

Supplemental Material, Table 1. List of manufactured nanoparticles and the pollutants potentially remediated*

Nanocrystalline zeolites

Toluene, nitrogen dioxide

Activated carbon fibers

Benzene, toluene, xylene, ethylbenzene, heavy metal ions

Carbon nanotubes

(CNTs)

Benzene, toluene, xylene, ethylbenzene, heavy metal ions

CNTs functionalized with polymers and Fe

p-nitrophenol Benzene, toluene, dimethylbenzene, heavy metal ions

Single-walled CNTs

Trihalomethanes (THMs)

Multi-walled CNTs

Heavy metal ions, THMs, Chlorophenols, Herbicides, Microcystin toxins

Self-assembled monolayer on mesoporous supports (SAMMS)

Inorganic ions, Heavy metal ions, Actinides, Lanthanides, Radionuclides

TiO₂ photocatalysts

Heavy metal ions, Azo dyes, Phenol, Aromatic pollutants, toluene

Zero-valent iron nanoparticles

Chlorinated methanes, Trihalomethanes, Chlorinated benzenes, Chlorinated ethenes, Pesticides, Polychlorinated hydrocarbons, Organic dyes, Heavy metal ions, Inorganic ions, Chlorinated organic compounds

Bimetallic nanoparticles Pd/Fe nanoparticles

PCBs, Chlorinated ethene, Chlorinated methanes

Ni/Fe nanoparticles Pd/Au nanoparticles

TCE, PCBs, Dichlorophenol, Trichlorobenzene, Chlorinated ethene, Brominated organic compounds

*Adapted from Theron et al. 2008 and Zhang, 2003.

References:

Theron J, Walker JA, Cloete TE. 2008. Nanotechnology and water treatment: Applications and emerging opportunities. *Critical Reviews in Microbiology* 34:43-69.

Zhang W-X. 2003. Nanoscale iron particles for environmental remediation: An overview. *Journal of Nanoparticle Research* 5:323-332.

Supplemental Material, Table 2											
	Site Name	Site Location	Start Date	Site Type	Geology	Media Treated	Contaminants Treated	Initial Contaminant Concentration	Final Conataminant Concentration	Type of Nanoparticle	Length of operation
1	AL-Metal Processing Plant	Northern Alabama	na	Abandoned Metal Processing Plant	Unknown	Soil and Groundwater	PCE, TCE, and PCBs	TCE: MW-1 (1655 ppb) MW-2 (3710 ppb)	TCE: MW-1 (72 ppb) and MW-2 (less than 10 ppb)	Carboxymethyl cellulose (CMC) stabilized zero-valent iron	29 days of field injection and monitoring - 1 full year including preparation
2	BP -- Prudhoe Bay Unit	North Slope, Alaska	na	Oil Field	Organics over alluvial gravels	Soil	TCA, Diesel fuel	Maximum TCA: 58,444 ug/kg	Shallow Test: TCA reduction of ~60% Deep Test: TCA reduction of up 90%	Pd-nZVI	Shallow test: n/a Deep Test: 40.5 hours
3	Slovakia-Brownfield	Slovakia	na	Private	Unconsolidated sediments	Groundwater	TCE, DCE	N/A	N/A	nZVI	N/A
4	FL-Dry Cleaner Sites (multiple sites)	Florida	2005	Private	Unconsolidated sediments	Groundwater	PCE, TCE, DCE	N/A	N/A	nZVI with Pd catalyst, and soy powder dispersant; nZVI	N/A
5	NJ-Former Chemical Storage Facility	Winslow Township, NJ	Apr-05	Private	Unconsolidated sediments	Groundwater	PCE, TCE, DCE	TCE 3,000 ug/L	One order of magnitude decrease in the injection well	nZVI	3 Months
6	NY-Industrial Plant	Rochester, NY	2006	Former Manufacturing	Glacial till overburden lying above fractured sedimentary bedrock.	Groundwater in overburden and weathered top of bedrock	TCE	TCE 1,900 ug/L	55-83% reductions in TCE from 1,900 ug/L to 330 ug/L (an 83% decline), and from 750 ug/L to 340 ug/L (a 55% decline).	nZVI	N/A
7	NY-Industrial Plant	Rochester, NY	2004	Former Manufacturing	Glacial till overburden lying above fractured sedimentary bedrock.	Groundwater in bedrock	Methylene chloride, 1,2-dichloropropane, 1,2-dichlorethane	500,000 ug/L	50,000 ug/L	nZVI	N/A
8	AL-Industrial Plant	Sheffield, AL	Feb-07	Private	Unconsolidated sediments	Groundwater	PCBs, PCE, TCE, DCE, VC	10,000-24,000 ug/L	Unknown	Polysaccharide stabilized bimetallic nanoiron	N/A

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9	SC-Industrial Plant	Rock Hill, SC	2005	Private	Unconsolidated sediments	Groundwater	TCE, DCE	N/A	N/A	nZVI	N/A
10	Ontario-Industrial Plant	Ontario, Canada	2005	Private	Unconsolidated sediments	Groundwater	PCE, TCE	TCE concentrations 86,000	TCE concentrations 26,700 ug/L	nZVI	N/A
11	Czech-Industrial Plant	Czech Republic	2004	Private	Fractured bedrock	Groundwater	PCE, TCE, DCE	Total chlorinated solvents 19,000 ug/L in monitoring well	Concentrations were maintained low for more than 6 months; after 180 days total chlorinated solvents were one order of magnitude lower	nZVI	N/A
12	Germany-Industrial Plant	Germany	na	Private	Unconsolidated sediments	Groundwater	TCE, DCE	N/A	N/A	nZVI	N/A
13	Italy-Industrial Site	Biella, Italy	2005	Private	Unconsolidated sediments	Groundwater	TCE, DCE	Total chlorinated solvent concentrations 20,000 ug/L to 50,000 ug/l	20-50% reductions in total chlorinated solvent concentrations after one month	nZVI	N/A
14	Edison-Industrial Site	Edison, NJ	na	Former Adhesives Manufacturer	Fractured bedrock, specifically Brunswick Shale. 4 to 6 feet of soil comprised of silt and clay over bedrock	Fractured Bedrock	TCA, TCE, DCA, DCE, chloroethane, vinyl chloride	Maximum TCA concentration: 37,000 mg/L; 10,000 µg/L TCA at injection well 1; presence of DNAPL possible	Decreased to a level below minimum detection limit; ethane concentration in well 1 steadily increased	nZVI (OnMaterial's Z-loy)	13 months

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15	Hamilton-Klockner Road Site	Hamilton Township, NJ	na	Fill Area	Middle Potomac Raritan Magothy (MPRM) Aquifer; consisting of water-bearing soils that extend to the underlying schist/gneiss bedrock from 130 to 160 feet bgs	Groundwater	TCE, DCE, TCA, DCA	Total VOC: 400-1600 ppb	Reduction in dissolved chlorinated contaminants at concentrations by up to 90%	Nanoiron slurry (NanoFe Plus) TM	Phase I - 20 days Phase II 10 days
16	FL-Launch Complex 15	Cape Canaveral, Canaveral, Air Force Station, FL	Feb-06	Abandoned Space Launch Complex Launch Complex	Groundwater encountered 4 to 5 feet bgs. Upper surficial aquifer mostly fine to medium grained sands with occasional silt/clay. Silty region around 45 ft bgs holding DNAPL migration.	Soil and Groundwater Groundwater	TCE and corresponding daughters corresponding daughters	Initial TCE as high as 439,000 ug/L	In the EZVI zone, the area with >400,000 ug/L the area with >400,000 ug/L has dropped to 28 ug/L	Emulsified ZVI (EZVI) (EZVI)	On-going, minimum 5 years
17	Trenton-Manufacturing Plant	Trenton, NJ	May-00	Manufacturer	Shallow aquifer, approximately 7 to 25 feet bgs	Soil and Groundwater	PCE, TCE, c-DCE, vinyl chloride, chloroform, carbon tetrachloride, 1,1-DCE	TCE pre-injection: 445 to 800ig/L Max TCE: 4600 ig/L	Contaminant concentrations reduced by 1.5% to 96.5%	BNP (Fe/Pd) Particles	Phase I - 45 days Phase II 23 days

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18	Passaic-Manufacturing Site	Passaic, NJ	na	Former Manufacturer	Soils from 0 to 20 feet bgs composed of high permeability sands; silt unit exists from 20 to 26 feet bgs	Groundwater	TCE	450 to 1,400 ug/L	90 to 100% reduction in TCE concentrations	nZVI	6 months
19	FL-Naval Air Station	Jacksonville, FL	Jan-04	Former UST Site	Silty to fine sand from 0 to 24 feet bgs; dense clay from 24 to 54 feet bgs	Groundwater	TCE, TCA, DCE, vinyl chloride	Max TCE: 26,000 ug/L Max TCA: 11,000 ug/L Max DCE: 44,000 ug/L	Rapid reductions by 65% to 99%	BNP	1st monitoring event was 5 weeks after initial injection, monitoring continued beyond the original 9 months
20	Lakehurst-Naval Air Engineering Station	Lakehurst, NJ	Nov-05	Aircraft launching activity testing	Coastal Plain Aquifer consisting of mostly sand and gravel	Soil and Groundwater	PCE, TCE, TCA, c-DCE, vinyl chloride	Maximum VOC concentration: 900 ug/L	Average total VOC concentration decreased by 74%	BNP	Unknown
21	Ohio-Nease Chemical	Salem, OH	2007	Former Pesticides Manufacturer	Glacial till overburden lying above fractured sedimentary bedrock	Groundwater in fractured bedrock	PCE, TCE, DCE, VC	100,000 ug/L	40-70% reductions in PCE, 20-70% reductions in TCE, increases in cis-DCE, net decrease in VOCs low	Golder Associates nZVI: under license from Lehigh University	N/A
22	CA-OU-2B	Alameda Point, CA	na	Navy Installation	Unknown	Groundwater	TCE	Approximately 1,600 ug/L	Not available (test not yet conducted)	Surface-modified NZVI	N/A

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23	CA-Palo Alto Site	Palo Alto CA	2006	Aerospace Facility	Groundwater encountered 8 to 10 feet bgs. Water table 6 feet bgs under confined conditions. Multiple water-bearing units. Sand and gravel zones separated by low-permeability clays.	Unknown	PCE, TCE, Freon	PCE in source zone up to 26,000 ug/L PCE in dissolved plume along northern property line at 850ug/L from 10 - 60 ft bgs Offsite sources impact site, with TCE > 70,000 ug/L, Freon 113 > 1,000 ug/L	Unknown	Starch-stabilized BNP (Fe/Pd)	N/A
24	SC-Parris Island	Port Royal, SC	Jun-06	Marine Corps Recruit Depot Former Dry Cleaner	Small, relatively flat, sandy island with minimal topographic relief. Highest elevation on site is approximately 9 feet above mean sea level (msl). Soil present is from Seabrook, Capers, and Bohicket series. 15 different soil types.	Soil and Groundwater	PCE, TCE, c-DCE, vinyl chloride	Groundwater: Max PCE: 32,000 ug/L Max TCE: 10,000 ug/L Max c-DCE: 3,400 ug/L Max vinyl chloride: 710 ug/L	N/A	EZVI	Ongoing

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25	FL-Patrick AFB, OT-30	Patrick AFB, FL	Nov-05	Industrial Area	Groundwater encountered 4 to 5 feet bgs. Upper surficial aquifer mostly fine to medium grained sands with occasional silt/clay. Silty region around 35 to 42 ft bgs holding DNAPL migration.	Soil and Groundwater	TCE and corresponding daughters	Initial TCE as high as 150,000 ug/L	highest remaining TCE post treatment - 3,580 ug/L	Emulsified ZVI (EZVI)	On-going, minimum 5 years
26	NC-Pharmaceutical Facility	Research Triangle Park, NC	Sep-02	Former Waste Disposal Area	Durham Triassic Sandstone interbedded with siltstone grading downward into mudstones	Groundwater in Fractured Bedrock	PCE, TCE, DCE, VC	14,000 µg/L	Over a 90% reduction of pre-injection baseline concentration at injection well and observation well. DCE concentrations reduced to near or below groundwater quality standards, with no accompanying increases in vinyl chloride concentrations	BNP	3 months

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27	AZ-Phoenix Goodyear Airport - North (Unidynamics) Phase I	Goodyear, AZ	Jan-07	Former Missile development R&D facility	Alluvial deposits of Western Salt River Valley. Deposits consist of upper alluvial unit, middle fine-grained unit, and lower conglomerate unit	Groundwater	TCE, PCE, Perchlorate	Up to 39,000 ug/L	Not available	nZVI	3 days
28	AZ-Phoenix Goodyear Airport - North (Unidynamics) Phase II	Goodyear, AZ	Jun-08	Former Missile development R&D facility	Alluvial deposits of Western Salt River Valley. Deposits consist of upper alluvial unit, middle fine-grained unit, and lower conglomerate unit	Groundwater	TCE	3,000-7,000 ug/L	Not available	nZVI	3 days
29	NJ-Picatinny Arsenal Superfund Site	Rockaway Township, NJ	Aug-04	Munitions Arsenal	Organics-rich soil	Groundwater	Carbon tetrachloride, TCE	250 ppb of CCl4 87 ppb of TCE	Carbon tetrachloride was 180 ppb four weeks after injection, but rebounded to 230 ppb four months after injection;	nZVI (Ferragel Particles)	1 year

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30	Ringwood-Residential Site	Ringwood, NJ	Jun-07	Residence	Contamination extended to 19 ft. below surface as well as under deck and residence. Groundwater was approximately 6 feet below surface.	Groundwater	Home heating oil: Tetrachloroethene Bis(2-Ethylhexyl)phthalate - Benzo[a]Anthracene	Tetrachloroethene - 1.1 ug/L Bis(2-Ethylhexyl)phthalate - 9.8 ug/L Benzo[a]Anthracene - 0.14 ug/L	Tetrachloroethene 1.1 ug/L Bis(2-Ethylhexyl)phthalate - 9.8 ug/L Benzo[a]Anthracene - 0.14 ug/L	Ca+ with noble metal catalyst (Nano-Ox) TM	2 DAYS
31	Czech-Solvent Manufacturing Plant	Czech Republic	Dec-04	Private	Unconsolidated sediments; alluvial terraces of the Elbe River	Groundwater	PCE, TCE, DCE	PCE (2,500 ug/L), TCE (1,500 ug/L), DCE (1,000 ug/L)	After one month concentrations dropped to PCE (500 ug/L), TCE (100 ug/L), DCE (250 ug/L)	nZVI	N/A
32	FL-Space Launch Complex 34	Cape Canaveral, FL	Jun-02	Former Rocket Launch Site	Upper portion of surficial aquifer known as Upper Sand Unit, underlain by Middle Fine-Grained Unit which makes up a hydraulic barrier to Lower Sand Unit	Soil and Groundwater	TCE	Not available	Average TCE reduction of 58%, where eZVI was present >80% reduction Chloride increase is attributed to reduction of TCE, pH level changes were short lived returned to low levels of pre-demonstration data, ethane and ethene concentrations increased.	Emulsified ZVI (EZVI)	8 months
33	Quebec-Valcariter Garrison	Quebec, Canada	Jul-06	National Defense Site	Deltaic and Proglacial Sands	Sands and clayey silts	TCE, DCE, VC	TCE = ~300 ppb, DCE = ~50 ppb	TCE = <5 ppb, DCE = <50 ppb	nZVI with Pd catalyst, and soy powder dispersant; nZVI	12 months

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34	CA-Vandenberg Air Force Base	Santa Maria, CA	na	Missile Launch Pad	Interbedded sands, silts, and clays referred to as the Orcutt Formation; bedrock encountered below the alluvium at depths of approximately 40 to 50 feet bgs	Groundwater	TCE, DCE	TCE: 2.5 mg/L	Unknown	BNP	N/A
35	SC-Industrial Site	Hampton, SC	Jun-06	product manufacture	Silty to fine sand from 25 to 45 feet bgs; dense clay from 45 feet bgs	groundwater	TCE, PCE	TCE = ~300 ppm		nZVI	N/A
36	PA-DOD Landfill	Mechanicsburg, PA		closed DOD landfill	fractured rock	groundwater	TCE			nZVI with Pd	N/A
37	Taiwan-Solvent Manufacturing Plant	Kaohsiung, Taiwan		Petroleum Manufacturer (VCM manufacturing plant)	Unconfined aquifer, composed of medium to coarse sand and few silt, lies approximately 4 to 18 meters below ground surface (m bgs).	Groundwater	TCA, TCE, DCA, DCE, vinyl chloride	VC 4562 µg/L, EDA 207 µg/L, DCE 1151 µg/L, TCE 682 µg/L	Shallow Test : VC reduction of > 90% Deep Test: VC reduction of 20-85%	Pd-nZVI	6 months

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38	PA-Electronics Plant	Titusville, PA		Electronics Manufacturing Plant			PCE, TCE, cis-DCE			nZVI	
39	NY-Superfund Site	Frankling Square, NY		Plating Facility			PCE, TCE, 1,1,1-TCA, Cr(VI)			nZVI	
40	PA-Chemical Plant	State College, PA		Chemical Plant			Pesticides (DDE, DDT)			nZVI	

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41	NJ-Manufacturing Plant	Newfield, NJ		Manufacturing Plant			TCE, cis-DCE, Cr (VI)			nZVI	
42	NJ-Landfill	Hamilton, NJ		Landfill Site			1,1,-TCA, 1,1-DCA, 1,1-DCE, Pb, Ni			nZVI	
43	NJ-Chromite Ore	Kearny, NJ		Chromite Ore Waste Disposal Site			Cr(VI)			nZVI	

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44	MD-DOD	Aberdeen, MD		DOD Facility			1,1,2,2-TeCA, 1,1,1-TCA, TCE, Cr(VI)			nZVI	