



# ADVENTUS

Proven Soil, Sediment, and Groundwater  
Remediation Technologies

## STATEMENT OF QUALIFICATIONS (March 2009)

### DRY CLEANER SITES AND CHLORINATED SOLVENT REMEDIATION

The Adventus Group is an environmental biotechnology company that provides various remediation biotechnologies - including those exclusive to our patent portfolio (see below). We are NOT consultants – we support our clients' project team(s) by providing unbiased design support and selection of the most cost-effective remedial solution or strategy. As appropriate, our proven products may provide significant advantages. Implementation is subsequently provided by partnering with engineering and construction firms.

ADVENTUS' staff has over 150 cumulative years of experience in conducting remedial investigations/feasibility studies (RI/FS), remedial design, engineering and modeling (RD), remedial actions (RA) and implementation (support) at dry cleaner and other, related sites impacted by chlorinated volatile organic compounds (CVOCs), such as perchloroethylene (PCE), trichloroethylene (TCE), and various chloroethanes. These projects have included industrial clients, federal, state and local governments, as well as public organizations. Useful knowledge and experience has been gained working at dry cleaner sites, manufacturing facilities, military facilities, landfills, bulk chemicals storage facilities, active railroads and airports, Superfund sites, and as part of Brownfield site redevelopment efforts while offering the following technologies and services:

**For Groundwater** – *In situ* chemical reduction (ISCR) using EHC™ or EHC-M (for simultaneous treatment of heavy metals) or granular zero valent iron (ZVI), permeable reactive barriers (PRB) with EHC and/or ZVI, and/or in-well stripping using modified groundwater circulation wells (mGCW).

**For DNAPL Stabilization** – *In situ* biogeochemical stabilization (ISBS) of DNAPL using RemOx™ EC to destroy CVOCs mass, rapidly reduce the flux of CVOCs from stabilized DNAPL into the groundwater, and facilitate enhanced remediation of dissolved plumes.

**For DNAPL Treatment** - Zero-valent iron-clay (ZVI-clay) is mixed *in situ* with suspected DNAPL and aqueous phase source areas to facilitate chemical reduction.

**For Soil Treatment** – *Ex situ*, or *in situ* treatment of soil and sediment using DARAMEND, which integrates controlled release carbon and reduced metals (*e.g.*, ZVI).

We also have significant experience in the area of fate and transport modeling and litigation support.

## Representative Project Experience

Adventus Group staff have been involved in over 200 applications of ZVI and EHC technologies for chlorinated solvent remediation, both in traditional PRB configurations for plume cut-off and more innovative injection based applications for CVOC mass reduction. The following list represents some of our project experiences.

1. **ISCR of PCE and catabolites** (Dry Cleaner Site, Oregon) Groundwater at a former dry cleaner site was impacted with PCE, TCE, DCE, and VC, as high as 22,000, 1,700, 3,100, and 7 ppb, respectively. Field scale pilot tests were performed for the Oregon DEQ's Dry Cleaner Program to evaluate the performance of EHC<sup>TM</sup> and also evaluate the effectiveness of the injection method in distributing EHC, given the low permeability of soils at the site (sandy silt and silty clay). Subsequent field monitoring has shown greater than 99.6% removal of total CVOC concentrations one year after the injections. No accumulation of VC or other daughter products was observed. The material cost for treatment of hot-spots was \$33/yd<sup>3</sup>.
2. **ISCR of TCE, TCA and catabolites** (United States Marine Corps Site, North Carolina) Working beneath a highly sensitive military building, 24,100 lbs of EHC was injected into areas of elevated CVOCs, as high as 80,000 ppb. Substantial efforts were undertaken to monitor indoor vapor, subsurface temperatures, and the production of catabolites (i.e., VC). Six months following the EHC injection, TCA levels had decreased by 94% and TCE levels had decreased by 84% to 90% at the target areas without the accumulation of problematic catabolites. No air issues were identified. With an estimated life of greater than 36 months, EHC is expected to continue stimulating reductive dechlorination at this site. The material cost of using EHC for plume treatment was \$3.65/yd<sup>3</sup>.
3. **ISCR of PCE and catabolites** (Dry Cleaner Site, Colorado) Adventus teamed with Vironex to inject 3,700 lbs of EHC into weathered shale. Three months following the injection of EHC, PCE concentrations were reduced up to 96% and TCE concentrations dropped in half. Monitoring continues at this site. The EHC product cost for plume treatment was \$19.64/yd<sup>3</sup>.
4. **ISCR of PCE and daughter products** (Confidential Client, Texas) 1 ton of EHC was placed into a trench yielding a PRB to intercept and treat a dissolved CVOC plume; in addition, 3 tons of EHC was placed into an open excavation containing groundwater (contaminated soil was removed). EHC installations were completed in two days. Complete CVOC removal was observed within one month in the open excavation, and 90% removal of PCE and daughter products was observed at locations downgradient of the PRB, after 11 months. Catabolites such as DCE or VC were not produced.
5. **ISCR of TCE and hexavalent chromium** (Confidential Client, Washington) Adventus injected 9,600 lbs of EHC-M into suspected hot-spot areas not amenable by an existing extraction system. One month following the injection, TCE was below the detection limit, and chromium was reduced by greater than 90%. Four months following injection, chromium was also below the detection limit. The EHC product cost for treatment of hot-spots was \$8.64/yd<sup>3</sup>.
6. **ZVI PRB for PCE and catabolites** (Dry Cleaner Site, Geneva, New York) Adventus installed a 200 foot ZVI PRB in a significant CVOC plume in a shallow aquifer. The removal of the source zone (excavation of impacted soils and free phase PCE), and installation of the ZVI PRB, has successfully prevented off-site migration. Catabolites such as DCE or VC were not produced.

7. **ISCR of TCE and CT** (Confidential Client, Southeastern USA) Adventus injected 45,000 lbs of EHC™ into three treatment barriers across a groundwater plume contaminated with CT and TCE. EHC injection was completed in twenty days. Three months following EHC additions, the concentration of chlorinated solvents decreased by as much as 97% throughout the plume without the accumulation of catabolic intermediates, such as VC. The EHC product cost for plume treatment was \$4.60/yd<sup>3</sup>.
8. **ISCR of TCE and daughter products** (Former Unregulated Solid Waste Management Unit, Ohio) A total of 11, 850 lbs of EHC was injected into existing gravel groundwater collection trenches positioned downgradient of suspected source areas. A microbial culture of *Dehalococcoides* species (KB-1 SiREM) was also applied to further enhance biological degradation. Subsequent monitoring showed that TCE and *cis* 1,2-DCE decreased below the detection limit within the trenches after six months, without the accumulation of catabolic intermediates. CVOCs have decreased by 99% downgradient of the PRBs after nine months. The EHC product cost was \$12/ft<sup>2</sup> of PRB cross-section.
9. **ISCR of TCE and catabolites** (Industrial manufacturing facility, NW USA) Groundwater on site was impacted by TCE and its conventional anaerobic degradation products (primarily *cis*-1,2-DCE and VC) up to a level of 290,000 ppb total CVOCs. Groundwater discharges to a river approximately 450 ft downgradient of a suspected source area. A total of 21 tons of EHC was injected to yield a PRB upgradient of the riverbank. An additional 13.5 tons of EHC was injected into the suspected source area. Post treatment monitoring showed between 97 and >99.9% CVOC removal downgradient of the riverbank PRB without the accumulation of problematic catabolites. TCE has decreased from 92,900 to 62 ppb within the source area 9 months following the injections.
10. **mGCW for TCE removal (U.S. EPA's Superfund Innovative Technology (SITE) Program, Sweden-3 Chapman Site, Sweden, NY)**. Staff now at Adventus provided Lead Project Scientists to field demonstrate the effectiveness of microbiologically enhanced *in situ* bioremediation technology for the treatment of chlorinated solvents. Employed UVB-type vertical groundwater circulation well technology integrating *in situ* and *ex situ* bioreactors housing a constitutive TCE-degrading bacterium (*Burkholderia cepacia* strain G4).
11. **ZVI-Clay for removal of source area CT and CF** (Industrial manufacturing facility, Martinsville, Virginia) Former waste pits were identified as source areas of chlorinated solvents, with a maximum CT concentration of 30,000,000 µg/kg. ZVI-Clay technology was used to treat the source area. Seventy-six columns of soil, 8 ft in diameter, were mixed with concurrent injection of a clay-granular iron slurry to a depth of 35 feet. One year following treatment, 20 soil cores from the injected zone showed that CT has decreased by 99.99%, and total chlorinated solvents, including byproducts of dechlorination, have decreased by 99%. Continued degradation is expected with time.
12. **ISCR of CF and CT** (Grain silo facility, KS) Groundwater was impacted with CT up to 2,700 ppb in the source area of a plume extending 2,500 ft, which finally discharges into a creek. 24 tons of EHC was injected into a 270 ft long PRB in March, 2005. After 36 months, the PRB continues to remove greater than 98% of the CT from influent concentrations without the accumulation of catabolites. The decreasing trend in CT concentrations has migrated a significant distance downgradient of the PRB and MCLS have been met in some downgradient wells.

A summary of experience at chlorinated solvent sites is provided in **Table 1**. Detailed project descriptions are available at [www.adventusgroup.com/projects/proj\\_ehc.shtml](http://www.adventusgroup.com/projects/proj_ehc.shtml).

Table 1: Representative Experience in Remediation of Chlorinated Solvents by the Adventus Group

| Site # | Site Location                 | State or Country | Chemicals Treated (maximum concentration- µq/L)                     | Remedial System                            | Duration of Clean up*/ Date of PRB installation**               | Results   |
|--------|-------------------------------|------------------|---|--|---|---|
| 1      | Dry Cleaner, Portland         | OR               | PCE (22,000), TCE (1,700), DCE (3,100) and VC (7)                   | EHC plume injection                        | 1 year  | >99.6% removal of total CVOCs without the accumulation of catabolites   |
| 2      | Former Delta Metals Site      | UK               | TCE (103,000), 1,2-DCE, VC  | EHC plume injection                        | 1 year  | TCE, DCE, VC reduced to non-detect in all monitoring wells, well below remedial goal                                |
| 3      | Dry Cleaner, Boulder          | CO               | PCE (up to 6,500), cis 1,2-DCE and catabolites                      | EHC plume injection                        | Remediation continuing  | Up to 96% reduction in PCE in 3 months.   |
| 4      | Manufacturing facility        | Portugal         | PCE, TCE and catabolites in fractured granite                       | EHC pilot scale injection in hot spot area | 18 months   | Despite fact that results were tempered by the presence of DNAPL, cleanup goals were met and full scale EHC planned |
| 5      | Industrial Facility           | TX               | PCE (23,000) and catabolites  | EHC in a PRB; EHC in open excavation       | 11 months and continuing  | Below detection limits in open excavation; 90% removal downgradient of PRB  |
| 6      | US Marine Corps Site          | NC               | TCE (73,000), TCA (24,000) and catabolites                          | EHC plume injection                        | 6 months and continuing   | 84% to 90% removal in target areas  |
| 7      | Confidential, Kansas          | KS               | CT (4000) and CF  | EHC in a PRB                               | Installed March 2005/continued performance                      | After 36 months, PRB continues to remove >98% CT and CF without catabolites. MCLs met in some downgradient wells    |
| 8      | Confidential                  | Southeastern USA | CT (260) and TCE (44)   | EHC plume injection                        | 3 months  | 97% removal of CT; non-detect TCE   |
| 9      | Former SWMU                   | OH               | TCE (750) and cis- 1,2-DCE (5,200), VC (630), and catabolites       | EHC in a PRB                               | 9 months and continuing   | 99% removal of CVOCs downgradient of PRB  |
| 10     | Industrial Facility, Portland | OR               | TCE and catabolites   | EHC in a PRB                               | 7 months and continuing   | 96.8 to 99.5% reduction total CVOCs in 7 months   |
| 11     | Manufacturing Facility        | Western NC       | TeCA (390), TCE (1,100), CF (1,200) in saprolite and fractured rock | EHC plume injection                        | 26 months (due to low permeability soils and fractured bedrock) | 95% removal of key CAHs; continued dechlorination expected due to organic carbon still remaining                    |
| 12     | Manufacturing                 | Belgium          | TCE (1000), cis-1,2-DCE   | EHC in a PRB (160 ft)                      | Installed 11/06   | TCE below groundwater   |

|    |                                  |               |  |   |                          |   |
|----|----------------------------------|---------------|--|---|--------------------------|---|
|    | Facility                         |               | (450)  |   |                          | standard and DCE reduced by 50% in PRB after 7 months. No accumulation of VC.                   |
| 13 | Confidential, Vancouver          | WA            | TCE (6.2) and hexavalent chromium (165)            | EHC-M in a PRB  | 4 months and continuing  | Non-detect hexavalent chromium and TCE (after 1 month) downgradient of PRB                      |
| 14 | Industrial Manufacturing Site    | Northwest USA | TCE (592,000) and cis-1,2-DCE (90,000), VC (5,000) | EHC in a PRB and source area injection                                  | 11 months and continuing | Non-detect CVOCs at riverbank, 450 ft downgradient of PRB; TCE reduced by 99.5% in source area. |
| 15 | Dry Cleaner, Tubingen,           | Germany       | TCE and cis 1,2-DCE                                | funnel and gate - ZVI in a PRB  | 10/98                    | CVOCs decreased below detection limits in PRB   |
| 16 | Dry Cleaner, Sudbury             | MA            | PCE and catabolites                                | ZVI in a PRB  | 8/99                     | CVOCs degraded below MCLs in PRB  |
| 17 | Geneva                           | NY            | PCE and catabolites                                | ZVI in a PRB and source zone removal                                    | 9/00                     | PRB successfully prevents off-site migration of CVOCs   |
| 18 | Dry cleaner, Burlington          | VT            | PCE, TCE and cis 1,2-DCE                           | ZVI in a PRB  | 9/01                     | Successful removal of CVOCs   |
| 19 | Dry Cleaner, Amersfoort          | Netherlands   | PCE (2,200) and TCE aqueous and free phase         | funnel and gate - ZVI in a PRB  | 9/02                     | >99.9% removal of PCE and TCE, some metabolite formation  |
| 20 | Rheine-Westphalia                | Germany       | PCE (20,000), TCE, cis 1,2-DCE                     | ZVI and iron sponge in a PRB  | 6/98                     | 99% removal of PCE downgradient of PRB  |
| 21 | Naval Weapons Station, Yorktown  | VA            | TNT, RDX, DNT and CVOCs                            | DARAMEND applied ex-situ  | 3 months                 | 99% to 99.9% removal of organic explosive compounds; well below cleanup criteria for CVOCs      |
| 22 | Sweden-3 Chapman Site, Sweden    | NY            | PCE, TCE, cis 1,2-DCE, and VC                      | UVB-type vertical groundwater circulation well (mGCW)                   | 1 year                   | US EPA SITE Demo; >90% removal achieved   |
| 23 | Nellis Air Force Base, Las Vegas | NV            | TCE and catabolites                                | mGCW  | 6 months                 | >90% removal achieved; project award recipient (main consultant)                                |
| 24 | Industrial Client                | Netherlands   | TCE and catabolites                                | mGCW coupled with advanced oxidation (ozone sparging) and NAPL recovery | Continued performance    | mGCW replaced existing pump-and-treat resulting in significant cost savings.                    |
| 25 | Confidential, Detroit            | MI            | TCE and catabolites                                | Phytoremediation system   | Installed 1998           | Not available   |

|    |                                      |        |   |   |                       |   |
|----|--------------------------------------|--------|---|---|-----------------------|---|
| 26 | Manufacturing Facility, Martinsville | VA     | CT (30 million), CF (150,000), MC, PCE, TCE | ZVI-Clay                                    | 1 year and continuing | 99.99% removal of CT; 99% total CVOC removal  |
| 27 | Sunnyvale                            | CA     |   | EHC in a PRB extension of existing ZVI PRB  | Installed 3/07        | Recent installation - no results to date  |
| 28 | Former Industrial Site, Anaheim      | CA     | PCE   | EHC direct injection                        | Installed 10/07       |   |
| 29 | Industrial Site, Dallas              | TX     | TCA, CHCs                                   | EHC direct injection                        | Installed 10/07       |   |
| 30 | Grain Silo, Ogden                    | UT     | CT  | EHC direct injection                        | 8 months              | Remedial objectives met within 8 months, no catabolites accumulated and site is in closure process. |
| 31 | Industrial Facility, Santa Clara     | CA     | PCE   | EHC pilot                                   | Installed 8/07        |   |
| 32 | Industrial Site, Sanford             | FL     | CHC   | EHC backfill UST                            | Installed 8/07        | Data not available  |
| 33 | Dry Cleaner Site, Houston            | TX     | PCE/TCE                                     | EHC in a PRB                                | Installed 10/07       |   |
| 34 | Industrial Site, Indianapolis        | IN     | CHC   | EHC pilot direct soil mixing                | Installed 10/07       | Data not available  |
| 35 | Grain Silo, Centralia                | KS     | CT  | EHC direct injection                        | Installed 11/07       | Greater than 90% decline in total chloromethanes within injection grid.                             |
| 36 | Dry Cleaner Site                     | NC     | CT/PCE                                      | EHC pilot injection                         | Installed 2/08        | Update pending  |
| 37 | Industrial Site                      | Taiwan | 1,2-DCA, VC, DCE (total CVOC 100,000)       | EHC direct injection pilot PRB in two areas | Installed 3/2008      | Initial total CVOCs (~100 ppm) were reduced to treatment standards within 6 months.                 |
| 38 | Former Dry Cleaner                   |        | PCE   | EHC Pilot injection                         | Installed 2/08        |   |
| 39 | Irvine                               | CA     | PCE   | EHC one point comparative pilot             | Installed 3/08        |   |
| 40 | Manchester                           | UK     | PCE   | EHC Direct injection                        | Installed 3/08        |   |
| 41 | Industrial Facility                  | Italy  | 1,2-DCA                                     | EHC Pilot direct injection                  | Installed 5/08        | Downward trend of DCA and full scale planned  |
| 42 | Former Industrial Site, San Jose     | CA     | TCE and DCEs                                | EHC direct injection                        | Installed 9/08        |   |

|    |                         |           |   |                                |                 |   |
|----|-------------------------|-----------|---|--------------------------------|-----------------|---|
| 43 | Victoria                | Australia | TCE   | EHC-A and EHC pilot            | Installed 9/08  | TCE decreased from 4000ug/L to 630ug/L in 1 week in the target well                     |
| 44 | Preston                 | Australia | TCE   | EHC-F                          | Installed 9/08  | Awaiting 1-month post-injection results   |
| 45 | Salina                  | KS        | PCE/TCE/DCE                                     | EHC direct injection           | Installed 9/08  |   |
| 46 | Charlevoix              | MI        | TCE/DCE/VC                                      | EHC direct injection           | Installed 9/08  | Awaiting results  |
| 47 | Poughkeepsie            | NY        | 1,1,1-TCA/1,2-DCE                               | EHC direct injection           | Installed 9/08  |   |
| 48 | Dry Cleaner, Nashville  | TN        | DCE   | EHC plume injection            | Installed 9/08  |   |
| 49 | DOD Facility, Fairbanks | AK        | TCE   | EHC source area injection      | Installed 10/08 |   |
| 50 | Rolling Meadows         | IL        | TCE/DCA/DCE                                     | EHC source area injection      | Installed 10/08 | TCE reduced 98% without catabolites after 4 months                                      |
| 51 | Oxnard                  | CA        | 1,2-DCA/DCE/VC                                  | DARAMEND direct placement      | Installed 2007  |   |
| 52 | Toronto                 | ON        | CVOCs   | DARAMEND direct placement      | Installed 07/08 |   |
| 53 | Dry Cleaner, Broomfield | CO        | PCE (170)                                       | EHC plume injection pilot test | Injected 6/07   | No results to date  |
| 54 | Dry Cleaner, Memphis    | TN        | PCE (up to 11,200), cis 1,2-DCE and catabolites | EHC plume injection pilot test | Injected 6/07   | Injection equipment on site not compatible with regional geology; reapplication pending |

\* Duration of cleanup represents the length of time to reach the remediation goals, however EHC continues to provide optimal conditions for chemical reduction and bio-stimulation for more than two years and in some cases up to five years.

\*\* ZVI - consistent PRB performance has been observed for over 10 years, with the expectation of total lifetimes in excess of 20 years.