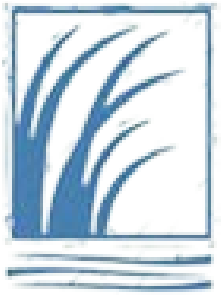
Emulsified Vegetable Oil (EVO)

What it is, how it removes nitrate, how it compares, how it's manufactured, and why and how we inject it.



Waquoit Bay National Estuarine Research Reserve

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Terra Systems INCORPORATED

What is EVO?

Emulsified Vegetable Oil (EVO) is manufactured by Terra Systems, Inc. as a micro emulsion of:

Artac Advisory - Soybeans

60% food grade soy bean oil,

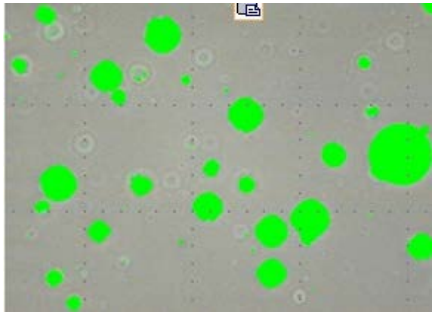
MaestroNews 2017

water,

Walgreens - Lecithin

anionic surfactant (so the EVO is sticky), and a proprietary yeast extract.

Terra Systems, Inc. - SRS®-NR



5 µm droplet size of soy bean oil for maximum soil adherence

Smart Cooky - 2017 NDTV Convergence

Ideal Application:

Nitrate removal where groundwater flowrates are greater than 0.5 ft/day, such as beach sands.

How Does EVO Remove Nitrate?

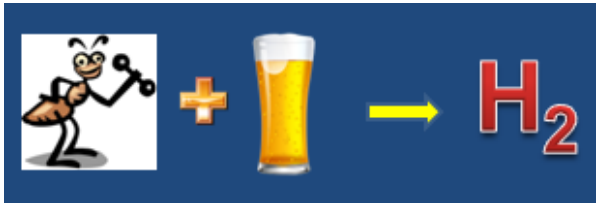
- Denitrifying bacteria are ubiquitous in the environment and use a cascade of enzymes to stepwise reduce nitrate to nitrogen gas:

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

- However, the biological reduction of a single nitrate molecule to nitrogen requires A LOT of electrons (e^-) and protons (H^+):

$$NO_3^- + \mathbf{5e^-} + \mathbf{6H^+} \rightarrow \tfrac{1}{2}\, N_2 + 3H_2O$$

- EVO, beer, whey, lactate, and molasses are all hydrogen rich substrates and excellent donors of molecular hydrogen (H_2) or electrons and protons ($H_2 \rightarrow 2e^- + 2H^+$) through fermentation:



- The fermentation of hydrogen rich substrates creates both molecular hydrogen (H_2) and low-molecular weight fatty acids such as acetate, lactate, propionate, and butyrate which in turn provide carbon and energy to the microorganisms which facilitate reductive denitrification.

How Does EVO Compare With Other Hydrogen Rich Substrates?

Substrate Comparison - Carbon Content & Molecular Hydrogen Yield

Product	Estimated Carbon Content %	Theoretical H_2 Yield (grams H_2/grams Substrate)
60% Sodium Lactate	19.3	0.054
Molasses	25.5	0.085
TSI's SRS®- NR EVO	50.5	0.232

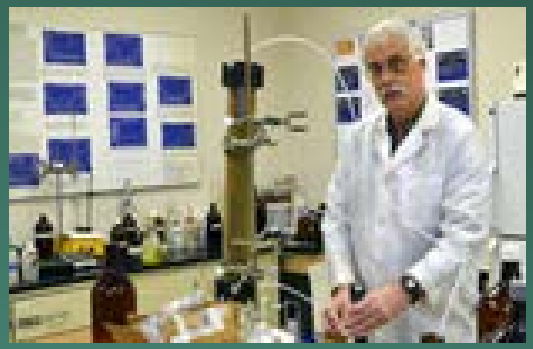
Theoretical hydrogen yield assumes complete conversion to CO_2 (carbon dioxide) and H_2 (hydrogen).

Terra Systems, Inc.'s Slow Release Substrate (SRS®) for Nitrate Removal (NR) EVO has one of the highest molecular hydrogen yields of any substrate. More molecular hydrogen means more nitrate removal.

How Does TSI Manufacture EVO?

- Terra Systems was founded in 1992 and has provided aerobic and anaerobic in-situ bioremediation solutions and laboratory analysis and treatability studies for 25 years.
- TSI manufactures its patented family of EVO formulations, including SRS®-NR for reductive dechlorination, at our plant and testing lab in Claymont, DE. Each EVO order is tailored to site specific hydrologic, geochemistry, and contaminant conditions and quality tested prior to shipment.





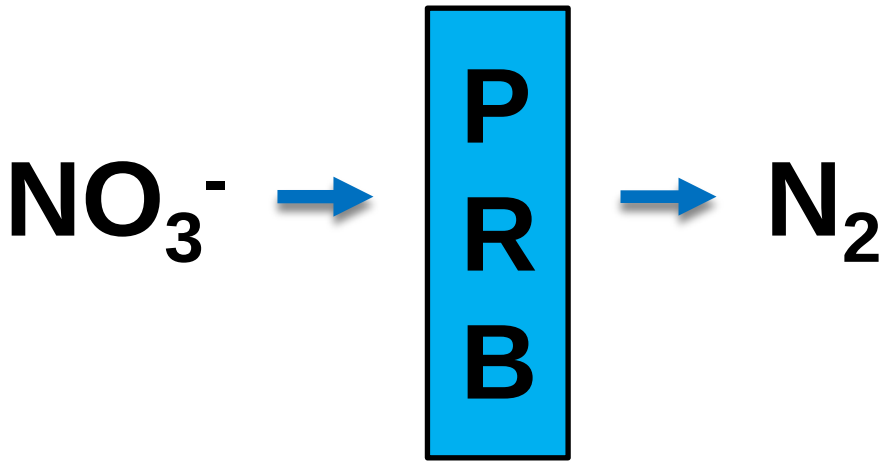
- Additionally, Terra Systems can prepare and ship EVO to your site in any quantity from 5-gallon pails, to 55-gallon drums and 300-gallon totes, to 6,000-gallon tanker trucks.



Why Do We Inject EVO?

To create Emulsified Vegetable Oil (EVO) Permeable Reactive Barriers (PRBs)

- An EVO PRB is constructed by injecting EVO into multiple points and depths creating a biobarrier capable of removing nitrate for years.
- Nitrate in groundwater passing through the EVO PRB is removed by naturally occurring bacteria.



How Do We Inject EVO?

Town of Orleans

Eldredge Park PRB Demonstration Test Site

TSI's SRS®-NR EVO delivered in totes

Pumping of diluted SRS®-NR EVO into injection borehole

Injection boreholes advanced using direct push drill rig

TSI's SRS®-NR EVO diluted with water prior to injection

(Photos courtesy of Jim Begley, LSP – MT Environmental Restoration)

Questions?

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