HRC TECHNICAL BULLETIN # 1.1.4

Hydrogen Release Compound HRC®

Competition for Hydrogen Between Reductive Dechlorinators and Other Microorganisms

The microbial population that inhabits the subsurface under conditions of low redox potential is sometimes referred to as the "anaerobic web". This is a revealing term which reflects the lack of knowledge we face when dealing with the microbial dynamics of the subsurface. One of the major challenges for some microbiologists is to better define this microcosm - but it is not an easy task. The anaerobic web is an ecosystem every bit as complex as those we experience at our sensory scale.

Among the complexities of the entire problem we want to focus in on a few relevant issues as they pertain to the dynamics of HRC and reductive dechlorination. A series of microbially mediated events can be set forth as follows:

1. First, the aquifer has to be driven anaerobic if it is not already in that condition. Obviously, this has to be achieved to support the growth and development of anaerobic microorganisms. To achieve this state, all the oxygen and the other electron acceptors such as nitrate and sulfate have to be consumed. As detailed in Technical Bulletin 2.6.1, this condition can be achieved by providing substrates such as lactic acid to the aquifer. HRC is a source of this lactic acid and its metabolism by anaerobic microorganisms to carbon dioxide and water "burns up" all of the electron acceptors.

2. Now the stage is set for the important reactions that remove chlorinated hydrocarbons. Recognize that the redox potential goes from positive to negative as electron acceptors are consumed. As soon as electron acceptors are gone the dynamics of the microbial web shift; as redox potential shifts so do the dominant species of microoganisms in the aquifer. As low to moderate negative redox conditions form, certain kinds of fermentative microorganisms can thrive that will attack the HRC derived lactic acid and turn it first into pyruvic acid and then acetic acid. It is through this process that the hydrogen is formed; one mole of H_2 is derived in the conversion of lactic acid to pyruvic acid and another mole of H_2 is derived from the conversion of pyruvic acid to acetic acid. Further details can be found in Technical Bulletin 1.1.3.

3. The hydrogen formed by fermentative microorganisms is now available for reductive dechlorination - however, there are other competing microbial processes that also demand hydrogen. The most common of these is methanogenesis. As the name implies this is a methane generating reaction that involves the combination of CO_2 with hydrogen.

Recently, some of the experts in the field of reductive dechlorination, including laboratory groups at Cornell and Stanford as represented in the references given, have offered the hypothesis that there is competition for hydrogen between reductive dehalogenators and methanogens. They believe that a low concentration of hydrogen favors the reductive dehalogenators and starves out the methanogens that have a larger appetite for hydrogen.

With an excess of hydrogen in the system the methanogens are favored and crowd out the reductive dehalogenators. The objective would then be to keep hydrogen concentrations low. This can be accomplished with the use of slow release organic acid materials such as HRC.

Returning to the subject of anaerobic web complexity, we have to remind the reader that the rules are not so standardized. In fact, some of the organisms that generate the hydrogen may also perform reductive dechlorination. Also, both reductive dechlorinators and methanogens may co-exist in some systems so that "everyone is satisfied". Lastly, not everyone accepts the hydrogen competition theory and there are dissenting opinions which have not yet reached the literature, but will in the near future.

HRC provides a basis for designing a low-cost passive system for plume control. When designing as HRC remediation system one must consider all competing uses for the hydrogen generated. If in a given aquifer system the dynamics of

hydrogen competition are present, and if HRC hydrogen generation is minimal enough given hydrogeological and microbial conditions, then there is a basis for expecting an additional benefit from using the HRC.

References

1. Fennel, D.E., J.M Gossett and S.H. Zinder. 1997. Environmental Science & Technology. 31: 918-926.

2. Yang, Y. and L. McCarty. 1998. The First International Conference on Remediation of Chlorinated and Recalcitrant Compounds. Platform Presentation. Monterey, California, May 19, 1998.

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