Patented *Injection Ready* 60% SRS®-M Small or Large Droplet Emulsified Vegetable Oil (EVO) Substrate for the Treatment of Mixed Chlorinated Solvents and Metals like Chromium (Cr^{6+}) United States Patent #RE40,448

Terra Systems patented "*injection ready*" **60% SRS®-M** Small or Large Droplet Emulsified Vegetable Oil Substrate is added to the groundwater to rapidly generate reducing conditions and provide the necessary carbon and hydrogen to support native or introduced microorganisms (*Dehalococcoides*) for the biodegradation of chlorinated solvents such as tetrachloroethene (PCE) and trichloroethene (TCE) to innocuous end products including ethene and ethane and the reduction of oxidized metals like hexavalent chromium - Cr(VI), molybdenum- Mo(VI), selenium - Se(IV, VI), and uranium - U(VI) to forms that are typically less mobile and toxic.

Terra Systems SRS®-M is designed for the treatment of oxidized metals like hexavalent chromium, molybdenum, selenium, and uranium a mixed chlorinated solvent plume. SRS®-M contains a proprietary food grade reductant plus the standard ingredients of our patented 60% SRS® Family of emulsified vegetable oil substrates. The proprietary reductant reacts directly with the oxidized metals to reduce them. SRS®-M provides a readily degradable carbon (lactate) to rapidly generate reducing conditions and a long-lasting carbon source (soybean oil) to maintain the reducing conditions.

Key Communication Points

- Effectively addresses mixed plumes of chlorinated solvents and oxidized metals like hexavalent chromium - Cr(VI), molybdenum- Mo(VI), selenium - Se(IV, VI), and uranium - U(VI) by maintaining reducing conditions for up to 36 months with a single application thus "***killing two birds with one product***".
- SRS®-M acts as a reductant when applied to oxidized metal contaminated aquifers. Using SRS®-M and its breakdown products, the microbial population removes the oxygen, nitrate, sulfate and other competing electron acceptors and depresses the redox potential where the conversion and precipitation of the hexavalent chromium or other metals can be achieved. The slow release characteristics of SRS®-M allow reducing conditions to be maintained for a long period of time (up to 36 months) with a single application.
- Can be manufactured with small (0.6 μm) or large (5 μm) droplet sizes. The small droplet (0.6 μm) results in better radius of influence while the large droplet (5 um) is designed for maximum retention like PRB's, fast flowing aquifers and sites near streams or estuaries.
- Provides 73% fermentable carbon.
- Has >98% biobased content.
- Includes sodium or potassium lactate to kick-start the anaerobic degradation process, nutrients and Vitamin B_{12} a micronutrient, which *He et al. 2007* demonstrated is an important micronutrient to enhance dechlorination activity.

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- It arrives as a homogenous ***injection ready substrate***, which results in lower field labor costs from inefficient field mixing.
- SRS®-M is used extensively by consultants working with current and former semiconductor plants and private firms and the Air Force, DOD, Navy, and EPA to cost effectively remediate mixed chlorinated solvent and metals sites. For example, at a naval base in Coronado, CA, the site is contaminated with concentrations of >20 mg/L TCE and >50 mg/L hexavalent chromium. Conventional EVO supported reduction of the hexavalent chromium over 80 days in a microcosm study, but not dechlorination of the TCE after 140 days. In combination with bioaugmentation and a new formulation of SRS®-**M** with a proprietary abiotic reductant, the hexavalent chromium was reduced within one day and complete biodegradation of the TCE occurred in 35 days. Field pilot and full-scale injections showed that the combination of SRS®-M and bioaugmentation culture could reduce the hexavalent chromium completely and biodegrade the TCE to ethene.

Table I: SRS®-M Small or Large Droplet Emulsified Vegetable Oil (EVO) Substrate for the Treatment of Mixed Chlorinated Solvents and Metals like Chromium (Cr^{6+}) Specifications

Ingredient	Percent	Description	Benefit
Food Grade U.S. Grown Soybean Oil	60%	Locally sourced soybean oil.	Long lasting slow release source of carbon and hydrogen.
Proprietary Food Grade Reductant	<4%	Reductant reacts directly with oxidized metals to reduce them.	Reduction of metals like Cr^{6+} up to 95% faster than with carbon substrate alone.
Food Grade Soluble Substrate	5.5%	Rapidly biodegradable soluble substrate	Fast release source of carbon and hydrogen to 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, Preservatives and other Organics	7.5%	Proprietary nonionic emulsifier and other organics.	Maximum radius of influence due to small droplet size and nonionic emulsifier in moderate to fine sand, silt and clay aquifers.
Vitamin B_{12}	<1%	250 µg/L of Vitamin B_{12}.	He et al. 2007 demonstrated Vitamin B_{12} to be an important micronutrient to enhance dechlorination activity with 25 µg/L providing maximum stimulation.
Median Oil Droplet Size (microns)	NA	0.6 µm or 5 µm	Can be manufactured with a small (0.6 µm) droplet for maximum radius of influence in moderate to fine sand, silt and clay aquifers or a large (5 µm) droplet designed for maximum retention in PRB's, fast flowing aquifers and sites near streams or estuaries.
pH	6.0 - 7	6.0 - 7	Optimum microbial activity

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Organic Carbon (wt%)	73%		60% soybean oil and 13% from lactate, nutrients, emulsifiers and VB_{12}
Zero Carbon Footprint	0%		Certified by The CarbonNeutral Co., SRS® has a carbon neutral footprint when it arrives at the job site.
Biobased Content	98%		Certified under USDA Biopreferred Program

Injection Ready Manufactured Emulsion

Terra Systems ***Family*** of patented SRS® emulsified vegetable oil substrates

- Arrives injection ready
- Proprietary food grade reductant is premixed into the SRS® during the manufacturing process - ensuring a homogenous substrate and avoiding the additional labor cost of mixing in the field
- Nutrients are premixed into the SRS® during the manufacturing process - ensuring a homogenous substrate and avoiding the additional labor cost of mixing in the field
- Vitamin B_{12} is premixed into the SRS® during the manufacturing process - ensuring a homogenous substrate and avoiding the additional labor cost of mixing in the field
- Sodium lactate, which kick starts the anaerobic process is premixed into the SRS® during the manufacturing process - ensuring a homogenous substrate and avoiding the additional labor cost of mixing in the field
- Arrives at the site with a zero-carbon footprint
- Certified under the USDA Biopreferred Program with >98% biobased content

Result: A consistent emulsified vegetable oil substrate, which arrives *ready to inject* for maximum distribution in the aquifer.

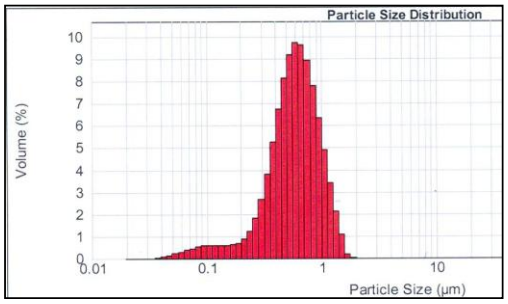
It Avoids Field Mixing and Their Hidden Costs Such As:

- The cost of inadequate distribution due to variable droplet size and emulsion inconsistency
- The inability to accurately determine if you have 100% emulsification
- The lack of QA/QC in the field

Terra Systems QA/QC

Terra Systems owns and operates a state-of-the-art US based "*just-in-time*" manufacturing plant with an in-house quality control laboratory for strict quality assurance of the emulsion, droplet size and pH. A Microscope with "***Droplet Size Calculation Software***" calculates the "***mean***" droplet size for each batch of SRS® before we transfer to a bucket, drum, tote or tanker for shipment to the customer. With every shipment, we include a QA/QC sheet for the actual batch that the customer receives. Included are:

- **Date Manufactured**: Freshly manufactured products have a longer shelf life in the field. Avoid buying substrates that have been stored for >1 month as fermentation can start and the pH will be negatively impacted.
- **pH**: We provide the pH of the product the day it is shipped
- **Droplet Size**: is a key measure of how effective the client can distribute the substrate in the sub-surface. The smaller the droplet, the more effective the distribution and ease of injection.



- **Lot#'s for all the ingredients**: This is especially useful if the driller accidentally hits a discharge pipe and the consultant needs to provide documentary evidence of what exactly was injected to the regulatory agency. All of our ingredients are GRAS (generally recognized as safe).

Packaging: Terra Systems patented SRS® Family can be shipped in 5-gallon buckets, 55-gallon drums, 275-gallon IBC totes, 275-gallon cardboard totes or bulk tankers.

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