Appendix C

Tables of Innovative Technology Demonstration Projects

TABLE C-1 Summary of In Situ Oxidation (Phase II) Field Sites

Site Location	Area of Concern	Contaminants of Concern	Regulatory Driver	Oxidant	Scale	Remedial Objectives	Ability to Meet Objectives	Follow-up Actions
Anniston Army Depot Calhoun County, AL	SWMU 12 soils in the former industrial lagoon area	VOCs in soil, primarily TCE	RCRA Corrective Action –Emergency Removal Action	Hydrogen peroxide	Pilot and full scale	Reduce chemical contamination that may be contributing to exceedances of health-based concentration limits in onsite and offsite groundwater	Reports claim up to 90% removal of total VOCs. Post-treatment sampling data show several areas above the 41-ppm TCE soil cleanup criteria.	Additional polishing treatment in selected locations.
Cherry Point UST Bogue, Carteret County, NC	Vadose zone soils and groundwater in former UST area.	Gasoline and diesel range organics in soil. VOCs in groundwater, primarily benzene	NCDENR environmental regulations and site cleanup criteria	Hydrogen peroxide	Pilot scale	Demonstration project to remediate soil and groundwater within the 1,000 μg/L benzene contour interval to levels acceptable to the NCDENR.	Project caused pavement upheaval, underground explosions, and fire. Post-incident sampling indicates that significant contamination still remains that will most likely require further site characterization and remediation by other means.	Additional site characterization and remediation alternatives will have to be evaluated.
CRREL Grafton County, NH	AOC 2 (Former TCE UST) & 9 (Ice Well) Vadose Zone Soils	TCE and MEK in soil.	Voluntary cleanup. NHDES is the primary oversight agency.	Potassium perman-ganate	Pilot and full scale	Reduce soil concentrations of TCE in vadose zone source area.	Pilot-scale testing is currently inconclusive. Increases in chloride concentrations in pore water during injection provide evidence that the dechlorination reaction is occurring, although pre- and post-injection soil samples indicate limited effect.	Full-scale trial is currently in operation.

Site Location	Area of Concern	Contaminants of Concern	Regulatory Driver	Oxidant	Scale	Remedial Objectives	Ability to Meet Objectives	Follow-up Actions
Kings Bay NSB Camden County, GA	Site 11- Former sanitary landfill along the western boundary of the NSB with contaminant plume moving toward residential area	VOCs in soil, primarily PCE	RCRA cleanup under a GDEP consent order	Hydrogen peroxide	Full scale	Aggressive source reduction with chemical oxidation to 100 ppb VOCs in source area	In situ oxidation was able to reduce total VOCs in the primary treatment zone to below 100 ppb. The success of this project may be linked to the sandy soil with high hydraulic conductivities (30 ft/day). GDEP rescinded the consent order and allowed the shutdown of the pump and treat system.	Natural attenuation to polish residuals outside the source area that are less than 100 ppb.
LEAD Franklin County, PA	OBP vadose zone Soils	VOCs in soil, primarily TCA	The OBP is located within an NPL site at LEAD; working under an IAG with USEPA/PADEP.	Hydrogen peroxide	Full scale	Reduce soil concentrations of select VOCs below Act 2 Soil Cleanup Criteria for groundwater.	In situ oxidation provided significant removals of contaminants. However, in situ oxidation did not meet cleanup objectives, and additional alternatives will have to be evaluated to achieve greater reductions.	LEAD evaluating enhanced biological treatment; soil vapor extraction; hot spot excavation; and natural attenuation
LEAD Franklin County, PA	SE DA bedrock aquifer	VOCs in groundwater, primarily TCE	The entire SE Area including the DA is an NPL site.	Hydrogen peroxide	Pilot scale	Evaluate pilot test results to determine whether ISO alone or combined with other technologies can be used for full-scale remediation	Not available	Not available
Nellis AFB Northeast of Las Vegas, NV	Site ST-44 along the flight line with a plume of TCE-impacted groundwater	TCE in saturated soils and groundwater	Environmental investigations undertaken through the IRP and overseen by the Nevada DEP; must comply with Nevada ARARs	Ozone sparging	Pilot scale	Determine the feasibility of using in situ ozone sparging to reduce TCE contamination at ST-44	While in situ ozone sparging appeared to be able to reduce TCE contamination at ST-44 by varying amounts in some wells and spargers, there were increases in other wells and rebound was seen in 4 out of 5 wells and 1 out of 3 spargers.	Full-scale treatment with system modifications

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Pensacola NAS Pensacola, FL	Former sludge drying beds were open surface impoundments that accepted paint wastes and listed hazardous waste	VOCs in groundwater, primarily TCE	State order based on monitoring data showing impact to groundwater. RCRA-regulated soils were removed and a P&T system installed.	Hydrogen peroxide	Full scale	To significantly reduce contamination in the aquifer	Groundwater results after Phase 2 indicate that in situ oxidation was successful in remediating chlorinated organics found in the treatment zone. However, the site experienced a rebound after Phase I, and the RPM expects it again after Phase 2.	Performing a phased evaluation of natural attenuation as a polishing technology
Shaw AFB Sumter, SC	OU 4 – Former Fire Training Area No. 1. Soil and groundwater contaminated from the use of combustible liquids in the fire training exercises	VOCs in soil and groundwater, primarily TCA and DCA	Site under an ACO. Pilot test performed under TERC.	Hydrogen peroxide	Pilot scale	1. Determine if groundwater contamination at OU-4 can be treated and significantly reduced using hydrogen peroxide solution. 2. Define the radius of influence of an injection well. 3. Gather sufficient data to support the design of a full-scale remediation system.	1. Pilot test showed that groundwater can be partially treated with in situ oxidation; it remains to be seen whether significant reductions achievable. 2. Pilot test further defined the radius of influence of an injection well at the site based on the interpolation of several different field measurements. 3. Pilot test data allowed contractors to adjust chemical requirements, further define radius of influence, and estimate an approximate cost for full-scale remediation. More information is required for remediating contaminants in vadose zone and the lower portion of the aquifer, for selecting appropriate injection rates for large-scale areas, and controlling releases of VOCs to the air.	The draft Pilot Test Report recommended performing an air sparging pilot test using the existing injector and monitoring well system

Site Location	Area of Concern	Contaminants of Concern	Regulatory Driver	Oxidant	Scale	Remedial Objectives	Ability to Meet Objectives	Follow-up Actions
DOE Kansas City Plant Kansas City, MO	Former Ponds Site with VOC contamination in vadose and saturated zone soils	TCE and DCE in soil	Not available	Potassi-um perman-ganate	Field demon-stration	Evaluate feasibility of degrading VOCs in situ by addition of $KMnO_4$ using a DSM process and evaluate impact of $KMnO_4$ addition to chemical, physical, and biological properties of the soil being treated	Oxidant introduction through the DSM process resulted in significant reductions of TCE within the vertical profile of the soil columns and homogenization of the treatment region. Average reduction of TCE levels by 67% in the test cells compared favorably with the 70% treatment goal.	Not discussed
DOE PORTS Piketon, OH	Former area X-701B holding pond used for the neutralization and settling of metal-bearing acidic wastewater and solvent-contaminated solutions	TCE in groundwater	Pond was closed under RCRA closure action; site agreed to collaborate with ORNL and support ISO field test at Area X-701B	Potassi-um perman-ganate	Full scale demon-stration	Field-scale treatability study of ISCOR to evaluate effectiveness in reducing sources of groundwater plumes and minimizing time pump-and-treat facilities are required to be operational	In situ oxidation via injection of $KMnO_4$ solution resulted in dramatic removal of TCE from the Gallia aquifer. However, the persistence of TCE in surrounding units will result in recontamination of the Gallia aquifer over time. Groundwater samples collected 12 weeks after the conclusion of the test suggest that the rate of contaminant rebound will be slow, and that the ISCOR test was successful in reducing the overall mass of TCE within the aquifer unit.	Monitor TCE groundwater levels to determine if further action is needed.

Site Location	Area of Concern	Contaminants of Concern	Regulatory Driver	Oxidant	Scale	Remedial Objectives	Ability to Meet Objectives	Follow-up Actions
DOE Savannah River Site Aiken, SC	A/M Area	PCE and TCE in vadose zone soils and soils below the water table	A/M Area RCRA Groundwater Corrective Action; Integrated Demonstration R&D Activities	Hydrogen peroxide	Pilot scale	Pilot-scale demonstration to evaluate the ability of Fenton's Reagent to destroy DNAPL (TCE & PCE) at a field site and assess the efficiency of Fenton's Reagent deployed at depth (150 ft).	In situ oxidation provided significant removals of DNAPL found below the water table in the test zone. Although in situ oxidation met the pilot test objectives (verify an alternative DNAPL destruction technology), additional remediation technologies would have to be used in conjunction with in situ oxidation to meet typical aquifer protection standards.	Not discussed
BMC Olen Irvine, CA	Site includes an operating plant that covers much of the source area	TCE, PCE, and MC in vadose zone soils and below the water table	Regional Water Quality Control Board	Potassi-um perman-ganate	Pilot and full scale	Phased objectives: 1. Reduce dissolved TCE and MC levels to asymptote. 2. Turn off active remediation (vapor recovery and groundwater extraction). 3. Obtain site closure. 4. Achieve dissolved TVOC levels below 500 µg/L site-wide.	The treatment met the most critical goals of: 1. reducing dissolved-phase CVOC levels (estimated at 97% reduction, to low ppb levels in the injection zone), and 2. terminating active remediation by vapor and groundwater recovery. The treatment did not meet the further objectives of: 1. site closure without long-term monitoring (partly due to the unexpected presence of MC), and 2. a site-wide average dissolved TCE concentration of < 500 µg/L.	Long-term monitoring will be required as part of the monitored natural attenuation strategy for residual contaminants, particularly MC

SOURCE: ESTCP. 1999. Technology Status Report: In Situ Oxidation. http://www.estcp.org/documents/techdocs/index.cfm (November).

TABLE C-2 Summary of Selected Steam Injection Projects for Subsurface Remediation

Site	Contaminant Concentration/Volume	Geology	Treatment System Design	Removal Efficiency or Volume	Comments
Solvent Services, Inc. San Jose, CA	VOCs and nonvolatile organic contaminants at concentrations > 1,000 ppm	Silts and clays, continuous poorly sorted sand layer at bottom, 0.61 to 1.5 m	7.3-m^2 area treated by 6 injection wells and 1 extraction well, 1.5 m between wells, 111.6 kg/hr of steam injected for 120 hrs, then 67 kg/hr for 20 hrs	Vacuum extraction: 99 kg in 40 hrs. Steam extraction: 146 kg in 140 hrs. Followed by intermittent operations.	Pilot-scale demonstration
Annex Terminal Port of Los Angeles, San Pedro, CA	Major contaminants were TCE, PCE, chloro-benzene. Initial average concentration of 466 ppm VOCs		33-m^2 area treated to 1.5-m depth by steam (200°C) and compressed air (135°C)	84.7% VOCs, 55% SVOCs. Treatment time was 1 month	Detoxifier system developed by NovaTerra, Inc.
AT&T New York	Chlorinated solvents, TCE & 1,1,1-TCA, DNAPL (separate and dissolved aqueous phase)	Tight, heterogeneous		4,500 kg of hydrocarbons recovered in 2 years	Nutrients injected at 40°C, vacuum extraction of 7.8 m^3/min, maximum vacuum of 41 cm Hg
Yorktown Naval Shipyards	Naval Special Fuel Oil, estimated 8,000 L [a]	Upper 6 m was homogeneous fine to coarse sand, below that was interbedded sands and clays. Water table 3.8 to 4.1 m below ground. Hydraulic conduct. 2.0 to 5.2 x 10^{-3} cm/s	83.6 m^2 area treated with five spot pattern of four injection wells and one extraction well, 9.1 m between injection wells; injected at 6.1- to 7.6-m depth, extracted from 3- to 9.1-m depth; Injection rate of 272 kg/hr	617 L recovered. Steam injected over 2-month period	Hot water may be more appropriate for this nonvolatile, viscous oil
Naval Air Station Lemoore, CA	JP-5, estimated 757,000 L	Sands and silts with hydraulic conduct. 3.9 x 10^{-3} to 1.4 x 10^{-2} cm/s. Water table at 4.9 m	12,140-m^2 area treated with two injection wells at the center, and eight vapor/groundwater extraction wells; Injection depth of 6 m	Approximately 976,000 L recovered in 3 months of operation. Final vadose zone concentration of 20 to 50 ppm TPH; 20,000 ppm remains at water table	Demonstration project
Pinellas Plant Northeast Site, Largo, FL	Volatile organic compounds including BTEX and chlorinated solvents	Silty sands, water table at 1 m below ground surface	1,566 m^3 treated by 48 holes to a depth of 9.8 m	Approximately 544 kg recovered	Dual auger rotary steam stripping demonstration project

SOURCE: Davis, E. L. 1998. Steam Injection for Soil and Aquifer Remediation, Ground Water Issue, EPA/540/S-97/505, January.

[a]The report does not contain an estimate of the amount of oil contained in the area treated by the pilot study. This estimate was made using the same assumptions made in the report to estimate the oil contained within the entire contaminated region, with an estimate of the contamination extending to a depth of 1.5 m.

TABLE C-3 Compilation of In Situ Thermal Treatment Projects

Project	Contaminant(s)	Technology	Status
LLNL Gas Pad	Gasoline	Steam Injection	Complete (115,000 lbs recovered)
Visalia Pole Yard NPL Site	Creosote, pentachlorophenol	Steam Injection	Ongoing full-scale (1 million lbs recovered in 18 months)
Skokie, IL	TCE	6-phase heating	Full-scale cleanup completed
Seattle, WA	PCE	6-phase heading	Full-scale cleanup completed
Ft. Richardson, AK	PCE	6-phase heading	Full-scale cleanup completed
Atlanta, GA	Diesel fuel	6-phase heading	Full-scale cleanup completed
Portland, IN	PCE, TCE	In situ thermal desorption	Full-scale cleanup completed
Tanapag, Saipan, NMI	PCBs	In situ thermal desorption	Full-scale cleanup completed
Fuel Terminal, Eugene, OR	Diesel fuel	In situ thermal desorption	Full-scale cleanup completed
Naval Facility, Ferndale, CA	PCBs	In situ thermal desorption	Full-scale cleanup completed
Dragstrip, Glen Falls, NY	PCBs	In situ thermal desorption	Demonstration project completed
Mew, Cape Girardeau, MO	PCBs	In situ thermal desorption	Demonstration project completed
Navy BADCAT, Vallejo, CA	PCBs	In situ thermal desorption	Demonstration project completed
Lemoore NAS, CA	JP-5	Steam injection	Full-scale cleanup completed
Petrochemical, TX	Solvents	3-Phase electrical heating	Sequential full-scale cleanup of hot spots
NAS North Island, San Diego, CA	TCE, JP-5	In situ thermal treatment	Full-scale cleanup underway following successful pilot
Yorktown Navy Facility, VA	Fuel oil	In situ steam heating	Full-scale project underway. Steam in pipes used to reduce viscosity, facilitate recovery in trenches
Rainbow Disposal, Huntington Beach, CA	Diesel fuel	Steam injection	EPA SITE demonstration
DESC, Whittier, AL	JP-5	Steam injection	Full-scale design and construction
Bulk oil plant, Jacksonville, FL	Motor oil	Steam injection	Full-scale design/startup Fall 2000
Metal recycling facility, Boston, MA	Heavy machine oil	In situ thermal treatment	Procurement and fabrication underway
Aircraft engine plant, Lynn, MA	PCBs	Steam injection	Design completed/implementation 2001
Safety Kleen Breslau, Ontario	PCBs	In situ thermal treatment	Pilot test

Project	Contaminant(s)	Technology	Status
DESC, San Pedro, CA	Diesel fuel	In situ thermal treatment	Pilot test
PSNS, Bremerton, WA	Fuel oil	In situ thermal treatment	Pilot test
Ft. Hood, TX	JP-8	Steam injection/3-phase heat	Demonstration
Panama City, FL	Diesel fuel	Steam injection	Full-scale
Plating facility, Danbury, CT	CVOCs	Steam injection	Full-scale designed and constructed
DOE Savannah River, SC	PCE, TCE	Steam injection	Contract awarded
A.G. Communications, North Lake, IL	Solvents	Steam injection	Ongoing
Waukegon, IL	Methylene chloride	6-phase heating	Full-scale cleanup in progress
Long Beach, CA	PCE	6-phase heating	Pilot project (awarded)
Portland, OR	TCE	6-phase heating	Full-scale cleanup (awarded)
Newark, CA	EDB	6-phase heating	Pilot project (awarded)
Air Force Plant 4, Ft. Worth, TX	Solvents	6-phase heating	Pilot project underway
Holyoke, MA	Styrene	Steam injection	Ongoing
Alameda NAS	TCE, diesel, motor oil	Steam injection	Pilot project completed
DOE Portsmouth, OH	TCE	Steam injection	Pilot project completed
Solvent Services, San Jose, CA	Chlorinated solvents	Steam injection	Pilot project completed
Port of Ridgefield, WA	PAHs, PCP	Steam injection	Contract awarded
Cape Canaveral, FL	TCE	Steam injection/oxidation	Joint DOD/DOE/EPA/NASA "treat-off"
Mobil Oil	Petroleum	RF Heating	Full-scale completed
Ashland Refinery, St. Paul, MN	Petroleum	Microwave Heating	Full-scale completed
Wyckoff Wood Treater NPL Site	Creosote Pentachlorophenol	In situ thermal treatment	Signed ROD, conceptual design underway
Rocky Mt. Arsenal Hex Pit Commerce City, CO	Pesticides	In situ thermal desorption	Full-scale design/EPA SITE demonstration
Pole Yard, Alhambra, CA	Creosote, PAHs	In situ thermal desorption	Under contract
N. Ryan St. Site, Lake Charles, LA	PAHs, PCBs	In situ thermal desorption	Administrative Order on Consent Action Memorandum issued

SOURCES: (1) GWRTAC. 2000. Advances on Innovative Ground-Water Remediation Technologies and In Situ Thermal Treatment, Conference Proceedings, Boston, MA, June and (2) J. Cummings, 2001, EPA Technology Innovation Office, personal communication.