Competition for Hydrogen Between Reductive Dechlorinators and Other Microorganisms

The term “anaerobic web” is sometimes used to refer to the microbial population that inhabits the subsurface under conditions of low redox potential. This term reflects the lack of knowledge available concerning the microbial dynamics within the subsurface and the challenge some microbiologists face to better define this unique microcosm.

The anaerobic web is a complex ecosystem. Rather than expounding on its vast intricacies and nuances, we will focus on a few issues as they pertain to the application of HRC and reductive dichlorination. With the addition of HRC, a series of microbially-mediated events will be set forth:

1. If the aquifer is not already anaerobic, it must be made so; an anaerobic environment supports the development and growth of anaerobic microorganisms. To promote this state, all oxygen and other electron acceptors such as nitrate and sulfate must be consumed. As detailed in Technical Bulletin 2.6.1, this can be achieved through the addition of electron donors, such as lactic acid, to the aquifer. In this case, HRC acts as a source of lactic acid and anaerobic microorganisms metabolize it to carbon dioxide and water, using up the electron acceptors.

2. As electron acceptors are consumed, the redox potential goes from positive to negative. As the redox potential shifts, dynamics of the microbial web change, altering the dominant species of the aquifer. At low to moderate negative redox conditions, certain kinds of fermentative microorganisms thrive. These microorganisms utilize the HRC-derived lactic acid, turning it first into pyruvic acid then into acetic acid. Through this process, hydrogen is released: stoichiometrically, one mole of H2 is released during the conversion of lactic acid to pyruvic acid and another mole of H2 is released during 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 use in reductive dechlorination. Unfortunately, there are other hydrogen-demanding microbial processes competing, the most common of these is methanogenesis which is a methane-generating process involving the combination of CO_2 with hydrogen.

Recently, experts in the field of reductive dechlorination, including laboratory groups at Cornell and Stanford (noted in references), have hypothesized about this competition for hydrogen between reductive dehalogenators and methanogens. They believe that a low concentration of hydrogen promotes reductive dehalogenators, while starving methanogens which have need of hydrogen in higher concentration. Conversely, an excess of hydrogen would promote the growth of methanogens, crowding out reductive dehalogenators. Our objective, therefore, is to keep hydrogen concentrations low, which can be accomplished with slow-release organic acid materials such as HRC.

Returning to the subject of anaerobic web complexity, it must be remembered that most generally, systems are not so standardized. Some of the organisms that generate hydrogen may also perform reductive dechlorination and both reductive dechlorinators and methanogens may coexist in some systems so that both are content. It should also be noted that not everyone accepts the hydrogen competition theory and there are dissenting opinion which may be in literature in the near future.

HRC is a proven technology for use in designing a low-cost, passive system for plume control. When implementing HRC for in situ remediation, competition for the hydrogen generated must be considered. If competing species are present and hydrogeological and microbial conditions allow slow hydrogen generation from HRC, there is basis in literature to expect additional benefit from the use of 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.