Advances in Electron Donor Amendments

Tersus Environmental

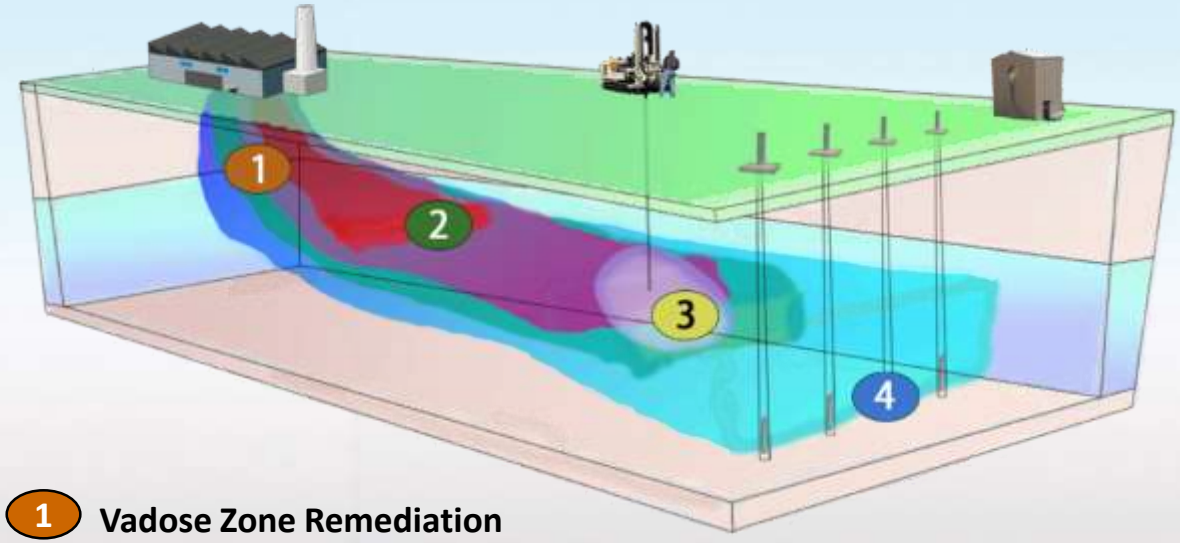
Presented by Gary M. Birk, P.E.

2018

Soil and groundwater remediation of:

For every zone of your plume, we've got you covered!

- Chlorinated Solvents
- Petroleum Hydrocarbons
- NAPL Recovery



1 **Vadose Zone Remediation**

2 **Saturated Zone NAPL Treatment**

3 **Dissolved Contaminant Anaerobic Remediation**

4 **Dissolved Contaminant Aerobic Remediation**

plus **Implementation and Monitoring Systems**

How Does Bioremediation Work?

For every zone of your plume, we've got you covered!

+

+

Electron Donor (Food)

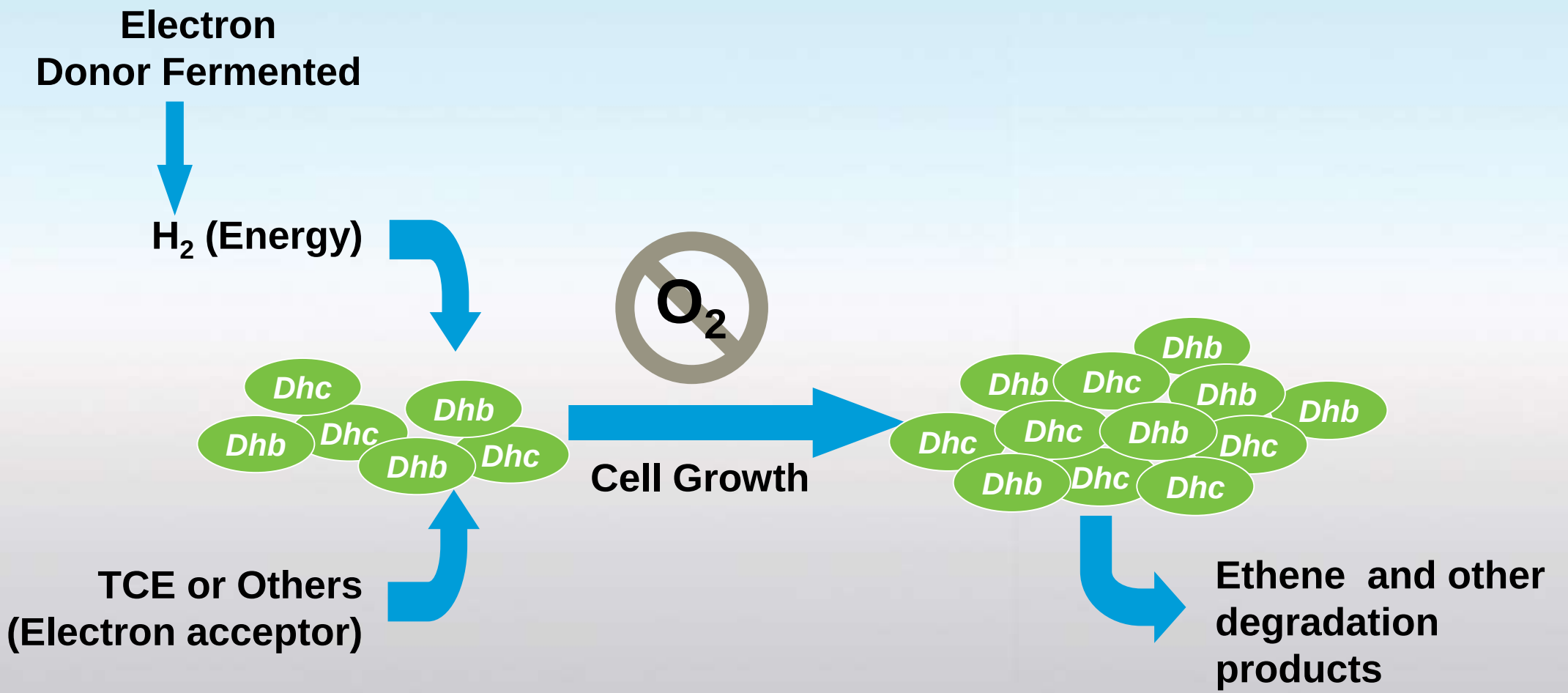
Electron Acceptor (something to breathe) [O_2, NO_3, SO_4, TCE, etc.]

Waste Products [CO_2, N_2, FeS_2, Cl^-]

Energy

(Drawing Modified from AFCEE and Wiedemeier)

Biological Reductive Dechlorination

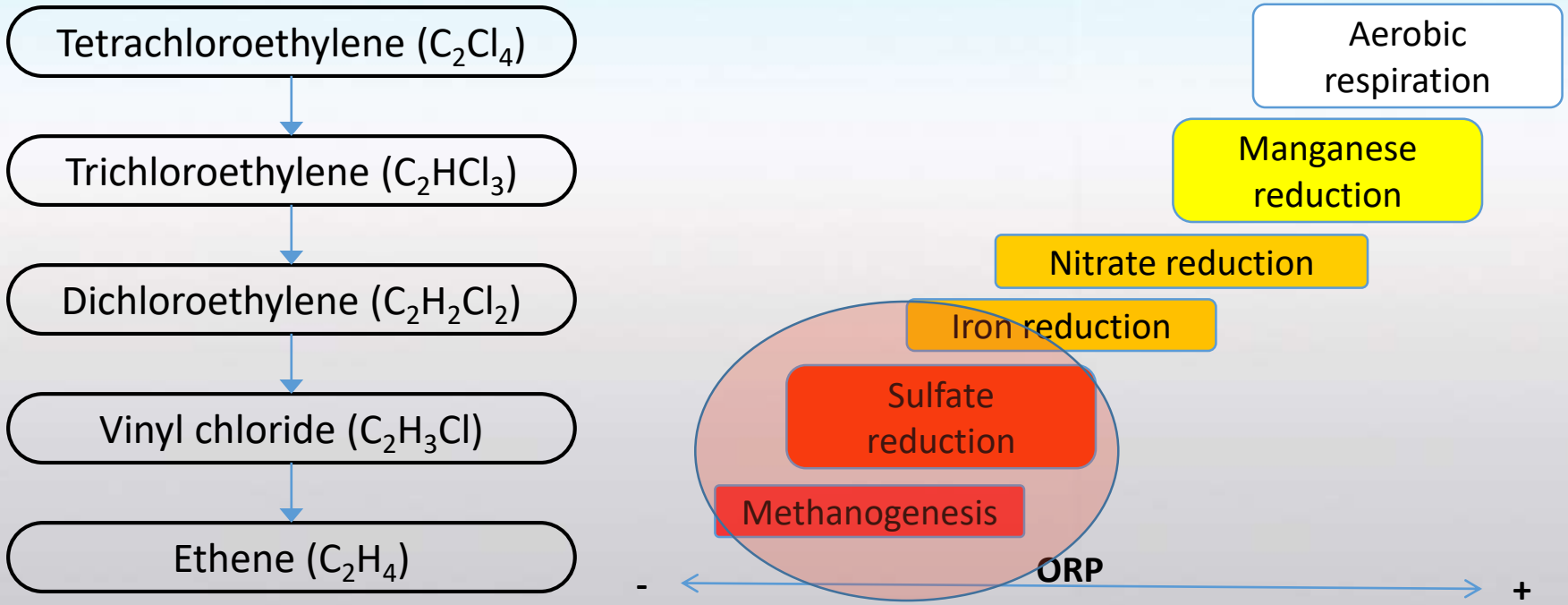


Slide Courtesy of SiREM

Bioremediation Mechanisms

For every zone of your plume, we've got you covered!

- **Anaerobic Reductive Dechlorination**



Modified from USGS WRI 99-2485

What is Needed for Effective Anaerobic Bioremediation?

- Organic substrates that ferment to:
  - Acetate
  - Hydrogen (H_2)
  - Hydrogen concentrations > 1 nM

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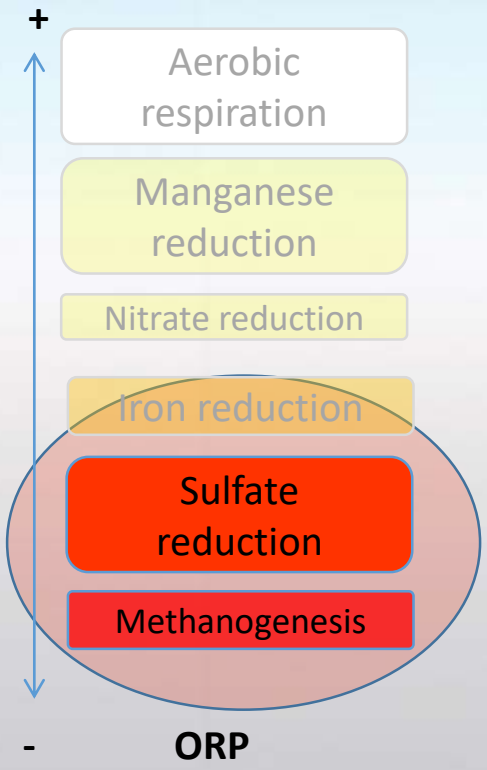
- Strongly reducing conditions
  - Sulfate Reducing or Methanogenic



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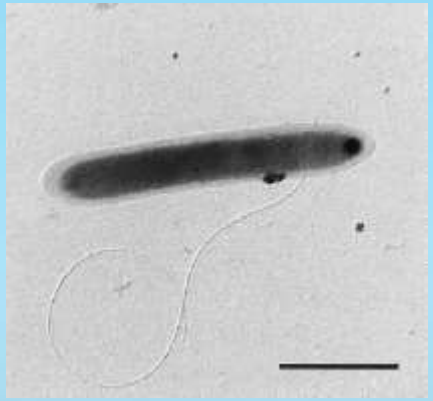
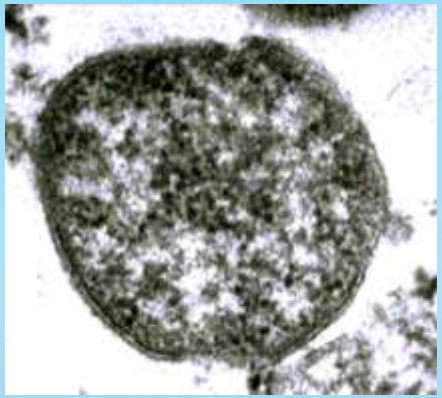
- Right halorespiring bacteria
  - *Dehalococcoides* for DCE / VC



Dehalobacter restrictus



Dehalococcoides mccartyi Strain 195

Dhc = *Dehalococcoides*
Dhb = *Dehalobacter*
Other = Desulfitobacterium, sulfurospirillum, Clostridium

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- Strongly reducing conditions
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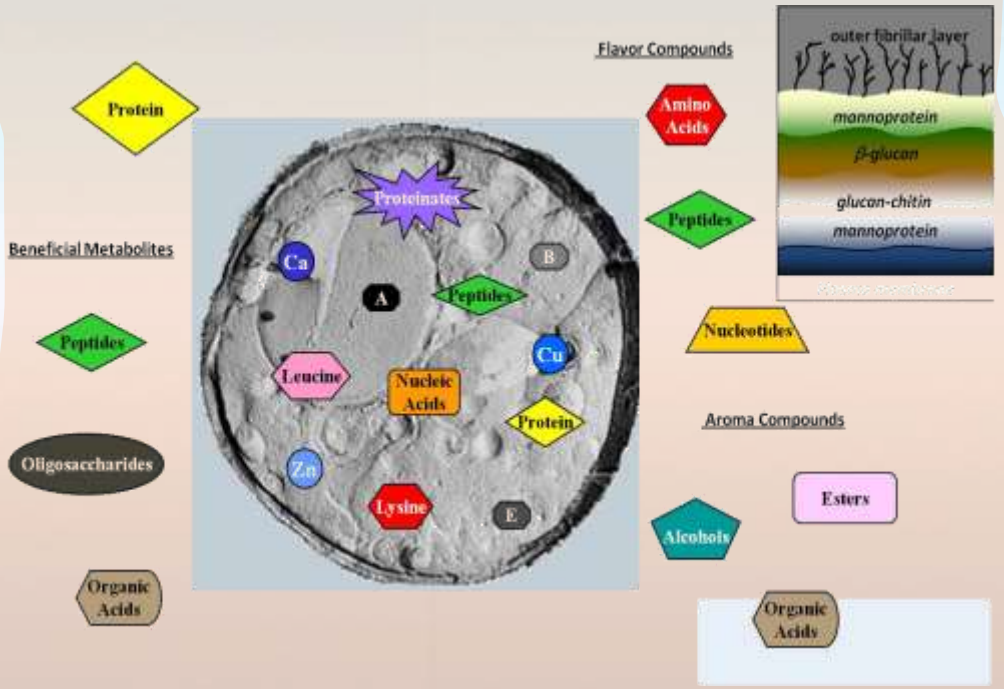
- Right halorespiring bacteria
  - *Dehalococcoides* for DCE / VC
- Nutrients
  - Vitamins and trace minerals to stimulate *Dehalococcoides* growth



Electron Donors

- Average Composition and Electrons Released during Anaerobic Fermentation

Electron Donor	Atoms per Mole Substrate			Average Molecular Weight	H2 Released per mole Substrate	Moles H2 released per gram substrate
	Carbon	Hydrogen	Oxygen			
Acetate	2	4	2	60.1	4	0.0666
Lactate	3	6	3	90.1	6	0.0666
Glucose	6	12	6	180.2	12	0.0666
Soybean Oil	56.3	99.5	6	873.1	156.5	0.1792

ESTCP, May 2006

Anaerobic Fermentation

- **Soybean oil ferments to acetic acid and hydrogen**

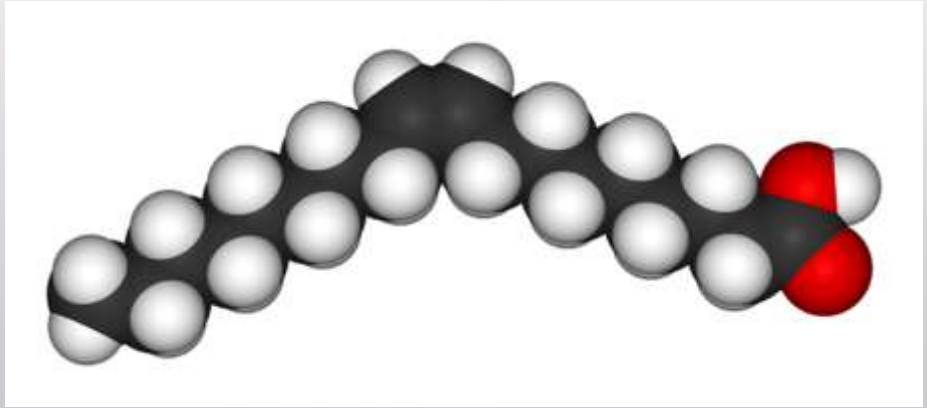
$C_{56}H_{100}O_6$ *(soybean oil[1])* + 50 H_2O -*B*->

-*B*-> 28 CH_3COOH *(acetic acid)* + 44 H_2

[1]Represents weighted average of constituent fatty acids and glycerol.

Soybean Fatty Acid Distribution

Fatty Acid		Percent
C-16:0	Palmitic	11.0 %
C-18:0	Stearic	4.0 %
C-18:1	Oleic	24.0 %
C-18:2	Linoleic	54.0 %
C-18:3	Linolenic	7.0 %



Why choose an EVO?

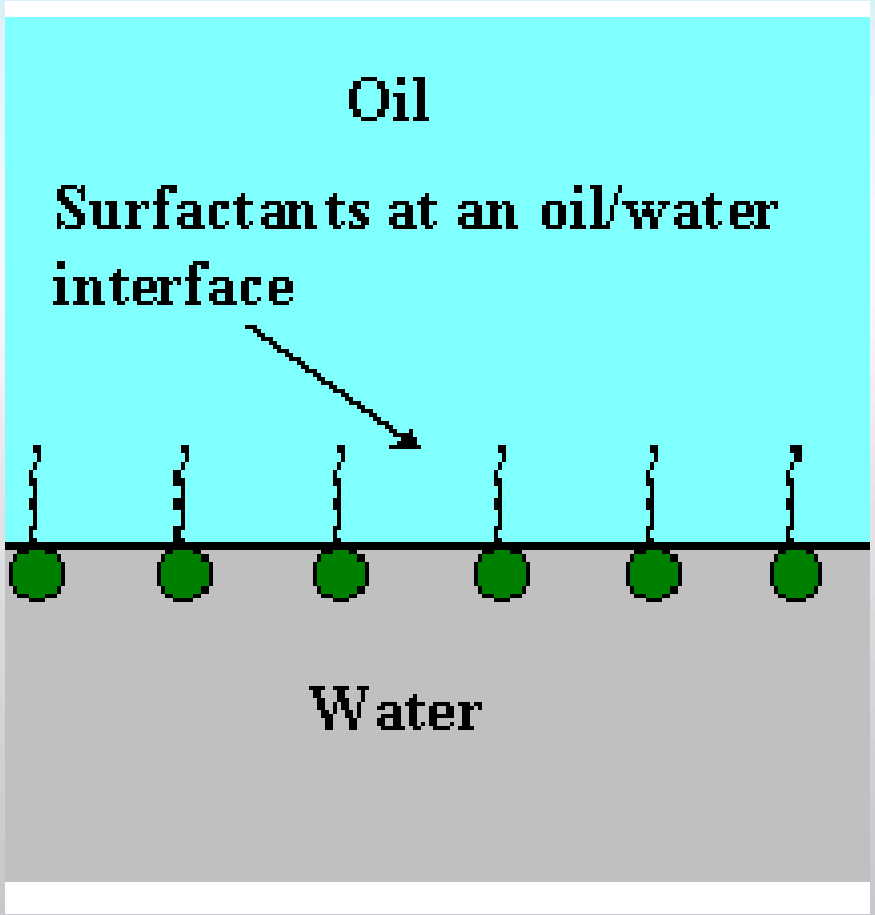
For every zone of your plume, we've got you covered!

- **Easily dispersed with groundwater**
  (Oil-in-water emulsions are miscible with water)
- **Low permeability loss**
- **Easy to implement**
- **Non-Toxic food-grade substance**
- **Limited chlorinated solvent sequestration**

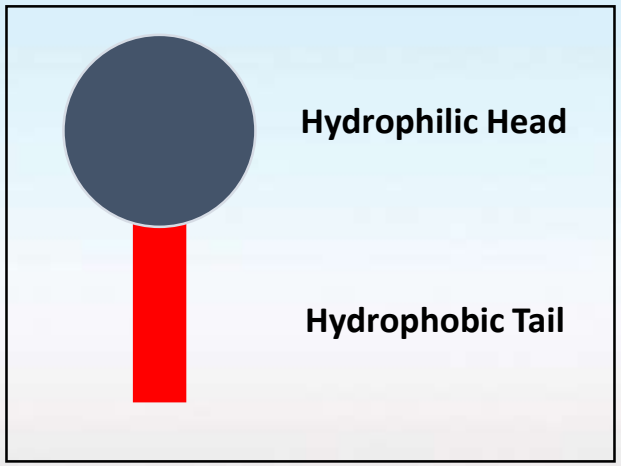
Oil in water emulsion, EDS-ER

What is a surfactant?

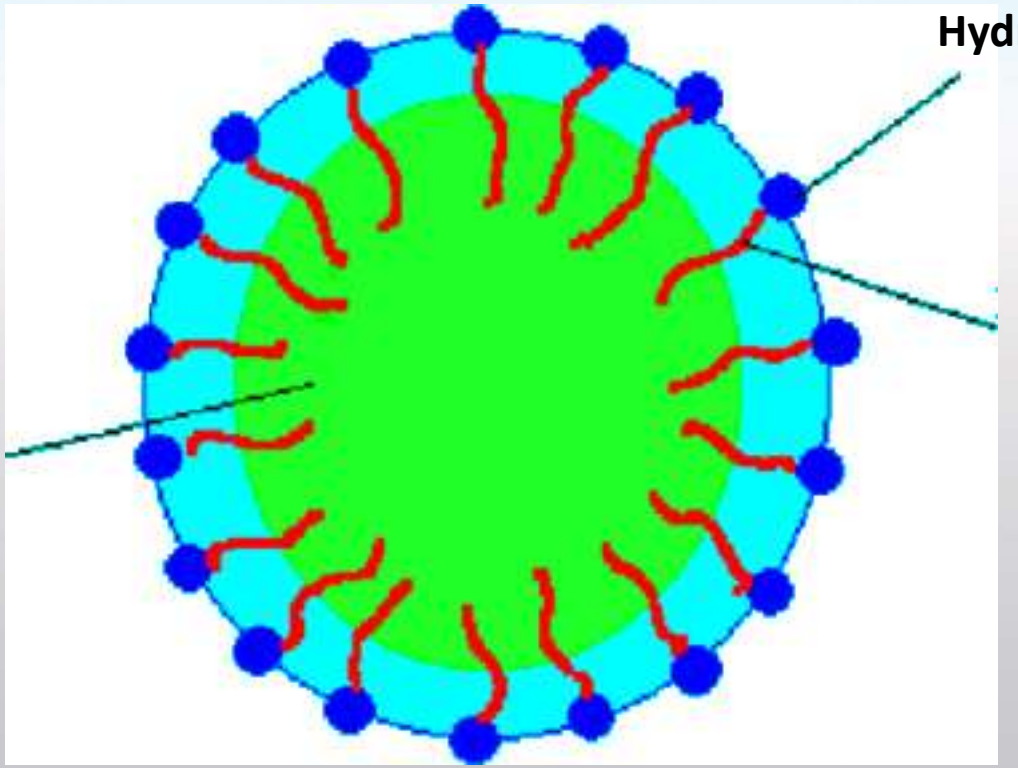
- Molecule fits between oil and water
- Common and safe
- Found in
  - Salad dressing
  - Toothpaste
  - Mouthwash
  - Shampoo
- Must contact NAPL to work



Emulsifying Agents



Aqueous Liquid
(Continous Phase)



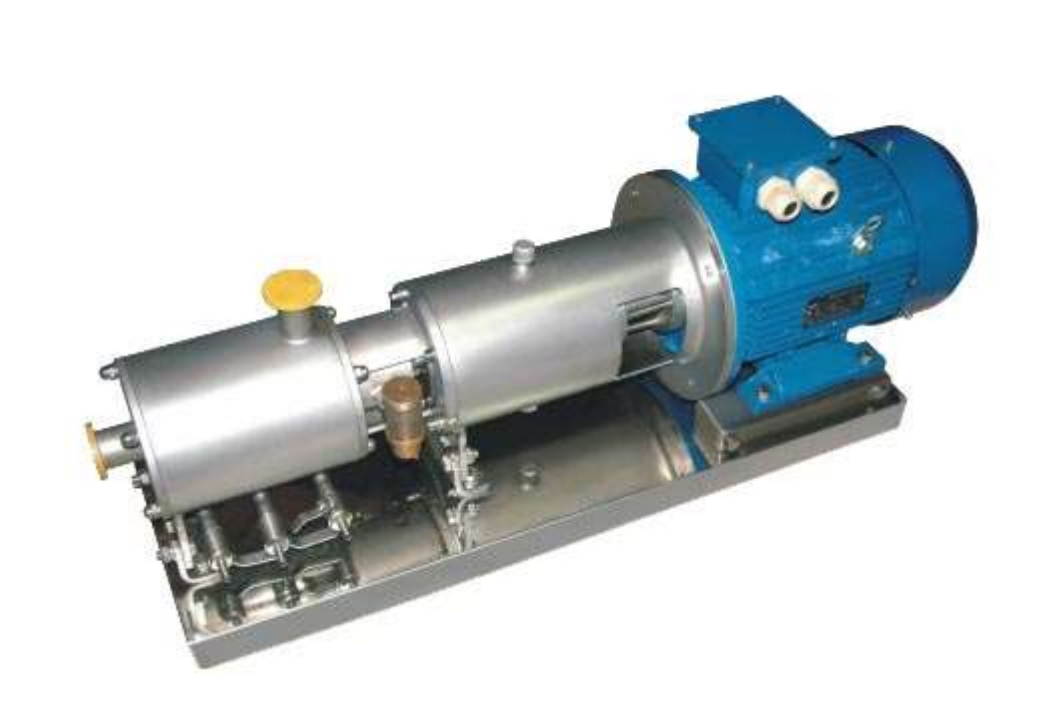
Hydrophilic Head

Hydrophobic Tail

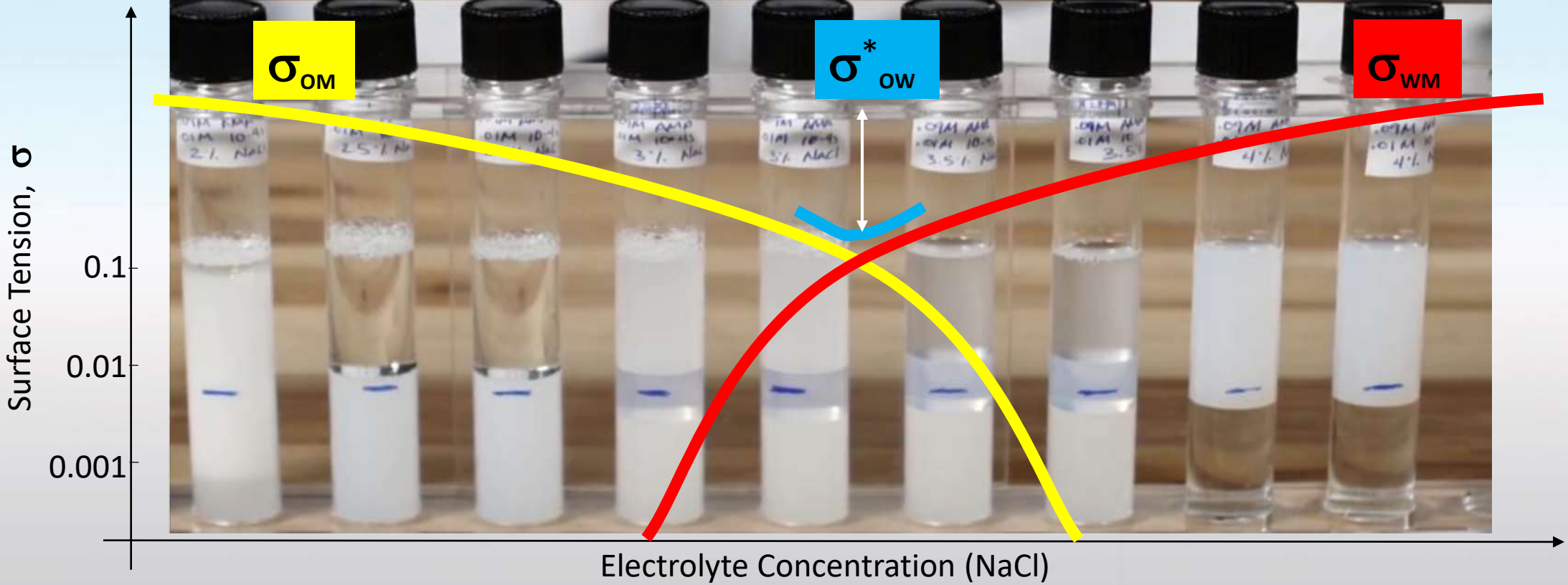
Vegetable Oil
(Dispersed Phase)

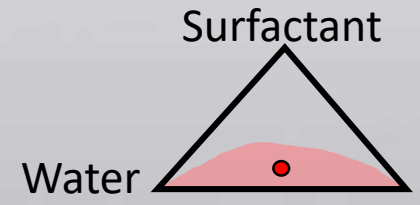
High Energy Shear Mixing

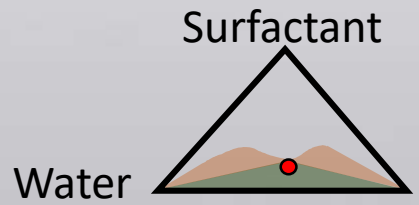
For every zone of your plume, we've got you covered!

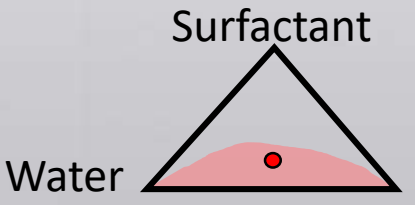


Surfactant-Oil-Water Systems Phase Behavior









Electron Donors

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“Greening” the cleanup

For every zone of your plume, we’ve got you covered!

- **EDS-ER:**
  - ✓ Eliminates Mechanical Energy inputs
  - ✓ Allows Bulk Storage (long shelf life) and intermodal transportation
  - ✓ Reduces need for excess drums and totes

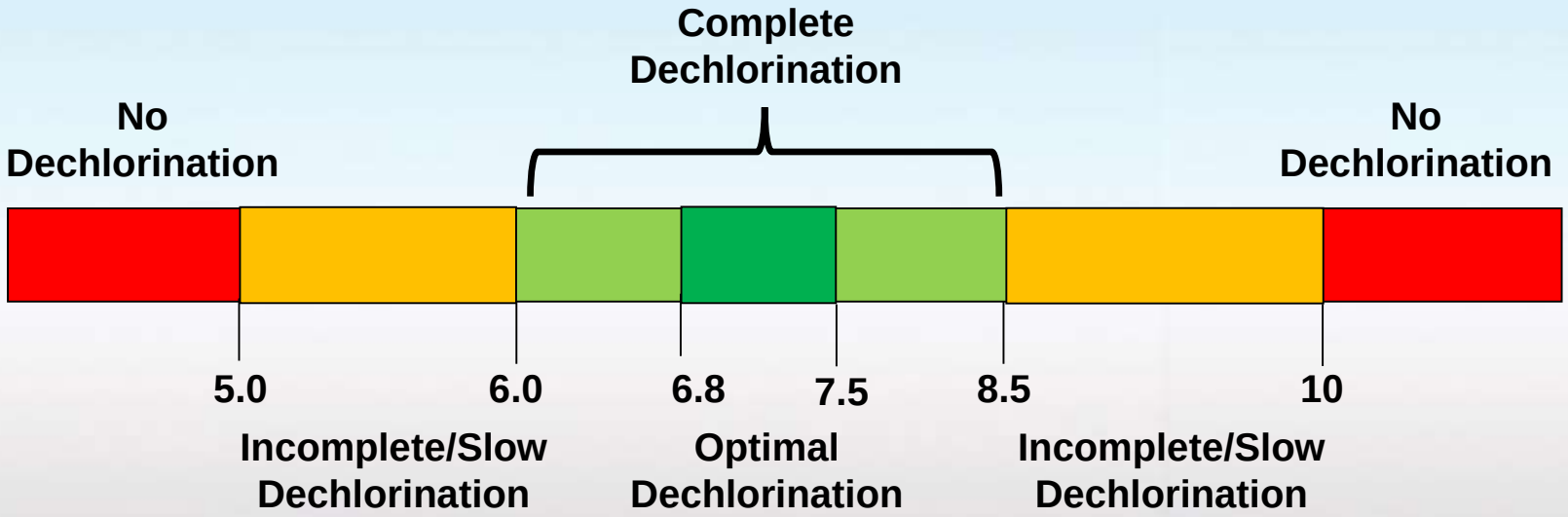
- TASK™ EVO Self-Emulsifier
  - ✓ Easy Field Mixing
  - ✓ Source Local Soybean Oil
  - ✓ Reduced Carbon Footprint

Field Mixing

- 7% TASK™ EVO Self-Emulsifier
- 93% RBD Soybean Oil

Impact of pH on Dechlorination

For every zone of your plume, we've got you covered!

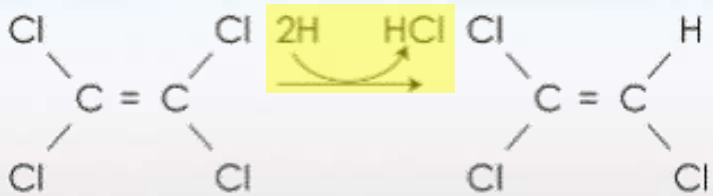


- pH of 6.0-8.5 is generally required for dechlorination to ethene*
- pH 6.8-7.5 is considered optimal range, 7.5 is best*
- Sites with low pH more likely to accumulate cDCE/VC

***Rowlands, 2004 (Slide Courtesy of SiREM)**

Why is low pH so Common?

- Some sites have intrinsic groundwater pH in the 5.0-6.0 range
- Reductive dechlorination produces hydrochloric acid



- Fermentation of **many** electron donors produces acidic by products such as acetic acid

Lactic Acid $\longrightarrow$ $2H_2$ + Acetate + CO_2

+ CO_2 dissolves in water forming carbonic acid

Acid Generation During Bioremediation

Slide Courtesy of SiREM

Ethene Production using KB-1® and Low pH KB-1® Plus at pH 6.0 and pH 7.0

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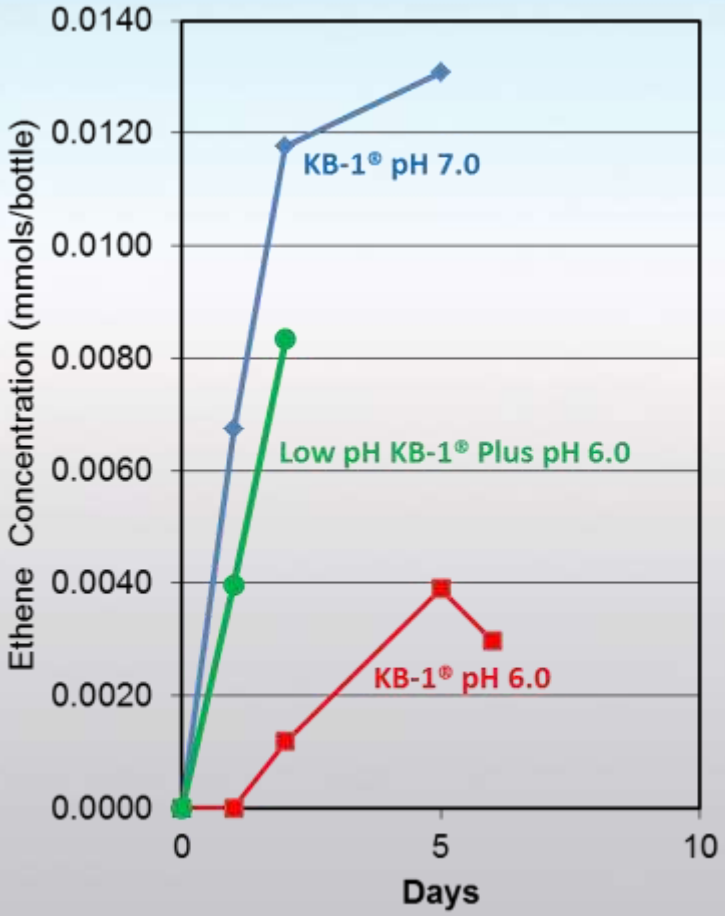

Ethene production rate of low pH KB-1® Plus is 5 times higher than standard KB-1® at pH 6.0

Slide Courtesy of SiREM

Site Evaluation

For every zone of your plume, we've got you covered!

- Options, Purpose & Due Date
- Tell Us About Your Site
  - Controlling Contaminant
  - Project Approach
  - Treatment Zone Physical Dimensions
  - Treatment Zone Hydrogeologic Properties
  - Aquifer Geochemistry
  - Natural Attenuation Parameters (not all applicable for each site)

Field Application

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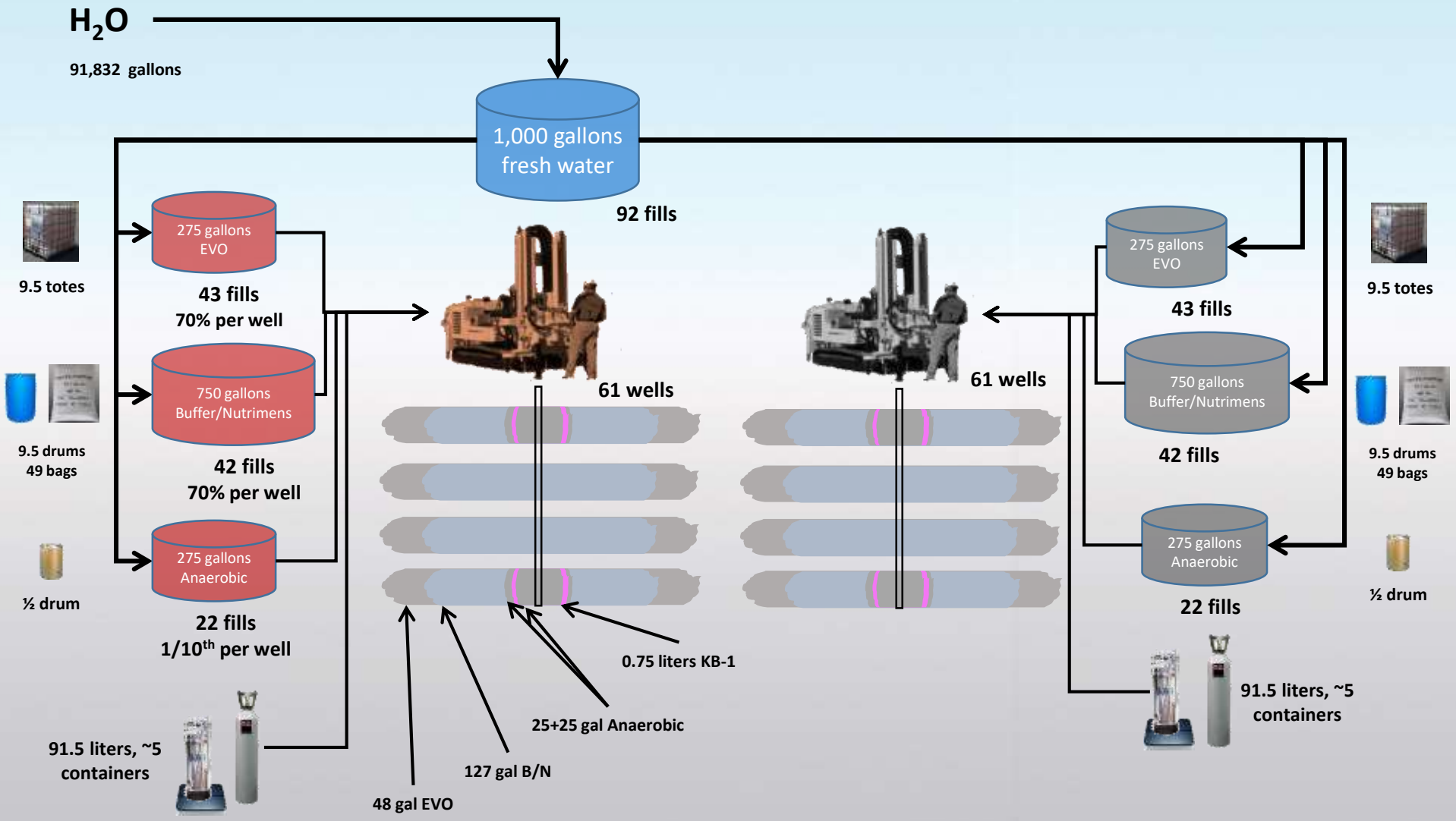
Project Approach



tersusenv.com

Thank You!

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