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The advantages and challenges of chlorinated solvent bioremediation in Florida

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Florida has a unique natural environment that includes aquifer systems characterized by distinct geochemical and hydrogeological con-ditions. The implications for the bioremediation of chlorinated solvents such as PCE and TCE are significant because successful bioremediation is highly dependant on a proper geochemical and hydrogeological context.

Florida's aquifers, in general, provide some of the most favorable geochemistry and hydrogeology for chlorinated solvent bioremediation in the U.S. Even where conditions are unfavorable, they can often be improved through the use of existing practices and technologies.

The implementation of bioremediation typically involves the injection of an electron donor (biostimulation), and may require the addition of a microbial culture (bioaugmentation). Bioaugmentation is usually applied when it is determined that Dehalococcoides, the only microorganisms known to mediate complete dechlorination of PCE and TCE to ethane, are absent.

Florida is second only to California in the number of sites bioaugmented with KB-1®, a bioaugmentation culture containing Dehalococcoides produced by SiREM, which anecdotally may imply a greater need for microbial enhancement in Florida compared to many other states. The need for bioaugmentation at specific sites can be determined using commercial Dehalococcoides testing of groundwater.

The addition of amendments, i.e., electron donor or microbial cultures, to the subsurface in Florida is generally uncomplicated because of the high proportion of permeable sand aquifers and low depth to groundwater. The high permeability aquifers allow for the ease of introduction and dispersion of electron donors and microorganisms, which can improve the performance of bioremediation systems.

One of the most important geochemical conditions determining the success of chlorinated solvent bioremediation is the absence of dissolved oxygen. Reductive dechlorination can only occur in moderately to fully anaerobic environments. If an aquifer system is initially aerobic, additional electron donor and time are required for microorganisms to consume dissolved oxygen and achieve anaerobic conditions. Fortunately many Florida aquifers are naturally anaerobic requiring less electron donor and time to achieve suitable conditions.

Another significant geochemical advantage provided by Florida's aquifers is the relatively high groundwater temperature, ranging from 72 to 78ºF. Temperature significantly impacts the rate of microbial processes, including bioremediation. A microbiology rule of thumb is that the rate of a microbial process doubles for every 10ºC (18ºF) increase in temperature. The optimal temperature for reductive dechlorination by Dehalococcoides is approximately 85ºF, which is just slightly above the average Florida surficial aquifer groundwater temperature. All else being equal, the rate of reductive dechlorination in Florida would be approximately double the rate observed in northern states.

One of the most challenging characteristics to overcome when implementing bioremediation in Florida is the low pH of groundwater in some aquifer systems. Particularly in central Florida, aquifers high in quartz grain have a low buffering capacity and a pH typically between 5.0 and 6.0. This naturally low pH combined with the generation of organic acids during fermentation of electron donor, and hydrochloric acid production from reductive dechlorination, can cause the pH of the groundwater to decrease to below 5.0. As with temperature, pH significantly impacts the rate of microbial processes. Below pH 6.0, complete reductive dechlorination to ethene is typically not observed. Fortunately, pH neutralization of aquifers is increasingly accessible and the availability of commercial pH neutralization formulations and buffering capacity testing services further lowers technical barriers. Examples of successful use of this approach include neutralization with sodium bicarbonate at the Kennedy Space Center and calcium bicarbonate neutralization at a site near Orlando.

Another challenge in implementing bioremediation in Florida's aquifer systems is that some contain groundwater with high sulfate concentrations. Sulfate itself is not inhibitory but common sulfate reducing bacteria reduce sulfate to hydrogen sulfide, which can be inhibitory to reductive dechlorinating organisms above 70 milligrams per liter. The production of 70 mg/L H2S only requires 200 mg/L sulfate, well below concentrations at many Florida sites. The process of reducing sulfate to H2S also requires electron donor; therefore, sulfate reducing bacteria may compete with reductive dechlorinating organisms for electron donor. Management of high sulfate conditions requires higher electron donor dosing, and may require approaches to limit the impact of H2S, which can include bench scale treatability studies to assess such actions as precipitation of H2S to non-inhibitory metal sulfides.

Florida's unique groundwater environment is a "mixed bag" of advantages and challenges with respect to bioremediation of chlorinated solvents. Innate advantages including high groundwater temperatures, a preponderance of anaerobic aquifers, and favorable hydrogeologic characteristics are balanced by the challenges of low buffering capacity and pH plus high sulfate concentrations. These factors make necessary the complete evaluation of geochemical and hydrogeological properties of the aquifer before implementation of bioremediation.

Fortunately, once a site's geochemical and hydrogeological conditions are determined, analytical tools, amendments and knowledge are available to help Floridians successfully implement and optimize bioremediation.

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