monitoring wells were installed at distances of 6.6, 13, and 19 meters downgradient of injection well.	September 2002	December 2002	3 months	The radius of influence of the injection, as measured by significant contaminant concentration reduction, was approximately 6 to 10 meters around the injection well. The pilot objectives were met. ORP conditions in most of the test area were indicative of iron-reducing conditions (i.e., approximately +50mV to −100mV redox potential), and were lowered during and after the injection, with measured in-situ redox potentials of approximately −700mV in the injection well, and −500mV in the nearby monitoring wells.	Not available	Full-scale system design to be completed in 2008	Florin Gheorghiu Golder Associates 856-793-2005 'florin@golder.com' Wei-xian Zhang Lehigh University 610-758-5318 wez3@lehigh.edu	Zhang. , Wei-wian. *Nanoscale iron particles for environmental remediation: An overview.* Journal of Nanoparticle Research 5: 323-332. 2003. *Applications of Iron Nanoparticles for Groundwater Remediation* Wei-xian Zhang and Daniel W. Elliot REMEDIATION Spring 2006 Glazier, Robert Venkatakrishnan, Ramesh; Gheorghiu, Florin; Walata, Lindsey; Nash, Robert; Zhang, Wei-xian. *Nanotechnology Takes Roo.* Civil Engineering Magazine. May 2003. Gheorghiu, Florin; Christian, Mace; Venkatakrishnan, Ramesh,; Zhang,Wei-xian.. *In-Situ Treatments using Nano-Scale Zero-Valent Iron Implemented in North America and Europe.* U.S. EPA Workshop on Nanotechnology for Site Remediation U.S. Department of Commerce, Washington DC. October 20 – 21, 2005. www.frtr.gov/nano/pdf/day1/gheorghiu_florin.pdf

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Selected Sites Using or Testing Nanoparticles for Remediation.

The list of sites includes information on current or planned applications of nanotechnology at pilot and full scale sites.

Site Information							Media		Contaminants			Technology Information		Vendor Information
Site Name	Site location (city, state)	EPA Region	Site type	Cleanup program	Scale	Geology	Media treated	Volume of media treated	Contaminants treated	Initial contaminant concentrations	Final contaminant concentrations	Type of nanoparticle	Technology design	
Nease Chemical	Salem, OH	5	Former Pesticides Manufacturer	CERCLA	Pilot	The geology at the site generally consists of glacial till overburden lying above fractured sedimentary bedrock. nZVI was selected to treat the bedrock groundwater and overburden contamination in the southern part of the site. The bedrock plume extends about 1,700 ft from the source areas toward the east.	Groundwater in fractured bedrock	Not available	PCE, TCE, DCE, VC	• PCE: 80 mg/L • TCE: 21 mg/L • cis-DCE: 11 mg/L • 1,2-Dichlorobenzene: 15 mg/L • Benzene: 7 mg/L	• 38 to 88% reductions in PCE • 30 to 70% reductions in TCE • increases in cis-DCE • complete reduction in 1,2-Dichlorobenzene	nZVI (produced by Golder Associates Inc. under license from Lehigh University)	The field pilot study was designed based on the results of the bench test. During the field pilot study, 100 kg of nZVI in 2,665 gallons of clean water was injected into a highly contaminated portion of the aquifer. The iron was injected in batches containing powdered soy as an organic dispersant (20 percent by weight of NZVI), and most batches contained a small amount of palladium (1 percent by weight).	Pilot test designed and implemented by Golder Associates Inc. (Stephen Finn, Allen Kane, Florin Gheorghiu)
BP -- Prudhoe Bay Unit	North Slope, AK	10	Abandoned Oil Field	RCRA	Pilot	Site soils are characterized as organic-rich soil over alluvial gravels	Soil	Not available	TCA, Diesel fuel	Max TCA: 58,444 µg/kg	Shallow Test: TCA reduction of 96% 1 year after application (mean concentration) Deep Test: TCA reduction of 40% (mean concentration using combined post-test results)	BNP	The pilot test used 2 distinct BNP delivery methods: • The shallow test involved physical mixing with lake water for shallow soil from 0 to 4 ft bgs. • The deep test involved pressurized injection via 20 injection points installed at 7.5 ft bgs. Treatment and control plots for each delivery method were subjected to identical treatment processes to validate the results.	• PARS Environmental, Inc. • Lehigh University
Industrial Plant	Rochester, NY	2	Former Manufacturing	RCRA	Pilot	The site is characterized by glacial till overburden lying above fractured sedimentary bedrock.	Groundwater in bedrock	Not available	Methylene chloride, 1,2-DCP, 1,2-DCA	Total contaminant concentration: 500,000 µg/L	Total contaminant concentration: 50,000 µg/L	nZVI (produced by Golder Associates Inc. under license from Lehigh University)	Gravity feed injection was used to inject a total of 100 kg of nZVI. An nZVI slurry concentration of 10 to 20 g/L was used.	Pilot test designed and implemented by Golder Associates Inc. (Allen Kane, Florin Gheorghiu)
Picatinny Arsenal Superfund Site	Rockaway Township, NJ	2	Munitions Arsenal	CERCLA	Pilot	Site consists of organics-rich soil.	Groundwater	Not available	CCl_4, TCE	• CCl_4: 250 µg/L • TCE: 87 µg/L	• CCl_4 concentration was 180 µg/L 4 weeks after injection, but rebounded to 230 µg/L 4 months after injection. •TCE was 54 µg/L 4 months after injection	nZVI (Ferragel Particles)	Approximately 120 lbs of nZVI were injected via two 4-inch temporary injection wells.	• Shaw Environmental, Inc. • PARS Environmental, Inc.

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		Cleanup/ remedial objectives and goals	Were cleanup goals and objectives met? (Yes/No)	Performance data available (Yes/No)	Maintenance (O&M) activities/ monitoring system	Start date/date installed	Anticipated end date of current phase	Length of operation	Comments				
Nease Chemical (continued)	Salem, OH	• Achieve reduction in target compounds • Collect information for design of full scale	Yes	No	4 wells installed at close range were monitored during injection for water levels and geochemical parameters. Chemical monitoring has been conducted periodically for 6 months. Monitoring of natural attenuation will occur to ensure remediation of the far downgradient portion of the plume.	• August 2006: Bench Scale Test • November 2006: Field Scale Test	Not available	Not available	Not available	• Pilot cost: $177,000 • Estimated full scale cost: $19 million	Enhanced biotreatment will be considered as a "polishing" step to address benzene expected to remain after nZVI treatment. Results from the treatability study will be used to design the full-scale system.	Dion Novak U.S. EPA Region 5 312-886-4737 Novak.Dion@epamail.epa.gov	U.S. EPA. *Technology Update #1: Nanotechnology Fact Sheet-Nease Chemical Site,* September 2006. U.S. EPA. *Technology Update #2: Nanotechnology* Fact Sheet - Nease Chemical Site, June 2007.
BP -- Prudhoe Bay Unit (continued)	North Slope, AK	• Assess any reduction in TCA concentrations in soil and water • Determine the effective radius on influence of the technology	Not available	Yes	Shallow test: Soil samples were collected from 4 well-distributed locations within the shallow test treatment plot and 3 locations within each of the control plots at 3 equally divided intervals. Deep Test: Soil Samples were collected from 6 locations within the treatment plot and one location within the control plot. 4 soil samples were collected at each location at different intervals. Post-test soil and water samples were collected from the treatment and control plots 3 weeks after treatment. Supplemental sampling and anlysis was conducted 1 year following the performance of the pilot test.	Fall 2006	Shallow Test: Not available Deep Test: August 20, 2008	Shallow test: Not available Deep Test: 40.5 hours	Physical mixing with BNP reagent at shallow depths was more effective than BNP reagent injection through vertical well points. Injection of the BNP slurry resulted in preferential flow of the reagent through subsurface fractures, with a radius of influence of approximately 5 to 6 ft. In addition, in-situ appliocation of the reagent using the injection method did not appear effective at distributing the BNP reagent within or below the active layer within the gravel pad.	Not available	Not available	Roberta Hedeen EPA, Region 10 206-553-0201 hedeen.roberta@epa.gov	Oasis Enviromental. *Bimetallic Nanoscale Particle Technology Test, Tuboscope Site Pilot Test Results Report. Greater Prudhoe Bay, North Slope Alaska.* December 12, 2008.
Industrial Plant (continued)	Rochester, NY	• Achieve reduction in target compounds • Collect information for the design of full scale system.	Yes	No	Not available	2004	Not available	Not available	Not available	Not available	Not available	Allen Kane, Golder Associates 610-941-8173 akane@golder.com	Macé, Christian; Gheorghiu, Florin; Desrocher, Steve; Kane, Allen; Pupeza, Michael; Cernik, Miroslav; Kvapil, Petr; Venkatakrishnan, Ramesh; Zhang, Wei-Xian. *"Nanotechnology and Groundwater Remediation, A Step Forward in Technology Understanding,"* Remediation Journal, Wiley Periodicals, Inc. 2006.
Picatinny Arsenal Superfund Site (continued)	Rockaway Township, NJ	• CCl_4: 2 µg/L • TCE: 1 µg/L	No	Yes	4 monitoring wells were installed and 4 rounds of sampling were conducted.	August 2004	August 2005	1 year	Not available	Not available	After reviewing the results of the pilot test, the remedial team decided to utilize different technology to cleanup the site.	Bill Roach, RPM EPA, Region 2 212-637-4335 roach.bill@epa.gov Jon Josephs EPA, Region 2 212-637-4317 josephs.jon@epa.gov	*Picatinny Task Order 17, Site 2, Nanoscale ZVI Pilot Study Report,* August 2005.

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Site Information							Media		Contaminants			Technology Information		
Site Name	**Site location (city, state)**	**EPA Region**	**Site type**	**Cleanup program**	**Scale**	**Geology**	**Media treated**	**Volume of media treated**	**Contaminants treated**	**Initial contaminant concentrations**	**Final contaminant concentrations**	**Type of nanoparticle**	**Technology design**	**Vendor Information**
Alabama Site	Northern Alabama, AL	4	Abandoned Metal Processing Plant	Not available	Pilot	The subsurface is characterized as heterogeneous with a relatively shallow semi-confined aquifer. The hydraulic conductivity is approximately 20 ft per day. The effective porosity is about 0.15.	Soil and groundwater	Not available	PCE, TCE, and PCBs	TCE: MW-1 (1655 µg/L) MW-2 (3710 µg/L)	TCE: MW-1 (72 µg/L) and MW-2 (less than 10 µg/L) The concentrations of PCE, TCE and PCB in monitoring well (MW)-1 were lowered by up to 77%, 85%, and 83%, respectively, and continuously reduced by 59%, 96%, and 10% respectively at the end of 29 days. In MW-2, the concentrations of PCE, TCE and PCB were lowered by up to 98%, 82%, and 95% respectively in the first 10 days and continuously reduced by 99%, 100%, and 93% at the end of 29 days.	CMC stabilized zero-valent iron	The test area was approximately 135 ft^2. 150 gallons of 0.2 g/L Fe-Pd nanoparticle suspension was synthesized on site and gravity fed into the test area over a 4-hour period. The 0.2 g/L nanoparticle suspension was injected into the ground to a depth of 44.5 to 49.5 below the injection well.	Collaboration between Golder Associates, Fisher, Acros Organics, and Strem (supplier of nanoparticles)
OU-2B Installation Restoration Site 4	Alameda Point, CA	9	Navy Installation	Navy Installation Restoration Program	Pilot	Alameda Island lies at the base of a gently westward-sloping plain that extends from the Oakland-Berkeley Hills in the east to the shore of San Francisco Bay in the west. The thickness of geologic units varies throughout Alameda Point. Artificial fill was encountered from the surface to a max depth of 8 ft bgs in borings at locations across OU 2.	Groundwater	48,000 ft^3 (total volume of soil and groundwater in treated zone)	TCE	The average initial TCE concentration was 2,500 µg/L. The range of TCE concentrations at the site ranged from below laboratory reporting limits to a max of 38,000 µg/L.	The average concentration throughout the treated volume was approximately 1,600 µg/L. The majority of the reduction occurred at a single monitoring point. Most of the other monitoring points showed an increase in TCE concentration.	Surface-modified nZVI	In November 2009, direct injection was used to injection over 500 gallons of nZVI at three injection locations on the site. 1 injection location was abandoned due to a surface breach; surfacing of significant amounts of ZVI material was observed as the injection progressed.	nZVI Product: OnMaterials Injection: ARS Technologies
Valcartier Garrison	Quebec, Canada	NA	National Defense Site	NA	Pilot	Site soils are characterized as Deltaic and Proglacial Sands	Soil	~4,500 m^3	TCE, DCE, VC	• TCE: ~300 µg/L • DCE: ~50 µg/L	• TCE: <5 µg/L • DCE: <50 µg/L	nZVI with a palladium catalyst and soy powder dispersant (nZVI produced by Golder Associates Inc. under license from Lehigh University)	About 4,550 kg of nZVI/BNP was injected with a soy protein surface modification. The mass of nZVI injected was based on TCE concentration distribution and depth within the aquifer. Injection used multiple screen wells and packers for unit specific placement. A very small mass of nZVI was injected under the silt layer. A metallic catalyst was added to nZVI particles prior to the injection event to speed up the degradation rate and a food-grade dispersing agent was also used to enhance particle migration distance and to reduce settling. Follow-up actitivies included groundwater recirculation and enhanced bioremediation.	Pilot test designed and implemented by Golder Associates Ltd. (Sylvain Hains)

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Site Name	Site location (city, state)	Performance Information								Cost Information	Future Work/ Current Plans	Contact Information	Information Sources
		Cleanup/ remedial objectives and goals	Were cleanup goals and objectives met? (Yes/No)	Performance data available (Yes/No)	Maintenance (O&M) activities/ monitoring system	Start date/date installed	Anticipated end date of current phase	Length of operation	Comments				
Alabama Site (continued)	Northern Alabama, AL	Confirm effectiveness of the nanoparticles, mobility of the particles in soil, and ability to degrade contaminants	Yes	Yes	Groundwater samples were collected from 2 monitoring wells MW-1 (5 ft down gradient) and MW-2 (10 ft down gradient) before and after injection.	March 2006	February 2007	• 29 days of field injection and monitoring • 1 full year including preparation	Approximately 37.4% and 9.0% of the injected iron was observed 5 ft and 10ft down-gradient MW-l and MW-2, respectively, confirming the soil mobility of the nanoparticles through the aquifer. Rapid degradation of primary contaminants PCE, TCE, and PCBs was observed in both MW-l and MW-2, with the max degradation being observed during the first week of the injections. The contaminant concentrations gradually increased back to their pre-injection levels in about 12 days. However, after 596 days from the first injection, the total chlorinated ethenes concentration decreased by about 40% and 61% in MW-1 and MW-2, respectively. It is proposed that CMC-stabilized nanoparticles facilitated the early stage rapid abiotic degradation. Over the long run, the existing biological degradation process was boosted with CMC as the carbon source and hydrogen from the abiotic/biotic processes as the electron donor, resulting in the sustained enhanced destruction of the chlorinated organic chlorinated ethenes in the subsurface.	Not available	Work is currently ongoing at the site.	Don Zhao Auburn University Phone: 334 844 6277 Fax: 334 844 6290 dzhao@eng.auburn.edu	*Project Completion Report: Pilot-Testing an Innovative Remediation Technology For In-Situ Destruction of Chlorinated Organic Contaminants in Alabama Soils and Groundwater Using a New Class of Zero Valent Iron Nanoparticles.* Auburn University. June 2007. water.usgs.gov/wrri/06grants/progress/2006AL48B.pdf *Pilot-Testing Carboxymethyl Cellulose Stabilized for In-Situ Destruction of Chlorinated Solvents at Alabama Site.* University of Massachusetts Amherst, June 2009, Pages 30-31.
OU-2B Installation Restoration Site 4 (continued)	Alameda Point, CA	There were no specific cleanup goals. The overall objective of the pilot study was to assess the viability of nZVI injection as a treatment technology to accomplish the degradation of dissolved contaminants, particularly TCE.	No	Yes	31 monitoring wells were installed to various depths ranging from 6 to 60 ft bgs to monitor the nZVI injection. These monitoring wells along with 2 existing wells were sampled prior to injection to establish baseline concentrations. Following the injection, all monitoring locations were sampled at 4 post-injection monitoring intervals, conducted approximately 1, 2, 6, and 12 weeks following injection completion.	November 10, 2009 (injection start date)	February 2010	100 days	1 monitoring well within 11 ft of an injection-site showed significant reduction of TCE from a baseline concentration of 38,000 µg/L to 12,000 µg/L. The majority of monitoring locations showed increases in concentrations of TCE as well as other VOCs, indicating desorption of VOC compounds from soil occurred at some locations. A composite radius of influence of 10.7 ft for the nZVI injection was calculated based on post injection sampling data.	The total cost of the treatability study was $838,165. Costs include: • Administrative and Planning Costs: $90,000 • Site Characterization Costs: $125,000 • Injection Costs: $327,165 • Monitoring and Sampling: $190,000 • Other Costs (Project management, waste disposal, report production): $106,000 • The total cost per pound of TCE removed was $1,175,131.	The results of this treatability study indicate that nZVI injection for the purpose of source reduction in the treatment area was not a cost-effective option for treatment and the technology was not implemented for the full-scale treatment of TCE.	Michael O'Hare Tetra Tech ECI 619-471-3512 michael.ohare@tetratech.com	TtEC (Tetra Tech EC, Inc.). 2010. *Preliminary Draft Zero-Valent Iron Treatability Study Repor*t. Alameda Point, Alameda, California. April 19
Valcartier Garrison (continued)	Quebec, Canada	• Achieve reduction in TCE concentrations to below 5 µg/L. • Collect information for design of a full scale system.	Yes	Yes	Not available	July 2006	May 2007	12 months	The treatment system achieved a 99% reduction after 1 year of treatment. The complete treatment (including biological contribution) needed about 6 months to be effective to reach the performance criteria. The treatment process helped to stimulate secondary reduction reactions (biological and chemical). The efficiency of the treatment process to reduce TCE concentrations was significantly enhanced by adding reactives (dissolved hydrogen) and by uniformizing geochemical conditions with groundwater recirculation. ORP levels reached approximately -500 mV after injection and remained lower than background levels for greater than 12 months.	Not available	Potential full-scale implementation was planned for 2009. No update received as of March 2011.	Sylvain Hains Golder Associates 418-781-0285 SHains@golder.com	Hains, Sylvain. *Implementation of nZVI Reactive Zone for the Treatment of TCE in a Deep Aquifer.* Power Point Presentation and Platform Paper. Battelle. 2008.

* Note: Sites with an '*' indicate that the data have not been independently verified.

The list of sites includes information on current or planned applications of nanotechnology at pilot and full scale sites.

Site Information							Media		Contaminants			Technology Information		
Site Name	Site location (city, state)	EPA Region	Site type	Cleanup program	Scale	Geology	Media treated	Volume of media treated	Contaminants treated	Initial contaminant concentrations	Final contaminant concentrations	Type of nanoparticle	Technology design	Vendor Information
Penn-Michigan Manufacturing Site Phase I and Phase III (Location 1)	West Lafayette, OH	5	Industrial Site	State remedial cleanup	Pilot	The TCE contaminant plume is located approximately 60 to 120 ft bgs in a sand and gravel aquifer with a high groundwater flow rate of 0.5 ft per day.	Groundwater	52,000 ft^3	TCE	300 to 1,000 µg/L	Performance monitoring 1 month after the initial injection indicated an average 64% reduction in VOC concentrations in test-area groundwater. Results showed TCE concentrations 10 to 90% lower than pre-injection concentrations. 7 months later, groundwater sampling at 4 of the 6 wells showed TCE concentrations had rebounded slightly, with TCE concentration reductions varying from 0 to 61%. Offsite groundwater sampling 21 ft downgradient of the injection site showed a TCE concentration of 597 µg/L, a 40% reduction from the initial 1,000 µg/L.	Iron-Osorb™. nZVI-silica hybrid nanoparticles	IronOsorb™ was injected into the contamination zone. IronOsorb™ is the incorporation of nZVI into Osorb forming a material that can dechlorinate captured organics. The glass matrix concentrates the chlorinated solvents and protects the embedded metal particles from deactivation by dissolved ions. After the Osorb has captured the organic compounds, it can be put through a thermal or rinsing process to release the compounds allowing for the capture of the organic compound and the reuse of the Osorb. The first injection (Phase I) at the site was performed on July 21, 2009, through use of a direct push rig. Due to its high hydrophobicity, the iron-silica matrix was injected in a sodium lauryl sulfate slurry to facilitate uniform distribution across a target radius of 15 ft. A total of 12 kg of the fine (200-350 mesh) powder was injected in one borehole at depths of 59, 64, and 69 ft bgs upgradient of an area of groundwater contamination. During Phase III of the demonstration project, citric acid was injected in addition to the Iron-Osorb™ at an injection point in the same location.	ABSMaterials, Inc. Wooster, OH
Penn-Michigan Manufacturing Site Phase II (Location 2)	West Lafayette, OH	5	Industrial Site	State remedial cleanup	Pilot	The TCE contaminant plume is located approximately 60 to 120 ft bgs in a sand and gravel aquifer with a high groundwater flow rate of 10 to 20 cm per day.	Groundwater	52,000 ft^3	TCE	About 500 to 800 µg/L	Test-area groundwater sampling in April yielded TCE concentrations of 200 to 500 µg/L, a 20-50% reduction from pre-injection levels.	Iron-Osorb™. nZVI-silica hybrid nanoparticles	In Phase II of the demonstration project, a second injection of reactive metals was administered to test an alternate formulation of nanometals. The injectant consisted of 27 kg of nanoscale material consisting of 10% iron (%w/w) and 0.3-1% palladium (%w/w). A single injection point was used at the site. Approximately 15 gallons of silica slurry was administered over 12 hours.	ABSMaterials, Inc. Wooster, OH
Penn-Michigan Manufacturing Site Phase IV	West Lafayette, OH	5	Industrial Site	State remedial cleanup	Pilot	The TCE contaminant plume is located approximately 60 to 120 ft bgs in a sand and gravel aquifer with a high groundwater flow rate of 10 to 20 centimeters per day	Groundwater	Not Available	TCE	About 250 to 500 µg/L	On-site TCE concentrations at 2 wells were reduced to below 5 µg/L. Current concentrations are at 97 to 266 µg/L	Iron-Osorb™. nZVI-silica hybrid nanoparticles	During Phase IV, a newly developed injection probe was used. The probe was approximately 6 ft in length (in contrast to the 14-inch probe previously used) and contained additional injection holes to facilitate more even distribution of the silica-based material. The trial also involved injection of a higher volume (57 kg) of material to blanket the treatment area more thoroughly.	ABSMaterials, Inc. Wooster, OH
Industrial Site	Ironton, OH	5	Industrial Site	private (Voluntary Action Program)	Pilot	Complex hydrogeology near the Ohio River	Groundwater	Not Available	TCE	TCE: 60 to 250 µg/L	TCE: 48 to 200 µg/L (20-55% decrease)	Iron-Osorb™. nZVI-silica hybrid nanoparticles	Iron-Osorb™ slurries with a tracer was added to the subsurface of the contamination zones through 3 injections.	ABSMaterials, Inc. Wooster, OH

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Site Name	Site location (city, state)	Performance Information								Cost Information	Future Work/ Current Plans	Contact Information	Information Sources
		Cleanup/ remedial objectives and goals	Were cleanup goals and objectives met? (Yes/No)	Performance data available (Yes/No)	Maintenance (O&M) activities/ monitoring system	Start date/date installed	Anticipated end date of current phase	Length of operation	Comments				
Penn-Michigan Manufacturing Site Phase I and Phase III (Location 1) (continued)	West Lafayette, OH	Achieve reduction in TCE concentrations to below 5 µg/L in groundwater	No	Yes	Groundwater was sampled over 2 months at 6 monitoring wells surrounding the injection point at distances of 7 to 15 ft from the injection point. Samples were taken from 2 monitoring wells and 4 piezometers. A fluorescent tracer glass was embedded in some of the silica-based material and was injected concurrently with the iron-silica material to monitor the travel distance of the iron matrix slurry across the test area.	First Injection (Phase I): July 21, 2009	Not available	9 months	Sampling and tracer results indicated that the slurry had traveled farther than the desired 15-ft radius, as evidenced by tracer material in soil 24 ft downgradient of the injection location. 8 soil borings within the test area indicated the matrix slurry also had dispersed to a volume larger than anticipated, reaching a total of 52,000 ft^3 instead of the targeted 14,000 ft^3. Due to its hydrophobic nature, the material did not easily distribute throughout the aquifer.	The cost of the iron-silica material was approximately $18,000.	Ohio EPA plans to inject additional iron-silica material at the initial injection point at the site (Phase IV). Modified techniques such as lower injection pressures or reduced dilutions in carrier fluids will be used to limit travel distance of the slurry. No interruption of ongoing manufacturing activities at the site is anticipated.	Paul Edmiston pedmiston@wooster.edu (330) 263-2113 Deanna Pickett ABSMaterials 614-257-8943 d.pickett@absmaterials.com Chris Osborne Ohio EPA 740-380-5258 chris.osborne@epa.state.oh.us	Edmiston, Paul. *Pilot Scale Testing of Swellable Organo-Silica-Nanoparticle Composite Materials for the in-situ and ex-situ Remediation of Groundwater Contaminated with Chlorinated Organics*. U.S. EPA. *Ohio EPA Tests TCE Reduction Capacity of Nanoscale Metal-Silica Hybrid Materials. Technology News and Trends.* Issue 49. August 2010. Email from Deanna Pickett on August 12, 2010.
Penn-Michigan Manufacturing Site Phase II (Location 2) (continued)	West Lafayette, OH	Achieve reduction in TCE concentrations to below 5 µg/L in groundwater	No	Yes	Not available	January 2010	Not available	Silica slurry was administered over a period of 12 hours.	Overall results indicated the palladium formula performed comparably to the earlier iron-based media. Due to its hydrophobic nature, the material did not easily distribute throughout the aquifer.	Slightly higher costs were incurred for the palladium formula used in the second injection compared to the Phase I cost.	Ohio EPA plans to inject additional iron-silica material at the initial injection point at the site (Phase IV). Modified techniques such as lower injection pressures or reduced dilutions in carrier fluids will be used to limit travel distance of the slurry. No interruption of ongoing manufacturing activities at the site is anticipated.	Paul Edmiston pedmiston@wooster.edu (330) 263-2113 Deanna Pickett ABSMaterials 614-257-8943 d.pickett@absmaterials.com Chris Osborne Ohio EPA 740-380-5258 chris.osborne@epa.state.oh.us	Edmiston, Paul. *Pilot Scale Testing of Swellable Organo-Silica-Nanoparticle Composite Materials for the in-situ and ex-situ Remediation of Groundwater Contaminated with Chlorinated Organics.* U.S. EPA. *Ohio EPA Tests TCE Reduction Capacity of Nanoscale Metal-Silica Hybrid Materials.* Technology News and Trends. Issue 49. August 2010. Email from Deanna Pickett on August 12, 2010.
Penn-Michigan Manufacturing Site Phase IV (continued)	West Lafayette, OH	Achieve reduction in TCE concentrations to below 5 µg/L in groundwater	Yes, TCE concentration at one MW are well below 5 µg/L.	Yes	Samples were taken from 2 MWs and 6 piezometers located 5 to 30 ft from the point of injection.	July 2010	Not available	Ongoing	Sampling results taken 1 week after the July 28 injection of Iron-Osorb™ materials, have indicated decreases on average of 80 to 90%. Monitoring of results is ongoing.	Slightly higher costs were incurred for the palladium formula used in the second injection compared to the Phase I cost.	Sampling is ongoing. If results of the latest trial are successful, Ohio EPA will evaluate this technology in late 2010 to determine its full-scale potential at the Penn-Michigan site.	Deanna Pickett ABSMaterials 614-257-8943 d.pickett@absmaterials.com Chris Osborne Ohio EPA 740-380-5258 chris.osborne@epa.state.oh.us	Edmiston, Paul. *Pilot Scale Testing of Swellable Organo-Silica-Nanoparticle Composite Materials for the in-situ and ex-situ Remediation of Groundwater Contaminated with Chlorinated Organics.* U.S. EPA. *Ohio EPA Tests TCE Reduction Capacity of Nanoscale Metal-Silica Hybrid Materials. T*echnology News and Trends. Issue 49. August 2010. Email from Deanna Pickett on August 12, 2010 and March 2, 2011
Industrial Site (continued)	Ironton, OH	Achieve reduction in TCE concentrations to below 5 µg/L in groundwater	No	Yes	Extensive soil testing was conducted.	Not available	Not available	3 months	Tracer tests showed the nanomaterials traveled in preferred paths seams within the soil system.	Not available	Not available	Paul Edmiston pedmiston@wooster.edu (330) 263-2113 Deanna Pickett ABSMaterials d.pickett@absmaterials.com	Edmiston, Paul. *Pilot Scale Testing of Swellable Organo-Silica-Nanoparticle Composite Materials for the in-situ and ex-situ Remediation of Groundwater Contaminated with Chlorinated Organics.* U.S. EPA. *Ohio EPA Tests TCE Reduction Capacity of Nanoscale Metal-Silica Hybrid Materials. Technology News and Trends*. Issue 49. August 2010. Email from Deanna Pickett on August 12, 2010 and March 2, 2011

The list of sites includes information on current or planned applications of nanotechnology at pilot and full scale sites.

Site Information							Media		Contaminants			Technology Information		Vendor Information
Site Name	Site location (city, state)	EPA Region	Site type	Cleanup program	Scale	Geology	Media treated	Volume of media treated	Contaminants treated	Initial contaminant concentrations	Final contaminant concentrations	Type of nanoparticle	Technology design	
Active Business Site	Dayton, OH	5	Business Site	private (Voluntary Action Program)	Pilot	Not Available	Groundwater	Not Available	PCE, TCE	• TCE: 50 µg/L • PCE:150 µg/L	20 to 50% decrease in TCE and PCE	Iron-Osorb™. nZVI-silica hybrid nanoparticles	Iron-Osorb™ slurries with a tracer were added to the subsurface of the contamination zones through three injections (15 kg of Iron-Osorb each). The injections were made approximately 7 ft up-graident of a monitoring well. A multi-hole injection tool was used for the injections to provide more uniform distribution of materials in the target remedial zone.	ABSMaterials, Inc. Wooster, OH
Former Manufacturing Site	Bridgeport, OH	5	Manufacturing Plant	State remedial cleanup	Pilot	Ex-situ treatment	Groundwater	Not Available	TCE, DCE, VC	TCE, DCE, VC: 5,800 µg/L	TCE, DCE, VC: non-detect levels	Palladium-Osorb™ palladium-silica nanoparticles	Palladium-Osorb is a metal-glass hybrid material used in ex-situ treatment systems for remediation of chlorinated VOCs. The ex-situ treatment system, tradename VOC-Eater 10™, is a system with 4 columns of Palladium-Osorb™ that influent waters pass through at rates from 10 to 40 gpm. A hydrogen gas source supplies a proton that completes the reductive dehalogenation of contaminants inside the Palladium-Osorb™, and reduces contaminants to benign products of ethane gas and salts (in the reduction of TCE). In this pilot test, the catalytic nanoparticles were fill media in an ex-situ system. Groundwater was pumped through at 3 to 10 gpm while palladium nanoparticles catalytically reduced TCE to ethane gas and salts.	ABSMaterials, Inc. Wooster, OH
Camp Pendleton	Southern CA	9	Marine Corps Base Camp	Not available	Pilot	Not available	Groundwater	Not available	TCE and 1,2,3-TCP	TCP concentration exceeds 0.005 µg/L (State of California notification level)	Not available	nanoscale zero valent zinc (ZVZ)	A pilot project utilizing ex-situ treatment columns is being prepared to test the use of ZVZ to treat the TCP-contaminated groundwater at the site Initial material analysis and treatability assessments were performed with bench-scale batch and column tests. ZVZ tested in the bench scale study included 3 industrial-grade materials, Zinc Dust 64 and Zinc Powders 1210 and 1239. The contractors on this site plan to use the ZVI as a base for ZVZ application rates, methodology, and design application. nZVI is being considered as option for the future pilot demonstration to treat PCE- and TCE- contaminanted groundwater	Parsons (site contractor)
Hill Air Force Base Operable Unit 2	Utah	8	Aircraft Maintenance and Repair	CERCLA	Pilot	Hill AFB overlies 2 formations, the Provo Formation and the Alpine Formation. The Provo Formation consists mainly of coarse-grained soils and overlies the Alpine Formation, which consists mainly of clay, silt, and fine sand and is approximately 200 ft thick. The Alpine Formation is characterized by low permeability, which impedes the downward migration of contaminants. There are 3 aquifer systems underlying Hill AFB OU 2, a shallow unconfined aquifer, the Sunset, and the Delta aquifers. Groundwater depth in the shallow unconfined aquifer was measured as 16.4 ft bgs.	Soil and groundwater	Assuming a test area of 10 ft by 5 ft and a depth interval of 5 ft, the volume of soil to be treated is estimated to be 250 f^{t3}.	TCE	• TCE: 12 mg/kg (Max concentration detected in soil) • TCE: 14.3 mg/L (Max concentration detected in groundwater)	Not available	Stabilized Fe-Pd bimetallic nanoparticles with CM.	The proposed work includes the installation of 4 temporary demonstration wells in a 10 ft by 5 ft test area. This relatively small test area design is based on previous field tests that indicated the max nZVI transport distance was approximately 10 ft. The proposed depth interval of the target treatment volume is approximately from 20 to 25 ft bgs. The proposed field testing will include 3 rounds of nanoparticle injection to deliver a total of 5,220 grams of stabilized Fe-Pd bimetallic nanoparticles to the subsurface. The 3 nanoparticle injection events are planned to progressively assess the transport of nanoparticles in the test area and address potential contaminant rebound after the first injection. Injection and extraction will be conducted simultaneously to create a groundwater recirculation system to optimize particle delivery. The injections will be scheduled approximately 1 month apart from each other. If the groundwater recirculation does not sustain an assumed flow rate of 0.5 gpm, a combination of groundwater recirculation and pressure injection will be used to increase the injection rate.	Not available

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Site Name	Site location (city, state)	Performance Information: Cleanup/ remedial objectives and goals	Were cleanup goals and objectives met? (Yes/No)	Performance data available (Yes/No)	Maintenance (O&M) activities/ monitoring system	Start date/date installed	Anticipated end date of current phase	Length of operation	Comments	Cost Information	Future Work/ Current Plans	Contact Information	Information Sources
Active Business Site (continued)	Dayton, OH	Achieve reduction in TCE and PCE concentrations to below 5 µg/L in groundwater	• TCE: Yes • PCE: No	Yes	Not available	Not available	Not available	3 months	Not available	Not available	Not available	Paul Edmiston pedmiston@wooster.edu (330) 263-2113 Deanna Pickett ABSMaterials d.pickett@absmaterials.com	Edmiston, Paul. *Pilot Scale Testing of Swellable Organo-Silica-Nanoparticle Composite Materials for the in-situ and ex-situ Remediation of Groundwater Contaminated with Chlorinated Organics.* U.S. EPA. *Ohio EPA Tests TCE Reduction Capacity of Nanoscale Metal-Silica Hybrid Materials. Technology News and Trends.* Issue 49. August 2010.
Former Manufacturing Site (continued)	Bridgeport, OH	Achieve concentrations below EPA regulations	Yes	Yes	Effluent samples were taken from the end pipe of the treatment system.	Not available	Not available	Two-week pilot test	Not available	Not available	Not available	Paul Edmiston pedmiston@wooster.edu (330) 263-2113 Dr. Stephen Jolly ABSMaterials s.jolly@absmaterials	*Edmiston, Paul. Pilot Scale Testing of Swellable Organo-Silica-Nanoparticle Composite Materials for the in-situ and ex-situ Remediation of Groundwater Contaminated with Chlorinated Organics.* U.S. EPA. *Ohio EPA Tests TCE Reduction Capacity of Nanoscale Metal-Silica Hybrid Materials. T*echnology News and Trends. Issue 49. August 2010. Email from Deanna Pickett on August 12, 2010 and March 2, 2011
Camp Pendleton (continued)	Southern CA	Evaluate the effectiveness of proprietary forms of ZVZ and high sulfur atomized iron in reducing TCP concentrations in groundwater to below the California action level of 0.005 µg/L	Not available	No	Not available	Not available	Not available	1 year implementation project	Not available	Not available	Based on the bench-scale analyses, Zn64 and Zn1210 were recommended for further testing at Camp Pendleton. If successful, the application of ZVZ could be a remedial alternative that the Navy will be proposing to use on more its sites.	Kimberly Day Department of Toxic Substances Control 8800 Cal Center Drive Sacramento, CA 95826 (916) 255-6685 kday@dtsc.ca.gov	Salter, A.J. Tratnyek, P.G., and Johnson, R.L. *Degradation of 1,2,3-Trichloropropane by Zero-Valent Zinc: Laboratory Assessment for Field Application.* Proceedings of the 7th International Conference on Remediation of Chlorinated and Recalcitrant Compounds 24-27 May 2010, Monterey, CA. Email from Kimberly Day on June 12, 2010
Hill Air Force Base Operable Unit 2 (continued)	Utah	• Test the feasibility (mobility and reactivity) of using stabilized nanoparticles for degrading chlorinated solvents under Hill AFB field conditions; • Quantify the effects of field environmental conditions, soil type, and properties on the process effectiveness, and validate bench-scale experimental data; • Determine the appropriate operating conditions, i.e., injection pressure, stabilizer concentration, and iron dosage; and • Generate field-scale process cost and performance data for general end-user acceptance.	Not available	No	• Post-injection groundwater monitoring will be conducted for 1 month after each of the first 2 injection events and 3 additional monitoring events will be conducted 1 month, 5 months, and 1 year, respectively, after the end of the third injection event. Groundwater samples will be collected using low-flow purging techniques approved by U.S. EPA • Post-injection soil monitoring will be conducted after each injection and 1 year after the third injection. Immediately following the end of each round of nanoparticle injection, soil cores will be drilled to a total depth of 30 ft bgs using a direct push rig.	Proposed Schedule: • First Injection: June 2010 • Second Injection: July 2010 • Third Injection: August 2010	September 2012	Not available	Not available	Estimated Budget: $349,758.00	Not available	Dr. Zhong Xiong and Dr. Dawn Kaback AMEC Geomatrix, Inc. 510 Superior Avenue, Suite 200 Newport Beach, California 92663 (949) 642-0245	AMEC Geomatrix, Inc. *Draft Work Plan for Demonstration of Stabilized Nanoparticles for In-Situ Destruction of Chlorinated Solvents in Soils and Groundwater. Operable Unit 2.* Hill Air Force Base, Utah. January 2010. Air Force Center for Engineering and the Environment (AFCEE). *Demonstration of "Green" and Stabilized Nanoparticles for In-Situ Destruction of Chlorinated Solvents in Soils and Groundwater. O*ctober 2009.

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U.S. EPA OSWER
Selected Sites Using or Testing Nanoparticles for Remediation.

The list of sites includes information on current or planned applications of nanotechnology at pilot and full scale sites.

Site Information							Media		Contaminants			Technology Information		
Site Name	Site location (city, state)	EPA Region	Site type	Cleanup program	Scale	Geology	Media treated	Volume of media treated	Contaminants treated	Initial contaminant concentrations	Final contaminant concentrations	Type of nanoparticle	Technology design	Vendor Information
*Manufacturing Plant	Middlesex County, NJ	2	Manufacturing Plant	NJDEP	Pilot	The geology of the site consists of about 5 to 10 ft of historic fill underlain by a moderately fractured Bruswick Shale Bedrock. Groundwater is present approximately 10 to 20 ft bgs.	Soil and groundwater	Not available	TCE and daughter compounds	500 µg/L	Less than 100 µg/L	nZVI	Over a period of approximately 8 years starting in 1998-2000, Honeywell implemented a series of different but complimentary in-situ technologies to improve groundwater quality beneath and downgradient of the site. Treatment technologies applied to the site included dual- phase vapor extraction, micro-scale ZVI, and nZVI. Two areas with TCE concentrations up to 500 µg/L were targeted for further treatment using nZVI. The bench scale testing was used to calculate the amount of nZVI required to treat the TCE. A total of 900 lbs of nZVI was injected at two separate injection events.	Not available
*Residential Site	Ringwood, NJ	2	Residence	Private	Full	Contamination extended to 19 ft bgs as well as under the deck and residence. Groundwater was approximately 6 ft bgs.	Groundwater	275 yd^3	Home heating oil: • PCE • Bis(2-Ethylhexyl)phthalate • Benzo[a]Anthracene	• PCE: 1.1 µg/L • Bis(2-Ethylhexyl)phthalate: 9.8 µg/L • Benzo[a]Anthracene: 0.14 µg/L	• PCE: 1.1 µg/L • Bis(2-Ethylhexyl)phthalate: 9.8 µg/L • Benzo[a]Anthracene: 0.14 µg/L	Nanoscale calcium ions with noble metal catalyst (Nano-Ox™)	825 lbs of Nano-Ox™ was mixed with water to form a slurry and direct-push injected into the impacted area.	Continental Remediation LLC
* Klockner Road Site	Hamilton Township, NJ	2	Fill Area	Private	Full	The subsurface conditions at the site consist of water-bearing soils that extend to the underlying bedrock at depths of 130 ft to 160 ft bgs. The upper portion of the soils (extending to depths of up to 20 ft bgs contains many discontinuous interbedded silt and clay lenses, which create Perched Water conditions at depths varying from 2 to 8 ft bgs. Horizontal outflow to the southeast from the Perched Water zone is believed to feed the low-lying wetlands in the southern portion of the site.	Groundwater	Not available	TCE, DCE, TCA, DCA	Total VOC concentrations: 400 to 1600 µg/L	Reduction in total VOC concentrations by up to 90%.	Nanoiron slurry (NanoFe Plus™)	Phase I injection contained 3,000 lbs of slurry and was injected at the northern end of the site over a period of 20 days. Phase II injection contained 1,500 lbs of slurry and was injected throughout the northern half of the site over a period of 10 days. • After completion of soil excavation actitvites, the nanoiron slurry was applied to approximately a one-half acre area of the site where the highest levels of dissolved chlorinated contaminants were observed within the Perched Water zone. • NanoFe Plus™ was injected in water slurry at injection concentrations of up to 30 g/L in 2 phases. • The nanoiron slurry was pumped from a mixing tank through a valved pressure hose to the Geoprobe® injection rods. • Relatively low injection pressures (<20 psi) were applied. • The nanoiron slurry was applied in a 20-ft injection grid pattern.	PARS Environmental, Inc.
* Ford Aerospace Site	Palo Alto, CA	9	Aerospace Facility	Not available	Pilot	Groundwater at the site is encountered at 8 to 10 ft bgs. There are multiple water-bearing units at the site. Site soils are characterized by sand and gravel zones separated by low-permeability clays.	Not available	Not available	PCE, TCE, Freon	• PCE: 26,000 µg/L (max detected in the source zone); 850 µg/L (max detected in the dissolved plume along northern property line at from 10 - 60 ft bgs). • TCE: > 70,000 µg/L • Freon 113 > 1,000 µg/L	Not available	Starch-stabilized BNP (Fe/Pd)	Push-pull tests were conducted in a field batch reactor.	Geomatrix
* Industrial Plant	Sheffield, AL	4	Private	N/A	Pilot	Site soils are characterized as unconsolidated sediments	Groundwater	Not available	PCBs, PCE, TCE, DCE, VC	Total contaminant concentrations: 10,000 to 24,000 µg/L	PCB concentrations were initially reduced but then rebounded. Chlorinated volatiles were reduced by over 90% from baseline concentrations.	Polysaccharide stabilized bimetallic nanoiron - Golder Associates, Auburn University on-site production of stabilized nZVI	The nanoiron was injected at 1 point on the site.	Pilot Test designed and implemented by Golder Associates Inc. (Jeff Paul and Feng He) and Auburn University (Don Zhao)

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Site Name	Site location (city, state)	Performance Information								Cost Information	Future Work/ Current Plans	Contact Information	Information Sources
		Cleanup/ remedial objectives and goals	Were cleanup goals and objectives met? (Yes/No)	Performance data available (Yes/No)	Maintenance (O&M) activities/ monitoring system	Start date/date installed	Anticipated end date of current phase	Length of operation	Comments				
*Manufacturing Plant (continued)	Middlesex County, NJ	Yes	Yes	Not available	Not available	1998	2006	8 years	nZVI injections sufficeintly reduced TCE mass concentrations to a point where sustainable downward trends have been demonstrated.	Not available	The results of the tests are being reviewed by the NJDEP.	Brent O'Dell MACTEC Engineering and Consulting bcodell@mactec.com Richard Galloway Honeywell	O'Dell, B; Galloway, Rich. *In-Situ Treatment of Trichloroethylene (TCE) Impacted Groundwater in Bedrock using n-ZVI* . Batelle. Platform Abstracts, A1. May 2009,
* Residential Site (continued)	Ringwood, NJ	Reduce contaminant concentrations to at or below NJDEP standards	Yes	Yes	The first groundwater samples were taken on July 2007. The final groundwater samples were taken in September 2007.	June 2007	September 2007	3 months	• Samples collected during the first sampling event in July 2007 indicated that only 1 compound was marginally over the NJDEP standards. • Samples collected in September 2007 indicated that all compound concentrations were below the NJDEP standards.	Not available	No future work is currently planned for the site.	Joe Malinchak, Ph.D. Environmental Restoration Services, LLC. 52 Lisa Drive Chatham, NJ 07928 973 632-0045 drjoseph1@comcast.net	Woodrow Wilson International Center for Scholars. 2009. The Project on Emerging Nanotechnologies - Inventories Remediation Map. www.nanotechproject.org/inventories/remediation_map/ E-mail from Joe Malinchak on June 4, 2008
* Klockner Road Site (continued)	Hamilton Township, NJ	Reduce dissolved chlorinated contaminant "hotspots" in the perched water zone and allow remaining contaminant concentrations to be reduced over time by MNA to achieve NJDEP Groundwater Quality Standards.	Yes	Yes	ORP, pH, and groundwater elevations were monitored during each phase of injection. The first post injection monitoring event began a week after completion of the Phase I injection. The second monitoring event was performed 2 weeks after Phase II injection. The thrid monitoring event was performed a month after the second monitoring event.	Not available	Not available	• Phase I - 20 days • Phase II - 10 days	Full-scale nanoiron injection at the site demonstrated that the groundwater contaminants were significantly reduced to levels that could potentially be reduced further by MNA to achieve the NJDEP Groundwater Quality Standards. Sampling results after full-scale injections indicated a 90% reduction in the overall contaminant concentrations. The nanoiron slurry effectively migrated through the perched water zone. The injections demonstrated that total VOCs were significantly degraded wherever they were contacted by the nanoiron slurry. These injections worked best in the central portion of the treatment area, where the presence of sandy soils allowed easier injection and subsurface flow of the slurry. ORP data: Pre-injection = 200 to 450 mV; Post-injection= -350 to 450 mV	Not available	Groundwater monitoring activities will continue including collection of groundwater quality data to demonstrate trends in remaining groundwater contamination.	H.S. Gill PARS Environmental, Inc. 609-890-7277	Varadhi, S., Gill. H, Apoldo, L.J.,Liao, P. Blackman, R.A., Wittman, W.K. *Full-Scale Nanoiron Injection For Treatment of Groundwater Contaminated With Chlorinated Hydrocarbons* . Presented at the Natural Gas Technologies 2005 Conference on February 1, 2005 in Orlando, Florida. www.parsenviro.com/reference/klockner-NGT-III-2005.pdf U.S. EPA. *Nanotechnology for Site Remediation Fact Sheet.* EPA 542-F-08-009. October 2008. www.epa.gov/tio/download/remed/542-f-08-009.pdf U.S. EPA. *Nanotechnology for Site Remediation: Fate and Transport of Nanoparticles in Soil and Water Systems. August 2006.* www.clu-in.org/download/studentpapers/B_Latif_Nanotechology.pdf
*Ford Aerospace Site (continued)	Palo Alto, CA	Assess *in-situ* transport and reactivity of nZVI particles	Not available	No	Not available	2006	January 2008	Not available	Not available	Assuming $50 per pound, the cost for treating 1 cubic yard is approximately $21 (materials costs only)	Decided to utilize different technology to remediate site.	Matt Dodt Ford Motor Co. 312-248-7554 Lester Feldman GeoMatrix, 510-663-4240	Feldman, L; Peischl, P; and Bennett, P. *Local Applications of Innovative Groundwater Cleanup Using Zero Valent Metal* s . U.S. EPA Region 9. http://www.epa.gov/region9/science/pdf/ZVmetals-for-GW-Cleanup.pdf Interim in-situ groundwater remediation, 21 August 06, Appendices D and E
* Industrial Plant (continued)	Sheffield, AL	Not available	Not available	Yes	Groundwater monitoring was conducted at 3 locations on the site.	February 2007	Not available	Not available	Not available	Not available	Not available	Jeff Paul, Golder Associates Inc. 770-492-8150 jpaul@golder.com	Woodrow Wilson International Center for Scholars. 2009. The Project on Emerging Nanotechnologies - Inventories Remediation Map. www.nanotechproject.org/inventories/remediation_map/ Email communication from Golder Associates

* Note: Sites with an "*" indicate that the data have not been independently verified.

U.S. EPA OSWER
Selected Sites Using or Testing Nanoparticles for Remediation.

The list of sites includes information on current or planned applications of nanotechnology at pilot and full scale sites.

Site Information							Media		Contaminants			Technology Information		Vendor Information
Site Name	Site location (city, state)	EPA Region	Site type	Cleanup program	Scale	Geology	Media treated	Volume of media treated	Contaminants treated	Initial contaminant concentrations	Final contaminant concentrations	Type of nanoparticle	Technology design	
* Former Chemical Storage Facility	Winslow Township, NJ	2	Private	CERCLA	Pilot	Site soils are characterized as unconsolidated sediments	Groundwater	Not available	PCE, TCE, DCE	TCE: 3,000 µg/L	Post injection sampling results indicated a 1 order of magnitude decrease of TCE concentrations in the injection well.	Golder Associates nZVI: produced by Golder Associates Inc. under license from Lehigh University	An nZVI slurry concentration of 5 to 10 g/L was injected into the subsurface through gravity feed injection. A total of 150 kg of nZVI was injected at the site.	Pilot test designed and implemented by Golder Associates Inc. (Stephen Finn, Heather Lin, Florin Gheorghiu)
* Manufacturing Plant	Trenton, NJ	2	Manufacturer	Private	Pilot	A shallow aquifer exists approximately 7 to 25 ft bgs at the site.	Soil and groundwater	Not available	PCE, TCE, c-DCE, VC, CCl_4, 1,1-DCE, chloroform	TCE: 4600 µg/L (max concentration detected)	Contaminant concentrations were reduced by 1.5% to 96.5%	BNP (Fe/Pd) Particles	• Nanoiron was slurried with 153 gallons of groundwater. • Approximately 1.7 kg of nanoscale particles were gravity fed into the test area over a 2-day period. • On the first day, 890 liters of 1.5 g/L of the nanoiron slurry were injected. • On the second day, 450 liters of 0.75 g/L of nanoiron slurry were injected. A total of 5 lbs were injected at the site.	Not available

* Note: Sites with an '*' indicate that the data have not been independently verified.

Site Name	Site location (city, state)	Performance Information								Cost Information	Future Work/ Current Plans	Contact Information	Information Sources
		Cleanup/ remedial objectives and goals	Were cleanup goals and objectives met? (Yes/No)	Performance data available (Yes/No)	Maintenance (O&M) activities/ monitoring system	Start date/date installed	Anticipated end date of current phase	Length of operation	Comments				
* Former Chemical Storage Facility (continued)	Winslow Township, NJ	Source mass reduction	Not available	Yes	Not available	April 2005	Not available	3 Months	The nZVI had a limited radius of influence. ORP data: Initial ORP levels were approximately. -100 mV; After injection, ORP levels were maintained at -300 mV for more than 3 months.	Not available	Not available	Heather Lin Golder Associates 856-793-2005 hlin@golder.com	Email communication from Golder Associates
* Manufacturing Plant (continued)	Trenton, NJ	• Evaluate amenability of synthesized nanoparticles • Assess groundwater chemistry changes • Evaluate the efficacy of nanoparticles for the transformation of chlorinated hydrocarbons	Yes	Yes	Not available	• Phase I - May 2000 • Phase II - Jun 2000	Not available	• Phase I - 45 days • Phase II - 23 days	ORP data: Pre-Injection ORP levels were approximately 150 to 250 mV with a pH between 4.5 and 5.5. The ORP and pH changes following injection will help aid in growth of anaerobic microorganisms. The nanoparticle plume traveled at an apparent velocity of 0.8 meters per day, exceeding the natural seepage velocity of 0.3 meters per day.	Approximately $450,00 was spent on BNP particles	Future plans include conducting laboratory and field tests to evaluate fate and transport; assessing the effectiveness of nanoparticles on other contaminants, and developing modeling tools to characterize subsurface transport of nanoparticles.	H.S. Gill PARS Environmental, Inc. 609-890-7277	*Field Assessment of Nanoscale Bimetallic Particles for Groundwater Treatment* Environmental Science & Technology Vol. 35, No. 24, 2001 Gill, H.S. *Nano Fe: Supported Zero-Valent Nano Iron: An Innovative Remediation Technology for Soils and Groundwater*. Pars Environmental Inc.

ACRONYM LIST

bgs: below ground surface
BNP: Bimetallic nanoparticles
CCl_4: Carbon tetrachloride
CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act
cm: centimeters
CMC: Carboxymethyl Cellulose
DCE: Dichloroethene
c-DCE: cis-1,2-dichloroethene
DNAPL: Dense non-aqueous phase liquid
DPT: Direct push Technology
DO: Dissolved oxygen
EC: Electrical Conductivity
EPA: Environmental Protection Agency
EZVI: Emulsified Zero Valent Iron
Fe: iron
ft: feet
ft^2: square feet
ft^3: cubic feet
g/L: grams per liter
gpm: gallons per minute
kg: kilograms
lb: pound
m3: cubic meters
Max: Maximum
MCL: Maximum Contaminant LeveL
µg/L: micrograms per liter
mg/kg: milligrams per killogram
mg/L: milligrams per liter
msl: mean sea level
MNA: Monitored Natural Attenuation
msl: mean sea level
mV: millivolts
MW: Monitoring well
NASA: National Aeronautics and Space Administration
NJDEP: New Jersey Department of Environmental Protection
nZVI: Nanoscale zero valent iron
ORP: Oxidation reduction potential
OU: Operable Unit
PCB: Polychlorinated biphenyls
PCE: Tetrachloroethylene
Pd: Palladium
psi: pound per square inch
RCRA: Resource Conservation and Recovery Act
R&D: Research and Development
SHMP: sodium hexametaphosphate
TCA: Trichloroethane
TCE: Trichloroethylene
TCP: Trichloropropane
UST: underground storage tank
VC: Vinyl Chloride
VOCs: Volatile Organic Carbons
yd^3: cubic yards