
**SOURCE ZONE AND PLUME TREATMENT OF CHLORINATED SOLVENTS
ACCEPTING THE CHALLENGE TO MEET CLIENT EXPECTATIONS
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Summary

Chlorinated solvents sites represent a significant portion of the engineering and consulting remediation market. These sites are difficult if not impossible to remediate and achieve MCL standards. Recent procurement initiatives by Government and the private sector are raising the bar as to what performance standards and guarantees are expected from remediation consultants and engineering firms. Even if consultant don't play in this high risk (potential high reward) guarantee market, those who realistically set their customer's and/or their own expectations, and then provide the most cost effective results will profitably capture the majority of this market.

The New Air Force Cleanup Challenge

At this year's 2011 Air Force Restoration and Technology Transfer Workshop, the Air Force made it clear that Remedy-In-Place (RIP) is only part of what is necessary to fully clean up contaminated sites. There are too many sites where the current remedies will prevent unconstrained use of transferred property and continue the perpetual legacy of land use controls. As a result, the current cleanup program is being refocused from process and study to results. This includes:

1. Fence-to-Fence accelerated site completion, which is a point where the Air Force will make essentially no additional appreciable investments of time and money.
2. The primary contract mechanism will be Performance-Based Cleanup (PBC) agreements.
3. Accelerated completion of 75% of BRAC sites by the end of 2012 and 90% by 2015.
4. Accelerated completion of 50% of all non-BRAC sites by 2012, 75% by 2015 and for sites not yet completed ensure 60% are under PBC contract by 2012 and 90% by 2015.

The Source Zone and Plume Chlorinated Solvent Matrix Diffusion Dilemma

"Source" (NRC, 2005):

- A subsurface reservoir that sustains the plume.
- The DNAPL containing region is initially the primary reservoir... also includes high concentration dissolved and sorbed-phase halos about the DNAPL containing region.

- Acknowledges that some source zones are depleted of DNAPL and that the high concentration halo can be a reservoir that sustains plumes.

Based on the "Decision Guide For Managing Chlorinated Solvent Sites" Tom Sale, Colorado State University and Chuck Newell, GSI Environmental Inc. March 7, 2011 as well the "Frequently Asked Questions Regarding Managing Chlorinated Solvents in Soil and Groundwater" Tom Sale, Chuck Newell, Hans Stroo, Robert Hinchee and Paul Johnson, (SERDP, 2008), the following challenges have been identified to fully cleanup these sites:

- Source delineation efforts commonly miss a portion of the source.
- Remediation by pump and treat (NRC, 1994) is a slow process and can range from a few years to thousands of years.
- Sorbed mass in the low permeability zones of the plume can continue to impact the plume through matrix diffusion. It's not just the dissolved phase in the transmissive zone that requires treatment.
- Well implemented source treatment technologies (Surfactants, Thermal, ZVI, Bioremediation, Chemical Oxidation, Dual Phase Extraction, Excavation, Pump and Treat) result in a 90% (one order of magnitude) to 99% (two orders of magnitude) of groundwater concentration reduction (NAVFAC, 2007). MCLs are extremely unlikely to be met.
- Treatment trains (successive applications of different technologies) may be one approach to reduce concentrations beyond what a single treatment technology can achieve.
- As a very general Rule-of-Thumb, investment of \$1 million per acre appears to have the potential to achieve one order of magnitude reductions in chlorinated solvent mass and concentration in source zones. Additionally, one order of magnitude source reduction gives one order of magnitude improvement down gradient. With fast groundwater flow, low mass storage, and/or active attenuation, 2 to 3 order of magnitude improvement can occur over several years.

Why Should What The Air Force Is Doing Be Important To You?

Obviously if you plan on bidding on these new PBC contracts, this is mission critical information. If you are not, this is a trend that we are seeing in the industry where the client is moving into a results oriented mindset to eliminate the perpetual legacy associated with contaminated land ownership. While the PBCs require substantial financial risk management and the best technological approaches for those who want to participate in this market, the Air Force is willing to competitively bid out these projects and pay what it takes for results.

What is interesting is many of the PBC RFPs will be small business set asides; however the financial risks and technical expertise requirements will be far greater than what they have experienced in other DOD work.

We often see a similar PRP procurement strategy in the commercial sector where remediation guarantees are requested or proposed, but the project values usually don't come close to these Fence to Fence PBCs. The remainder of the market I believe is composed of PRPs, with many having full expectations that their investments will lead them to closure, where optimistically a longer term MNA only strategy will be a realistic goal.

Therefore to compete in the chlorinated solvent remediation market, consultants will have to develop methodologies to better define source and plume zones in regards to DNAPL and sorbed mass respectively. Once identified, they will need to cost effectively implement technologies that can provide them with the order of magnitude concentration reductions they need to meet the client expectations they have set.

New Vironex Tools to Meet the Challenge

DNAPL and Sorbed Mass ID

Vironex has performed over 100 high resolution profiling MIP investigations at chlorinated solvent sites. This is a very cost effective way to determine to identify your source areas as well as the solvent mass distribution within the site lithology. This is over half the battle in source zone remediation. MIP followed by a more focused traditional Hydropunch water and dual wall soil sampling can provide more quantitative results to support your ultimate technology selection. Note however that typical soil analysis by solvent extraction has shown to underestimate the amount of chlorinated sorbed mass and that new high resolution soil core subsampling and microwave desorption methods (Chapman and Parker, 2005) are being used to more accurately quantify sorbed mass in both the source and plume. Additionally estimates can be made using groundwater data and knowing FOC, with models like NAPLANAL available on the Vironex website.

Together these data sets provide a much higher resolution understanding of the contaminant distribution and therefore can only enhance the effectiveness of the treatment technologies employed.

Overall remediation efficacy can be verified by post remediation high resolution MIP profiling to compare pre and post remediation mass reduction results. This is a very cost effective way to optimize additional remediation events, including another treatment technology as part of a treatment train.

Technology

As we know, there are numerous technology options for treatment of the both the source and plume with estimated order of magnitude treatment efficiencies (1 to 3) based on the quality of the design and implementation.

Vironex currently provides source zone injection and/or extraction (chemical oxidation and reduction, bioremediation and bioaugmentation) and shallow soil mixing services for chlorinated solvent sites, as well as plume injection (bio barriers). These technologies are "contact" dependent and Vironex has developed specific technical enhancements to traditional "driller type" injection equipment to optimize

both contaminant contact and overall injection efficiency for a wide range of lithologies. Also based on our experience at these sites, we can also support your design for injection spacing and volumes/dosing to meet your treatment objectives.

Vironex has also developed a unique methodology that we call Search and Destroy® (S&D), where we integrate the high resolution MIP profiling source identification phase into a pilot test injection approach to verify distribution and contact, followed by a targeted injection strategy. We believe that S&D will increase the overall treatment efficiency of your source zone treatment events.

Being an innovator in this market, Vironex continues to explore and pilot new remediation technologies including; new reagents, radio frequency heating, in-situ stimulation to enhance reagent distribution, conditioning soils to enhance permeability, and surfactants that enhance dissolution of DNAPL and sorbed mass for more effective in-situ treatment.

The Collaborative Design Process

Chlorinated solvent site remediation requires a robust design to be successful. There are numerous factors that must be taken into account including:

- Remediation objectives for source and plume
 - Order of magnitude reduction expectations
 - Timing
 - Role of MNA in the design
- Site Characterization
 - Contaminant distribution vs. lithology with a focus on sorbed mass
 - High resolution profiling
 - Remchlor¹ modeling
- Remediation technology(s)
 - Bioremediation or Chemical Oxidation
 - Dosing assumptions
 - Bench-Scale determination of any unique site chemistry interferences
- Contaminant contact approach
 - Distribution technology
 - Distribution design
 - Distribution verification through pilot testing
- Remediation performance monitoring
 - High resolution profiling mass reduction verification
- Post remediation groundwater monitoring to verify objectives have been met

While some consultants prefer to subcontract the total remediation design and implementation, Vironex believes that the best way to manage remediation is through a collaborative process. This maximizes the strength of the team and also reduces your risk of losing control of the project, especially in this new PBC role or high PRP expectation market. Even with performance guarantees from

technology vendors or applicators, most do not have the financial resources (unless they provide performance bonds and or insurance, which most can't obtain) to stand behind projects that don't obtain results.

Through a collaborative process, Vironex can support your remediation design staff with our in-house bioremediation and chemical oxidation expertise as well as in-situ soil mixing and the most extensive set of field injection experience in the industry today. This expertise, coupled with our ability to utilize high resolution profiling data sets through our S&D methodology, can support your design process to ensure a sound basis for all aspects of the remedial approach to ensure remediation objects are met.

The net result is a transparent design that is well documented with all risks quantified. This will allow for further optimization in the field to face the challenges posed by any chlorinated solvent site, as well as providing ongoing productive communications to meet your client expectations.

¹REMChlor, or Remediation Evaluation Model for Chlorinated Solvents, is an analytical solution for simulating the transient effects of ground water source and plume remediation. In the analytical method, the contaminant source model is based on a power-function relationship between source mass and source discharge, and it can consider partial source remediation at any time after the initial release. See <http://www.epa.gov/ada/csmos/models/remchlor.html>

For more information on how Vironex can support on existing projects or partner with you on bidding for new projects please contact Eliot Cooper at 303-669-7443 or ecooper@vironex.com