Optimizing in situ Remediation Amendments Using Innovative Surfactant System Formulations

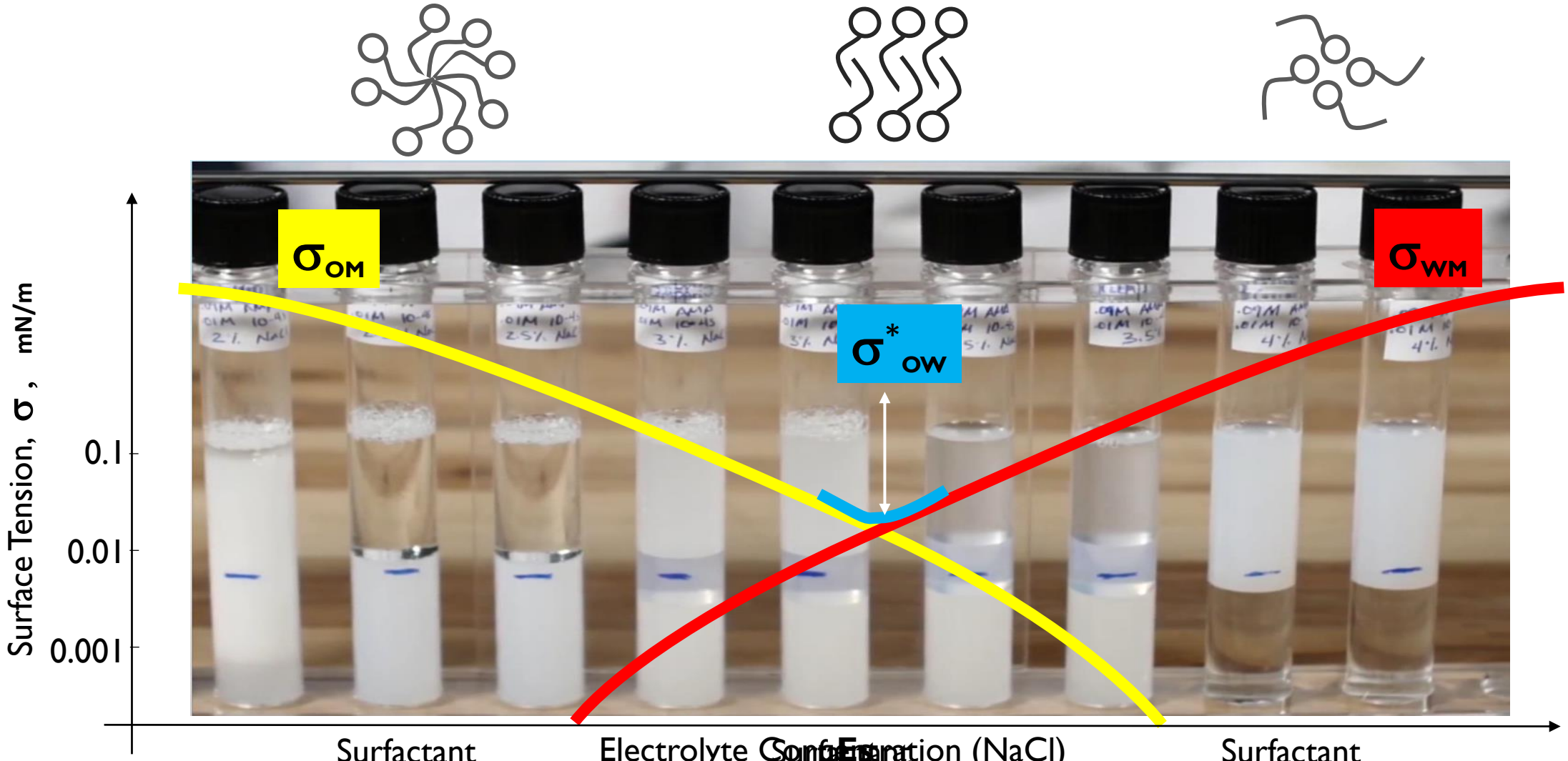
David Alden, P.E.

Tersus Environmental

You apply surfactants to **mobilize NAPL**.

Hydraulic control is imperative during injection and extraction process.

SOW Phase Behavior



$$\mathrm{HLD} = \ln(S) - k \cdot \mathrm{EACN} + C_c - a_T(T - 25°\mathrm{C}) + f(A)$$

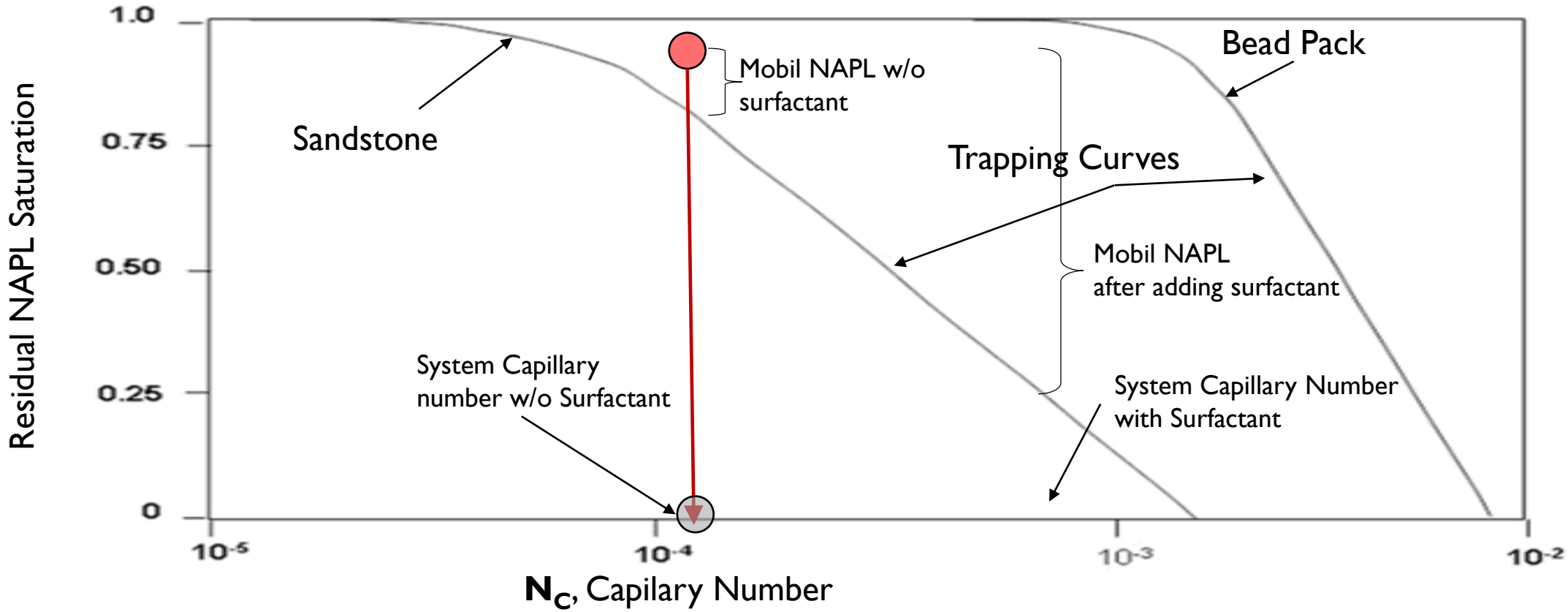
$$\textbf{\textit{Capillary Number}}\ N_C = \frac{\mu v}{\sigma}$$

μ = fluid viscosity

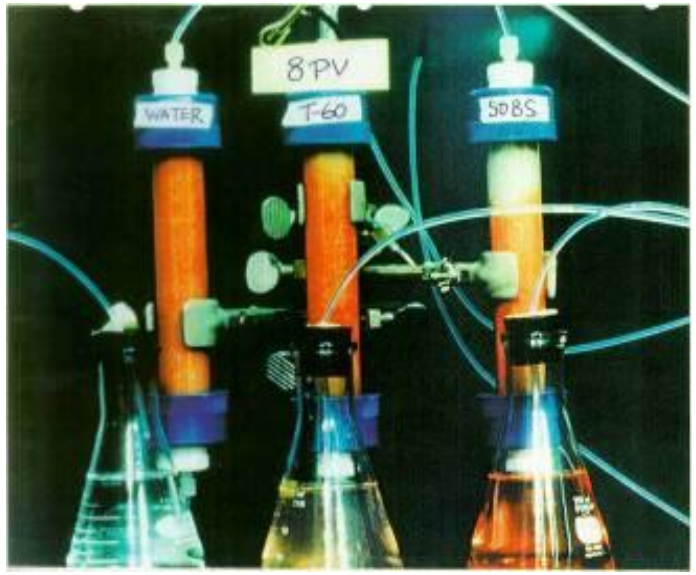
v = fluid velocity

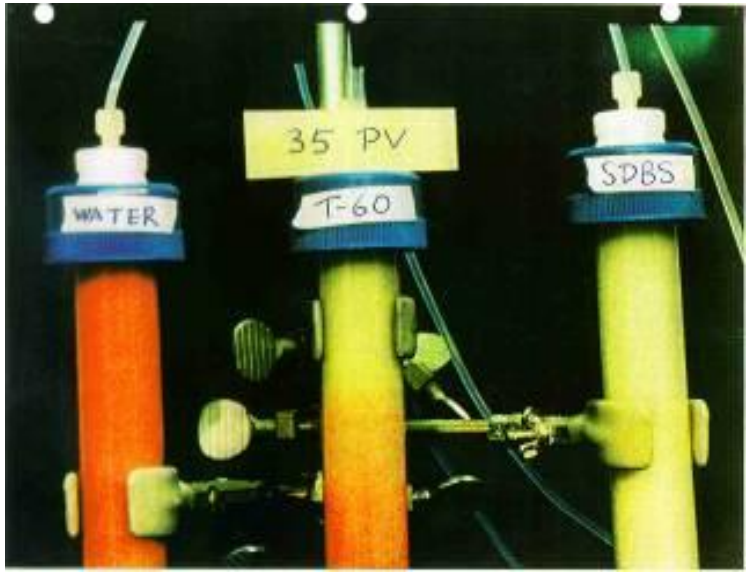
σ = surface tension

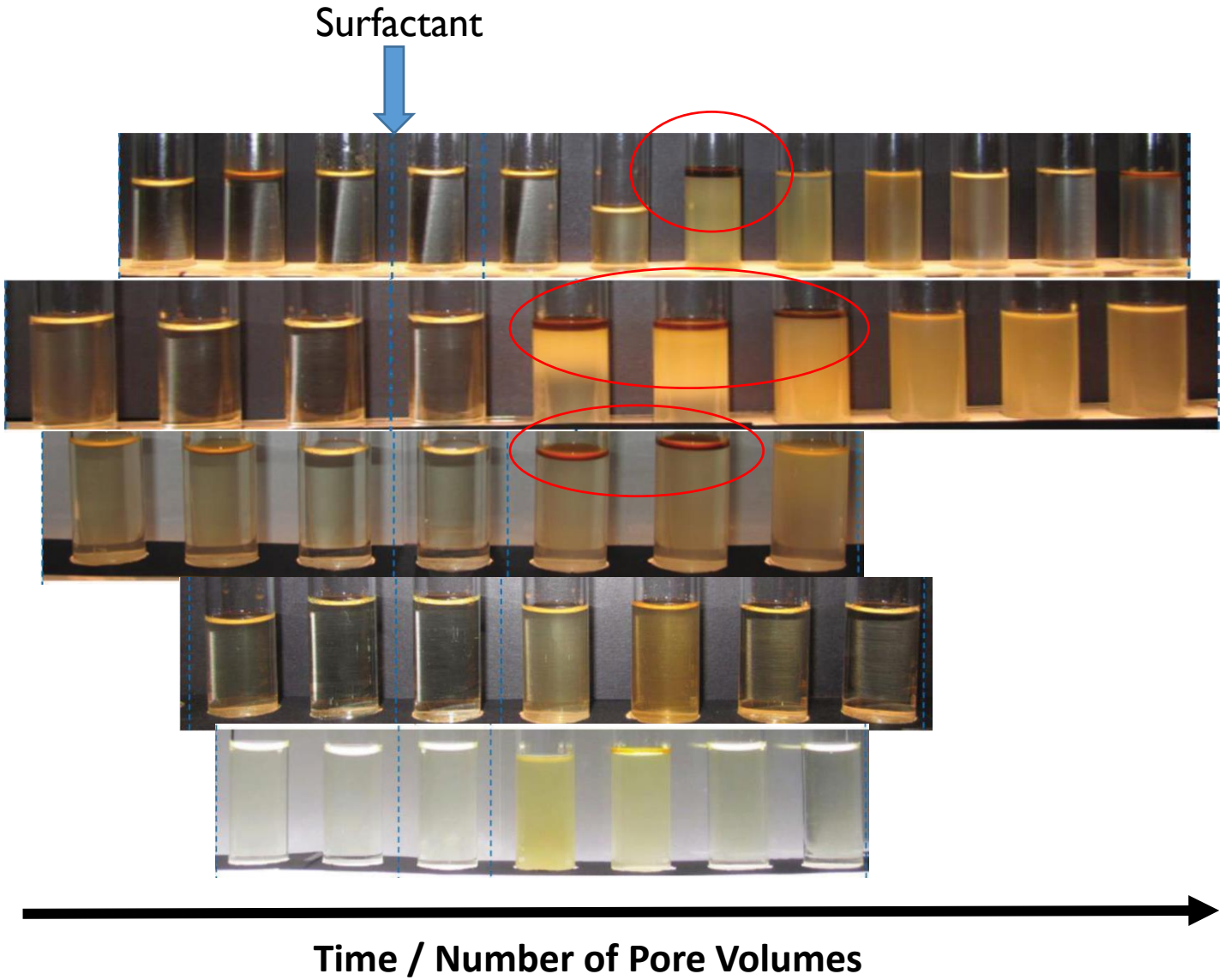
σ = 30	mN/m	w/o surfactant
σ = 2	mN/m	with a synthetic detergent
σ = 10^{-3}	mN/m	optimized



Optimized Formulation







Surfactant	# PV	Recovered NAPL
Tersus (1.6%)	1.0	93%
Tersus (1.6%)	1.5	92%
Brand X (4%)	1.0	59%
Brand Y (4%)	1.0	48%
Brand Z (4%)	1.0	18%

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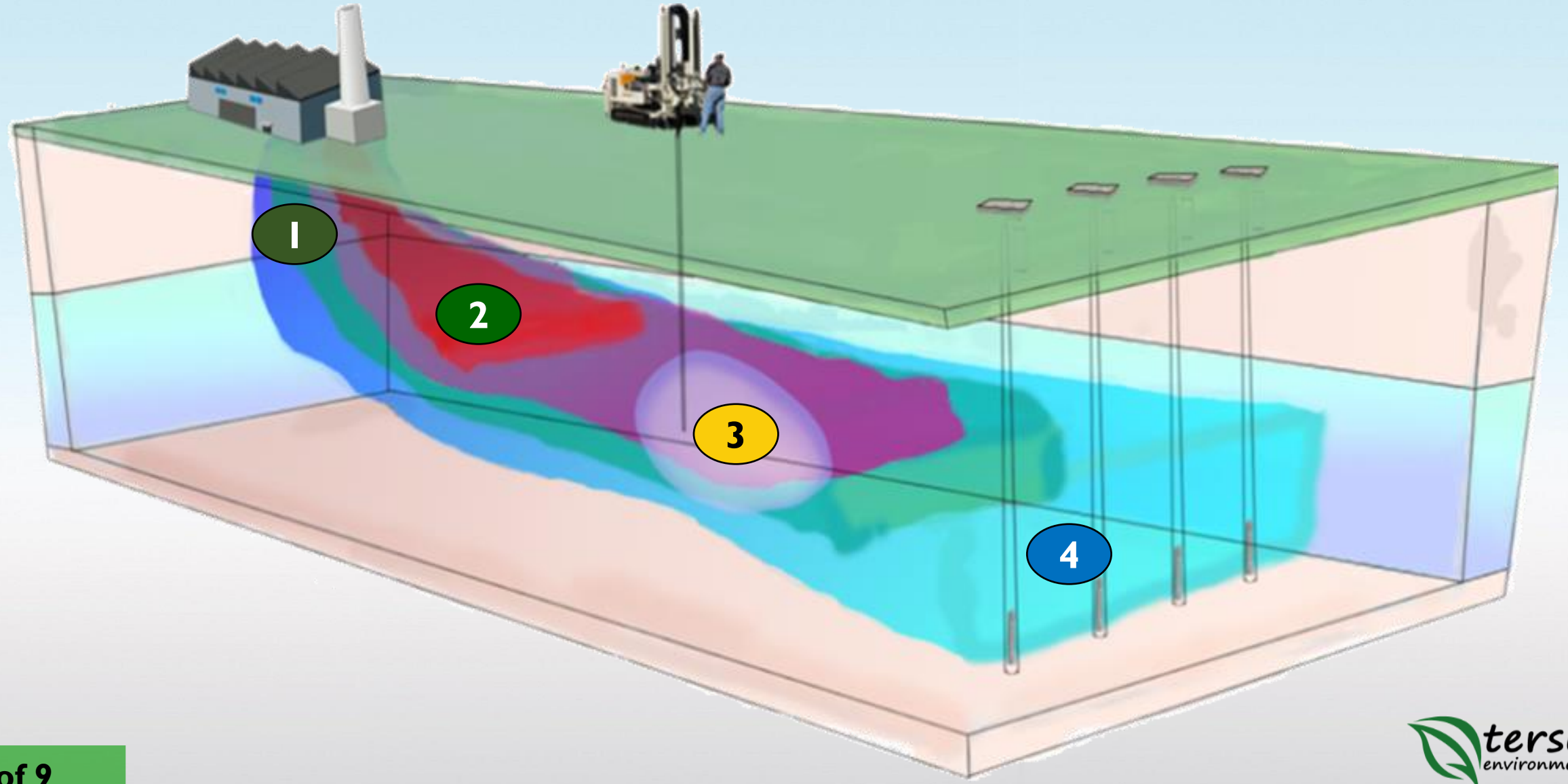
Other Amendments That Use Surfactants



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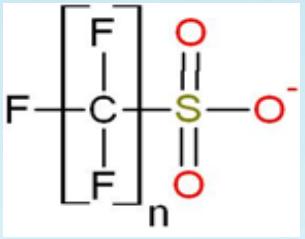
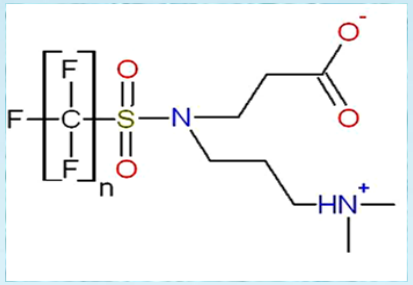
- PFOS
- PFOA
- 6:2 FtS
- 8:2 FtS
- PFOSA
- N-Me-FOSA
- N-Et-FOSA
- N-Me-FOSE
- N-Et-FOSE
- PFBS
- PFHxS
- PFDcS
- PFHxA
- PFHpA
- PFNA
- PFDcA
- PFUnA
- PFDoA
- PFTriA
- PFTeA

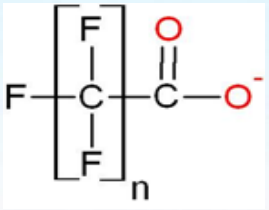
Perfluoroalkyl Sulfonates (n = 2-10)



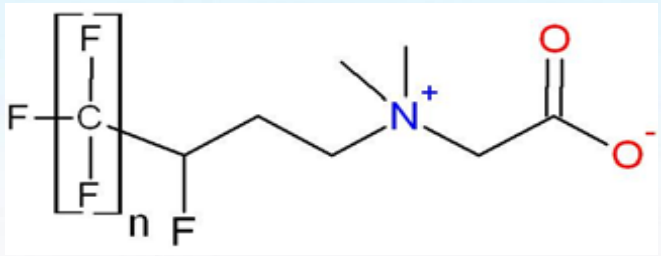
Perfluoroalkyl Sulfonamide Amino Carboxylates (n = 3-8)

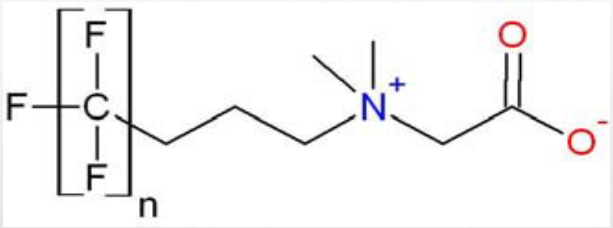


Perfluoroalkyl Carboxylates (n = 2-13)

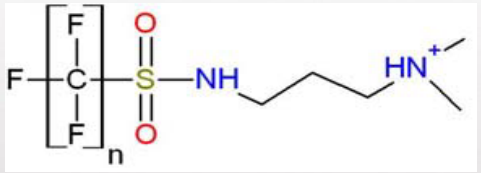


Fluorotelomer Betaines (n = 5,7,9)

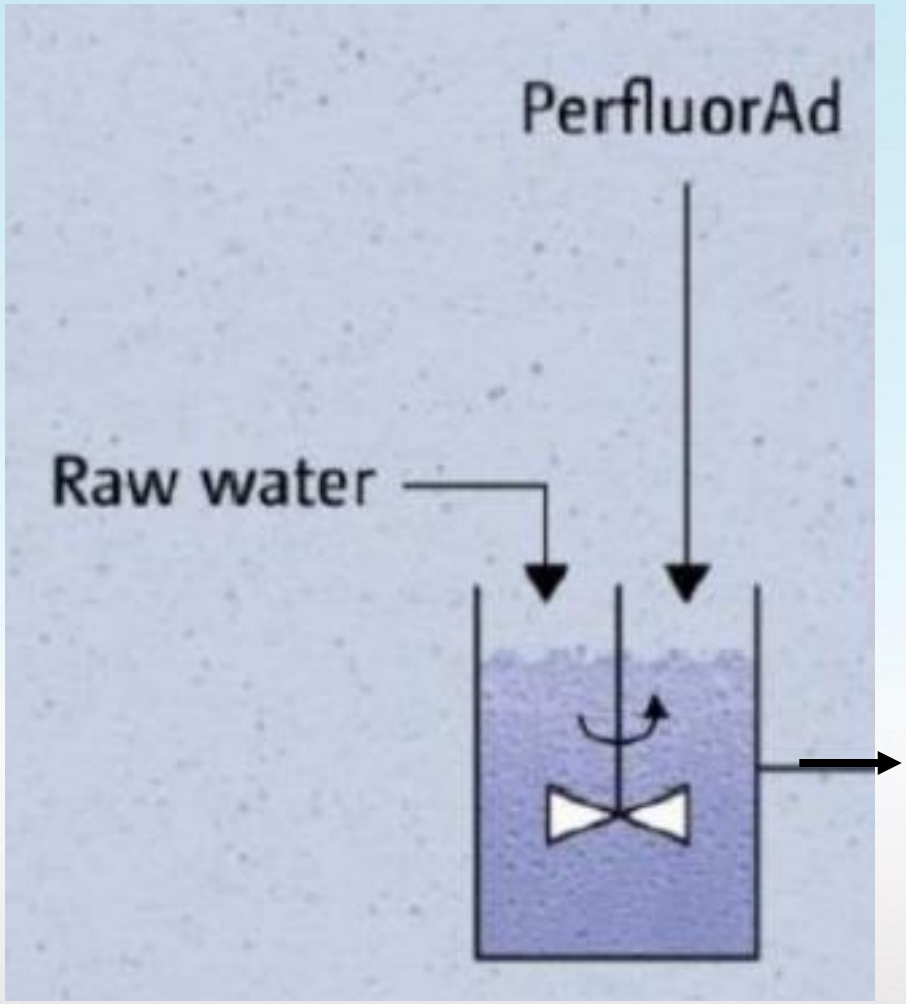




Perfluoroalkyl Sulfonamido Amines (n = 3-8)



PFAS in AFFF Formulations and Groundwater
Jennifer A. Field, Ph.D., April 2015



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EDS-ER

EDS-ER:

- Eliminates Mechanical Energy Inputs
- Allows Bulk Storage (long shelf life) and Intermodal transportation
- Reduces Need for Excess Drums and Totes
  – and required energy to recycle them

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ZVI-Micrometal

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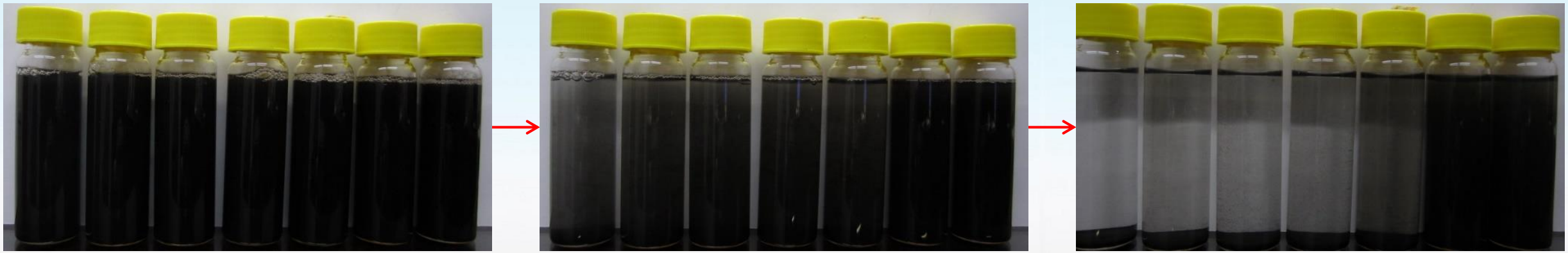
In Situ Amendments

Proppants

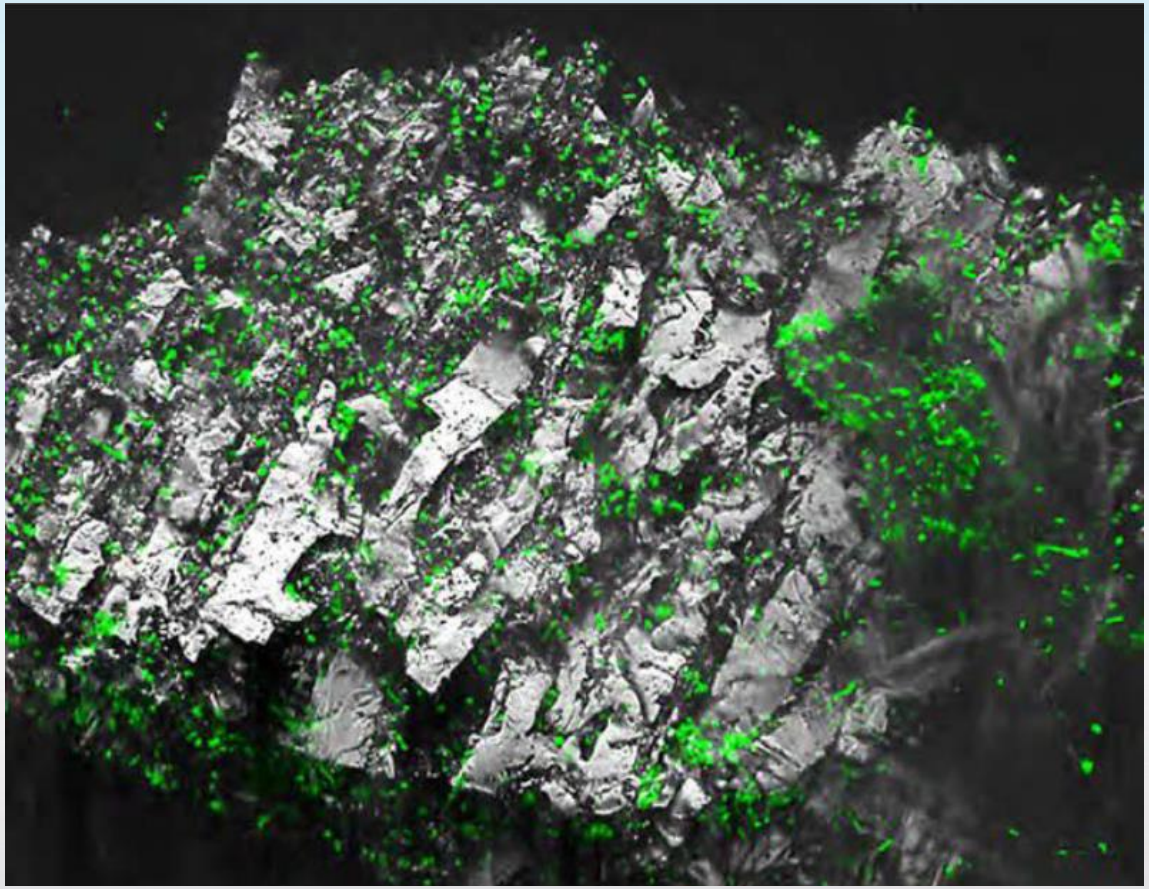


T = 0

30 mins

1 day

Proppants



Kjellurup et al., 2013 SERDP ER2135

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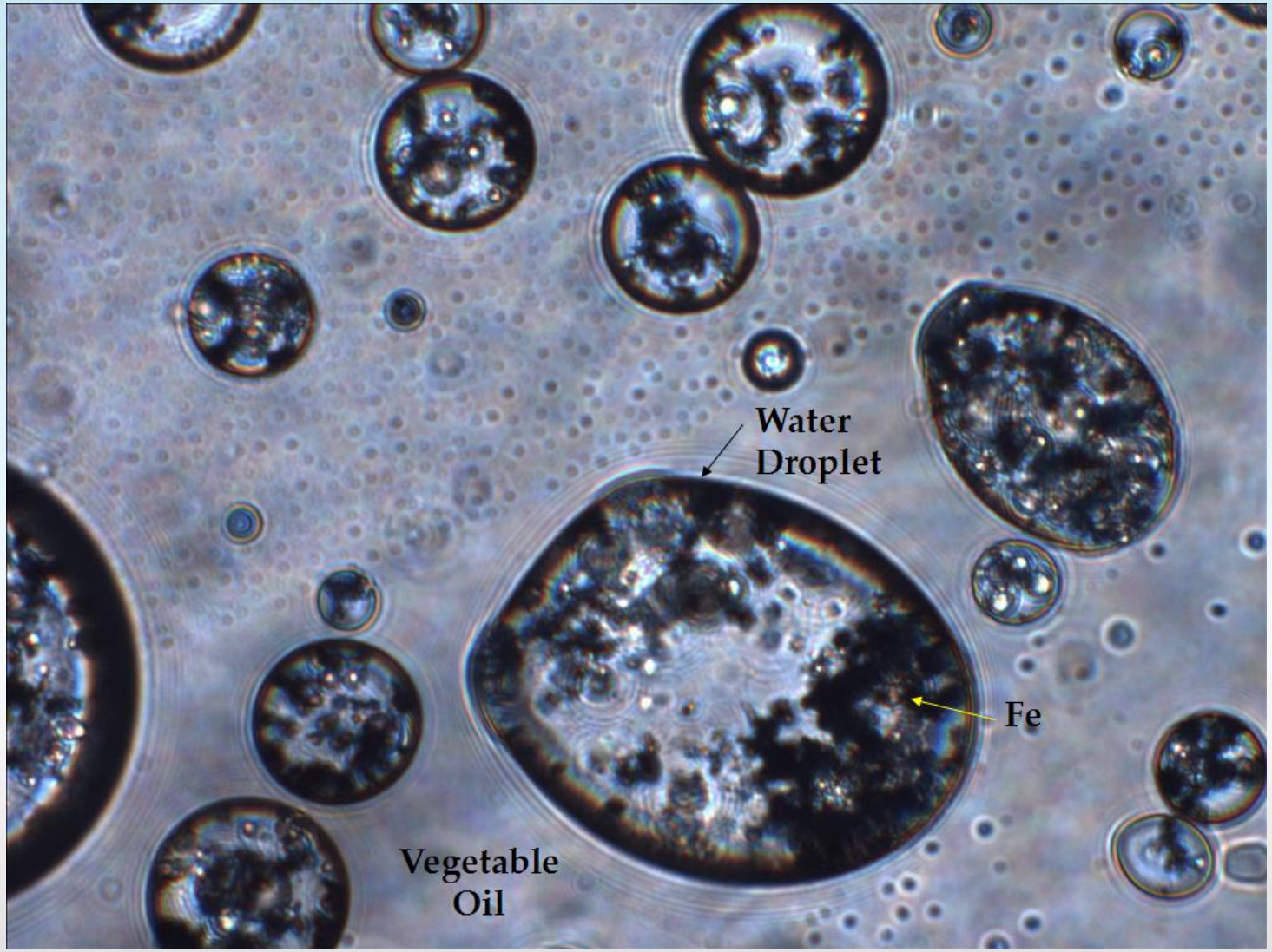
In Situ Amendments

EZVI



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Self-Emulsifier

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Tersus NanoEVO™ Self-Emulsifier

NanoEVO™ : Water	D_{10} (nm)	D_{50} (nm)	D_{90} (nm)
1 : 1	31.30	58.01	107.53
1 : 4	15.37	46.20	138.93
1 : 10	18.54	51.48	142.98

Features

Nanometer Oil Droplets

Increased Bioavailability

100% Fermentable Carbon

Benefits

Easy Field Mixing

Source Local Donor

Reduced Carbon Footprint

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Conclusions

Optimize Surfactants for Site Specific Conditions

Source Your Donor Locally

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