

## **TIME-RELEASE ELECTRON DONOR TECHNOLOGY: RESULTS OF FORTY-TWO FIELD APPLICATIONS**

Stephen S Koenigsberg<sup>1</sup>, Craig A. Sandefur<sup>2</sup> and Kevin A. Lopus<sup>3</sup>

Abstract: Hydrogen Release Compound (HRC<sup>®</sup>) is a food grade, polylactate ester that, upon being deposited into the aquifer, is slowly hydrolyzed to release lactic acid and other organic acid derivatives. The organic acids are fermented to hydrogen, which in turn donates electrons that drive reductive bioattenuation processes. HRC delivers electrons in a time-release fashion for about one year. The material is applied to the aquifer by push-point injection or backfill-auguring and is normally indicated for treatment dissolved phase plumes and hydrophobically sorbed contaminant. It has long been known that enhancing bioremediation can facilitate desorption of the residual, sorbed phase; now this has been specifically established in an HRC-mediated environment. HRC has now been used on over 150 sites, which we believe make it the most widely used electron donor for accelerating bioattenuation. Overall and representative site results are discussed.

An emerging and highly desirable strategy for the management of groundwater contaminated with anaerobically degradable compounds is to simply provide organic substrates to the aquifer. The organic materials can donate electrons that facilitate the destruction of contaminants, such as chlorinated hydrocarbons, nitroaromatics and oxyanions, by microbially mediated chemical reduction. The electron donating processes are typically linked to the production of hydrogen by the fermentation of the organic matter. One option in implementing this technology is to use a time-release hydrogen/electron donor, which can eliminate or reduce major design, capital and operational costs, as well as allow for the engineering of a low-impact application and a subsequently invisible remediation process.

Hydrogen Release Compound (HRC) is one option currently available to deliver electrons in a time-release fashion. HRC is based on a food grade, polylactate ester that can be applied to the aquifer by push-point injection or backfill-auguring. It will slowly hydrolyze over a period of about a year and generate readily fermentable lactic acid and its derivatives. This technology is most applicable to the passive, long term and low cost treatment of dissolved phase plumes, associated hydrophobically sorbed contaminants, and moderate levels of residual DNAPL.

The basic HRC chemistry and laboratory performance verification was published by Koenigsberg and Farone (1999). A mathematical model for HRC performance was later described by Farone et al. (1999). The first field tests were performed by Kallur and Koenigsberg (1999) and Wu (1999). In these studies HRC laden canisters were placed in a well and significant reductive dechlorination was observed. Soon after, Dooley et al. (1999) used canisters in a recirculation well system and added to the proof-of-concept for this technology. At this point, direct injection into the aquifer was trialed. The first direct injection was carried out by Sheldon et al. (1999), in which the addition of 240 pounds of

---

<sup>1</sup> VP R&D Regenesis, 1011 Calle Sombra, San Clemente, CA 92675, 949-366-8000, [steve@regenesis.com](mailto:steve@regenesis.com)

<sup>2</sup> Director Regenesis, 1011 Calle Sombra, San Clemente, CA 92675, 949-366-8000, [craig@regenesis.com](mailto:craig@regenesis.com)

<sup>3</sup> Engineer Regenesis, 1011 Calle Sombra, San Clemente, CA 92675, 949-366-8000, [kevin@regenesis.com](mailto:kevin@regenesis.com)

HRC in a 60 square foot area led to an 80% reduction in PCE after four months with a classical pattern of rise and fall in daughter products and expected changes in geochemical parameters. This was followed by other field injection work including three barrier applications (Anderson et al. 2000, Dooley and Murray 2000, Schuhmacher et al., 2000) and two full scale source treatments (Boyle et al. 2000, Lodato et al. 2000).

At this writing, HRC has now been used on over 150 chlorinated hydrocarbon sites; which we believe make it the most widely used electron donor for bioattenuation. Of these applications, 42 were mature enough to be evaluated. From among these there were 9 sites that displayed exceptional results, defined as demonstrating very rapid and complete dechlorination (type A). At 22 sites results are very positive, displaying accelerated degradation rates with varying degrees of daughter product formation depending on the age of the data set (type B). Finally, 9 sites show moderately accelerated or mixed rates of dechlorination with varying degrees of daughter product formation depending on the age of the data set (type C), and 2 of the sites were not responding at all after a single application (type D). A number of the specific cases are being independently presented at this Conference. Three representative examples from the A-C data sets not being reported on at the conference are as follows:

Type A- Industrial site in New Jersey: 1,080 lbs. of HRC was injected via 23 direct-push points, arranged in a grid, covering an area of 1,100 square feet. After 124 days, PCE concentrations decreased by an average of 85%. Total cost for this effort was \$15,000 and the site is scheduled for closure. This represented a significant savings over projected ongoing operations and maintenance at the site.

Type B- Dry Cleaner in Oregon: A barrier containing 2300 pounds of HRC was installed across the plume in two locations. After 143 days there was a 53% reduction in PCE. The total cost of the project was \$31,000 versus an estimated \$150,000 for extraction.

Type C- Industrial site in Illinois: Three barriers were installed that used 2500 pounds of HRC. After three months there were positive results at two barriers and a third performed less efficiently; it was in a high sulfate zone, where sulfate reduction may have competed with reductive dechlorination. A re-application of HRC was made and sulfate was reduced dramatically after another three months; reductive dechlorination is expected to follow. Total accumulated costs are in the range of \$60,000 and represents about an order of magnitude lower cost than the alternatives that were considered.

#### References:

Anderson, D. 2000. "Remedial Action Using HRC Under a State Dry Cleaning Program". In: Wickramanayake, G.B., Gavaskar, A.R., Chen, A.S.C. (eds.), *Bioremediation and Phytoremediation of Chlorinated and Recalcitrant Compounds*, pp. 213-219. Battelle Press, Columbus, OH.

Boyle, S.L., V.B. Dick, M.N. Ramsdell and T.M. Caffoe. 2000. "Enhanced Closure of a TCE Site Using Injectable HRC<sup>TM</sup>". In: Wickramanayake, G.B., Gavaskar, A.R., Chen,

A.S.C. (eds.), *Bioremediation and Phytoremediation of Chlorinated and Recalcitrant Compounds*, pp. 255-262. Battelle Press, Columbus, OH.

Dooley, M., W. Murray and S. Koenigsberg. 1999. "Passively Enhanced In Situ Biodegradation of Chlorinated Solvents". In: Leeson, A., Alleman, B.C. (eds.), *Engineered Approaches for In Situ Bioremediation of Chlorinated Solvent Contamination*, pp. 121-127. Battelle Press, Columbus, OH

Dooley, M. and W. Murray. 2000. "HRC-Enhanced Bioremediation of Chlorinated Solvents". In: Wickramanayake, G.B., Gavaskar, A.R., Chen, A.S.C. (eds.), *Bioremediation and Phytoremediation of Chlorinated and Recalcitrant Compounds*, pp. 287-294. Battelle Press, Columbus, OH.

Farone, W.A., S.S. Koenigsberg and J. Hughes. 1999. "A Chemical Dynamics Model for CAH Remediation with Polylactate Esters". In: Leeson, A., Alleman, B.C. (eds.), *Engineered Approaches for In Situ Bioremediation of Chlorinated Solvent Contamination*, pp. 287-292. Battelle Press, Columbus, OH.

Kallur, S. and S. Koenigsberg. 1999. "Enhanced Bioremediation of Chlorinated Solvents-A Single Well Pilot Study". In: Leeson, A., Alleman, B.C. (eds.), *Engineered Approaches for In Situ Bioremediation of Chlorinated Solvent Contamination*, pp. 181-184. Battelle Press, Columbus, OH.

Koenigsberg, S.S. and W. Farone. 1999. "The Use of Hydrogen Release Compound (HRC<sup>TM</sup>) for CAH Bioremediation". In: Leeson, A., Alleman, B.C. (eds.), *Engineered Approaches for In Situ Bioremediation of Chlorinated Solvent Contamination*, pp. 67-72. Battelle Press, Columbus, OH.

Lodato, M., D. Graves, and J. Kean. 2000. "Enhanced Biological Reductive Dechlorination at a Dry-Cleaning Facility". In: Wickramanayake, G.B., Gavaskar, A.R., Chen, A.S.C. (eds.), *Bioremediation and Phytoremediation of Chlorinated and Recalcitrant Compounds*, pp. 205-211. Battelle Press, Columbus, OH.

Schuhmacher, T., W. Bow and J. Chitwood. 2000. "A Field Demonstration Showing Enhanced Reductive Dechlorination Using Polymer Injection". In: Wickramanayake, G.B., Gavaskar, A.R., Chen, A.S.C. (eds.), *Bioremediation and Phytoremediation of Chlorinated and Recalcitrant Compounds*, pp. 15-22. Battelle Press, Columbus, OH.

Sheldon, J.K., S.S. Koenigsberg, K.J. Quinn, and C.A. Sandefur. 1999. "Field Application of a Lactic Acid Ester for PCE Bioremediation". In: Leeson, A., Alleman, B.C. (eds.), *Engineered Approaches for In Situ Bioremediation of Chlorinated Solvent Contamination*, pp. 61-66. Battelle Press, Columbus, OH.

---

Wu, M. (1999). "A Pilot Study Using HRC™ to Enhance Bioremediation of CAHs". In: Leeson, A., Alleman, B.C. (eds.), *Engineered Approaches for In Situ Bioremediation of Chlorinated Solvent Contamination*, pp. 177-180. Battelle Press, Columbus, OH.

---