H R C T E C H N I C A L B U L L E T I N # 4 . 1 . 3

Hydrogen Release Compound HRC™

# HRC and Application of Organic Substrates

In this technical bulletin, HRC technology is compared to the use of common organic substrates to promote degradation of chlorinated solvent compounds *in situ.*

In order to understand the advantages of HRC technology, one must recognize that HRC is a passive method. Once installed it then stimulates the continuous release of low dissolved hydrogen concentrations for over a year's time, without the need for active infiltration, batch dosing of wells, etc. Engineers and scientists in the field have attempted to use other common substrates (such as sugars). In each case however, the organic substrate application required costly mechanical design and infrastructure to allow for continuous or semi-continuous substrate, and costly O&M associated with routine applications. HRC technology completely eliminates these design, installation and maintenance tasks, and all of the associated costs.

In addition to the dramatic cost advantage of HRC technology compared to the use of other substrates, there is also a distinct technical advantage- the consistent release of low dissolved hydrogen concentrations from HRC does not promote the formation of methane, as other substrates do.

The following discussion gives greater details to these benefits of HRC over the use of other organic substrates.

***Organic Substrate Injection is Costly***

The use of common organic substrates to stimulate chlorinated solvent degradation in groundwater requires mechanical design and construction of continuous or semi-continuous injection systems. There are a number of concerns with these approaches:

1) Organic compound delivery systems are costly. To continuously inject a soluble substrate like sugar or molasses, one must install multiple substrate application wells. Piping and trenching are required to continuously feed these wells. An electronically activated solenoid system to control the substrate dosing is generally required as well. In the event the substrate is injected directly into the subsurface without a well (e.g. push-points) then reapplication will be required at regular intervals (e.g. every 7 to 14 days with molasses). This comes at a very high labor/ subcontractor cost. Thus, while the common organic substrate is cheap on a per pound basis, the actual treatment will be very costly. HRC on the other hand does not require continuous or semi-continuous feeding. HRC is simply injected once into the subsurface through push-points or borings (or placed in excavations prior to backfilling) and left to do its work- continuously releasing low concentrations of dissolved hydrogen.

2) Organic compound delivery systems all plug. Due to the very nature of substrates such as molasses or corn syrup, biodegradation of the material results in biomass buildup (slime). This rapidly plugs the injection system requiring labor costs associated with well cleaning (with either hydrogen peroxide or acid- both are compounds which are very detrimental to the process which

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the system is installed to stimulate). With HRC technology, this problem is completely avoided, as HRC requires only a one-time injection into the subsurface through a boring resulting in the production of hydrogen for year's time.

3) Injection Introduces Oxygen. The continuous or semi-continuous injection of substrate inherently introduces oxygen and increases the redox of the subsurface environment. This tends to stop the dechlorination process, until redox potential is re-established in the proper range. This

slows the overall remediation as the subsurface micro-flora adjust to the every shifting redox.

***HRC Technology- Minimizes Methane Production***

Common Substrates Produce Methane. The application of large amounts of dissolved organic substrates to the subsurface stimulates methane production. This is the result of too much hydrogen produced when a "slug" of substrate is added to the subsurface all at once. This is an almost unavoidable phenomenon with the use of common substrates such as molasses, corn syrup, lactate, etc. This methane production dramatically reduces the efficiency of the substrate addition, stealing hydrogen from the desired dechlorination reaction. Generating this condition in the aquifer can result in the buildup of dangerous gases. HRC release hydrogen at a slow controlled rate, thereby keeping dissolved hydrogen concentrations low, avoiding the creation of methanogenic conditions.

HRC Maximizes Dechlorination. HRC releases hydrogen at a continuous slow rate. The result is the maintenance of low concentrations of hydrogen in the contaminated groundwater. Sites where HRC has been applied have been shown to contain dissolved hydrogen concentrations in the range of 2-8 nM. In a recent publication (Yang and McCarty, 1998), it was shown that maintaining a concentration of hydrogen below 10nmolar produced efficient dechlorination while concentrations in excess of 10 nM (as produced by common substrate application) stimulated methanogenesis. Other research has indicated that the production of methanogenic conditions often inhibits the dechlorination process altogether.

3) HRC is More Efficient. Common substrates, which have been tested for stimulating the cleanup of chlorinated solvents from groundwater, include molasses, corn syrup, alcohols, etc. Each of these substrates, in addition to stimulating methane production as they are dosed into the subsurface, are inherently less efficient at stimulating dechlorination compared to HRC. In most cases this is the result of lower hydrogen production on a molar basis (i.e., more of the other substrates is required to produce the same amount of reducing power). In addition, many organic mixes such as molasses contain detrimental salts such as sulfates. Sulfates reduce the efficiency of the dechlorination process by accepting electrons that otherwise would have resulted in dechlorination. Thus the presence of impurities such as sulfates have an interfering effect on the dechlorination process, extending the time and cost of the remediation process in comparison to the use of HRC.

**The Advantages of Using HRC**

Given that bioremediation is a viable option for the accelerated natural attenuation of contaminated sites, the following are some advantages of using slow-release compounds.

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1. Low Capital, Design, and O&M Costs:

Since the slow-release compounds are part of a passive, *in situ* approach, substantial design, capital, and operations/maintenance (O&M) costs are avoided. Actively engineered systems such as injection well patterns, solenoids dosing systems, etc. are expensive, time-consuming, and often burdened with costly and extensive design considerations. Sometimes even the design costs alone of mechanical systems will approach or exceed the costs of an ORC or HRC treatment.

2. Minimal Site Disturbance:

HRC offers the potential for *in situ* treatment without the requirement for aboveground equipment after initial injection, thereby allowing remediation without disrupting normal business or commercial activities. Applying these slow-releasing substrates to the subsurface is fast and easy. After application, there are no aboveground indications that the product has been applied because it works silently below ground.

3. Applicability at Difficult to Manage Sites:

HRC is ideal for sites where geological or physical conditions make active systems inappropriate. Particularly in clay soils, where pumping is difficult and sparging promotes channeling, the slow release of diffusible lactic acid and hydrogen has distinct advantages.

4. Limited Disturbance of the Contaminant Plume:

Any mechanical action in the aquifer has the potential to distort the dynamics of a contaminant plume—usually not to the benefit of the project. The very small volume of HRC injected has minimal if any impact on plume dimensions, and the slow release of lactate and hydrogen simply disperse passively without any potential for plume disruption.

5. Usefulness at Remote Sites:

HRC is ideal at geographically remote sites, particularly in regions that are difficult to access. The HRC process, being passive in nature, requires no utilities such as power or water. This represents a great advantage over mechanical delivery systems required in the use of other organic substrates which utilities and constant attention for batch dosing or operation and maintenance.

6. Constant and Persistent Source of Electron Acceptor/Donor:

HRC will remain where emplaced and generate diffusible active agents slowly over time. Particularly in the case of chlorinated hydrocarbons, where plumes are difficult to locate, a continuous source of diffusible materials increases the effectiveness of contact, containment, and remediation.