EPA United States Environmental Protection Agency

Extramural Research

Final Report: Field Demonstration of the Use of Reactive Zero-Valence Iron Powder to Treat Source Zone Sites Impacted by Halogenated Volatile Organic Chemicals

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EPA Grant Number: R825511C017
Subproject: *this is subproject number 017 , established and managed by the Center Director under grant R825511*
(EPA does not fund or establish subprojects; EPA awards and manages the overall grant for this center).
Center:HSRC (1989) - Northeast HSRC
Center Director: Sidhu, Sukh S.
Title: Field Demonstration of the Use of Reactive Zero-Valence Iron Powder to Treat Source Zone Sites Impacted by Halogenated Volatile Organic Chemicals
Investigators: Liskowitz, John W.
Institution:New Jersey Institute of Technology
EPA Project Officer: Manty, Dale
Project Period: June 1, 2000 through June 30, 2001
RFA: Hazardous Substance Research Centers - HSRC (1989)
Research Category: Hazardous Substance Research Centers

Description:

Objective:

To demonstrate that zero - valence iron powder has the potential as a cost - effective in-site treatment technology of halogenated organic contaminants found in a contaminated plume at Picatinny arsenal.

Summary/Accomplishments (Outputs/Outcomes):

Rationale: The recent use of in-situ chemical reduction technologies appears to provide the best approach to cost - effectively remediate the halogenated organic contaminants in groundwater, and bring a rapid end to site closure. In-situ reduction of dissolved-phase halogenated organics in groundwater has typically consisted of contaminants flowing through a subsurface permeable reactive wall containing zero-valent iron, which causes dehalogenation of the organic contaminants. Although this technology improves upon the pump and treat concept, since it requires no aboveground structures or treatment equipment, permeable reactive walls do not address source contamination.

ARS Technologies, Inc. (ARS) along with the New Jersey Institute of Technology (NJIT) have expanded upon the above approach through the development of an in-situ remediation process (Ferox) that involves the injection of specific quantities of highly reactive amorphous iron powder directly into contaminant zones. These joint efforts have advanced the knowledge base of the iron powder dehalogenation technology through the identification of critical parameters affecting the reaction performance. This work has also expanded the iron dehalogenation kinetic database to include desired ranges of iron ratios that should be used to generate target reactivity without the production of undesirable daughter products such as vinyl chloride and alkaline conditions that shorten the reactive lifetime of the iron powder.

This project addresses a critical DOD need for cost-effective in-situ organic treatment technology through the interpretation of several integrated innovative technologies. Pneumatic Fracturing and in-situ dechlorination using injected zero-valent iron powder. Pneumatic Fracturing has been successfully applied to a number of sites to enhance subsurface permeability, thus increasing formation permeability several orders of magnitude.

The Ferox technology is an in-situ subsurface remediation process for the treatment of halogenated hydrocarbons. This process involves the subsurface injection, using vertical points or wells and dispersion of targeted quantities of highly reactive zero-valent iron powder into the saturated or unsaturated zones of the contaminated formation.

The project will specifically address the remediation of contamination at the Picatinny site by demonstrating and validating the applicability of the iron powder approach for Area B which is a section of land (32 acres) in the southwestern portion of the Arsenal where chlorinated solvent use has contaminated soils and groundwater.

Approach: This project will be conducted in three phases: Phase I: Field Sampling; Phase II: Laboratory Bench-Scale Kinetic Testing and Phase III Pilot-Scale Field Demonstration. All phases of work will be completed within a 12-minth period.

Phase I - Field Sampling
The field sampling phase of the project includes the collection of representative soil and groundwater samples from the Area B source and impacted plume areas, with particular emphasis on the former sanitary landfill location. The collection and analysis of samples from this site will provide representative baseline contaminant concentrations and natural geologic conditions and will serve as the test media for the treatability kinetic testing. The sample collection will be performed in coordination with ARDEC's continued investigation of the plume.

Phase II - Bench-Scale Kinetic Testing
Laboratory bench-scale kinetic testing will provide the necessary site-specific design and treatment specifications required for the optimal application of Ferox under the pilot-scale treatment phase of the project. The design parameters which will be investigated include: kinetic rates for treating the site-specific media, the target dosage of iron powder to meet treatment objectives and the confirmation that no detrimental by-products will result from the field application of the process. The treatability test will be performed utilizing soil core and groundwater samples obtained from the site. The laboratory analysis is designed to simulate the subsurface conditions following the Ferox application. To accomplish this, the laboratory testing will consist of two kinetic batch reactor system analyses over a 45-day period. The batch reactors will be set up with targeted quantities of zero-valent iron powder and contain the contaminated soil samples. The target chlorinated organic concentrations; total chloride, soluble Fe^{+2} and pH will be monitored at specified time intervals throughout the test. The phase II bench-scale kinetic testing will encompass a 90-day period. All work will be performed at NJIT's environmental lab with 10% replicate samples sent to an outside certified laboratory.

Phase III - Field Demonstration (50 x 35 x 10 foot reactive treatment cell)
Upon completion of the treatability test, a field demonstration will be conducted in a section of the plume where elevated ground water concentration levels has been detected. A total of seven injection wells will be installed and utilized to create a reactive treatment zone 10 feet wide by 50 feet long. Prior to the emplacement of the reactive iron powder, Pneumatic Fracture injections will be performed to reduce geologic heterogeneities within the formation. A total of 50 iron powder injections/ well ranging in depth from 10-35 feet over 6 inch injection intervals will be applied at the site. The progress of treatment effectiveness will be monitored through post-injection soil and groundwater sample analyses during three separate sampling events. All analyses will be performed at NJIT's environmental lab with a minimum of 10% replicate samples sent to an outside certified laboratory for date quality assurance purposes.

Status: The Bench-Scale Kinetic testing has been completed. The results of this testing indicated that at least 5 tons of iron powder be injected and dispersed into a pilot scale iron powder treatment cell that is 75 feet in length, 20 feet wide and extending to a depth of 16 feet below ground surface. Groundwater sampling of two up gradient wells, two

down gradient and one side gradient well for TCE, CIS, DCE indicated that the dimensions of the test cell be the above and vinyl chloride rather than the 50 x 35 x 10 feet cell originally proposed. These changes were made to insure that a major portion of the contaminants in the ground water would pass through the treatment cell. Forty injections were required to place and disperse 5.32 tons of iron powder into the test cell. The test cell is now active and the first quarterly groundwater monitoring results will be available in early March, 2001.

Technology Transfer and Outreach Plan: It is anticipated that data and conclusions regarding the use of these technologies will focus upon their performance in dehalogenating the target contaminants and the cost in achieving this reduction at PTA. A detailed cost model will be prepared which will provide cost scale-up numbers for PTA and provide broad unit price costs to expand the applicability to other sites within EPA's Region 1 and 2 area. In addition, a technology case study bulletin will be prepared for electronic distribution to EPA personnel and to all relevant EPA and DOD sponsored technology databases such as VISIT.

Supplemental Keywords:

Pneumatic fracturing, in-situ dechlorination, zero-valent iron., Water, Geographic Area, Waste, Scientific Discipline, RFA, Remediation, Chemical Engineering, Analytical Chemistry, Hazardous Waste, Environmental Engineering, Environmental Chemistry, Contaminated Sediments, Hazardous, Ecology and Ecosystems, State, risk assessment, iron, extraction of metals, soil and groundwater remediation, chemical transport, permeable reactive barrier, groundwater, technical outreach, contaminated sediment, remediation technologies, halogenated organic compounds, contaminant transport, permeable barrier technology, environmental technology, hazardous waste management, contaminated soil, field monitoring, contaminated marine sediment, Picatinny arsenal, hazardous waste treatment, sediment treatment, technology transfer, New Jersey (NJ), chemical contaminants

Progress and Final Reports:
Original Abstract

Main Center Abstract and Reports:
R825511 HSRC (1989) - Northeast HSRC
Subprojects under this Center: (EPA does not fund or establish subprojects; EPA awards and manages the overall grant for this center).
R825511C001 Development of Mechanisms and Kinetic Models on Formation of Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans from Aromatic Precursors
R825511C002 Real-Time Monitoring and Control of Emissions from Stationary Combustors and Incinerators
R825511C003 Development of Sampling Systems for Continuous Monitoring of Volatile Organic Compounds (VOCs)
R825511C004 Investigation into the Effectiveness of DNAPL Remediation Strategies in Fractured Media
R825511C005 Advanced Leak Detection and Location Research: Extending the SERDP-funded Technical Base
R825511C006 Three-Dimensional Geostatistical Site Characterization with Updating
R825511C007 Anaerobic Biodegradation of PAHs in Soils and Dredged Sediments: Characterizing, Monitoring and Promoting Remediation
R825511C008 Substrate Accelerated Death and Extended Lag Phases as Causes of the Recalcitrance of Halogenated Compounds in Anoxic Environments
R825511C009 Fate and Transport of Nonionic Surfactants
R825511C010 In Situ Degradation of Petroleum Hydrocarbons and PAHs in Contaminated Salt Marsh Sediments
R825511C011 Design and Operation of Surfactant-Enhanced Bioslurry Reactors
R825511C012 Experimental Study of Overland Transport of Cryptosporidium parvum Oocysts
R825511C013 Development of a Framework for Evaluation of Leaching from Solid Waste
R825511C014 Use of a New Leaching Test Framework for Evaluating Alternative Treatment Processes for Mercury Contaminated Mixed Waste (Hazardous and Radioactive)
R825511C015 Field Pilot Test of In Situ Ultrasonic Enhancement Coupled With Soil Fracturing to Detoxify Contaminated Soil
R825511C016 Development of Sampling Systems for Continuous Monitoring of Volatile Organic Compounds (VOCs)
R825511C017 Field Demonstration of the Use of Reactive Zero-Valence Iron Powder to Treat Source Zone Sites Impacted by Halogenated Volatile Organic Chemicals
R825511C018 Technology Transfer of Continuous Non-Methane Organic Carbon (C-NMOC) Analyzer
R825511C019 Field Sampling and Treatability Study for In-Situ Remediation of PCB's and Leachable Lead with Iron Powder
R825511C020 Experimental and Modeling Studies of Chlorocarbon Incineration, PIC Formation, and Emissions Control
R825511C021 Experimental Studies and Numerical Modeling of Turbulent Combustion During Thermal Treatment of Hazardous Wastes: Applied Research for the Generation of Design and Diagnostic Tools
R825511C022 Electrochemical Sensor for Heavy Metals in Groundwater - Phase IV
R825511C023 Novel Molecular Tools for Monitoring In-Situ Bioremediation
R825511C024 Surfactant-Enhanced Bioremediation of Soils in the Presence of an Organic Phase
R825511C025 Enhanced Microbial Dechlorination of PCBs and Dioxins in Contaminated Dredge Spoils
R825511C026 Toward A Risk-Based Model for Bioremediation of Multicomponent NAPL Contaminants
R825511C027 Removal and Recovery of VOCs and Oils from Surfactant-Flushed Recovered Water by Membrane Permeation
R825511C029 Field Pilot Test of In-Situ Ultrasonic Enhancement Coupled With Soil Fracturing to Detoxify Contaminated Soil in Cooperation with McLaren/Hart Environmental Engineers at the Hillsborough, NJ Site
R825511C030 In-Situ Field Test of Electroremediation of a Chromate-Contaminated Site in Hudson County, New Jersey
R825511C031 Electrokinetic Removal of Heavy Metals and Mixed Hazardous Wastes from Partially and Fully Saturated Soils
R825511C032 Effects of Clay Charge and Confining Stresses on Soil Remediation by Electroosmosis
R825511C033 Assessment of Surfactant Enhanced Bioremediation for Soils/Aquifers Containing Polycyclic Aromatic Hydrocarbons (PAHs)
R825511C034 In-Situ Bioremediation of Organic Compounds: Coupling of Mass Transfer and Biodegradation
R825511C035 Investigation into the Effectiveness of DNAPL Remediation Strategies in Fractured Media
R825511C036 Field Pilot Scale Demonstration of Trench Bio-Sparge: An In-Situ Groundwater Treatment Technology
R825511C037 In-Situ Reductive Dehalogenation of Aliphatic Compounds by Fermentative Heterotrophic Bacteria
R825511C038 The Effect of Carbon-Nitrogen Ratios on Bacterial Transport and Biodegradation Rates In Soils
R825511C039 Ultrasonic Enhancement of Soil Fracturing Technologies for In-Situ Detoxification of Contaminated Soil
R825511C040 Full Field Demonstration of Integrated Pneumatic Fracturing and In-Situ Bioremediation
R825511C041 Determination of Adsorption and Desorption Behavior of Petroleum Products on Soils
R825511C042 Evaluation of the Potential for Complete Bioremediation of NAPL-Contaminated Soils Containing Polycyclic Aromatic Hydrocarbons (PAHs)
R825511C043 Characterization of Subsurface NAPL Distributions at Heterogeneous Field Sites
R825511C044 Development of a Thermal Desorption Gas Chromatograph/Microwave Induced Plasma/Mass Spectrometer (TDGC/MIP/MS) for On-site Analysis of Organic and Metal Contaminants
R825511C045 Using Trainable Networks for a Three-dimensional Characterization of Subsurface Contamination
R825511C046 Application of Advanced Waste Characterization to Soil Washing and Treatment
R825511C047 Electrochemical Sensor for Heavy Metals in Groundwater Phase III
R825511C048 Improved Luminescence Sensors for Oxygen Measurement
R825511C049 Preconcentration, Speciation and Determination of Dissolved Heavy Metals in Natural Waters, using Ion Exchange and Graphite Furnace Atomic Absorption Spectrometry
R825511C050 Experimental and Modeling Studies of Chlorocarbon Incineration and PIC Formation
R825511C051 PIC Emission Minimization: Fundamentals and Applications
R825511C052 Project Title: Development of a Two Stage, Pulse Combustion, VOC Destruction Technology
R825511C053 Development of Sampling Systems for Continuous Monitoring of Volatile Organic Compounds (VOCs)

R825511C054 FTIR Analysis of Gaseous Products from Hazardous Waste Combustion
R825511C055 Toxic Metals Volatilization for Waste Separation and Real-time Metals Analyses
R825511C056 Mixed Metal Removal and Recovery by Hollow Fiber Membrane-Based Extractive Adsorber
R825511C057 Removal of Volatile Organic Compounds (VOCs) from Contaminated Groundwater and Soils by Pervaporation
R825511C058 Simultaneous SO2/NO Removal/Recovery by Hollow Fiber Membrane
R825511C059 Superfund Sites and Mineral Industries Method
R825511C060 Soil Washing of Mixed Organics/Metal Contamination
R825511C061 Removal of Cesium, Strontium, Americium, Technetium and Plutonium from Radioactive Wastewater
R825511C062 Development of a Method for Removal of Nonvolatile Organic Materials from Soil using Flotation
R825511C063 Recovery of Evaporative Fuel Losses by Vapor Permeation Membranes
R825511C064 Surfactant Selection Protocol for Ex Situ Soil Washing
R825511C065 Biofiltration for the Control of Toxic Industrial VOCs Emissions
R825511C066 Catalytic Oxidation of Volatile Organic Compounds in Water
R825511C067 Soil Washing for Remediating Metal Contaminated Soils
R825511C068 Aqueous Absorption and Kinetics of NO by Strong Oxidizing Agents
R825511C069 Remediation of Dredging Spoils
R825511C070 Freeze Concentration for Zero-Effluent Processes
R825511C071 Life Cycle/Pollution Prevention Response to Executive Order 12856
R825511C072 Faster Better, Cheaper Hazardous Waste Site Characterization and Cleanup: an Adaptive Sampling and Analysis Strategy Employing Dynamic Workplans
R825511C073 Development of a Comprehensive Computer Model for the Pneumatic Fracturing Process
R825511C074 Technology Demonstration and Validation of CFAST Field Analytical Instrumentation for Use in Hazardous Waste Site Characterization, Clean-up and Monitoring
R825511C075 XFLOW: Training Software Simulating Contaminant Site Characterization and Remediation