THE ORACLE

News and Recent Developments from Regenesis - Leaders in Accelerated Natural Attenuation

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Regenesis: A Resource for Environmental Consultants

by Scott Wilson, President

Recently I was asked "what is the single most important factor that has led to Regenesis' success?" Without hesitation I responded that Regenesis' success is the result of our relationship with environmental consulting firms around the world.

Regenesis is known for developing unparalleled products such as ORC® and HRC®. But equally important is the availability and technical depth of the Regenesis staff who welcome the opportunity to provide technical support ranging from a quick phone call to chat about the degradability of a specific pollutant to providing peer reviewed journal articles on aspects of remediation. This high level of technical support, offered by Regenesis free of charge, is what many environmental consultants from around the world have come to rely on as an "extension of their own consulting firm."

"Regenesis' success is the result of our relationship with environmental consulting firms around the world."

Information on Biodegradability

Environmental microbiologists on the Regenesis support staff are up to date on the latest advances in academic and industrial research on biodegradation. These scientists are available to discuss the potential for bioremediation at your specific project site and to point out limitations that may preclude the use of biological approaches. A new service recently made available from Regenesis is the availability of technical information packets (TIPs) which are designed to answer questions on specific technical issues relating to bioremediation in a manner that is concise and backed up with third party literature.

Electron Donor/Acceptor Application Design

Application engineers and hydrologists at Regenesis are standing by to develop ORC and HRC application designs- again free of charge. This service has proven invaluable to hundreds of consulting firms around the world that have contacted Regenesis to determine the feasibility and costs associated with using ORC or HRC. The designs are developed taking into consideration all relevant geochemical and hydrogeological aspects of the project site, the best estimate of contaminant mass and stoichiometric requirements of contaminant and alternate electron donors and acceptors. The result is a technically sound design

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HRC Granted Patent

by Bryan Vigue, Marketing Manager

Regenesis is pleased to announce that Hydrogen Release Compound (HRC®) was recently granted a U.S. Patent on July 16, 2002. HRC is a proprietary polylactate ester used for the purpose of accelerating reductive bioremediation processes that effectively degrade chlorinated hydrocarbons, nitroaromatics and oxyanions in groundwater and saturated soils. HRC also has the capability to remove certain metals such as chromium from the subsurface through the facilitation of precipitation reactions. HRC has been applied on over 350 sites and makes up about 75% of all electron donor applications performed in the U.S. It has been used on a variety of contaminated groundwater sites from dry cleaners and microelectronics manufacturing facilities to chemical depots and agricultural lands. Using simple direct-push injection as the preferred method of delivery, HRC can be applied almost anywhere very quickly, unobtrusively and cost-effectively. With the ability to degrade a wide-range of chlorinated compounds and other anaerobically degradable constituents, HRC has captured the attention of groundwater remediation professionals around the globe, and is quickly outpacing other electron donors as the long-lasting, cost-effective substrate of choice.

The Role of ORC and HRC in Brownfield Development

by Mike Sieczkowski, Central District Manager

In many states Brownfield programs have been designed to provide incentives for the redevelopment and revitalization of "environmentally challenged" properties. Many of these programs include financial incentives to redevelop properties and may also include negotiated cleanup levels for various contaminants. Surficial remediation hasn't changed from the days of scrubbing and dig-and-haul concepts, but groundwater cleanup has developed almost exponentially. Part of the evolution includes the process of manipulating the balance of electron donors and electron acceptors. ORC

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- **HRC Gains U.K. Regulatory Approval**
- **Guest Author Column: Enhanced Anaerobic Biodegradation of Chloroethenes with HRC**
- **Unique Dry Cleaner Bedrock Application**
- **Announcements**

HRC Gains UK Regulatory Approval

by Craig Sillars, Managing Director, Churngold Remediation

New technology approval in the UK is often a slow and laborious process with the regulatory agencies often requiring years of technical proof, via detailed case studies, before having the confidence to grant a required license for use. It is with some pride, therefore, that Regenesis products have quickly gained approval from the regulators as an accepted tool for the remediation of a range of contaminants. While ORC has been used for sometime, mainly on petrol station sites, particularly as a treatment for the base of excavations around tank pulls, it is the recent success in implementing remediation of chlorinated solvent contamination using HRC that is seen by Regenesis UK partners as the first step to establishing ORC and HRC as primary remediation technologies. Problem stakeholders have also bought into the benefits of using HRC over more traditional vacuum extraction or chemical oxidation options due to the significant cost savings that HRC offers and the fact that the use of this product has very little effect on either the development of a site or the normal day to day revenue generating activities. The first license to inject HRC has now been granted to Churngold Remediation Limited and it is hoped that this will result in an increase in the number of HRC injections over the three that have very recently been completed. The three sites treated to date have included a dry cleaning facility, a factory producing gas canisters and a former industrial site currently under redevelopment for manufacturing units and offices. For two of these sites the area of chlorinated solvent contamination was beneath the proposed floor slabs for a new house and industrial facility respectively. Neither development could wait for the nine months or so which would have been required by the more traditional vacuum extraction techniques to reach remedial targets, particularly as the pipe work and above ground treatment unit would prevent the sought after development of these areas. The use of HRC was also chosen because it alleviates the operations and maintenance associated with more costly and energy dependent active systems. The consultants were so confident that HRC would meet the remedial targets for the chlorinated solvent concentrations that they presented the first 3 months of data to the regulatory agency illustrating the classic decrease in contaminant (TCE) and an increase in daughter products (DCE and VC) and projecting it forward showed that remedial targets could be met. Regulatory approval was granted allowing construction at the site to proceed prior to reaching the target levels.

"Regenesis products have quickly gained approval from the regulators as an accepted tool for the remediation of a range of contaminants."

For more information please contact Craig Sillars at 44 (0117) 900 7100 or Pen Herring our International Business Representative at Regenesis at (949) 366-8000 or at pen@regenesis.com.

Brownfields, Continued from First Page

and HRC, two of the leading electron acceptor and electron donor technologies, are uniquely suited to this type of remedial approach as they are an extension of the natural attenuation process.

Although the ultimate cleanup goal for most sites is program-defined ground-water concentrations, Brownfields programs stray from this approach and often rely on contaminant mass reduction to meet specific risk milestones. This approach not only makes the process more streamlined but also reduces assessment and remediation costs. The program goal changes from meeting a program-specific regulatory level to site-specific reduction of risk within a specific allocation of resources.

"...ORC and HRC are uniquely suited to this type of remedial approach as they are an extension of the natural attenuation process."

ORC has been used to enhance aerobic degradation on thousands of sites with literally hundreds of sites being granted no-further-action status. Since most of these projects are conducted under well-defined underground storage tank programs, the use of ORC in risk-based remedial approaches is not as prevalent as the use of HRC. ORC has been used very successfully to reduce contaminant mass at Brownfield sites in situations where significant construction precludes the installation or operation of more site-disruptive options such as pump-and-treat or air sparge mechanical systems and in situations involving more non-standard aerobically degradable contaminants such as vinyl chloride, DCE, MTBE, naphthalene, and various low fraction petroleum products.

For chlorinated solvents, the addition of electron donors through the application of HRC has shown to be very effective in promoting reductive dechlorination and is currently being used on over 350 sites throughout the country. Many of these sites are properties that would have otherwise remained unproductive due to the high cost and low performance of older technologies. Others are Federal facilities where HRC has been used to assist in remediating areas to be returned to the private sector or in areas contaminated with materials like explosives that are too much of a threat to consider risk-based closure. A recent review of past projects has shown that eighteen HRC remediated sites have been granted no-further-action status over the past several years. Here in the Midwest, HRC has shown to reduce contaminant mass by more than 90%within the first few months after application on at least four brownfield sites for considerably less cost than other options. In several cases, regulatory levels were reached within six months and because of the slow release nature of HRC, rebound of contaminants did not occur within the treated areas. This permanent reduction in contaminant mass represents a significant reduction in risk and becomes a natural partner in the development of Brownfield properties.

For more information on how HRC can be used within a Brownfields program, contact your local Regenesis representative or our corporate office at (949) 366-8000.

Enhanced Anaerobic Biodegradation of Chloroethenes with HRC

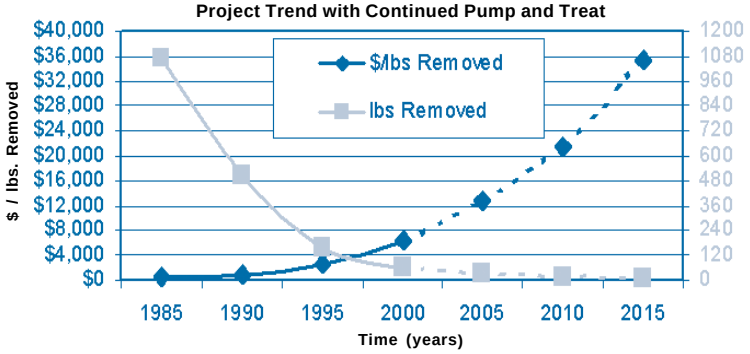
by Pawan Sharma, Camp Dresser & McKee, Inc.

Prior operation at two facilities in the South Bay Area in California resulted in tetrachlorethene (PCE), trichloroethylene (TCE), and other chloroethene impacts to soil and groundwater. The two sites are the former Microware electronics facility in Sunnyvale and the former Anadite Inc. facility in Santa Clara. Over the last several years, Camp Dresser & McKee Inc. (CDM) has managed the environmental requirements of these two facilities.

In 1985, TRW implemented a groundwater pump and treat system and groundwater-monitoring program to address and monitor changes in the groundwater plume. In 1987, Anadite implemented a groundwater-monitoring program to monitor any changes to their groundwater plume.

In 1996, CDM began evaluations of the effectiveness of the pump and treat system at the former TRW site. Figure 1 shows the approximate mass of volatile organic compounds (VOCs) removed from the aquifer and the approximate operating cost of the pump and treat system per pound of VOCs removed. Values through year 2000 are actual values and values after year 2000 are extrapolated values continuing the observed trend. Figure 2 shows the actual and projected TCE mass over this same period with the pump and treat system in operation. Based on this evaluation, CDM concluded that the pump and treat system was no longer cost effectively removing contaminant mass and an alternative remedial technology was necessary to achieve acceptable regulatory contaminant levels in a cost effective manner.

Figure 1
Project Trend with Continued Pump and Treat

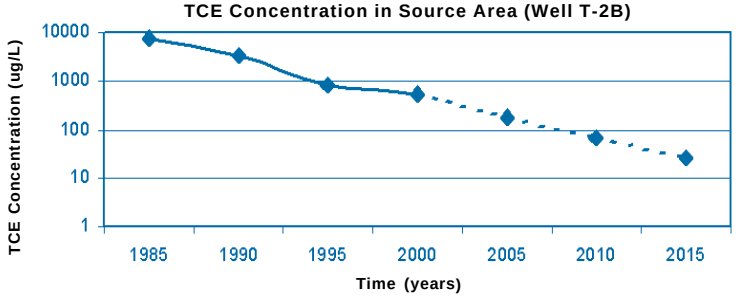


In 1999, CDM performed a natural attenuation study for the former Anadite site. Based on the results of the study, CDM concluded that PCE and TCE were degrading biologically through reductive dechlorination as evidenced by the increasing concentration of their anaerobic biodegradation product, cis-1,2-dichloroehtene (DCE), (see Figure 3). Supporting lines of evidence for anaerobic biodegradation of PCE and TCE included low oxidation-reduction potential (ORP); depleted dissolved oxygen and nitrate concentrations; and, elevated alkalinity, chloride, and methane concentrations in the source area groundwater. Overall, the biodegradation process was limited by low total organic content (TOC) and elevated sulfate concentrations. Based on these observations, CDM concluded that the rate of natural attenuation was not sufficient to decrease the concentration of the contaminants to acceptable regulatory levels in a timely fashion; although, the low hydraulic gradient at the site limited the groundwater plume migration.

Following the evaluation of the pump and treat system at the former TRW site and natural attenuation at the former Anadite site, CDM evaluated remedial technologies for treating the chloroethenes in groundwater at both sites. These alternative technologies included the following:

- Pump and Treat (for the former Anadite site only)
- Monitored Natural Attenuation (MNA)
- Enhanced Anaerobic Biodegradation (EAB)
- In-Situ Chemical Oxidation (ISCO)

Figure 2
TCE Concentration in Source Area (Well T-2B)



CDM evaluated installing a pump and treat system at the former Anadite site as a comparison against the other technologies. Bench-scale chemical oxidation tests were conducted on saturated soils from both sites. The results of these tests indicated that ISCO would be an effective alternative for remediating the contaminants at both sites, provided enough reagent was applied to meet the chemical oxidant demand of the saturated soils.

However, bench-scale chemical oxidation studies do not offer a complete understanding of the fate and transport of contaminants in the subsurface during the chemical oxidation process. In field applications of chemical oxidation, the heat generated from the process has often desorbed contaminants from soil to groundwater. This mobilization has led to migration of contaminants downgradient of the chemical oxidation treatment area and effectively increased the size of the groundwater plume.

Based on site-specific groundwater conditions, and the effectiveness, implementability, and the estimated cost of the technologies, EAB was chosen as the technology that would reduce the concentration of chloroethenes in groundwater at both sites. Based on a literature review of EAB studies that used several substrates (HRC, sodium lactate, molasses) to induce reductive dechlorination, CDM determined that HRC would be the most effective. HRC is a proprietary polylactate ester, manufactured by Regenesis Inc., that slowly releases lactate into the groundwater.

Monitored natural attenuation was eliminated because it would not lead to regulatory closure in an appropriate time frame at either site. A successful EAB application was estimated to take 5 to 7 years to

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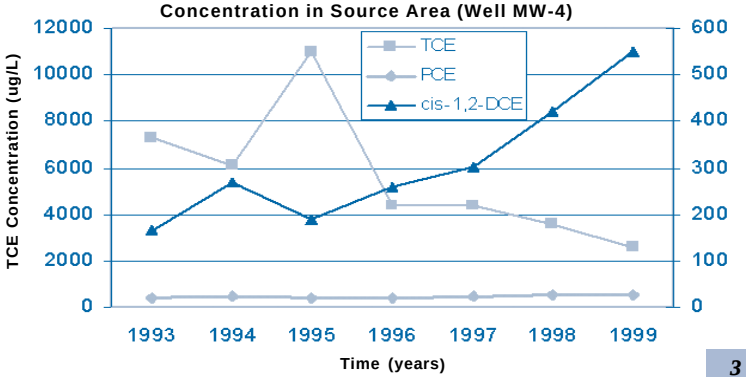
Figure 3
Concentration in Source Area (Well MW-4)



APPLICATIONS ISSUES

Unique HRC Bedrock Application at Dry Cleaner Shows Good Results

By Maureen Dooley, Northeast Regional Manager

A dry cleaner site in Cohassett, MA was found to have PCE and TCE concentrations of greater than 50,000 ppb. The underlying geology was composed primarily of bedrock, making the site that much more difficult to treat. From the surface down to bedrock (12 feet) the source area was excavated and approximately 250 cubic yards of contaminated overburden soil was removed. Although the source was eliminated, fractures and porous areas within the bedrock still harbored high concentrations of PCE and TCE. Hydrogen Release Compound (HRC) was chosen to accelerate the slow but naturally occurring reductive dechlorination process to degrade PCE and TCE. A total of 1200 pounds of HRC was applied directly to exposed rock surface and 30 pounds poured directly into existing, deep, bedrock wells. The results indicate a significant reduction in the concentration of volatile organics 6 months post HRC application. PCE and TCE levels were reduced by over 80% in 2 wells and an increase in daughter products DCE, VC and ethene were observed. A downgradient, sensitive receptor (a wetland) that was also impacted with PCE and TCE contamination is also showing encouraging results as levels were reduced below the regulatory limits.

Excavation down to bedrock layer

For more information contact Maureen Dooley of Regenesis at (781) 245-1320 or at maureen@regenesis.com

ANNOUNCEMENTS

Corporate Headquarters
San Clemente, CA

Mr. Scott Wilson was recently elected President by the Regenesis Board of Directors. Scott had previously served as Vice-President of Regenesis for two years and Central Region District Manager for three years prior.

Ms. Anna Willett joined the company in May as an addition to the Research and Development team as R & D Manager.

Mr. Kim Sakata was brought on board in June to oversee Technical Services operations.

Mr. Jason Peery joined Regenesis in July as Product Manager to focus on market research and product development.

In an effort to better serve our existing and growing customer base, Regenesis is pleased to announce the expansion of sales service in several regions throughout the U.S. and Canada.

Southeast Region

Headquartered in North Carolina, **Niki Case** will manage technical sales and business development for the states of Georgia, North Carolina, South Carolina and Tennessee. A hydrogeologist by trade, Ms. Case joined Regenesis roughly six months ago after working in environmental and engineering consulting for several years. Her background and expertise in site characterization and groundwater remediation, including bedrock aquifer applications compliments Regenesis' products well. Ms. Case has also authored numerous publications and presentations with some of the leading technical professionals in the environmental industry. Niki can be reached at (919) 676-4017 or at niki@regenesis.com

Working out of New Jersey, **Doug Shattuck** is responsible for technical sales and business development for the states of Virginia, Eastern Pennsylvania, New Jersey, part of New York, Maryland, Washington D.C.. His education and background are extensive in the fields of environmental geology, biological research and business. His professional experience has afforded him the opportunity to work for a well-known environmental engineering company as well as a publicly traded environmental biotechnology firm. Mr. Shattuck also brings with him an extensive knowledge of DOD and DOE remediation activities. Doug can be reached at (617) 686-1509 or at doug@regenesis.com

Eastern Canada

Leonard Chan, residing in Ontario, Canada, will be handling technical sales and business development for the eastern portion of Canada including Ontario, Quebec, Nova Scotia, Newfoundland, New Brunswick, Prince Edward Island and the Buffalo, New York Area. Mr. Chan is a chemical engineer and has a good working knowledge of the Canadian environmental consulting industry. He is also well versed in the application and design of remediation systems for groundwater treatment. Leonard can be reached at (905) 881-9841 or at leonard@regenesis.com.

Ohio Valley

Based in Ohio, **Todd Balzer** will be managing technical sales and business development for the states of Ohio, Kentucky, West Virginia and the western half of Pennsylvania. Todd brings with him over 14 years of sales and marketing experience with a solid background in the sales and development of environmental remediation projects. His experience has also gained him a professional and working knowledge of groundwater treatment, bioremediation, thermal desorption, fixation and incineration technologies. Todd can be reached at (513)934-0567 or at todd@regenesis.com.

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reach regulatory closure. A successful ISCO application was estimated to take 4 to 5 years to reach closure, but cost approximately $150,000 more than EAB. A successful pump and treat system was estimated to take 15 to 30 years to reach closure and cost at least $1 million more than EAB.

Once agreement from the regulatory agencies was achieved, CDM implemented EAB via injection of HRC at the former Anadite site in December 1999 and at the former TRW site in October 2000. A second application was implemented at the former TRW site in June 2001 and at the former Anadite site in August 2001. At the former TRW site, approximately 6,200 pounds of HRC have been injected into 56 locations. At the former Anadite site, approximately 6,500 pounds of HRC have been injected into 60 locations.

Figures 4 and 5 show the concentration of chlorinated VOCs in the source area monitoring well at the former TRW and former Anadite sites, T-2B and MW-4, respectively. Table 1 and 2 shows selected data for these two wells.

Following the injections, increased levels of total organic carbon (TOC) and dissolved hydrogen and decreased ORP values were observed in groundwater at both sites. The increased TOC stimulated nitrate and sulfate reduction. In parallel to the sulfate reduction, reductive dechlorination of TCE occurred with an immediate increase in cis-1,2-DCE levels.

At the former TRW site, where complete reductive dechlorination was previously observed, cis-1,2-DCE rapidly degraded to vinyl chloride (VC) and ultimately increased levels of ethene and ethane were observed. Increased aqueous concentrations of cis-1,2-DCE and VC, greater than initial aqueous levels of TCE present at the site, likely indicate that significant amounts of TCE adsorbed to the saturated soils have also been degraded. With the continued high TOC levels observed in the groundwater, significant amounts of HRC likely remain in the groundwater to continue stimulating the reductive dechlorination process. For the former TRW site, it is projected that EAB will meet the regulatory requirements within budget.

However, at the former Anadite site, TCE dechlorination proceeded at a slower rate with a build up of cis-1,2-DCE. Small concentrations of VC production and negligible concentrations of ethene and ethane were observed. Based on the results to date, it appears that the complete microbial system to reduce cis-1,2-DCE to ethene is not present at this site. However, DCE and VC have been reported to biodegrade through other microbial mechanisms, including anaerobic oxidation to carbon dioxide under iron reducing conditions. High levels of ferrous iron have been observed at both sites. Recently, a considerable decrease in cis-1,2-DCE concentrations has been observed at the former Anadite site, without a significant increase in VC concentrations. However, the decrease in cis-1,2-DCE may also be due to other natural attenuation processes (dilution and adsorption).

Continued monitoring at the former Anadite site is required prior to evaluating the effectiveness of EAB. Monitoring of carbon dioxide at the site is continuing to evaluate microbial oxidation of DCE and VC. For the former Anadite site, it is still too early to determine if EAB will provide results that will fulfill regulatory requirements within the estimated cost.

Figure 4
Concentration in Source Area (Well T-2B) After EAB Application

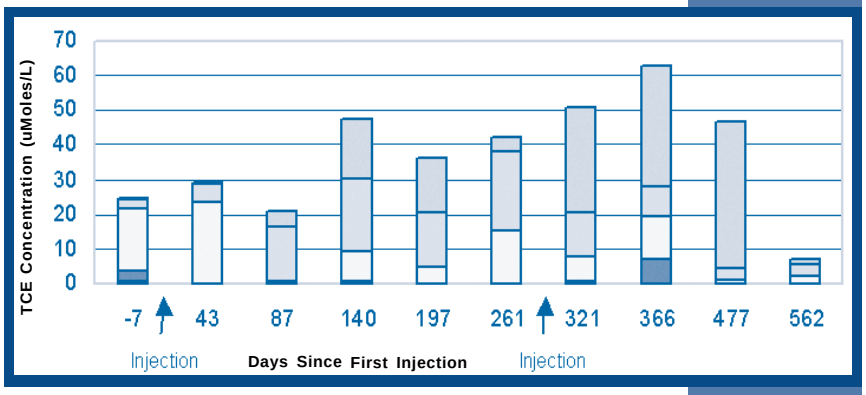
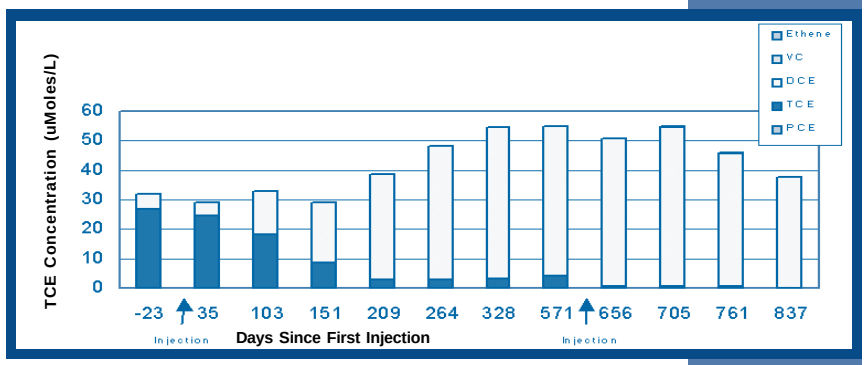


Figure 5
Concentration in Source Area (Well MW-4) After EAB Application



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backed up by all relevant calculations available in a "proposal ready" format.

Journal Articles and Case Histories

Hundreds of journal articles and presentations have been delivered by third parties such as regulators and consulting firms on the success of ORC and HRC remediation projects (In fact 29 presentations on ORC and HRC were just presented at the Battelle Sponsored, Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds Symposium in Monterey, California). Additionally, case histories of ORC and HRC projects are available on topics that cover a broad range of project types (e.g. plume cut-off or excavation treatment), contaminant types, geological conditions, etc. These case histories and many of the journal articles / presentations are available for download on our website or can be emailed to you upon request.

Regenesis, in the years to come, will continue in its lead position of developing cost effective solutions for groundwater and soil remediation. But hand in hand with this new product development will come a consistent focus on technical support and customer service. It is this attention to technical support that will ensure our continued success in product performance and maintaining unprecedented technical credibility in the environmental industry.

FROM THE RESEARCH DESK

Treating Difficult Chlorinated Sites Needs a "Differential Diagnosis"

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

When a patient sees a doctor for an evaluation it is standard procedure to follow a "differential diagnosis". The core of this exercise, when faced with several possibilities, is to go through a logical progression of deductive reasoning until the likely cause is identified. So it should be with analyzing putative difficulties with a bioremediation protocol. A rush to judgment on treating a DCE accumulation at a chlorinated site by immediately calling for costly bioaugmentation practices violates the core wisdom of a differential diagnosis. How would you feel if a physician rolled you off to an expensive CAT Scan (at a facility where they had a financial interest) on little or no basic work-up?

As the frequency of use of reductive dechlorination protocols increases, certain phenomenon are being observed with DCE build-up and degradation. On certain sites DCE may accumulate in excess of what seems possible based on initial concentrations of source material, and then appear to degrade at a slower rate. We believe it is important to understand why intermediates accumulate and further – to differentiate the degrees of rate slowdown so that the sites which are truly recalcitrant and require further intervention can be identified.

Often the early accumulation and / or a slower rate of removal of DCE has nothing to do with inhibition phenomenon, but that impression is created. What may be happening is all or some of the following: 1) unknown sources are providing a constant feed of source material, 2) rates of removal of source compounds are faster than those of degradation products ("kinetic disparity") and 3) differences in solubility from source compounds and their derivatives make the latter more prevalent in the dissolved phase. We believe that once these issues are examined, only then is it appropriate to search for valid inhibition phenomena. To that end we would cite both the biological hypothesis (absence of necessary microorganisms) and the lesser recognized geochemical hypothesis (elevated reduction of iron which blocks electron flow to DCE).

The majority of chlorinated hydrocarbon sites (about 75%) that have been treated with electron donors have been treated with HRC. Based on that broad experience, we believe that a truly problematic inability to handle DCE is only present on a very small percentage of sites — given that we provide "enough time and enough electrons". Specifically, we find that the geochemical inhibition is often transient as competing electron scavenging reactions run their course. Also, we believe that microbial insufficiency can often be corrected naturally unless there is a complete absence of requisite dechlorinating microorganisms. In the final analysis one needs a logical progression through a "differential diagnosis" to understand the problems and choose the appropriate remedy on a conservative basis.

As a final note, the synthesis of a differential diagnostic strategy involves lessons learned from several important collaborators, including but not limited to Dr. Joe Hughes of Rice University, Dr. Patrick Evans of Camp Dresser and McKee, Dr. David White from the University of Tennessee at Knoxville and Dr. Frank Loeffler of Georgia Tech. For more information on their work do not hesitate to contact me at 949-366-8000 or by email steve@regenesis.com.

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