Lecithin + Ferrous Gluconate (EHC® Liquid) for Anaerobic Bioremediation:

1. Dr. Alan G. Seech, FMC Corporation
2. Emulsfied Lecithin + Ferrous Gluconate.
3. MSDS & Technical Data Sheet - Attached
4. Number of Field-scale Applications to Date: 100+ sites.
5. Case Studies – Attached
6. Technical Summary: EHC® Liquid Amendment is an *in situ* chemical reduction (ISCR) product for the treatment of impacted groundwater. It is a cold-water soluble formulation that is specially designed for injection via existing wells or hydraulic injection networks for the treatment of a wide range of groundwater contaminants. EHC® Liquid will serve to create strong reducing conditions and promote both biotic and abiotic dechlorination reactions. EHC Liquid is composed of organic carbon and an organo-iron compound. It is shipped in two parts, a liquid component (EHC Liquid Amendment) and a corresponding powdered mix that can be easily combined and diluted for injection. This product is food grade material and there are no health and safety issues involved with its use.

Material Safety Data Sheet

EHC® Liquid - liquid component

MSDS #: EHCL-C
Revision Date: 2013-04-11
Version 1.02

FMC
ENVIRONMENTAL SOLUTIONS

This MSDS has been prepared to meet U.S. OSHA Hazard Communication Standard 29 CFR 1910.1200 and Canada's Workplace Hazardous Materials Information System (WHMIS) requirements.

1. PRODUCT AND COMPANY IDENTIFICATION

Product name — **EHC® Liquid - liquid component**

Recommended use — Bioremediation product for the remediation of contaminated soil and groundwater
Uses advised against — Not for use in potable drinking water

Manufacturer

FMC CORPORATION
Environmental Solutions
1735 Market Street
Philadelphia, PA 19103
Phone: +1 215/ 299-6000 (General Information)
E-Mail: msdsinfo@fmc.com

Emergency telephone number

For leak, fire, spill or accident emergencies, call:
+1 703-527-3887 (CHEMTREC)
1 303 / 595 9048 (Medical - U.S. - Call Collect)

2. Hazards identification

Emergency Overview

CONTAINMENT HAZARD:
Any vessel that contains wet EHC-L must be vented due to potential pressure build up from fermentation gases

Potential health effects

Acute Toxicity	No significant health effects anticipated
Eyes	May cause slight irritation.
Skin	May cause irritation.
Inhalation	No information available.
Ingestion	No information available.

3. Composition/information on ingredients

Ingredients

Chemical Name	CAS-No	Weight %
Water	7732-18-5	60-80
Lecithin	8002-43-5	20-30
Sorbitan monooleate, ethoxylated	9005-65-6	2-4
Sodium Benzoate	532-32-1	2-4

4. First aid measures

Eye contact In case of contact, immediately flush eyes with plenty of water. Get medical attention if irritation develops and persists.

Skin contact Wash skin with soap and water. Get medical attention if irritation develops and persists.

Inhalation Move to fresh air in case of accidental inhalation of vapors. Consult a physician if necessary.

Ingestion Drink 1 or 2 glasses of water. Get medical attention if symptoms occur.

Notes to physician Treat symptomatically.

5. Fire-fighting measures

Flammable properties Combustible material: may burn but does not ignite readily.

Flash Point > 200 °F

Suitable extinguishing media Carbon dioxide (CO_2). Dry chemical. Dry powder.

Explosion Data

Sensitivity to Mechanical Impact Not sensitive.
Sensitivity to Static Discharge Not sensitive.

Protective equipment and precautions for firefighters As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

NFPA	Health Hazard 1	Flammability 1	Stability 0	Special Hazards -

6. Accidental release measures

Personal precautions For personal protection see section 8.

Methods for containment Absorb with earth, sand or other non-combustible material and transfer to containers for later disposal.

Methods for cleaning up After cleaning, flush away traces with water.

7. Handling and storage

Handling Handle in accordance with good industrial hygiene and safety practice.

Storage Any vessel that contains wet EHC-L must be vented due to potential pressure build up from fermentation gases. Keep away from open flames, hot surfaces and sources of ignition.

8. Exposure controls/personal protection

Exposure guidelines

This product does not contain any hazardous materials with occupational exposure limits established by the region specific regulatory bodies.

Occupational exposure controls

Engineering measures	None under normal use conditions.
General Information	If the product is used in mixtures, it is recommended that you contact the appropriate protective equipment suppliers These recommendations apply to the product as supplied
Respiratory protection	Use only with adequate ventilation.
Eye/face protection	Safety glasses with side-shields
Skin and body protection	Wear suitable protective clothing.
Hand protection	Protective gloves

Hygiene measures

Handle in accordance with good industrial hygiene and safety practice Wash hands before breaks and immediately after handling the product.

9. Physical and chemical properties

9.1 Information on basic physical and chemical properties

Appearance	Light amber emulsion
Physical state	Liquid
Odor	odorless
pH	6.5 - 6.9
Melting Point/Range	No information available.
Freezing point	No information available.
Boiling Point/Range	No information available.
Flash Point	> 200 °F
Evaporation rate	not applicable
Flammable properties	Combustible material: may burn but does not ignite readily
Vapor pressure	No information available.
Vapor density	No information available.
Specific Gravity	1 - 1.1
Relative density	
Bulk density	not applicable
Water solubility	Dispersible in water
Percent volatile	No information available.
Partition coefficient:	not applicable
Viscosity	No information available.

9.2 Other information

Decomposition Temperature	No information available.

10. Stability and reactivity

Stability Stable.

Conditions to avoid Temperatures above 71°C

Materials to avoid Water, Alkalis

Hazardous decomposition products None under normal use.

Hazardous polymerization Hazardous polymerization does not occur.

11. Toxicological information

Acute effects

Remarks The product has not been tested. Ingredients in this product have been designated as GRAS (Generally Recognized as Safe) by govenment agencies.

Eye irritation No information available.
Skin irritation No information available.

LD50 Oral There are no data available for this product
LD50 Dermal There are no data available for this product
LC50 Inhalation: No information available.

Sensitization Not expected to be sensitizing based on the components.

Chronic Toxicity

Carcinogenicity Contains no ingredient listed as a carcinogen

12. Ecological information

Ecotoxicity
Contains no substances known to be hazardous to the environment or that are not degradable in waste water treatment plants

Persistence and degradability Expected to biodegrade, based on component information

Bioaccumulation Bioaccumulation is unlikely.

Mobility No information available.

Chemical Name	log Pow
Sodium Benzoate	-2.13

Other adverse effects None known

13. Disposal considerations

Waste disposal methods

This material, as supplied, is not a hazardous waste according to Federal regulations (40 CFR 261). This material could become a hazardous waste if it is mixed with or otherwise comes in contact with a hazardous waste, if chemical additions are made to this material, or if the material is processed or otherwise altered. Consult 40 CFR 261 to determine whether the altered material is a hazardous waste. Consult the appropriate state, regional, or local regulations for additional requirements.

Contaminated packaging

Dispose of in accordance with local regulations.

14. Transport information

DOT not regulated

TDG not regulated

ICAO/IATA not regulated

IMDG/IMO not regulated

15. Regulatory information

International Inventories

TSCA Inventory (United States of America)	Complies
DSL (Canada)	Complies
NDSL (Canada)	Complies
EINECS/ELINCS (Europe)	Complies
ENCS (Japan)	Complies
IECSC (China)	Complies
KECL (Korea)	Complies
PICCS (Philippines)	Complies
AICS (Australia)	Complies
NZIoC (New Zealand)	Complies

U.S. Federal Regulations

SARA 313

Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product does not contain any chemicals which are subject to the reporting requirements of the Act and Title 40 of the Code of Federal Regulations, Part 372.

SARA 311/312 Hazard Categories

Acute Health Hazard	no
Chronic Health Hazard	no
Fire Hazard	no
Sudden Release of Pressure Hazard	no
Reactive Hazard	no

CERCLA

This material, as supplied, does not contain any substances regulated as hazardous substances under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (40 CFR 302) or the Superfund Amendments and Reauthorization Act (SARA) (40 CFR 355). There may be specific reporting requirements at the local, regional, or state level pertaining to releases of this material.

International Regulations
Mexico - Grade Minimum risk, Grade 0

Canada
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR.
WHMIS Hazard Class
Non-controlled

16. Other information

HMIS	Health Hazard 1	Flammability 1	Stability 0	Special precautions -

NFPA/HMIS Ratings Legend
Severe = 4; Serious = 3; Moderate = 2; Slight = 1; Minimal = 0

Revision Date: 2013-04-11
Reason for revision: Qualify trade name.

Disclaimer
FMC Corporation believes that the information and recommendations contained herein (including data and statements) are accurate as of the date hereof. NO WARRANTY OF FITNESS FOR ANY PARTICULAR PURPOSE, WARRANTY OF MERCHANTABILITY OR ANY OTHER WARRANTY, EXPRESSED OR IMPLIED, IS MADE CONCERNING THE INFORMATION PROVIDED HEREIN. The information provided herein relates only to the specified product designated and may not be applicable where such product is used in combination with any other materials or in any process. Further, since the conditions and methods of use are beyond the control of FMC Corporation, FMC corporation expressly disclaims any and all liability as to any results obtained or arising from any use of the products or reliance on such information.

Prepared By

FMC Corporation
FMC Logo and EHC - Trademarks of FMC Corporation

End of Material Safety Data Sheet

Material Safety Data Sheet

ELS™ bioremediation amendment

MSDS #: ELS-C
Revision Date: 2013-04-11
Version 1.03

FMC
ENVIRONMENTAL SOLUTIONS

This MSDS has been prepared to meet U.S. OSHA Hazard Communication Standard 29 CFR 1910.1200 and Canada's Workplace Hazardous Materials Information System (WHMIS) requirements.

1. PRODUCT AND COMPANY IDENTIFICATION

Product name — **ELS™ bioremediation amendment**

Recommended use — Bioremediation product for the remediation of contaminated soil and groundwater only. Not for use in potable drinking water

Manufacturer

FMC CORPORATION
Environmental Solutions
1735 Market Street
Philadelphia, PA 19103
Phone: +1 215/ 299-6000 (General Information)
E-Mail: msdsinfo@fmc.com

Emergency telephone number

For leak, fire, spill or accident emergencies, call:
+1 703-527-3887 (CHEMTREC)
1 303 / 595 9048 (Medical - U.S. - Call Collect)

2. Hazards identification

Emergency Overview

CONTAINMENT HAZARD:
Any vessel that contains wet ELS must be vented due to potential pressure build up from fermentation gases

Potential health effects

Acute Toxicity	No significant health effects anticipated
Eyes	May cause slight irritation.
Skin	May cause irritation.
Inhalation	No information available.
Ingestion	No information available.

3. Composition/information on ingredients

Ingredients

Chemical Name	CAS-No	Weight %
Water	7732-18-5	60-80
Lecithin	8002-43-5	20-30
Sorbitan monooleate, ethoxylated	9005-65-6	2-4
Sodium Benzoate	532-32-1	2-4

4. First aid measures

Eye contact In case of contact, immediately flush eyes with plenty of water. Get medical attention if irritation develops and persists.

Skin contact Wash skin with soap and water. Get medical attention if irritation develops and persists.

Inhalation Move to fresh air in case of accidental inhalation of vapors. Consult a physician if necessary.

Ingestion Drink 1 or 2 glasses of water. Get medical attention if symptoms occur.

Notes to physician This product has low oral, dermal and inhalation toxicity. It is non-irritating to the eyes and skin and non-sensitizing to the skin.

5. Fire-fighting measures

Flammable properties Combustible material: may burn but does not ignite readily.

Flash Point > 200 °F

Suitable extinguishing media Carbon dioxide (CO_2). Dry chemical. Dry powder.

Explosion Data

Sensitivity to Mechanical Impact Not sensitive.
Sensitivity to Static Discharge Not sensitive.

Protective equipment and precautions for firefighters As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

NFPA	Health Hazard 1	Flammability 1	Stability 0	Special Hazards -

6. Accidental release measures

Personal precautions For personal protection see section 8.

Methods for containment Absorb with earth, sand or other non-combustible material and transfer to containers for later disposal.

Methods for cleaning up After cleaning, flush away traces with water.

7. Handling and storage

Handling Handle in accordance with good industrial hygiene and safety practice.

Storage Any vessel that contains wet ELS must be vented due to potential pressure build up from fermentation gases. Keep away from open flames, hot surfaces and sources of ignition.

8. Exposure controls/personal protection

Exposure guidelines This product does not contain any hazardous materials with occupational exposure limits established by the region specific regulatory bodies.

Occupational exposure controls

Engineering measures None under normal use conditions.

General Information If the product is used in mixtures, it is recommended that you contact the appropriate protective equipment suppliers These recommendations apply to the product as supplied

Respiratory protection Use only with adequate ventilation.

Eye/face protection Safety glasses with side-shields

Skin and body protection Wear suitable protective clothing.

Hand protection Protective gloves

Hygiene measures Handle in accordance with good industrial hygiene and safety practice Wash hands before breaks and immediately after handling the product.

9. Physical and chemical properties

9.1 Information on basic physical and chemical properties

Appearance	Light amber emulsion
Physical state	Liquid
Odor	odorless
pH	6.5 - 6.9
Melting Point/Range	No information available.
Freezing point	No information available.
Boiling Point/Range	No information available.
Flash Point	> 200 °F
Evaporation rate	not applicable
Flammable properties	Combustible material: may burn but does not ignite readily
Vapor pressure	No information available.
Vapor density	No information available.
Specific Gravity	1 - 1.1
Water solubility	Dispersible in water
Percent volatile	No information available.
Partition coefficient:	not applicable
Viscosity	No information available.

9.2 Other information

10. Stability and reactivity

Stability Stable.

Conditions to avoid Temperatures above 71°C

Materials to avoid Water, Alkalis

Hazardous decomposition products None known .

Hazardous polymerization Hazardous polymerization does not occur.

11. Toxicological information

Acute effects

Remarks The product has not been tested. Ingredients in this product have been designated as GRAS (Generally Recognized as Safe) by govenment agencies.

Eye irritation No information available.
Skin irritation No information available.

LD50 Oral There are no data available for this product
LD50 Dermal There are no data available for this product
LC50 Inhalation: No information available.

Chronic Toxicity

Carcinogenicity Contains no ingredient listed as a carcinogen

12. Ecological information

Ecotoxicity
Contains no substances known to be hazardous to the environment or that are not degradable in waste water treatment plants

Chemical Name	log Pow
Sodium Benzoate	-2.13

13. Disposal considerations

Waste disposal methods This material, as supplied, is not a hazardous waste according to Federal regulations (40 CFR 261). This material could become a hazardous waste if it is mixed with or otherwise comes in contact with a hazardous waste, if chemical additions are made to this material, or if the material is processed or otherwise altered. Consult 40 CFR 261 to determine whether the altered material is a hazardous waste. Consult the appropriate state, regional, or local regulations for additional requirements.

Contaminated packaging Dispose of in accordance with local regulations.

14. Transport information

DOT	not regulated
TDG	not regulated
ICAO/IATA	not regulated
IMDG/IMO	not regulated

15. Regulatory information

International Inventories

TSCA Inventory (United States of America)	Complies
DSL (Canada)	Complies
NDSL (Canada)	Complies
EINECS/ELINCS (Europe)	Complies
ENCS (Japan)	Complies
IECSC (China)	Complies
KECL (Korea)	Complies
PICCS (Philippines)	Complies
AICS (Australia)	Complies
NZIoC (New Zealand)	Complies

U.S. Federal Regulations

SARA 313

Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product does not contain any chemicals which are subject to the reporting requirements of the Act and Title 40 of the Code of Federal Regulations, Part 372.

SARA 311/312 Hazard Categories

Acute Health Hazard	no
Chronic Health Hazard	no
Fire Hazard	no
Sudden Release of Pressure Hazard	no
Reactive Hazard	no

CERCLA

This material, as supplied, does not contain any substances regulated as hazardous substances under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (40 CFR 302) or the Superfund Amendments and Reauthorization Act (SARA) (40 CFR 355). There may be specific reporting requirements at the local, regional, or state level pertaining to releases of this material.

International Regulations

Mexico - Grade	Minimum risk, Grade 0

Canada

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR.

WHMIS Hazard Class

Non-controlled

16. Other information

HMIS	Health Hazard 1	Flammability 1	Stability 0	Special precautions -

NFPA/HMIS Ratings Legend
Severe = 4; Serious = 3; Moderate = 2; Slight = 1; Minimal = 0

Revision Date: 2013-04-11
Reason for revision: Product transferred to new business group.

Disclaimer
FMC Corporation believes that the information and recommendations contained herein (including data and statements) are accurate as of the date hereof. NO WARRANTY OF FITNESS FOR ANY PARTICULAR PURPOSE, WARRANTY OF MERCHANTABILITY OR ANY OTHER WARRANTY, EXPRESSED OR IMPLIED, IS MADE CONCERNING THE INFORMATION PROVIDED HEREIN. The information provided herein relates only to the specified product designated and may not be applicable where such product is used in combination with any other materials or in any process. Further, since the conditions and methods of use are beyond the control of FMC Corporation, FMC corporation expressly disclaims any and all liability as to any results obtained or arising from any use of the products or reliance on such information.

Prepared By

FMC Corporation
FMC Logo - Trademark of FMC Corporation

End of Material Safety Data Sheet

FMC

Soil & Groundwater remediation

CASE STUDY

EHC ® Liquid and ELS™ Lecithin-based Amendments for Treatment CVOCs in Chalk Aquifer, Swaston, UK

Summary

Groundwater at a confidential site in UK is impacted with chlorinated solvents (primarily PCE, TCE and 1,2-DCE). A pilot test was first conducted in Dec 2011 by injecting EHC® Liquid amendment, a lecithin-based substrate that includes supplemental ferrous iron, in the shallow chalk. Based on positive data, a second application (Phase II) was done in March 2013 using lecithin-based ELS™ amendment. Significant reduction in concentrations of CVOCs was observed following these two applications. Complete mineralization was observed as evident by the formation of ethene. Based on further plume delineation conducted in mid-2013, a full-scale ELS™ amendment injection program is planned beginning early 2014.

Remedial Strategy

The site geology consists of a thin layer of unconsolidated drift deposits followed by weathered chalk and competent chalk down to several 100 meters. Vertical impacts span from 4 m to 51 m bgs. The upgradient source cannot be accessed so the preferred remedy is treatment of the plume downgradient of the source by flux reduction before the plume migrates under residences. Natural reductive dechlorination is occurring at the site but the TOC is very low in the aquifer.

Solution

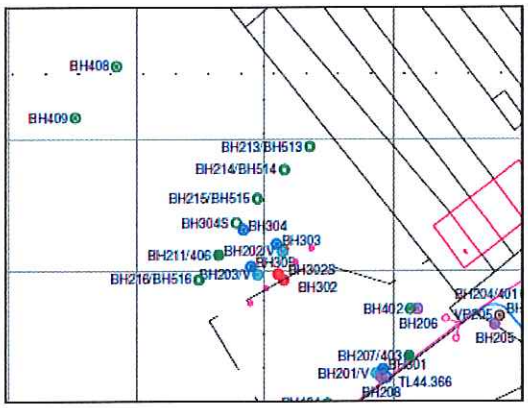
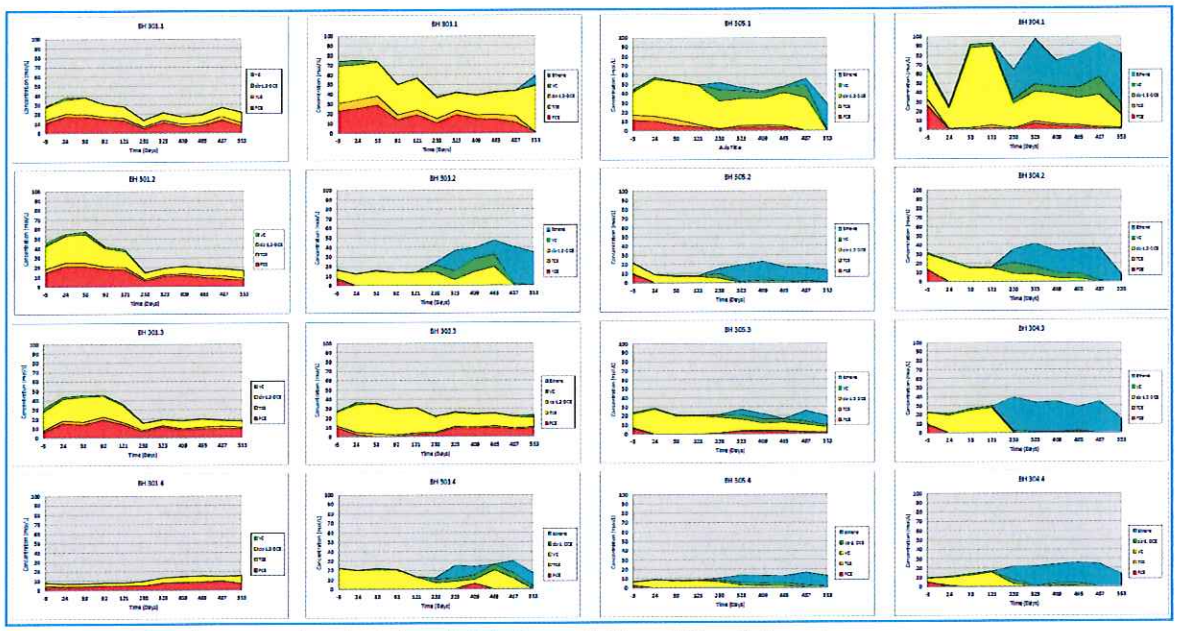


Figure 1 shows the site map with the layout of injection and monitoring wells. EHC® Liquid amendment and ELS™ amendment were injected in well BH302. Well BH301 is the upgradient well and wells BH303, BH304 and BH305 are the downgradient wells. For Phase I, 4,750 L of EHC® Liquid amendment was injected in BH302 in Dec 2011. In Phase II 10,000 L of ELS™ amendment was injected in BH302S + DHC culture in Mar 2013. Targeted vertical zone was from 10 to 37 m bgs, over 7 vertical ports.

Results

Figure 2 on next page shows the concentrations of PCE, TCE, DCE, VC and ethene in the upgradient and downgradient wells since the beginning of the pilot test in Dec 2011 (553 days). The data shown is for the top four ports where the CVOCs concentrations were the highest. The upgradient well (BH301) continues to show elevated levels of CVOCs. The three downgradient wells indicate that the transformation from PCE and TCE is occurring overtime with the formation of DCE, VC and ultimately ethene. Overall, the data shows between 46 to 78% reduction in the concentrations of CVOCs.

Upgradient - 301 Down gradient 303 Down gradient 304 Down gradient 305



Legend: Red (PCE), Orange (TCE), Yellow (DCE), Green (VC) and Blue (ethene)

Lessons Learned

- Bioaugmentation with DHC culture was essential after the first injection of EHC® Liquid amendment.
- To prevent wash-out of the ELS™ amendment, EHC® Liquid amendment or any liquid based amendment in this permeable aquifer, injections must be done at a higher concentration and minimize the total volume of solution to inject.

FMC

Soil & Groundwater remediation

CASE STUDY

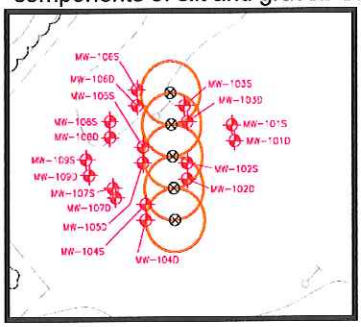
EHC® Liquid PRB Application, Farmingdale, NJ

Summary

Groundwater at a former industrial site in Farmingdale, NJ is impacted with chlorinated solvents (TCE, PCE, 1,1 DCA and 1,1 DCE). A pilot test was conducted in Nov 2011 to evaluate the efficacy of EHC® Liquid Permeable Reactive Barrier (PRB) to reductively treat the CVOCs, and reduce the flux of CVOCs immediately downgradient of the source area. EHC® Liquid amendment is an *in situ* chemical reduction amendment consisting of lecithin (electron donor) and an organo-iron salt (to promote formation of reactive iron minerals). Performance monitoring conducted for six months showed 63% reduction in the flux of TCE at monitoring points 30 ft downgradient of the EHC® Liquid PRB.

Remedial Strategy

The highest concentrations are found behind the former manufacturing building where TCE concentrations range from 10 to 100 mg/L (ppm). Groundwater is encountered at a depth of between 5 to 10 ft bgs. The site geology consists of 160 ft of unconsolidated sediments of the Kirkwood Formation (clayey to silty mud rock, massive sand and thin pebbly lenses), followed by the Manasquan Formation (clay) which acts as an Aquitard. The Lower Member of the Kirkwood Formation is where most of the contaminants reside and is comprised of 10 to 30 ft of coarse sand with components of silt and gravel. Groundwater velocity is estimated at 35 ft/yr in the central portion of the main plume.



Solution

Due to the size of the plume, the overall remedial strategy will have multiple components which will provide mass reduction in source area and a PRB in the diffused part of the plume. The EHC® Liquid PRB was 50 ft long, and constructed by injecting the amendment through five injection points spaced 10 ft apart. The targeted vertical zone was from 5 ft to 30 ft bgs. Approximately 425 lbs of EHC® Liquid solution was injected in each of the five points of the PRB. Performance monitoring was conducted by monitoring and collecting groundwater samples from 18 monitoring wells (9 shallow and deep nested wells). Real time data (pH, DO, ORP, conductivity) was collected from some of the wells using sensors. **Figure 1** (left) shows layout of injection and monitoring wells.

Results

Figures 2 and 3 below show trends in concentrations of TCE in shallow and deep monitoring wells. TCE concentrations decreased in all monitoring wells within the PRB and downgradient of the PRB except well MW-104D which was located at the downgradient edge of the PRB. **Figure 4** shows the trends in CVOCs concentration in monitoring well MW-108D (20 ft downgradient from the PRB).

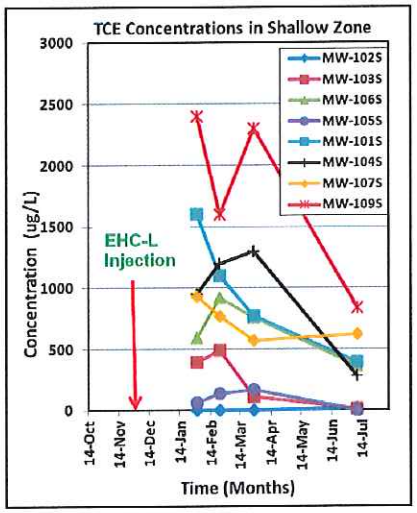


Figure 2: TCE Trends in Shallow Wells

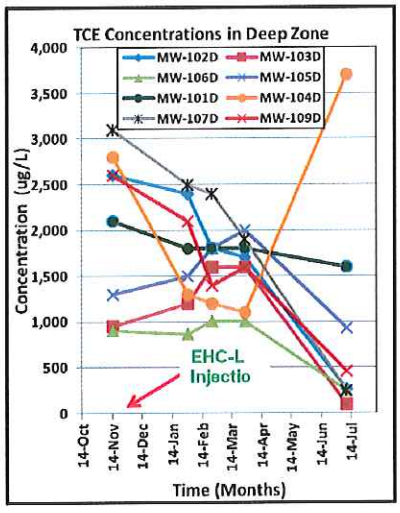


Figure 3: TCE Trends in Deep Wells

FMC CORPORATION
1735 Market Street | Philadelphia, PA 19103 | 215-299-6000
ENVIRONMENTAL.FMC.COM

Figure 5 shows trends in CVOCs concentrations in monitoring well MW-109D (25 ft downgradient of the PRB). Both wells show significant reduction in concentrations of TCE with some generation of cis-1,2 DCE after six months. Vinyl chloride (VC) generation was none to minimal in these wells. Some wells showed close to 100% conversion of TCE to cis-1,2 DCE. Concentrations of cis-1,2 DCE ranged from ND to 3,800 ppb. Nine out of sixteen wells had cis-1,2 DCE concentrations above the regulatory limit of 70 ppb after six months. Concentrations of VC ranged from ND to 39 ppb. Seven out of sixteen wells had VC concentrations above the regulatory limit of 1 ppb after six months.

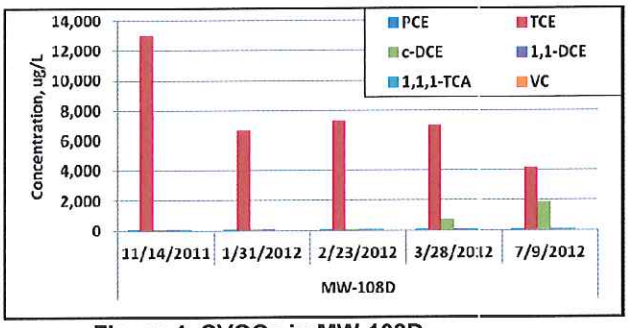


Figure 4. CVOCs in MW-108D

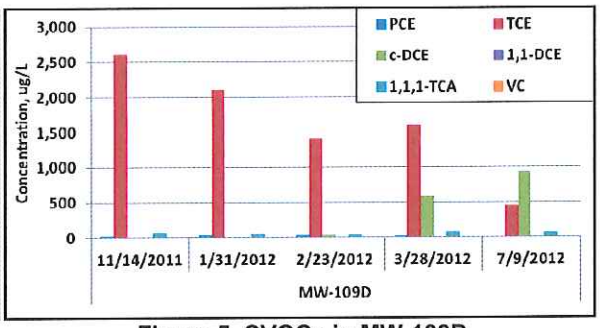


Figure 5. CVOCs in MW-109D

Post-injection anlysis showed the presence of *Dhc* hydogenase genes. Due to the short evaluation time for the pilot test (6-months) and the high concentrations of CVOCs, the increase in concentration of cis-1,2 DCE could be transitory. Microbial analysis and geochemical conditions monitored suggest that with time, cis-1,2 DCE concentrations would decrease.

The primary objective of the pilot test was to show flux reduction of TCE downgradient of the EHC® Liquid PRB. **Figures 6 and 7** below show pre and post-injection distribution of TCE in the pilot test area. The figures show a slice taken downgradient where the flux of TCE is calculated. The flux calculations showed that there was a 73% reduction (from 18.56 g/day to 5.08 g/day) in discharge of TCE between Nov 2011 and July 2012

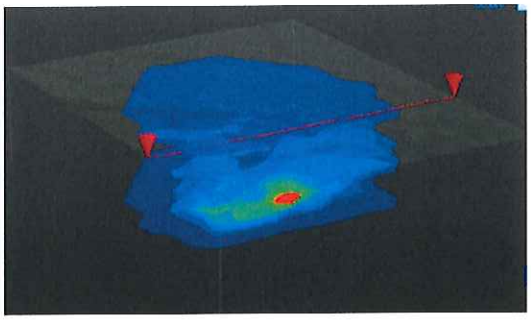


Figure 6. TCE Before Injection

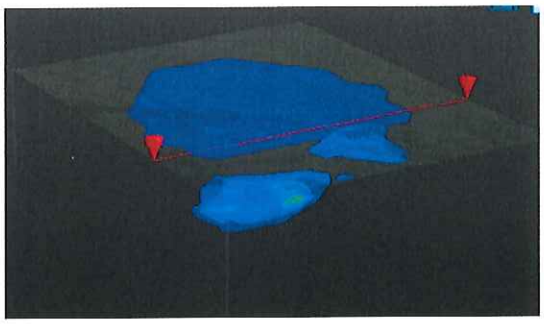


Figure 7. TCE after Injection

Lessons Learned

- Real-time geochemical data collected using sensors assisted in quick understanding of how EHC® Liquid amendment was distributed during injection.
- Advanced diagnostic tools such as CSIA and MBT confirmed the involvement of contaminant degrading microorganisms in the process.
- The assessment of TCE concentrations over time, using traditional analytical evaluation methods, coupled with the calculation of mass flux and mass discharge confirmed that contaminant concentrations were attenuating post EHC® Liquid PRB injection.
- The mass flux and mass discharge metrics in particular are very expressive at a "whole systems" level and enhances the value of evaluating discrete changes in individual wells.
- Bioaugmentation with Dhc culture would have helped with continued degradation of cis-1,2 DCE and VC.

FMC

Soil & Groundwater remediation

CASE STUDY

EHC ® Liquid Application to Treat CVOCs at an Industrial Site, Denver, CO

Objective

Objective of the project was to demonstrate the efficacy of EHC Liquid Injections for treatment of residual TCA and DCE contamination beneath the building and to reduce contaminant mass in the deeper saturated zone (20-25 ft bgs).

Remedial Strategy

Given limited access to contamination under the building due to ongoing operations, the gravel-filled former source area excavation west of the building was used as a large storage or reaction vessel. Pumping wells were installed east of the building to enhance groundwater movement under the building and promote reductive dechlorination of the remaining contaminants.

Solution

From June 11 through June 14, 2012, approximately 5,000 lbs of EHC® ISCR reagent and 7,114 lbs of lecithin-based EHC® Liquid amendment were injected into the gravel-backfilled former source area excavation along the west-side of the building. Groundwater extraction was conducted at E-4, E-15, E-16, and TPW-2 following the injection of EHC® ISCR reagent in an attempt to create anaerobic conditions in groundwater in the area beneath the building.

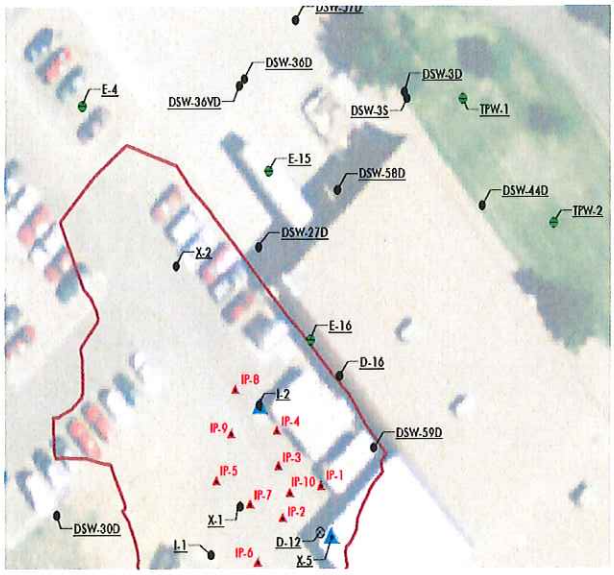
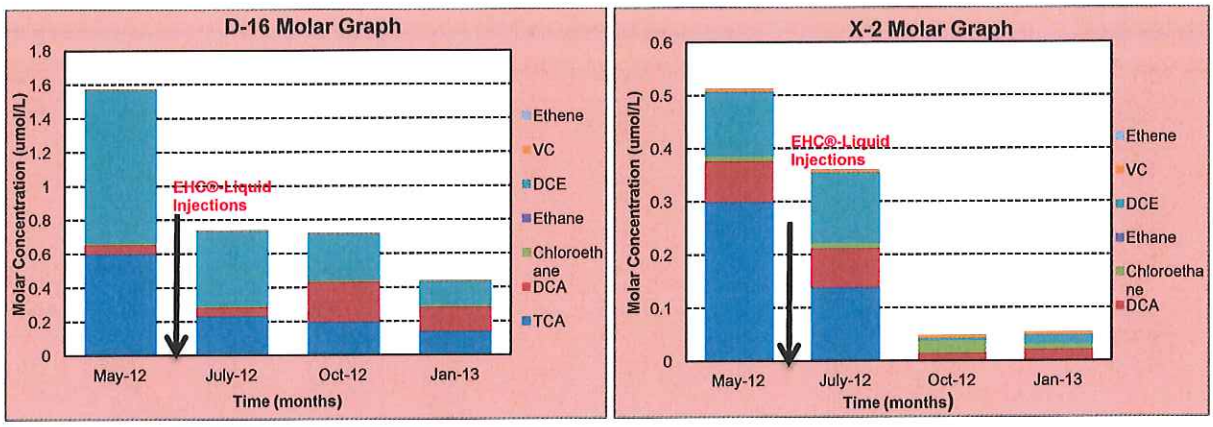


Figure 1 indicates the layout of direct push injection points depicted in red, EHC® Liquid amendment injection wells depicted in blue and the downgradient extraction wells in green.

Results

Figure 2 on next page shows the molar concentrations of CVOCs in wells X2 and D16 pre and post injection indicating that the delivery method successfully created anaerobic conditions downgradient of the area injected in the wells along the west side of the building.



Discussion and Future Scope of Work

- The amendments were successful at establishing long-lasting, highly-reducing conditions conducive to chemical and biological reduction of cVOCs.
- Monitoring results at D-16 and X-2 will be used in determining whether additional EHC® Liquid is necessary to maintain ISCR conditions.
- Multiple lines of evidence that anaerobic conditions have been generated have not been observed at DSW-44D, but the increasing trend in methane concentrations and the decreasing trend in nitrate concentrations are positive indications that anaerobic conditions may be observed in the upcoming year along the east side of the building.
- Sampling will continue on a quarterly basis till the end of 2013 followed by additional investigation/delineation of contamination under the building to identify multiple residual sources (if any).

FMC

Soil & Groundwater remediation

CASE STUDY

EHC ® Liquid Application to Treat CVOCs at a Dry Cleaning Facility, Millbrae, CA

Background

Jiffy Cleaners is a dry cleaning facility located in Millbrae, California that is underlain by groundwater impacted with tetrachloroethene (PCE). Several small spills occurred in the vicinity of the dry cleaning machine during of the early years of operation, which date back to the 1960s. Although PCE impacts to underlying soil have attenuated over time, a relatively stagnant groundwater plume of PCE presents a vapor intrusion risk to the existing dry cleaning facility and adjacent businesses.

Remedial Strategy

After detailed site characterization, TRC (consultant) developed a strategy for remediating on-site groundwater via enhanced in-situ bioremediation (EISB). TRC evaluated the naturally existing microbial community at the site to determine if the appropriate bacteria were present in groundwater to facilitate degradation of PCE, and if so, whether or not the addition of a carbon food source for the bacteria would promote higher rates of degradation. Based on the analytical results from the Bio-Traps® with various amendments, EHC® Liquid amendment, a lecithin-based carbon substrate, was selected as the remedial approach for the pilot study injection test. This amendment provides a controlled-release of carbon used to support the growth of fermenting bacteria, and allows for less frequent injections.

Solution

On March 13, 2012, TRC conducted an injection test at IW-1. A mixture consisting of 550 gallons of water, 50 gallons of EHC® Liquid amendment (lecithin-based), 25 lbs of a water soluble EHC® Liquid mix and 2.5 kg of potassium bromide was injected at 10 to 12 psi. TRC injected 3 liters of DHC, followed by 94 gallons of semi-anoxic, distilled (DI) chase water as recommended by the manufacture of EHC® Liquid amendment. The intent of the inoculation was to introduce DHC under anaerobic, non-toxic conditions with excess electron donor and carbon source present to encourage the population of DHC in the treatment zone and formulate a thriving, sustainable microbial community. Three post-injection monitoring events were conducted for wells IW-1, MW-3R and MW-5. The first post-injection monitoring event took place on March 27, 2012, the second on April 23, 2012 and the third on June 4, 2012.

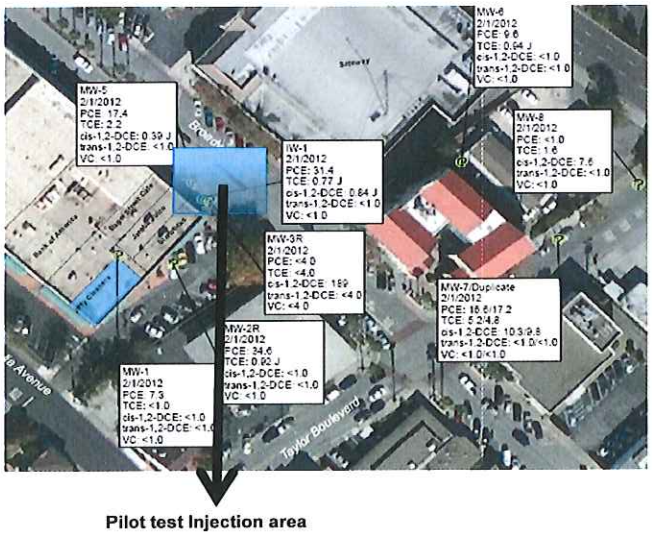
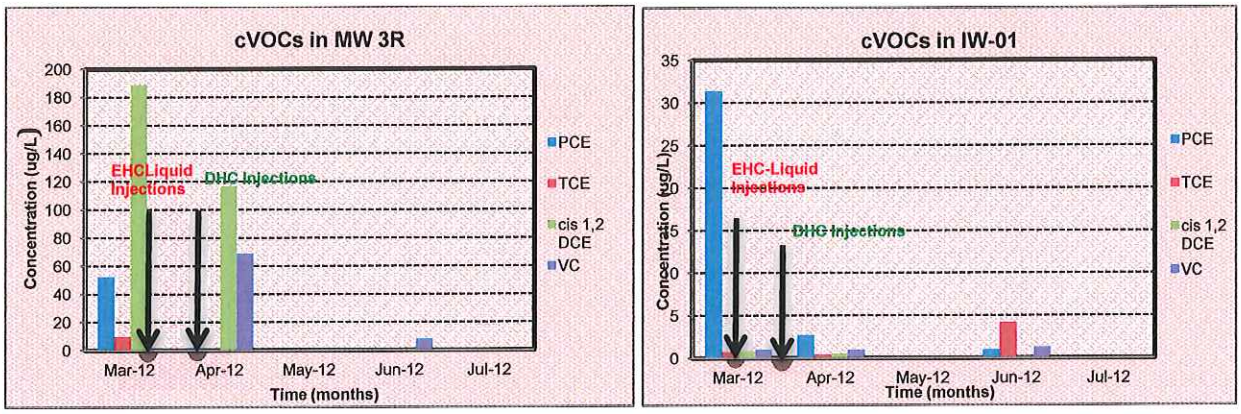


Figure 1 indicates the pilot test injection area and performance monitoring wells.

Results

Figure 2 shows the concentrations of CVOCs in wells MW 3R and IW-01 pre and post injection indicating significant reduction in contaminant concentrate post substrate and Inoculum injections in a short time frame.



Discussion and Future Scope of Work

- A substantial decrease in CVOC concentrations and an increase in ethene concentrations was observed in IW-1 during the three rounds of post monitoring event.
- Geochemical data from MW-3R suggests acceptable reducing conditions for PCE biodegradation. Nitrate levels have consistently been below reporting limits, and sulfate concentrations have generally been low (less than 10 mg/L to 67.0 mg/L) and likely do not pose a substantial competitive threat to PCE degradation. ORP levels are also relatively low (-38.8 mV to -170.7 mV), suggesting reduced conditions. Increases in ferrous iron concentrations from 4.9 mg/L to 30.7 mg/L imply that naturally-occurring ferric iron concentrations are being depleted and/or DVI is being utilized for abiotic PCE degradation.
- Pilot study results suggest EISB using EHC® Liquid amendment is a valid remediation technology at the site. Evidence of complete reductive dechlorination of PCE was observed over a relatively short time period and DHC inoculation appears to have been successful in IW-1.
- With regard to potential future EISB injections at the site, TRC recommends continued use of controlled-release carbon amendments with DVI, such as EHC® Liquid amendment, due to its demonstrated effectiveness and less frequent injections needed. Additionally, TRC recommends adding a buffer to the EHC® Liquid amendment injection solutions to maintain ideal pH levels for DHC bacteria and performing DHC inoculation approximately one month after the amendment injection.

FMC

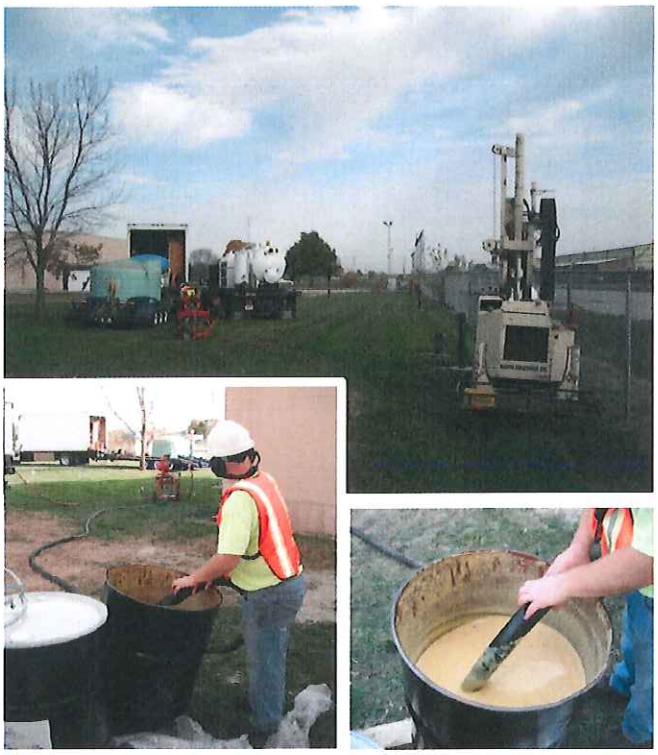
Soil & Groundwater remediation

CASE STUDY

ISCR for Treatment of TCA NAPL Source Area - Illinois

Summary

Saturated soil and groundwater at an active industrial facility located in Illinois is impacted by CVOCs, with the primary constituent of interest being 1,1,1-TCA, which prior to treatment was present at concentrations indicating the presence of DNAPL. Groundwater also measured lower concentrations of 1,1-DCA, CA and VC. To address these impacts, EHC® ISCR reagent was injected within the source and hot-spot area, which served to significantly reduce concentrations at the source area; 1,1,1-TCA concentrations decreased from an average of 3,450 mg/kg measured at the baseline to an average of 93 mg/kg in 12 months. This constituted a 97% reduction and reduced soil concentrations well below the target Csat concentration of 1,200 mg/kg. To expedite treatment, a supplemental injection utilizing a more fast-releasing soluble ISCR substrate, EHC® Liquid amendment, was performed to polish remaining source impacts and expedite treatment of the groundwater plume. These combined measures has served to reduce 1,1,1-TCA concentrations in groundwater by over 99%, from a maximum of 709 mg/L measured in December 2008 to 0.782 mg/L measured in March 2013.



Remedial Strategy

1,1,1-TCA was historically measured at concentrations of up to 5,600 mg/kg in saturated soil. This is above the soil saturation limit (Csat) for 1,1,1-TCA calculated at 1,200 mg/kg, suggesting the presence of DNAPL. The primary remedial objective was to reduce saturated soil concentrations within the source area to below Csat, to allow for calculation of Tier 2 remediation objectives and long term reduction in groundwater concentrations. The Tier 2 objectives were determined by applying site-specific data to pre-established modeling equations to quantify the risk to human health and the environment.

Solution

The remediation utilized a combined approach, with application of EHC® ISCR reagent into the hottest areas for source mass removal, followed by the application of EHC® Liquid amendment for groundwater polishing:

- EHC® ISCR reagent is composed of a slow-release source of organic carbon derived from plant fibers and zero-valent iron and provides a long-term source for enhanced reductive dechlorination / ISCR.
- EHC® Liquid amendment is a more quickly-releasing soluble ISCR substrate, which combines emulsified lecithin with a source of ferrous iron.

The areas targeted during each injection event are outlined below and shown on **Figure 1**. All injections were performed using direct push technology.

Pilot Study: A pilot-scale injection was conducted in December 2008. A total of 1,350 lbs of EHC® ISCR reagent was injected into a total of 10 points covering an area measuring approximately 50 ft long x 10 ft wide x 5 ft deep (from 14 to 19 ft bgs). This resulted in an EHC® ISCR reagent application rate of 0.6% EHC® ISCR reagent to soil mass within the injection area.

Full-Scale Application: Based on the promising results achieved at the pilot scale, EHC® ISCR reagent was selected for a larger-scale application at the site. In June 2010, a total of 17,200 lbs EHC® ISCR reagent was injected into two areas at the site:

- TCA Source Area (area with concentrations exceeding soil saturation limit for 1,1,1-TCA): EHC® ISCR reagent injected in a 10-ft grid throughout an area measuring ca. 50 ft long x 65 ft wide x 5 ft deep at an average loading rate of 1% EHC® ISCR reagent to soil mass, for a total of 15,950 lbs of EHC® ISCR reagent.

- VC Hot-Spot Area: EHC® ISCR reagent was injected in a PRB configuration (line of injection points). An total of 1,250 lbs EHC® ISCR reagent was injected into 10 injection points spaced 10 ft apart, covering an area measuring roughly 100 ft long x 10 ft wide x 5 ft deep, resulting in an application rate of 0.25% EHC® ISCR reagent to soil mass.

EHC® Liquid amendment Application: To expedite treatment, supplemental injections were conducted in October 2011, targeting a larger treatment depth from 5 to 19 ft bgs and using a more quickly-releasing soluble ISCR substrate, EHC® Liquid amendment. The EHC® Liquid amendment was injected as a 10-fold dilution, targeting a concentration of 1,000 mg/L of active ingredients in groundwater.

-TCA Source Area: A total of 5,880 lbs EHC® Liquid amendment was injected at a total of 48 locations spaced 10 ft apart, targeting an area measuring ca. 60 ft wide x 80 ft long x 14 ft deep.

- VC Hot-Spot Area: A total of 2,520 lbs EHC® Liquid amendment was injected at a total of 18 locations spaced 10 ft apart, targeting an area measuring ca. 90 ft wide x 20 ft long x 14 ft deep.

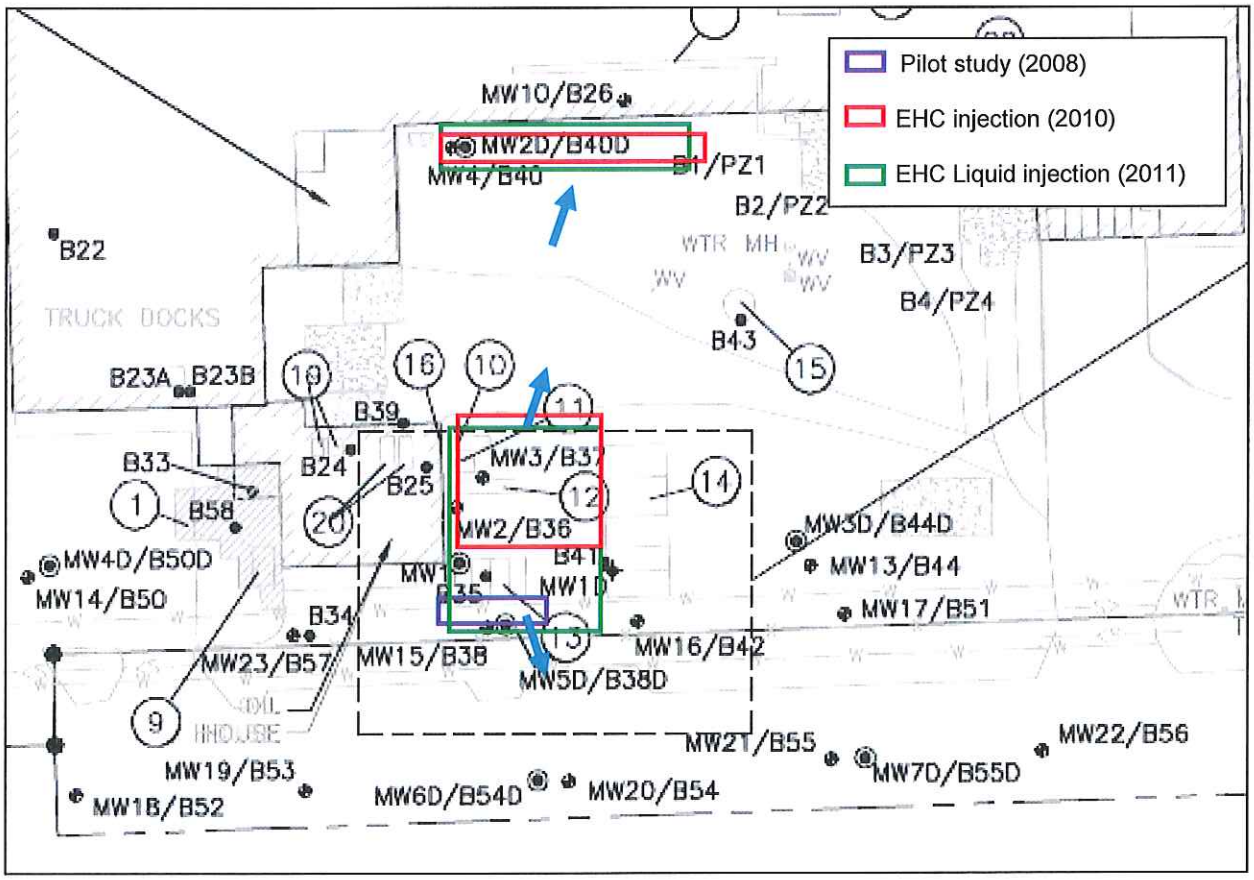


Figure 1: Site plan showing injection areas, monitoring wells and estimated groundwater flow direction.

Result

Following pilot and full-scale application of EHC® ISCR reagent into the source area, 1,1,1-TCA concentrations decreased from an average of 3,450 mg/kg measured at the baseline to an average of 93 mg/kg measured in February 2011. This constituted a 97% reduction and reduced soil concentrations well below the target Csat concentration of 1,200 mg/kg. In response to the combined EHC® ISCR reagent and EHC® Liquid amendment applications, groundwater concentrations decreased >99% from a maximum of 709 mg/L measured in December 2008 to 0.782 mg/L measured in March 2013 at the source area well MW-15, with limited generation of catabolites (**Figure 2**). A decreasing trend in total CVOC concentrations has also been observed down gradient from the hot-spot treatment area (**Figure 3**). The Tier 2 remedial objectives have been met for all constituents except VC, which has remained relatively steady at between 0.1 and 0.5 mg/L, but is expected to decline over time. The site has petitioned for No Further Remediation, with approval still pending.

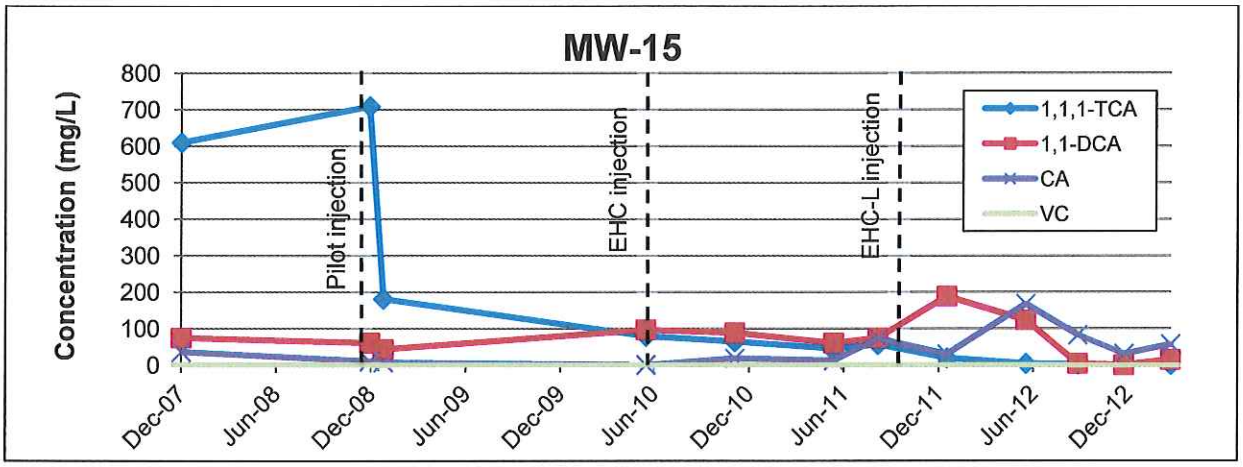


Figure 2: CVOCs measured in groundwater in the highest concentration well MW-15.

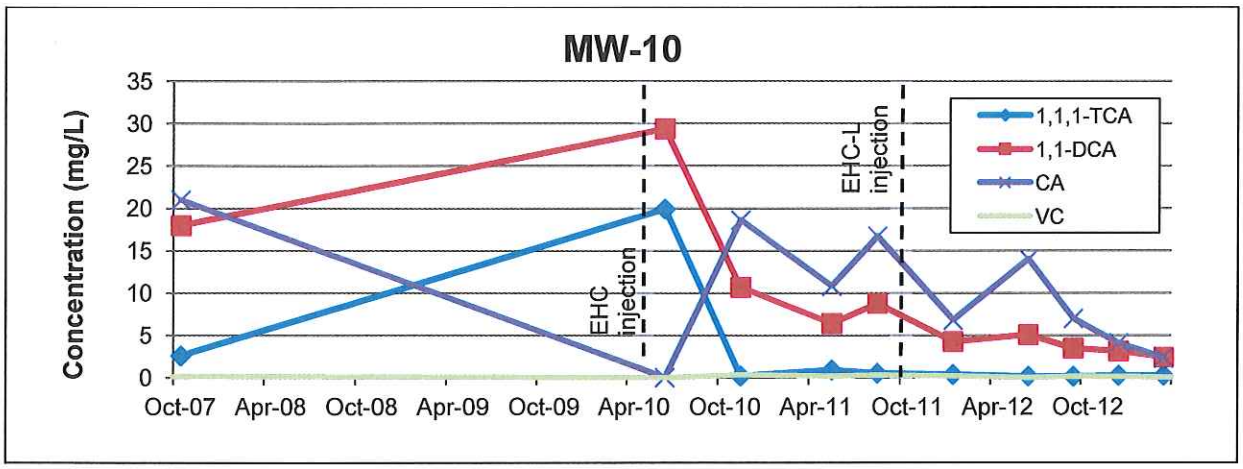


Figure 3: CVOCs measured in groundwater downgradient from the VC hot-spot treatment area.