A Regenesis Bioremediation Products Review

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Striving for Cost Effective Remediation of Contaminated Groundwater

by John Griffiths, President

Eight years ago, the National Research Council publishe a study, "Alternatives for Ground Water Cleanup". At that time pump-and-treat was the predominant treatment technology, used on 73% of the Superfund sites where ground water was contaminated. The study focused on the cost-effectiveness of this traditional technology. It concluded that remediation through pump-and-treat (P/T) was a slow, expensive process and that 90% of the pump-and-treat sites studied had not achieved cleanup goals after an average of eight continuous years of use!

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Prior to the NRC study, other studies of the effectiveness of P/T systems had been conducted. In the early 1990's the EPA, the American Petroleum Institute, The California Water Quality Board and Oak Ridge National Laboratories conducted separate studies involving 90 P/T systems. Their conclusions were similar to the NRC study. Recently The Environmental Business Journal's 2001 Remediation Market survey concluded that P/T systems outnumbered in-situ treatment by a factor of 2.5. Still, many years after recognizing the high expense and marginal effectiveness, P/T systems and are being used on over 70% of contaminated groundwater sites! Why?

The Strategic Environmental Research and Development Program (SERDP) has provided part of the answer. At their August 8-9, 2001 workshop several key themes were: (1) focus on source zone treatment, (2) improve assessment tools, and (3) focus on existing innovative technologies, particularly thermal and bioremediation technologies. P/T systems are often used for containment. With source zone reduction and improved assessment P/T systems can be turned off at great savings. Field data from existing applications of new, less costly technologies, should be carefully considered according to the SERDP workshop participants. As a result SERDP is requesting proposals to fund these projects. For details see the SERDP website: www.serdp.org.

With the widespread understanding that P/T systems are costly and marginally effective, it is incumbent upon the consulting community to carefully analyze the alternatives. The Environmental Protection Agency, the Department of Defense and the Department of Energy all have programs and funding to encourage the investigation and use of new technology. We at Regenesis particularly appreciate and support these efforts.

Best wishes for the New Year.

WHAT'S INSIDE

Regulators Back the Use of HRC at Dry Cleaner Sites

The power of Hydrogen Release Compound (HRC®) to cost-effectively clean up drycleaner sites has been recognized by regulators from across the country. In Oregon, the Oregon Dry Cleaning Fund recently designated HRC as a "presumptive remedy" technology that is effectively pre-approved for use on hazardous waste sites with similar characteristics. The Oregon Department of Environmental Quality (ODEQ) has also had first hand experience in the use of HRC to treat very high concentrations of perchloroethene (PCE) at drycleaner sites. As a result the ODEQ recently stated in a press release that with the use of HRC "the chlorinated compounds have decomposed to below levels that would pose a risk to human health and the environment".

The State Coalition for Remediation of Drycleaners, (SCRD), an association of state regulators with established drycleaner remediation programs that is sponsored by the USEPA, has also recently demonstrated and documented the cost effectiveness of HRC. Technical profiles of five drycleaner sites treated with HRC were recently added to the SCRD website (www.drycleancoalition.org). These profiles, documented on the website, are actual projects in Florida, Oregon, and Wisconsin. Several of the projects were completed under the Florida Dry Cleaning Solvent Cleanup Program and the ODEQ's Dry Cleaner Environmental Response Program, respectively. Groundwater monitoring showed that PCE mass was reduced by 96% at Contemporary Cleaners in Florida after just 152 days of HRC treatment, and by 87% at the Hayden Island Cleaners in Oregon after 15 months, with other contaminants declining as well.

HRC, which has now been implemented on over 300 project sites is becoming recognized by regulators as a proven technology for rapid, low cost cleanup of sites containing chlorinated solvents, such as dry cleaner sites. For additional information on the SCRD profiles or on the performance of HRC at dry cleaner sites please contact us at (949) 366-8000.

To Access the SCRD Website visit www.drycleancoalition.org

TNRCC Grants Conditional Certificate of Completion to Dry Cleaner Facility

by Rick Gillespie, Southeast Region Business Development Manager,

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The Texas Natural Resource Conservation Commission (TNRCC) recently granted a Conditional Certificate of Completion (CCOC) for a retail dry cleaner facility in Arlington, TX. The CCOC was granted approximately 18 months after a single application of HRC®. ProGEA, Inc. of Dallas, TX installed the HRC in May 2000. Rick Railsback, President of ProGEA, Inc., stated "HRC achieved groundwater cleanup standards quickly and efficiently. The client was ecstatic with the fast cleanup

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results, low cost relative to other remedial options, and minimal site disturbance." Primary groundwater contaminants at the site included, perchloroethylene (PCE), trichloroethylene (TCE), *cis*-1,2-dichloroethylene (cis-DCE) and vinyl chloride (VC). Prior to HRC injection, groundwater contaminant concentrations for PCE (10,000 µg/L), TCE (2,300 µg/L), cis-DCE (7,500 µg/L), and VC (1,100 µg/L) were recorded in the source area. The treatment area was approximately 279 $m^{2,}$ including a portion that underlies the building foundation. HRC was injected into 45 borings within the contaminated area. All 45 direct-push borings were installed to 6.7m below ground surface (bgs). Sixteen direct-push borings were installed at angles of 15 and 30 degrees from vertical to access contaminated groundwater beneath the building's foundation. A total of 5,200 lbs of HRC were injected at the site. Eighteen months after injection, PCE, TCE, cis-DCE, and VC levels decreased to 408, 87.4, 438, and 132 µg/L, respectively. This represents a greater than 90% reduction of the parent compounds from a single HRC application. All contaminant concentrations are below the TNRCC-mandated, risk-based target concentrations.

Enhanced In-Situ Bioremediation in Clay Soils

by Jeff Bensch - HSI GeoTrans (Guest Author), (916) 853-1800

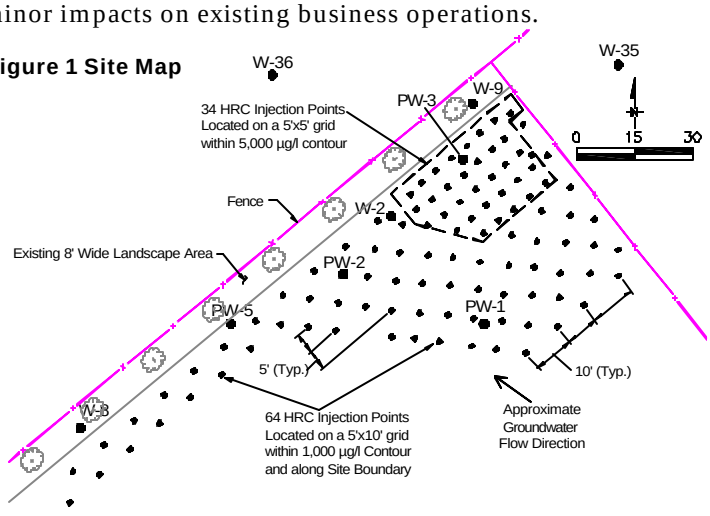
On behalf of FMC Corporation, GeoTrans implemented an in-situ bioremediation cleanup using Hydrogen Release Compound (HRC®) to remove trichloroethylene (TCE) and other volatile organic compounds (VOC) from shallow soils and groundwater.

GeoTrans, and Dr. William Mahaffey, of Pelorus Environmental & Biotechnology Co., initially reviewed existing groundwater VOC data from a former manufacturing site to further define the nature of site impacts and develop remediation alternatives to prevent impacted groundwater from migrating off site. Using a relational database and geographic information system (GIS), GeoTrans evaluated VOC degradation fingerprints of PCE and TCE concentrations at existing groundwater monitoring wells. Through this evaluation and previous soil data, GeoTrans determined that natural attenuation daughter products were present in site soils and groundwater. The potential for further natural attenuation was evaluated by collecting groundwater and soil samples for analyses in accordance with AFCEE protocol. This evaluation indicated that anaerobic reductive dechlorination activity occurred at the site, but was limited due to insufficient organic carbon.

The property is currently occupied by active commercial and light industrial businesses. The impacted shallow groundwater is in a homogenous silty clay with a very flat gradient and low flow velocity. The following in-situ remediation alternatives and approximate life-cycle budget estimates were evaluated: Chemical Oxidation $24,600,000, Bioremediation with Benzoate / Lactate Mixture $1,220,000, Bioremediation with HRC $1,230,000, Zero Valent Iron Barrier $922,000.

Chemical oxidation costs were extremely high due to the organic content and elevated pH of the site soils. The zero valent iron barrier as proposed would not address the source area and was considered undesirable. Bioremediation with the benzoate / lactate mixture would require groundwater extraction downgradient, chemical addition, and groundwater injection upgradient to create the treatment zone. This active process was not desired within the commercial business setting. Therefore, in-situ bioremediation using HRC was selected as the preferred technology because it provided a low cost remediation with only minor impacts on existing business operations.

Figure 1 Site Map

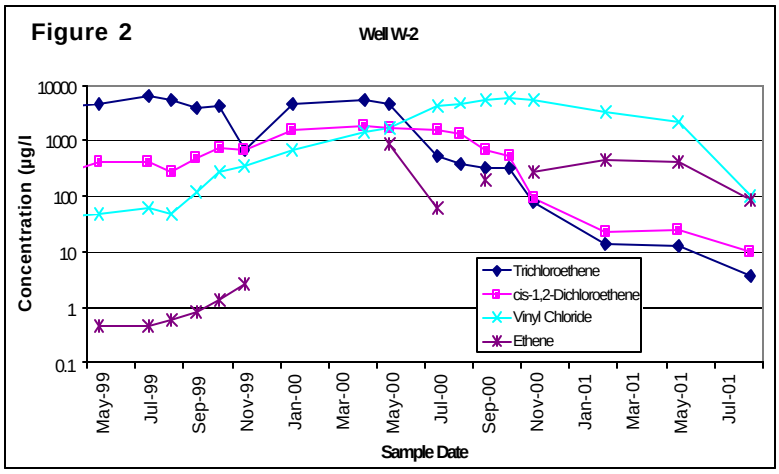


Bench-and-pilot scale studies were conducted in the remediation was implemented in May 2000.

The full-scale application of HRC stimulated the reductive dechlorination process to bioremediate TCE to daughter products *cis*-1,2 DCE, vinyl chloride, and ethylene. The scope of the full-scale remediation included injecting approximately 12,000 pounds of HRC through 103 direct-push points in the northeast corner of the property and along the northern property boundary to remediate an apparent TCE source area and to provide a barrier to downgradient TCE migration. The HRC application was conducted during 10 days of field work.

Groundwater samples for baseline testing were collected prior to HRC injection from monitoring wells. As shown in Figure 2, wells PW-3, W-2, and W-35 are located in an area where TCE concentrations were approximately 3,000 to 5,000 micrograms per liter (ug / L). Wells PW-1 and W-36 are located upgradient and downgradient, respectively, of the area with elevated TCE concentrations. Monitoring was conducted every other month for six months from June through November 2000, then at three month intervals in February and May 2001.

Figure 2



Times series evaluations for TCE, cis-1,2-DCE, VC, and ethylene provide an indication of the remediation effectiveness at each monitoring well. The time series information for W-2, W-8, and W-35 illustrate differences between HRC treated and untreated areas.

The TCE and daughter product concentrations changed by orders of magnitude following the HRC application in wells PW-1, PW-2, PW-3, and W-2. Rising then falling concentrations of cis-1,2-DCE and VC further indicate enhanced TCE breakdown. An accumulation of vinyl chloride was observed during the first six to nine months, and this was followed by slowly decreasing concentrations in the following nine to twelve months. The increase of ethylene concentrations through May 2001 indicate that the TCE dechlorination process is continuing to completion.

The hydrogen concentrations in some wells were extremely high during the six months following HRC injection. Well W-2 contained 153,248 nano-moles (nM) in July 2000. These elevated hydrogen concentrations together with the initially low oxidation reduction potential (ORP) measurements indicate that methanogenic conditions existed through May 2001 in many of the high activity wells. This is further supported by increasing methane concentrations in these wells.

FIELD RESULTS CONTINUED

Sulfate concentrations dropped to less than 10 milligrams/liter (mg/L) in some wells coincident with high hydrogen concentrations and the significant declines in TCE concentrations. Well W-8 exhibited results that were consistent with Yang and McCarty (1998)[1], where competing methanogenic, sulfate reducing, and dehalogenation reactions were studied with respect to hydrogen concentrations. At well W-8 (Table 1), the hydrogen concentrations remained close to an optimum range of 2 to 11nM, and reductive dechlorination proceeded while sulfate reduction did not.

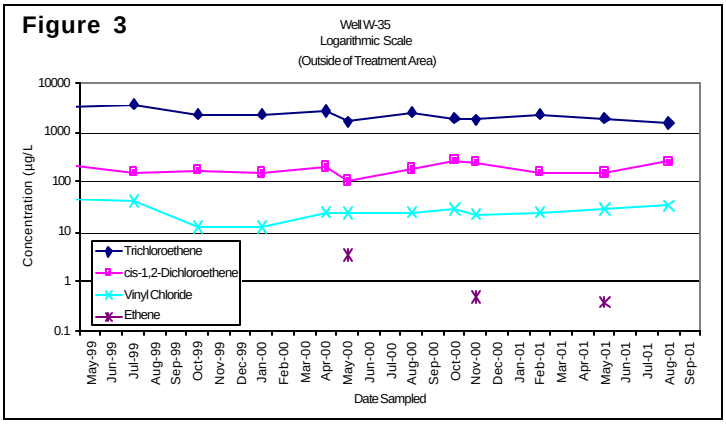
Wells W-35 and W-36 lie outside thearea of near-terminfluence from the full-scale HRC implementation. The results at W-35 demonstrate that TCE reductions did not occur in untreated areas.

Table 1. Selected Data for Well W-8

Parameter	Units	May 2000	July 2000	Sep 2000	Nov 2000	Feb 2001	May 2001	Aug 2001
TCE	ug/L	224	570	51	34	13	23	21
cis-1,2 DCE	ug/L	6.4	960	120	96	87	77	89
Vinyl Chloride	ug/L	<2.0	<25.0	27	58	90	62	55
Ethene	ug/L	<20.0	0.047	0.189	0.17	0.21	0.12	0.12
Sulfate	mg/L	270	243	214	214	208	239	255
Methane	ug/L	<10	16	188	740	2300	2400	2200
Hydrogen	nM	1.48	2.17	2.05	2.2	1.8	1.1	2.5
ORP	mV	-40	-121	3	97	-81	-169	-185

Microbial analyses were also performed in addition to the standard natural attenuation parameters. Groundwater samples were submitted to Michigan State University (Mike Dollhopf) for Terminal Restriction Fragment Length Polymorphism (T-RFLP) analyses, and to Georgia Tech University (Frank Loeffler) for analysis of the presence of dehalogenating microbial populations using specific primers for dehalogenating bacteria. The evaluations were particularly interesting because the site provides an opportunity to sample upgradient of the high impact area (PW-1); within the high impact area where HRC treatment occurred (W-2); within the high treatment area where no treatment occurred (W-35) (Figure 3); and downgradient (W-36). The preliminary results indicate that the application of HRC correlates to increased biomass and specific dehalogenating bacteria targeted in the analyses were present. These results provide further indication that the reductive dechlorination process will be successful in achieving the site remediation goals.

Figure 3



A second HRC application was completed during November 2001. It is anticipated that continued monitoring following this application will demonstrate complete reductive dechlorination of the vinyl chloride during the next one to three years.

1. Yang and McCarty, 1998, Environmental Science & Technology, 32, 3591-3597. Competition for Hydrogen within a Chlorinated Solvent Dehalogenating Anaerobic Mixed Culture.

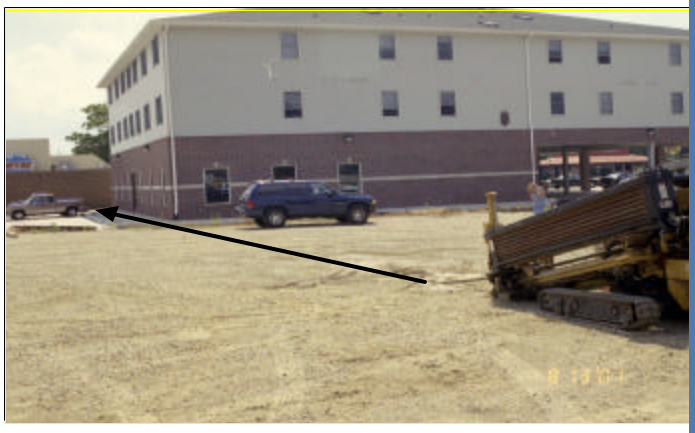
Regenesis and NJCAT Host NJ Brownfield Seminar

On January 25, 2002 Regenesis and the New Jersey Corporation for Advanced Technology (NJCAT) hosted a seminar on the use of innovative technologies for the remediation and economic redevelopment of contaminated sites in New Jersey. The main focus of the seminar was to provide site owners, real estate developers, lawyers and environmental consultants with the tools necessary to utilize innovative approaches to return contaminated sites to productive use. Also emphasized was the fact that technology verification and certification programs are carving through the traditional regulatory barriers and opening up strategic financial opportunities for emerging environmental technologies. The seminar included a discussion of the Energy and Environmental Technology Verification Act which can help promising new technologies obtain approval for use, resulting in faster, cheaper and better environmental solutions. Officials from the New Jersey Department of Environmental Protection, the Division of Taxation and the Economic Development Commission participated in panel discussions on the opportunities for state assistance and fast tracking of the redevelopment projects. Experts from the banking and insurance industries were also present and provided valuable information on funding opportunities as well as the limitations of financial liability in the redevelopment process. Additionally, The Honorable James J. Florio served as the Keynote Speaker for this special event.

For additional information about this event or others that may be up and coming please refer to our website at www.regenesis.com

New ORC & HRC Application Technique: Horizontal Directional Drilling

by Jack G. Peabody, Western Region Manager, (925) 944-5566



Do you have a site with contaminated groundwater under a building or a petroleum plume moving through a sand lens surrounded by less permeable soil? Horizontal Directional Drilling (HDD) may be the most efficient, least disruptive and cost effective method of applying ORC® or HRC® to remediate that site.

Midwest Environmental Consulting & Remediation Services (MECRS) of Tremont, IL was the first to apply ORC using HDD on a site in central Illinois. ORC slurry was injected into a sand lens that allowed a gasoline plume to migrate onto an adjacent property. Originally, direct push equipment was going to be used to install ORC slurry via 45 vertical injection points. When the adjacent property was redeveloped with a new apartment building and a concrete parking surface around the building, access to this impacted sand lens from above was significantly limited. After researching alternate application methods to reduce costs and damage to the adjacent property, MECRS determined that HDD offered the best delivery system to inject ORC into this site. Six horizontal borings between 150 and 220 feet long were installed (3 east-west and 3 north-south) into this offsite plume in lieu of the 45 direct push injection points. The Vermeer HDD equipment was staged on the former gas station site and never disturbed the surface of the adjacent property under which the ORC was applied. The HDD ORC injection process took about 12 hours of drilling time. The rods were advanced to the appropriate distance and depth using only water as drilling fluid. Just over 3 lbs per foot of ORC were injected as the rods were retracted. First quarter groundwater data shows a 3X increased dissolved oxygen, a decrease in dissolved iron, and reducing benzene and BTEX concentration.

More HDD application of ORC and HRC are scheduled and proposed for other sites as soon as April 2002.

Since this first HDD application of ORC in August 2000, Regenesis has worked with HDD contractors and Vermeer Manufacturing Company to determine that several HDD equipment models are also capable of injecting HRC. This equipment has been active in laying underground cables for the world's information superhighway since the early 1990's. HDD equipments' capabilities to drill through several hundred feet of soil or even bedrock while injecting liquids using high pressure, low volume pumps makes it ideally suited to apply ORC and HRC in areas that were previously cost prohibitive or physically inaccessible. Contact Regenesis for further information on HDD applications of ORC or HRC.

ORC Remediation of Natural Gas Condensates

by Jack G. Peabody, Western Region Manager, (925) 944-5566

Gas-gathering systems have been used to collect, dehydrate, and transport natural gas from northern California gas fields for decades. Facilities in the gas gathering system primarily include compressor stations, dehydrator stations, and gas condensate drip stations. These facilities are generally located in remote locations where electric and other utilities are often lacking. At a gas dehydrator station near Manteca, California, petroleum hydrocarbons were discovered in soil and groundwater at concentrations approaching 10,000 mg/kg and 100 mg/L respectively. The petroleum hydrocarbons included both gasoline and diesel range compounds and are believed to be from natural gas condensates that were removed from the gas during the dehydration process. ORC was chosen and applied at the site to accelerate aerobic bioremediation of the petroleum hydrocarbons present in both soil and groundwater. In the summer of 1998, approximately 3,100 pounds of ORC were delivered into the subsurface via 28 injection points to a vertical thickness of 18 ft. The aquifer consisted of sand and sandy silt, with groundwater generally flowing toward the west at an approximate velocity of 5 to 10 ft. per year. Results after a two-year period show that the treatment had accelerated biodegradation of TPH significantly. Concentrations of BTEX, TPHg and TPHd were reduced by approximately 90% with substantial reductions of petroleum hydrocarbons in groundwater, even during periods of high water levels. The data also indicate that the ORC may have helped in the remediation of TPH-impacted soils. The total cost of the ORC and its injection was approximately $40,000.

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FROM THE RESEARCH DESK

Regenesis - A Resource in Environmental Biotechnology

by Stephen Koenigsberg, Ph.D., Vice President, R&D

It's hard to escape the biotechnology revolution as witnessed by all of the front page stories on the human genome, cloning and a raft of new options in molecular diagnostics and therapeutics. However, while these are the glamour topics, there are many other venues that are poised to be significantly impacted by the advances in biotechnology. Some of these include chemical engineering, alternative energy and our own field of environmental monitoring and remediation.

Well - Regenesis has been actively working on "sorting out" the practical and useful elements from among the suite of possibilities brought forth in this new landscape. One area of interest to us is advanced environmental sensing as both a pre-diagnostic tool and for on-going site monitoring. The future holds promise for a host of "better, faster and cheaper" means of obtaining field data and, when combined with the parallel developments in nanotechnology we are confronted with the reality of "lab on a chip". We also think that under appropriate conditions and circumstances that bioaugmentation has merit and aspects of its implementation now involve the molecular biology tool chest. On that note we see these tools at work in site management as witnessed in our guest article by Jeff Bensch of HSI GeoTrans.

"We are hosting an Environmental Biotechnology Session at the upcoming Twelfth Annual West Coast Conference on Contaminated Soils, Sediments and Water hosted by the AEHS." (www.aehs.com)

While we move with enthusiasm into the new world of possibilities, we would like to announce that we are hosting an Environmental Biotechnology Session at the upcoming Twelfth Annual West Coast Conference on Contaminated Soils, Sediments and Water, hosted by the Association for Environmental Health and Sciences (AEHS). It will feature seven distinguished speakers with a Keynote opening by Dr. Bruce Rittmann, John Evans Professor at Northwestern University and a presentation by Dr. Charles Greer, a co-author on the recent cover story in ES&T on "Genomic Technologies for Environmental Science". We will also hear from Dr. Aaron Peacock on the use of DNA and lipid biomarkers for determining bioremediation efficacy and endpoints and Dr. Lance Laing of Regenesis will discuss emerging options with environmental biosensors. The Conference is March 18-21, 2002 and details with the full program can be found at www.aehs.com.

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