60% SRS®-B Buffered Small or Large Droplet Emulsified Vegetable Oil (EVO) Substrate for Low pH Aquifers

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.

pH control at anaerobic sites is a key driver of success with an optimal pH range between 6.5 and 8.5. Terra Systems patented **SRS®-B** buffered Small or Large Droplet Emulsified Vegetable Oil Substrate provides the PM with several options to increase and maintain optimal pH conditions. One misconception is that knowing the pH of the water alone will lead to an appropriate quantity of buffering agent. Unfortunately in most aquifers it is the saturated soil, not the groundwater that controls the buffering capacity of the aquifer. We have seen between 76 and 99% of the buffer demand associated with the soil phase. Terra Systems patented **SRS®-B** Buffered Small or Large Droplet Emulsified Vegetable Oil Substrate includes a pH buffer to adjust the pH of acidic aquifers to optimal levels for biodegradation. The choice and quantity of buffer can be tailored to the site.

Table I: SRS®-B Buffered Small or 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 slow release 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	Fast release source of carbon and hydrogen to rapidly generate anaerobic conditions
Slow release pH buffer	1 – 15%	Adjust the pH of acidic aquifers to optimal levels for biodegradation.	Improved microbial activity and faster demonstration of dechlorination
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 nonionic emulsifier	Maximum radius of influence or retention the aquifer
Vitamin B_{12}	<1%	At least 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	Maximum radius of influence or retention the aquifer
pH	6.5 - 7	6.5 - 7	Optimum microbial activity

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Buffer Options:

Ingredient	Buffer	Reason
The pH of the groundwater is between 5-6.5, however the pH of saturated soil is not known	2 – 8 g/L of sodium bicarbonate	1. Does not exceed pH 8.4 2. Typically lowest cost 3. Relatively soluble 96 g/L at 20 C
The pH of the groundwater and the saturated soil is known (pH 5 -6)	sodium bicarbonate calcium carbonate sodium carbonate/soda ash or magnesium oxide	1. Sodium bicarbonate or calcium carbonate can raise the pH to 8.3 or 9.4 2. Magnesium oxide and sodium carbonate have higher maximum pHs of 10.5 and 11.6
The pH of the groundwater and the saturated soil is known (pH 4 - 5)	sodium carbonate/soda ash or magnesium oxide	Sodium carbonate and magnesium oxide are strong buffers, but can raise the pH too high

Recommendation: if the pH of the saturated soil is not known we recommend that a pH buffering capacity of the site's soil and groundwater be determined. We determine the quantity of several potential amendments to neutralize the acidity of the groundwater at a potential bioremediation site, which include.

1. sodium bicarbonate
2. calcium carbonate
3. sodium carbonate or soda ash
4. magnesium oxide

The objective is to select a buffering agent that can be added during the manufacturing process to help increase and maintain the groundwater pH and maintain neutral conditions needed for biological reductive dechlorination. The criteria for selecting the pH buffering agent are the following:

1. Increases the pH to between 7 and 9
2. The lowest price (either the lowest cost per unit or lower price for a larger quantity)
3. Is relatively soluble or has fine particles that can be suspended in the chase water

Application: Terra Systems **patented**, nutrient enriched, proven slow release SRS®-B **buffered** emulsified vegetable oil substrate with a **slow release buffer** is used when the aquifer pH is between 4.0 and 6.5.

Customers: SRS®-B is used by consultants working with Air Force, DOD, Navy and current and former drycleaners, semiconductor plants and private firms to cost effectively remediate chlorinated solvent sites with sub optimal pH's. SRS®-B 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.

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Terra Systems
INCORPORATED

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 mix the ingredients together to form an emulsion using pumps. 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.

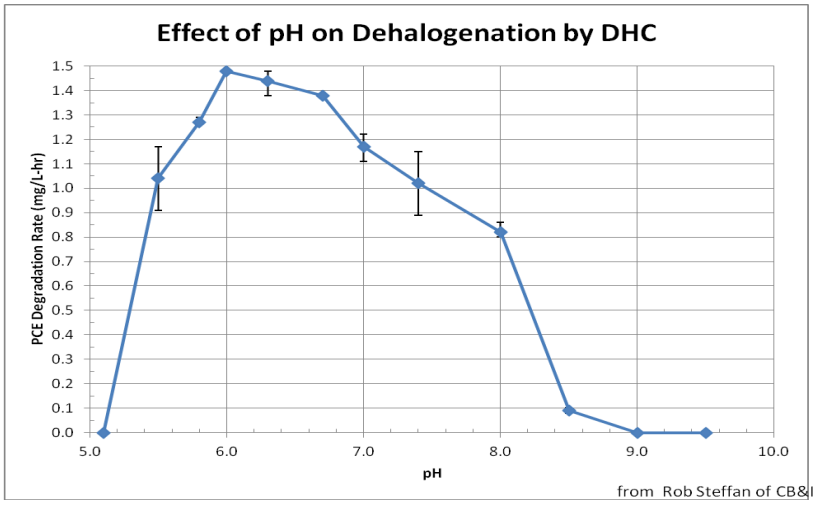
Don't be "***penny wise and pound foolish***".

Consider:

- ✓ The labor and equipment time and cost of mixing in the field.
- ✓ The need to mix the nutrients and Vitamin B_{12} 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

- 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®-B arrives at the site "***injection ready***" with all the ingredients – Vitamin B_{12}, proprietary nutrients, buffer, sodium or potassium lactate and emulsifier(s) already blended together.

Optimal microbial activity occurs between pH 5.5 and 8.5



- SRS®-B 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 (hexavalent chromium and some radionucleides).
- Terra Systems holds United States Patent #**RE40,448** for the use of emulsified vegetable oil for remediation of chlorinated solvents.

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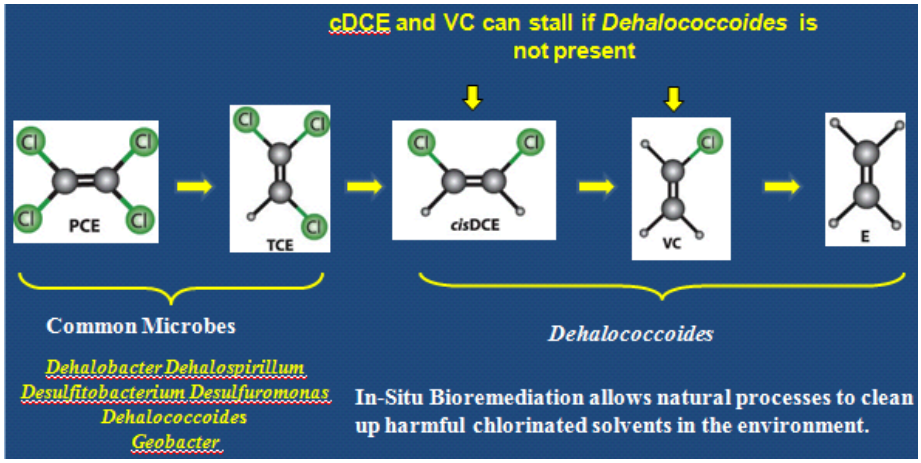
- The soy bean oil is grown in the United States and provides a **slow release** biodegradable carbon source, which promotes long-term biological activity.
- SRS®-B comes **standard** with **biostimulating vitamins** like Vitamin $B_{12,}$ which He et al. 2007 demonstrated is an important micronutrient to enhance dechlorination activity.
- SRS®-B 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®-B comes with **at least 4% sodium** or **potassium lactate** a quick release biodegradable substrate, which helps to "*jump start*" bacterial growth.
- SRS®-B emulsified vegetable oil substrate has been validated by the Florida DEP, California Water Board and others.
- SRS®-B contains only non-toxic food grade materials, which results in green, sustainable remediation.

Packaging: Terra Systems patented SRS®-B 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®** Bioaugmentation Culture can also be injected.



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