Emulsified Vegetable Oil Use in Hard Water Aquifers: Implications and Strategies for Successful Substrate Distribution

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Background/objectives. Emulsified vegetable oil (EVO) has been used successfully at thousands of sites around the world for in situ bioremediation of chlorinated compounds and other contaminants of concern in groundwater. Vegetable oil is typically emulsified with surfactants that minimize interactions with the negatively charged soil particles to maximize distribution. However, EVO injection in aquifers with a high concentration of divalent cations such as calcium (Ca^{2+}) and magnesium (Mg^{2+}), commonly defined as hard water, may require some additional considerations to achieve an optimal substrate distribution. The objective of this presentation is to discuss the challenges associated with EVO injected in hard water aquifers, their causes, as well as the degree of success of the strategies utilized to overcome them.

Approach/activities. Several challenges observed during EVO distribution in hard water aquifers including suboptimal oil distribution, undesirable side reactions, fouling, and decreased phosphate availability will be discussed throughout the presentation along with their causes. A high concentration of divalent cations in groundwater affects charge distribution of both soil and EVO droplets, limiting substrate distribution due to the increased oil retention and leading to potential issues such as “cDCE-stall” (accumulation of daughter chlorinated compounds) or “biofouling” (fouling due to excessive biomass growth). Additionally, Ca^{2+} and Mg^{2+} can react with long-chain fatty acids, forming insoluble compounds such as calcium and magnesium linoleate (commonly known as soap scum) which can potentially clog injection wells and further limit substrate distribution. Divalent cations may also react with phosphate, a nutrient required for bioremediation, decreasing its availability when insoluble minerals such as hydroxyapatite are formed. The effectiveness of several strategies to overcome these issues, including using soft water for substrate dilution, utilizing chelators to limit Ca^{2+} and Mg^{2+} activity, and adding cleaning solutions such as EOS Clean to clear injection wells for reuse will be presented and evaluated.

Results/lessons learned. Hard water aquifers present some challenges that must be acknowledged when EVO is injected to remediate chlorinated compounds and other contaminants of concern. The strategies to prevent and overcome the most pressing issues have shown varying degrees of success. Chelators and soft water have moderately improved oil distribution, whereas EOS Clean has successfully dissolved soap scum and biofouling in several injection wells. Choosing the most appropriate solution will ultimately depend on the nature of the observed issues and their implications, the geochemistry of the aquifer, and the available alternatives based on budget and project demands. Understanding the possible impacts of hard water on EVO distribution and use will help users design low cost, effective injection systems and meet cleanup goals.