Catalyzed Enhanced Reductive Bioremediation

With all the injectable remediation options available, it's worth understanding the advantages *EDS-Advanced*™ provides as a catalyzed enhance reductive bioremediation technology.

Emulsified vegetable oil (EVO) slowly ferments and can act in the subsurface as an organic carbon and hydrogen source that stimulates organohalide-respiring bacteria that in turn mineralize chlorinated solvents. Indigenous microorganisms first consume and ferment EVO to generate hydrogen, fatty acids and other important nutrients and cofactors. The prevailing anaerobic conditions are ideal to reduce chlorinated solvents like PCE and TCE through dechlorination processes such as dehaloelimination. Then specialized bacteria such as *Dehaloccocoides mcCartii*, *Dehalobacter, or Dehalogenomonas* use subsurface-generated hydrogen when transforming reduced solvent compounds like 1,2-DCA, 1,1,2-TCA, cis and trans-DCE to Vinyl Chloride and innocuous Ethene.

Although emulsifying vegetable oil allowed overcoming limitations of pure vegetable oil injection and minimize field interventions by using a long-lasting electron donor, hundreds of EVO injection events over the past years has demonstrated that EVO effects are limited to the area in the immediate vicinity of the injection point. This is evident through low TOC values measured even tens of meters downgradient to injection points where only acetic acid predominates. A favorable fatty acid diversity seems to be limited to the injection points immediate vicinity (< 5 meters). Another inconvenience that becomes more evident when using permanent screened wells is biofouling. This phenomenon is typically attributed to biomass developing in the aerobic vicinity of injection wells due to hydrophobic oils creating a film (residual electron donor) that stimulates biomass growth. In many cases, biofouling or permeability losses could very well be attributed to geochemical incompatibilities between EVO and cations in the subsurface, or EVO's intrinsically high retention to soils.

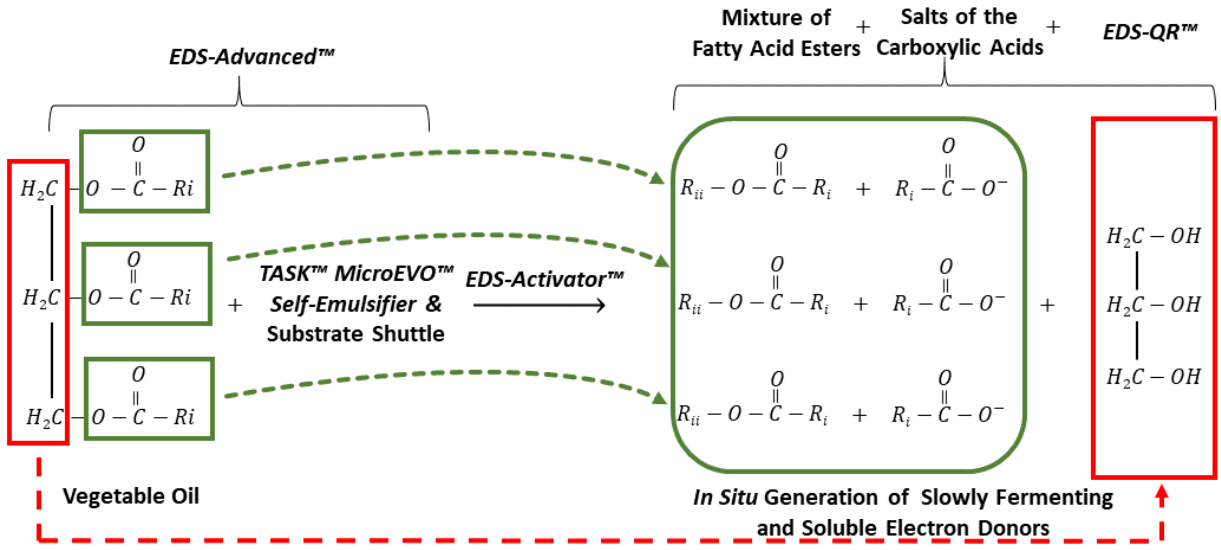
Surfactant specialists at Tersus designed *EDS-Advanced*™ (US Patent11,577,231 B2) to overcome two of the main challenges associated with EVO injection: poor fatty acid subsurface distribution and biofouling. *EDS-Advanced™* is a water-miscible, slowly-fermenting and aquifer buffering electron donor.

Shipped as a two-part system, *EDS-Advanced™* comprises:

- A water-miscible vegetable oil blended with a substrate shuttle. A substrate shuttle is a water-miscible solvent that dissolves the vegetable oil creating a solution with the distribution properties of a soluble electron donor.
- A catalyst (branded as *EDS-Activator™*) to promote the formation of fatty acid alkyl esters, carboxylic acid salts, and glycerol (*EDS-QR™*).

The addition of the substrate shuttle creates a solution that is more readily dispersible than EVO in aquifers and the subsurface by advection. An easy-to-distribute substrate such as *EDS-Advanced™* means that an injection point can create greater radii of influence (ROI) which in turns reduces the required number of injection points to adequately supply a contaminated aquifer with electron donor.

By reacting *EDS-ER*™, a water-mixable vegetable oil based organic substrate, *in-situ* with *EDS-Activator*™, a homogeneous alkaline catalyst, the fatty acids of the triglyceride molecule are cleaved to form fatty acid alkyl esters, carboxylic acids, and glycerol. The products formed *in-situ* travel far easier than EVO, add a pH buffer to the system, and leave the system less susceptible to clogging and biofouling. This allows for high volume applications with fewer injection points. Recent field work has demonstrated that *EDS-Advanced*™ can treat over 90% of the contaminant mass within the first 90 days.



Transesterification of vegetable oils, reaction of a triglyceride with a catalyst.

Advantages

- Improved subsurface distribution of a vegetable oil-based electron donor
- Improved ROI, fatty acid distribution and TOC when compared to EVO
- Eliminates dependence on EVO droplet size
- Aids in reducing cVOC inhibitory concentrations by sequestering DNAPL
- Less susceptible to clogging and biofouling

Thermally Enhanced Bioremediation

EDS-Advanced™ is also an *in-situ* bioremediation technology tailored for thermally enhanced bioremediation (TEB). This approach is a cost-effective method to address chlorinated solvent plumes and eliminate rebound. As opposed to traditional *in-situ* heating technologies (e.g., ERH, TCH), TEB is tailored to maximize natural degradation potential by targeting *in-situ* temperatures to 30°C, where biodegradation activity is maximized (Löffler et al. 2013). The addition of heat further enhances the process as the reaction temperature significantly influences the transesterification reaction shown in the above figure. By heating the injection fluids prior to emplacement, the time needed for the *in-situ* transesterification reactions drops to hours from the expected months.

Tersus Provides Site-Specific Remediation Programs and Performance Monitoring Plans To Meet Your Budget

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