

# 60% SRS<sup>®</sup>-FRL Large Droplet Emulsified Vegetable Oil (EVO) Substrate for Maximum Retention

## United States Patent# RE40,448

The anaerobic bioremediation process uses native or introduced microorganisms (*Dehalococcoides*) to degrade chlorinated solvents such as tetrachloroethene (PCE) and trichloroethene (TCE) to innocuous end products including ethene and ethane. Terra Systems patented **SRS<sup>®</sup>-FRL** Large Droplet Emulsified Vegetable Oil Substrate includes an anionic emulsifier, which sticks to soil particles and is specifically designed when adherence to the formation is key to making contact with the bacteria. It is particularly useful in high groundwater flow formations such as fractured bedrock formations and is added to the groundwater to rapidly generate reducing conditions and provide the necessary carbon and hydrogen to support biodegradation of the chlorinated solvents.

**Table I: SRS<sup>®</sup>-FRL Large Droplet Emulsified Vegetable Oil Substrate Specifications**

Ingredient	Percent	Description	Benefit
Food Grade U.S. Grown Soybean Oil	60%	Terra Systems operates its own state-of-the-art manufacturing facility.	Long lasting source of carbon and hydrogen, consistent product quality, uniform droplet size, neutral pH, QA/QC lab on floor to check product before shipment.
Food Grade Sodium or Potassium Lactate	4%	Rapidly biodegradable soluble substrate	Rapidly generate anaerobic conditions
Proprietary Food Grade Nutrients	<1%	Proprietary organic and inorganic nutrients such as yeast extract, nitrogen and phosphorus.	Nutrients have been demonstrated to support the growth of the anaerobic microbial population.
Proprietary Food Grade Emulsifiers and Preservatives	7.5%	Proprietary anionic emulsifier	Maximum retention in high groundwater flow-rate aquifers
Vitamin B <sub>12</sub>	<1%	At least 250 µg/L of Vitamin B <sub>12</sub>	He et al. 2007 demonstrated Vitamin B <sub>12</sub> to be an important micronutrient to enhance dechlorination activity with 25 µg/L providing maximum stimulation
Median Oil Droplet Size (microns)	NA	5 µm	Maximum retention in high groundwater flow-rate aquifers
pH	6.5 - 7	6.5 - 7	Optimum microbial activity

**Application:** Terra Systems **patented**, nutrient enriched, proven slow release SRS<sup>®</sup>-FRL **large droplet** emulsified vegetable oil substrate with an **anionic emulsifier** is used when a long lasting carbon substrate is desired that provides maximum retention in high groundwater flow-rate aquifers. SRS<sup>®</sup>-FRL sticks to soil particles and is specifically designed when adherence to the formation is key to making contact with the bacteria.



**Customers:** SRS<sup>®</sup>-FRL is used extensively by consultants working with the Air Force, DOD, Navy, and EPA, current and former drycleaners, semiconductor plants and private firms to remediate chlorinated solvent sites and is designed for fractured rock formations, PRBs and high groundwater flow-rate aquifers. SRS<sup>®</sup>-FRL releases bio-available hydrogen over a period of 3 to 5 years thus enhancing the long-term anaerobic biodegradation of the chlorinated solvents and reducing the frequency of reinjection.

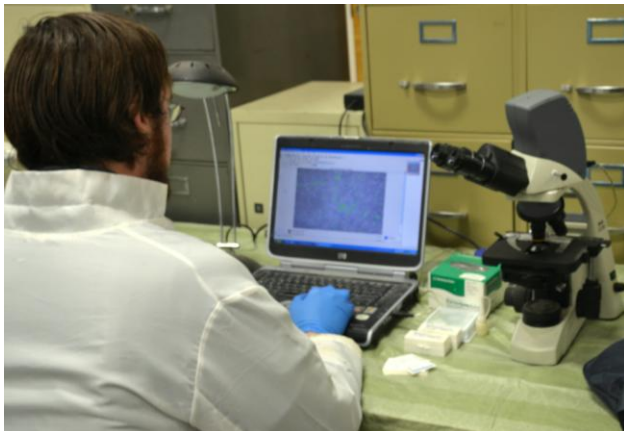
### **Manufactured vs. Field Emulsion**

In the early days of in-situ bioremediation when Terra Systems first patented the technology, it was common to bring the water, emulsifiers, oil, and other ingredients to the site and using trash or other pumps to mix the ingredients together to form an emulsion. It soon became apparent that poor emulsion consistency and a broad range of droplet sizes resulted in inadequate and uneven distribution when injected. This resulted in higher long-term costs due to higher reinjection frequency and higher substrate volumes to adequately make contact with the COC.

Don't be "*penny wise and pound foolish*".

Consider:

- ✓ The labor and equipment time and cost of mixing in the field.
  - ✓ The need to mix the nutrients and Vitamin B<sub>12</sub> longer to achieve consistency.
  - ✓ The cost of inadequate distribution due to droplet size and emulsion inconsistency
  - ✓ The inability to accurately determine if you have 100% emulsification.
  - ✓ The lack of QA/QC in the field
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- Terra Systems owns and operates a state of the art US based manufacturing plant with an in-house quality control laboratory for strict quality assurance of the emulsion, droplet size and pH.
  - SRS<sup>®</sup>-FRL arrives at the site "*injection ready*" with all the ingredients – Vitamin B<sub>12</sub>, proprietary nutrients, sodium or potassium lactate and anionic emulsifier(s) already blended together.
  - At the PM's request Terra Systems will blend 2-8 g/L of sodium bicarbonate into the SRS<sup>®</sup>-FRL during manufacturing to counter the acids produced during the fermentation process in the aquifer. This is especially beneficial for marginal pH aquifers of pH 5 – 6.



A Digital Microscope is connected to a laptop computer with proprietary "*Droplet Size Calculation Software*"

- SRS<sup>®</sup>-FRL optimizes the naturally occurring biodegradation system by supplying the rate limiting factor (in this case hydrogen) in the degradation of CVOC's, certain pesticides/herbicides, perchlorate, and immobilization of certain metals (Chromium, Arsenic, and some radionuclides).
- The **large droplet size of 5 µm** combined with the **negative surface charge** on the droplets results in a higher retention in the subsurface.
- Terra Systems holds United States Patent#**RE40,448** for the use of emulsified vegetable oil for remediation of chlorinated solvents.
- The soy bean oil is grown in the United States and provides a **slow release** biodegradable carbon source, which promotes long-term biological activity.
- SRS<sup>®</sup>-FRL comes **standard** with **biostimulating vitamins** like Vitamin B<sub>12</sub>, which He et al. 2007 demonstrated is an important micronutrient to enhance dechlorination activity.
- SRS<sup>®</sup>-FRL contains proprietary organic and inorganic nutrients such as yeast extract, nitrogen and phosphorus, which have been demonstrated to support the growth of the anaerobic microbial population.
- SRS<sup>®</sup>-FRL comes with **at least 4% sodium** or **potassium lactate** a quick release biodegradable substrate, which helps to “*jump start*” bacterial growth.
- SRS<sup>®</sup>-FRL emulsified vegetable oil substrate has been validated by the Florida DEP, California Water Board and others.
- SRS<sup>®</sup>-FRL contains only non-toxic food grade materials, which results in green, sustainable remediation.

**Packaging:** Terra Systems patented SRS<sup>®</sup>-FRL can be shipped in 5-gallon buckets, 55-gallon drums, 275-gallon IBC totes, 275-gallon cardboard totes or bulk tankers.



If the *Dehalococcoides* are not present or are in small numbers Terra Systems **TSI DC<sup>®</sup>** Bioaugmentation Culture can also be injected.

