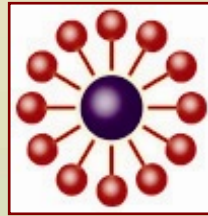
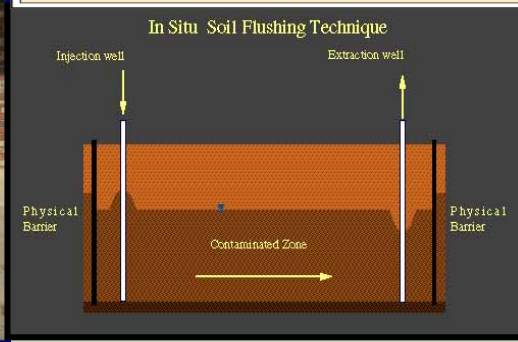
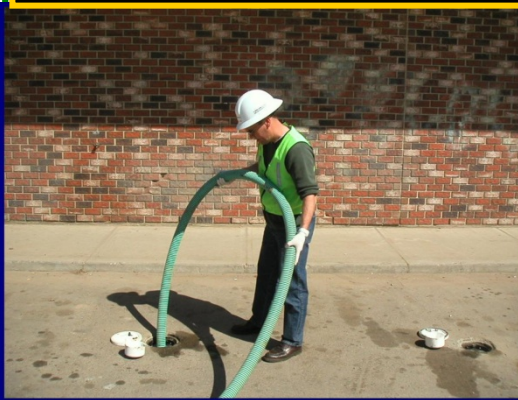
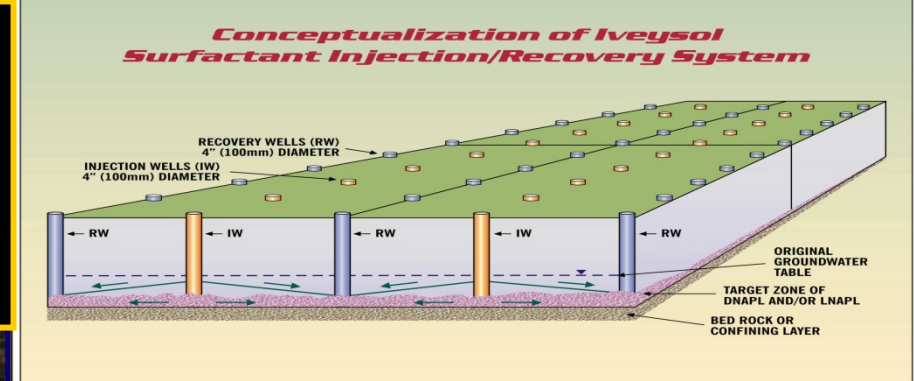
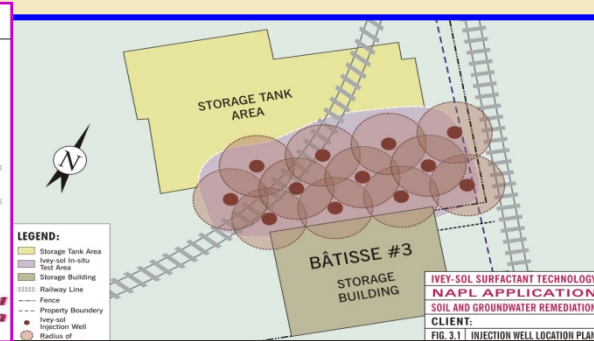
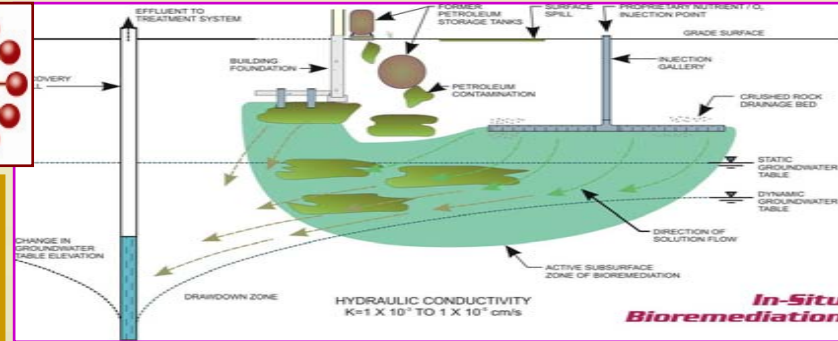
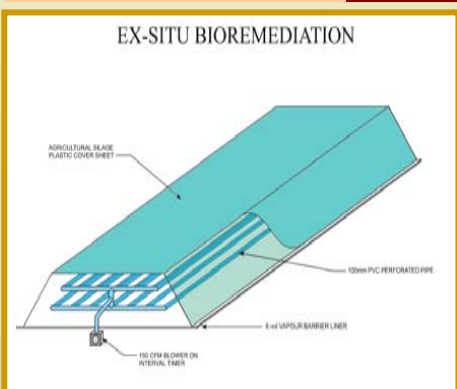


Surfactant Enhanced Bioremediation (SEB) of F2, F3, and F4 Hydrocarbons Technical Overview & Case Studies



REMTECH 2008
October 15 – 17, 2008
Banff, Alberta

Surfactant Enhanced Bioremediation (SEB)



Environmental Remediation Market Value
In USA Estimated at **23 Billion** Annually

Bioremediation Market Is Estimated At
Between **5 to 7 Billion** Annually And Growing!

Ref: John Sankey, True Blue Technologies

Considerable effort and resources (Millions \$) are
being poured into research and development for
innovative Bioremediation Technologies to meet the
growing Bio Market Demands.

In North America

We Have Been Undertaking In-situ and Ex-situ
Bioremediation Since The Early 1980's.

From This Success and Failure Have Lined The Path

Lessons Learned have prevailed...we now better
understand what affect success and failure when
conducting Bioremediation.

**I will share from this to reveal the #1 limiting
factor for successful Bioremedaition...**

In North America

The Typical Cost For Bioremediation

Ranges From \$30 to \$100 US /m³

(\$20 to \$80 US per cubic yard)

For Petroleum Hydrocarbons

The Rate /m³ Is Much Higher For

Hazardous Materials Like

PCB, PAH, DDT, DCB, TCE, PCE, Etc...

SEB of F2, F3 and F4 Contamination

Presentation Overview

- i) Overview of Bioremediation;
- ii) Factors affecting Bioremediation;
- iii) False Assumption On F3-F4 Bioremediation;
- iv) Contaminant Sorption Overview;
- v) Overview of Surfactants;
- vi) SEB Mechanism;
- vii) Case Studies;
- viii) Q&A

BIOREMEDIATION

- ▶ Bioremediation can be *defined* as any process that uses microorganisms or their enzymes to remove and or neutralize contaminants within the environment (i.e., within soil and water) to their original condition.
- ▶ Bioremediation can be employed to remediate specific types of contaminants such as: petroleum hydrocarbons (F1, F2, F3, F4), PAH, PCB, chlorinated solvents, pesticides - **all of which can be bio-degraded by microorganisms given proper treatment conditions.**

Aerobic

In the presence of sufficient oxygen (aerobic conditions), and other nutrient elements, microorganisms will ultimately convert many organic contaminants to carbon dioxide, water, and microbial cell mass. *F2, F3 and F4 Bioremediation is an aerobic biodegradation process.*

Anaerobic

In the absence of oxygen (anaerobic conditions), the organic contaminants will be ultimately metabolized to methane, limited amounts of carbon dioxide, and trace amounts of hydrogen gas. *eg. Reductive dechlorination.*

BIOSTIMULATION

Where you stimulate existing microorganisms in the soil through addition of amendments to degrade the contaminants present. This assumes the bacteria are capable of breaking down the contaminants present.

BIOAUGMENTATION

Where you add microorganism as part of the amendment process to achieve bioremediation of the subject soils.

ENHANCED BIODEGRADATION

The use of special chemical additives, such as Surfactants (SEB-Surfactant Enhanced Bioremediation) to help with the desorption of contaminants and nutrients making them more Bio-Available to the bacteria during Biostimulation or Bioaugmentation.

'SEB Newest Innovative Form of Bioremediation'

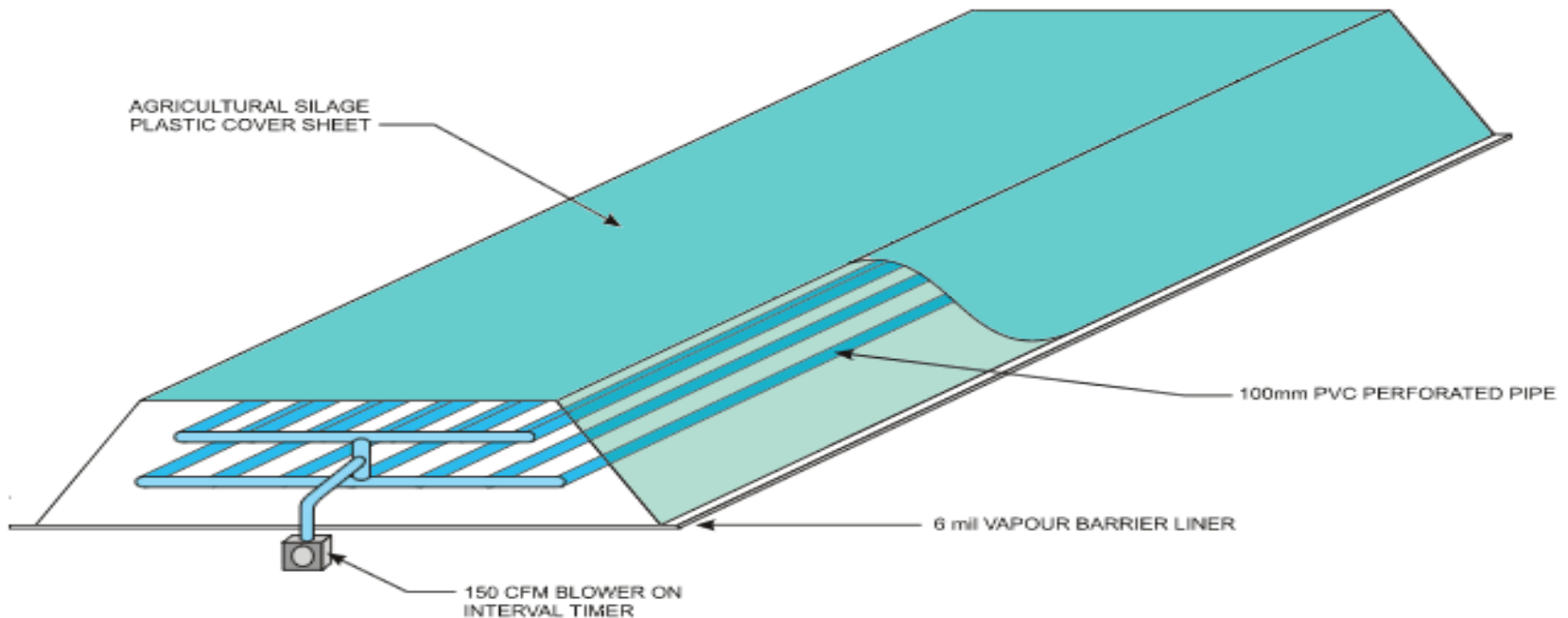
Advantages of Bioremediation

- Bioremediation is a ‘*natural process*’ and is therefore perceived by the public as an acceptable waste treatment process for contaminated material. The residues for the treatment are harmless products, including carbon dioxide, water, and cell biomass.
- Bioremediation is useful for the ‘*complete destruction*’ of a wide variety of contaminants. Many compounds that are legally considered to be hazardous can be transformed to harmless products after treatment.

In-situ & Ex-situ SEB Application Options

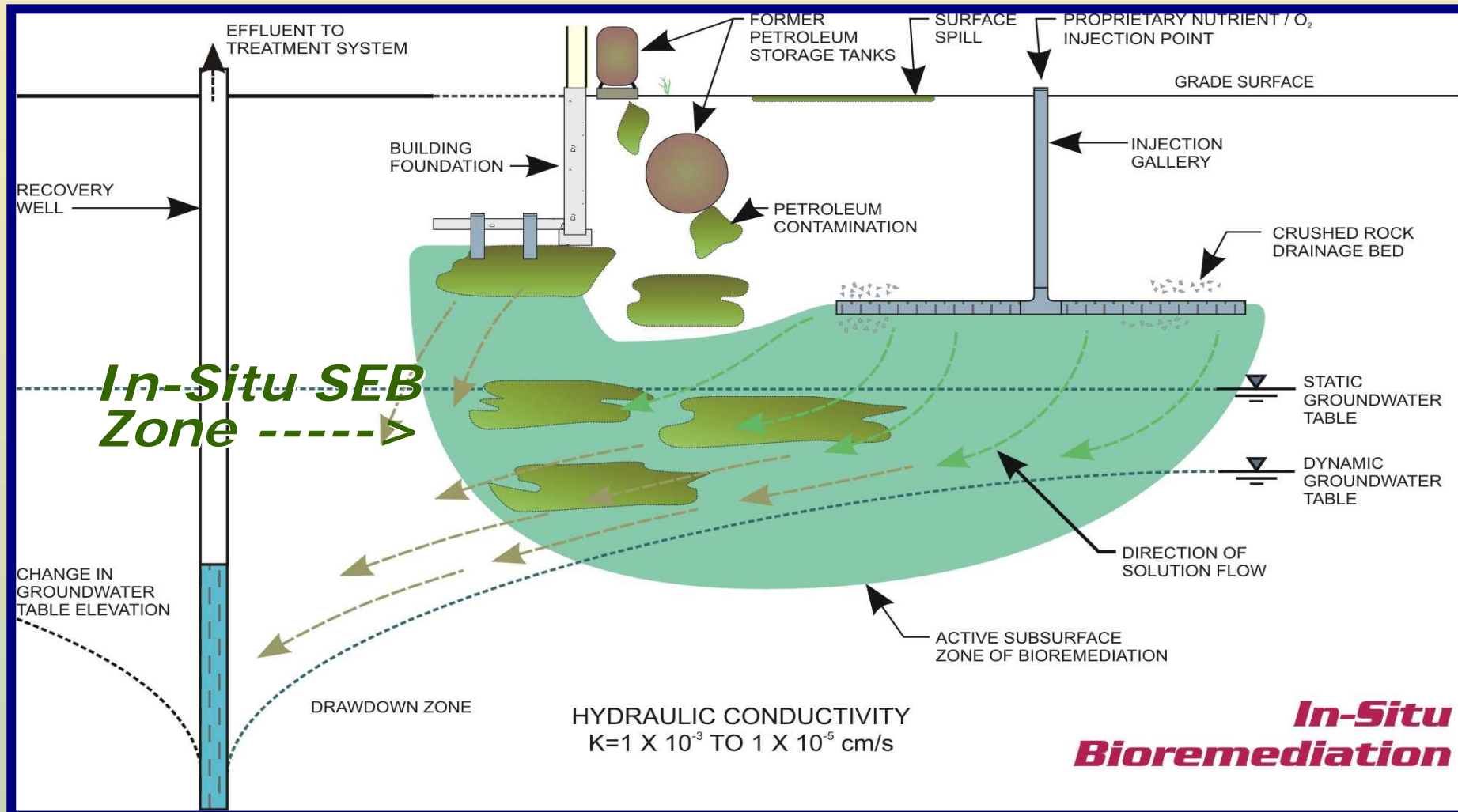
Ex-Situ (SEB) Surfactant Enhanced Bioremediation of F2, F3 and F4 Petroleum Hydrocarbons

EX-SITU BIOREMEDIATION



In-Situ SEB

Surfactant Enhanced Bioremediation



Advantages of Bioremediation

- Bioremediation can often be '*carried out on site*', often without causing a major disruption of normal activities. This also eliminates the need to transport quantities of waste off site, and the potential threats to human health and the environment that can arise during transportation.
- Bioremediation can prove '*less expensive*' than other technologies that are used for clean-up of hazardous wastes.
- *Sustainable* and Natural

Factors Affecting Bioremediation

- **Contaminant Type & Concentration**
- **Moisture Content**
- **Soil Type (Clay, Silt, Sand and Gravel)**
- **Oxygen (Concentration & Availability)**
- **Nutrient C:N:P (Ratio and Availability)**
- **Salinity (NaCl)**
- **pH**
- **Temperature**
- **Red-Ox Potential**
- **Contaminant Sorption (i.e., absorption and adsorption)**
- **Bacterial & Microbial Consortium (Presence & Availability)**
- **Soil Science (i.e., Compaction, Charged Surfaces, etc.)**
- **Sorption of Contamination (Absorption & Adsorption)**
- **Any toxic compounds to microorganisms (If Present)**

***When Other Factors Are Fair to Good, Sorption Is
The #1 Limiting Factor Affecting Successful
F2, F3 & F4 Bioremediation***

Question: Is F3 and F4 Petroleum Hydrocarbon Bioremediation Possible???

Industry Quotes Collected In 2006 & 2007

- ▶ 'Bacteria do not like F3 and F4 hydrocarbons'
- ▶ 'F3 and F4 petroleum hydrocarbons are toxic to the soil bacteria'
- ▶ 'F3 and F4 bioremediation takes too long to be considered cost effective...'
- ▶ 'The salinity in F3 and F4 contaminated soils is what limits their biodegradability...'
- ▶ 'Bioremediation of silt and clay soils with F3 & F4 is not possible...'

The Above Beliefs Are All Wrong!

F3 and F4 hydrocarbons are among the most biodegradable organic chemical structures.

They are generally ‘not’ toxic to bacteria.

Slow F3 and F4 biodegradation is due to not addressing contaminant ‘SORPTION’ and associated reduced ‘bio-availability’ of the contaminants to the bacteria present.

Salinity may inhibit bacteria, but is less significant compared to contaminant sorption. Recall bacteria thrive in the oceans.

Fine grain soils (silt/clay) can affect bioremediation, but mostly due to contaminant sorption given the greater surface areas for absorbing and adsorbing of the contaminants.

Bio-Availability - Sorption Factor

'...During the past decade, much discussion has centered on the unavailability of absorbed and adsorbed compounds to soil microorganisms. It is generally now assumed that desorption and diffusion of bound contaminants to the aqueous phase is required for microbial degradation...'

**W.P. Inskeep, J.M. Wraith, C.G. Johnston,
Hazardous Substance Research Center, 2005.**

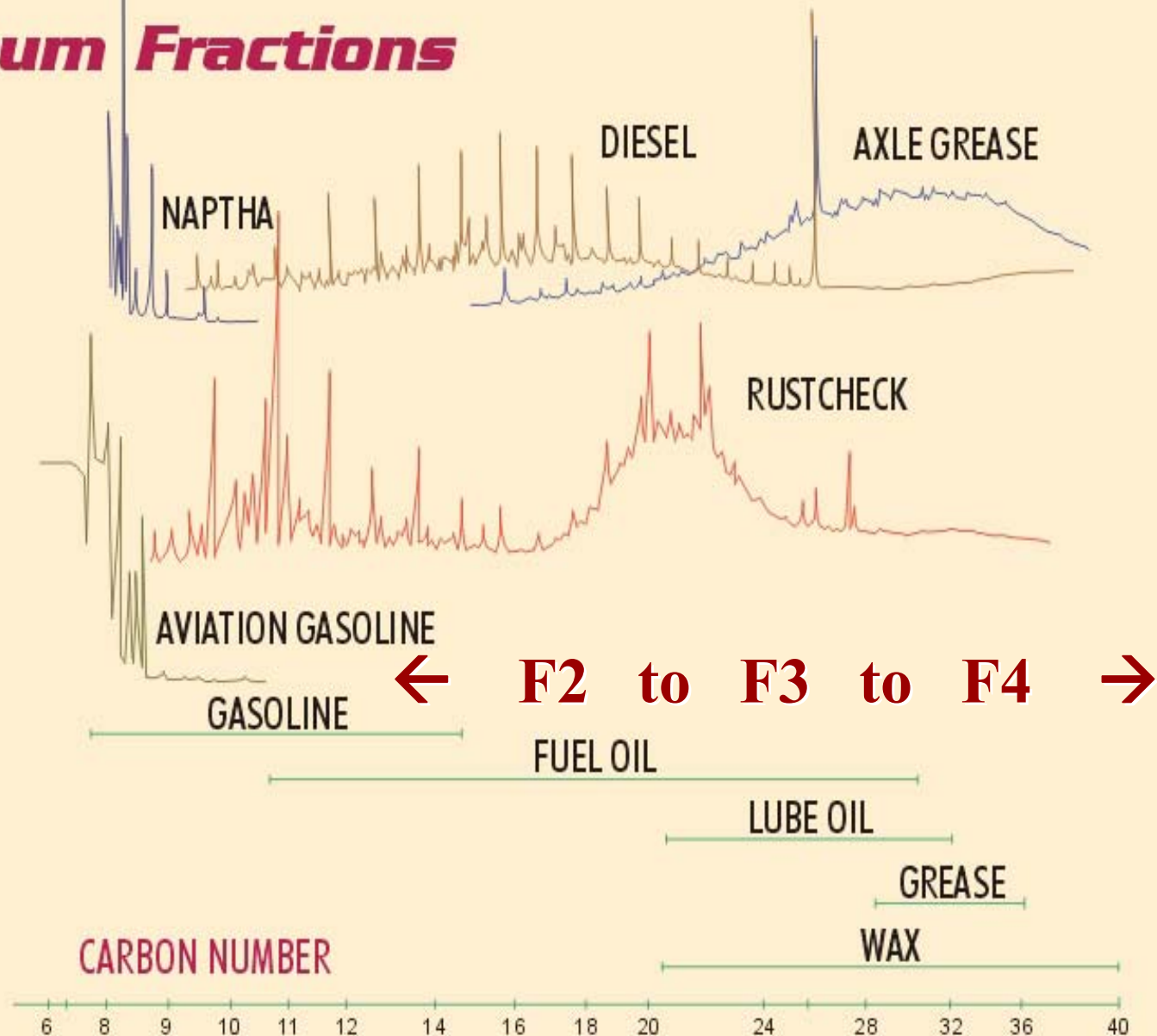
F2 - F3 - F4 Compounds

Generally speaking, the higher the molecular weight of a petroleum compound, the more likely it is to sorb onto the soil matrix verses being free and more bio-available

Sorption For F1 to F4 Fractions:

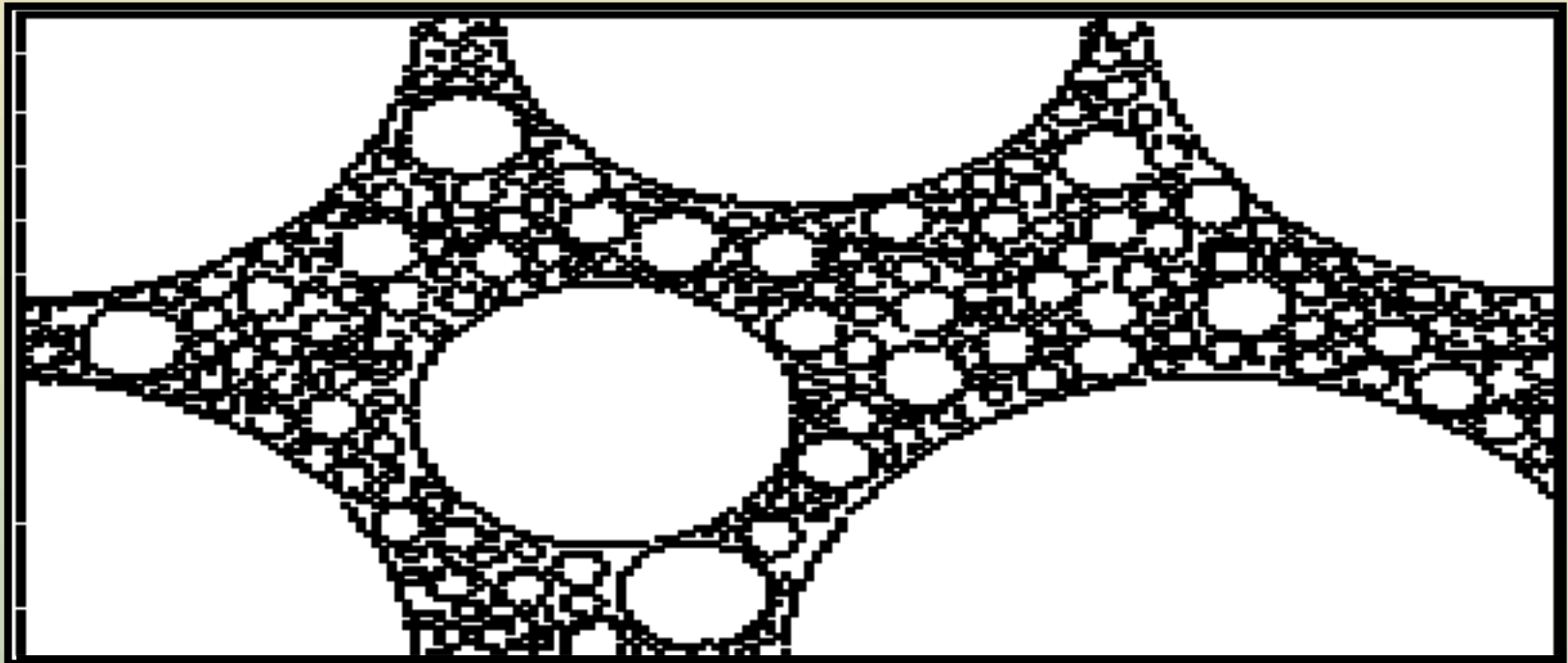
$$*F4 > F3 > F2 > F1*$$

Petroleum Fractions



Sorption (i.e., *Absorption and Adsorption*) of Contamination in Soil Matrix Limits The Bio-Availability of Contaminants

Soil Bioremediation Must Address This Factor To Be Successful For F2, F3, & F4.



FACTS

**90 to 95 % of All Contaminants Are
Sorbed To Particles In Soil, Bed Rock and
Groundwater**

•

**Contaminant Sorption
Limits Availability of Contaminants For
Bioremediation**

•

**Sorption #1 Reason Why Many In-situ and Ex-situ
Remediation Project are Slow, Costly or Fail.**



**Soil From AB
See Clay, Silt
and Sand
Seams**

**Lots of
Surfaces for
F2, F3 & F4
Sorption**

**For Effectively Bioremediation of
F3 and F4 Contaminated Soil**

YOU MUST ADDRESS SORPTION

Sorption = Limited Bio-Availability

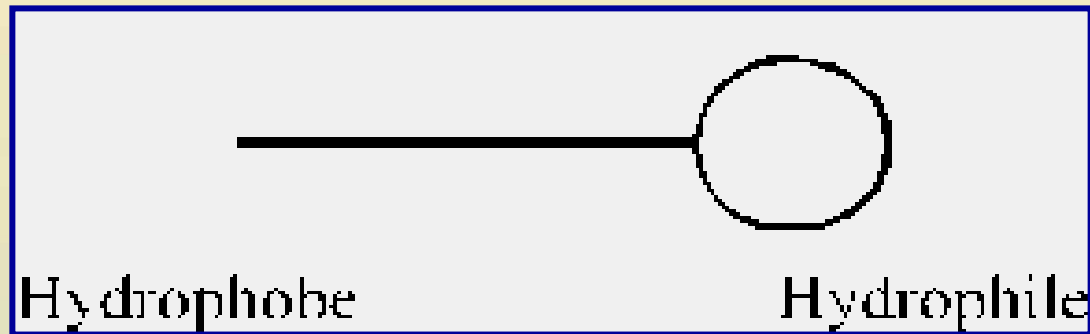
**Contaminant Sorption Is the #1 Limiting
Factor Negatively Affecting All
In-situ & Ex-situ Remediation of F2, F#,
and F4 Contaminants.**

SURFACTANT ENHANCED BIOREMEDIATION (SEB)

**New Innovative Process to Desorb F2, F3, and F4
Contaminants Making Them
Bio-Available For Bioremediation**

Overview of Surfactants & Case Studies

Structure & Definition



Surface Active Agent (SAA), i.e., Hydrophilic (water loving) and Hydrophobic (oil-liking) Groupings Shown.

Classes Of Surfactants

Anionic: They have one or more negatively charged groupings. They have very good detergent ability and are commonly used as *laundry detergent*.

Cationic: They have one or more positively charged groupings. They typically have poor detergency, but are well suited for use as *germicides, fabric softeners, and emulsifiers*.

Non-ionic: As their name implies, they have no ionic constituents or groupings. They are the largest single group of SAA and have a correspondingly wide range of chemical characteristics and application. Some (Ivey-sol, SPT, SPTT) have the unique ability to selectively dissolve LNAPL, DNAPL, polycyclic aromatic hydrocarbons (PAH's), dichloroethane (DCE), trichloroethane (TCE), perchloroethylene (PCE) and other similar petroleum products.

Amphoteric: They contain both anionic and cationic groupings and have the characteristics of both anionic and cationic SAA. They work well at neutral pH and are found in products such as *hair shampoo, skin cleaners, and carpet shampoo*.

Application & Uses

Surfactants are used in cleaners and detergents to:

- ▶ Improve wetting / spreading
- ▶ Provide detergency by solubilizing & suspending soil (*particulate, oily*)
- ▶ Produce, modify or control foam
- ▶ Emulsify / disperse (e.g., silicone, wax)
- ▶ Couple or compatibilize formulation components
- ▶ Modify viscosity

Other commercial and environmental uses include:

- Vapour and odour suppression;
- Storage tank and parts cleaning;
- Off-shore dispersants, and shoreline spill clean-up;
- In-situ Surfactant Enhanced Aquifer Remediation (SEAR);
- In-situ and Ex-situ Surfactant Enhanced Bioremediation (SEB);
- In-situ and Ex-situ Surfactant Enhanced Oxidation (SEO);
- Oil recovery from oil sand and oil-shale;
- Treating drilling mud and drilling cuttings; and
- Improving oil recovery from oil production fields.

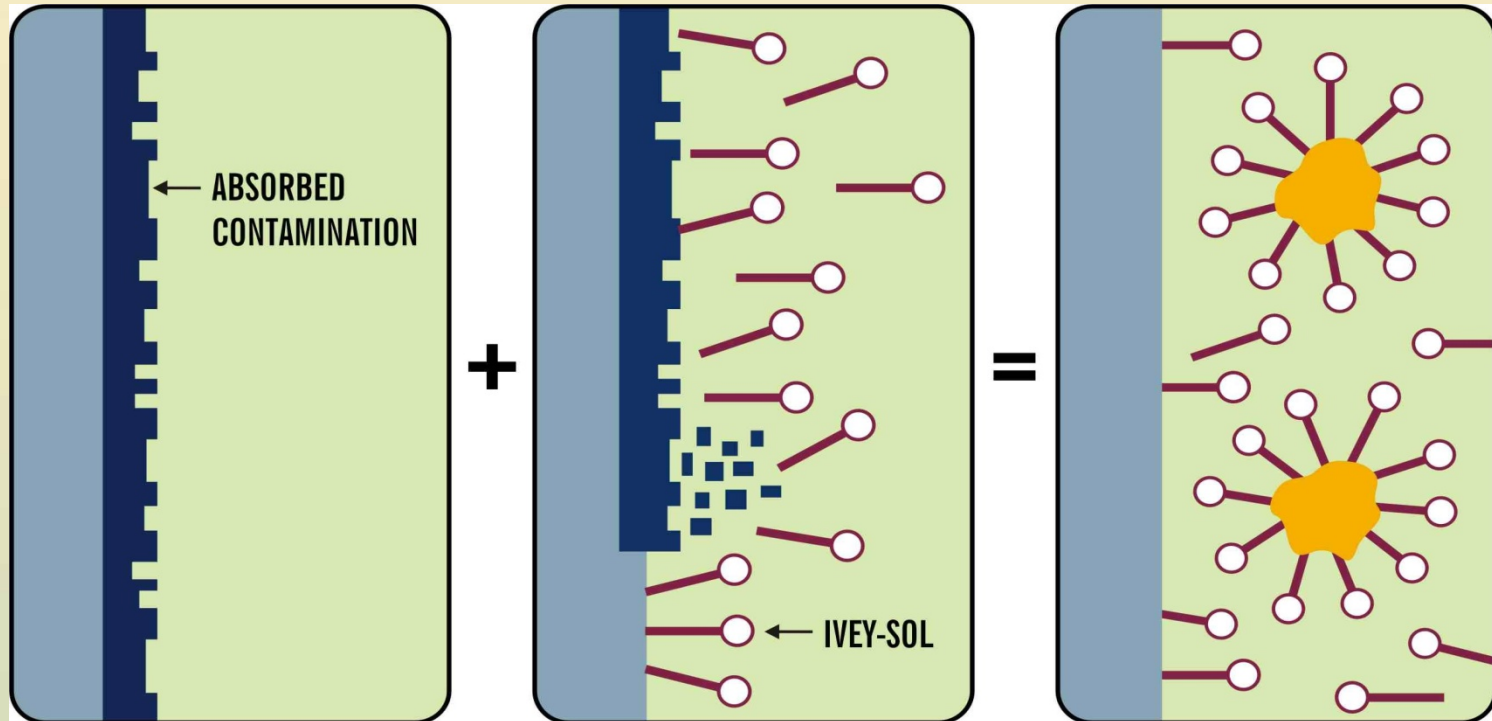
Surfactants Lower The Surface Tension of Water From 72 Dynes to <50 dynes with some capable of < 30 dynes.

This increases the wetting ability of the water when present, makes surfactant application possible in fine grain soils improving Water Permeability (K).

Helps Improve Desorption In Finer Grain Soil Aiding Bioremediation By Increasing Bio-Availability

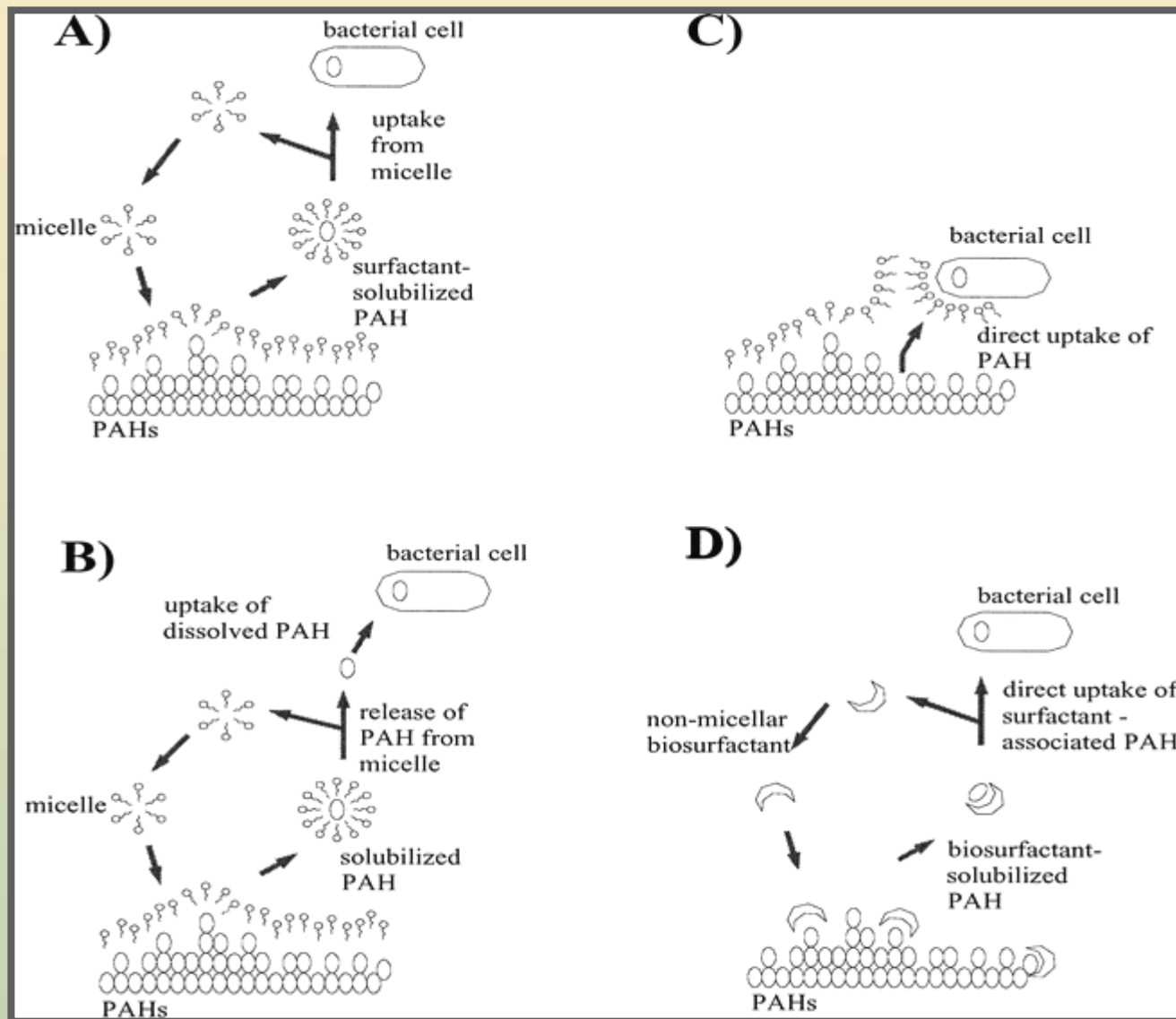
Surfactant Enhanced Bioremediation (SEB)

Mechanism of Surfactant Desorption To Increase Bio-Availability



**Surfactant Interaction With Organic (NAPL) On A
Surface With Partial Micelle of F2, f3, or F4
(Surfactant Effective Below CMC – No Emulsification)**

SEB Mechanism For PAH

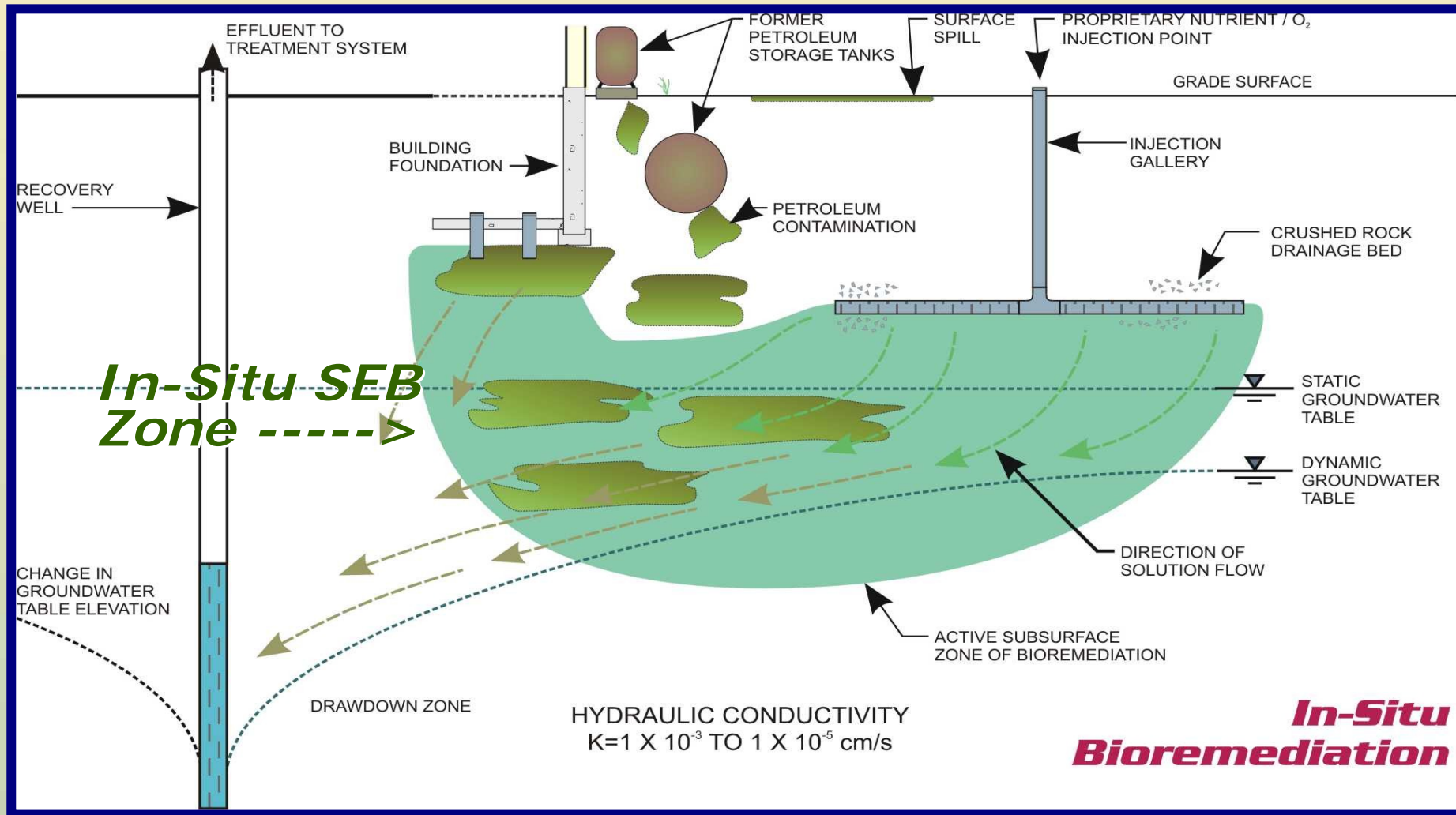


In-situ & Ex-situ SEB Applications

Overview & Case Studies

In-Situ SEB

Surfactant Enhanced Bioremediation (Aerobic)



In-situ Bioremediation.

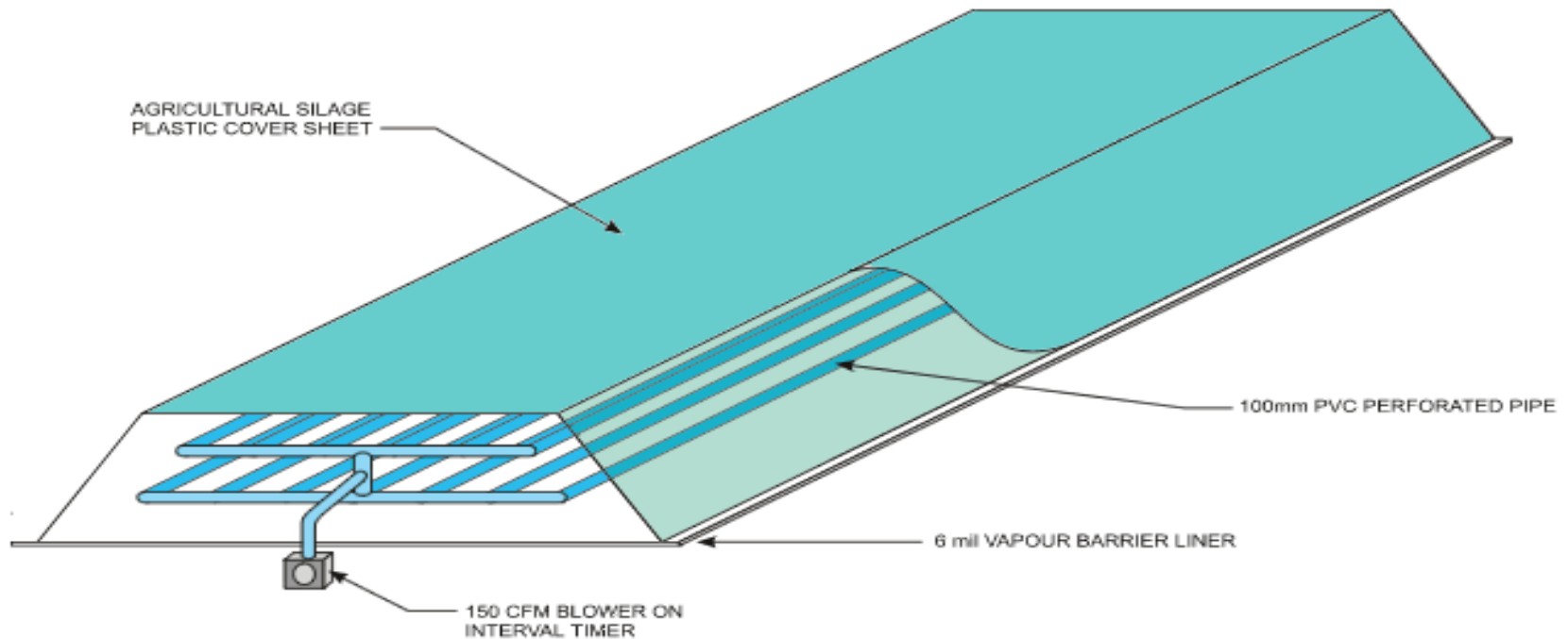
**Injection of
amendments to
stimulate
Bioremediation of
contamination**

**Injection at an
Injection Well (IW).**



Ex-Situ SEB Surfactant Enhanced Bioremediation (F3 &F4)

EX-SITU BIOREMEDIATION



Ivey-sol • SPTT



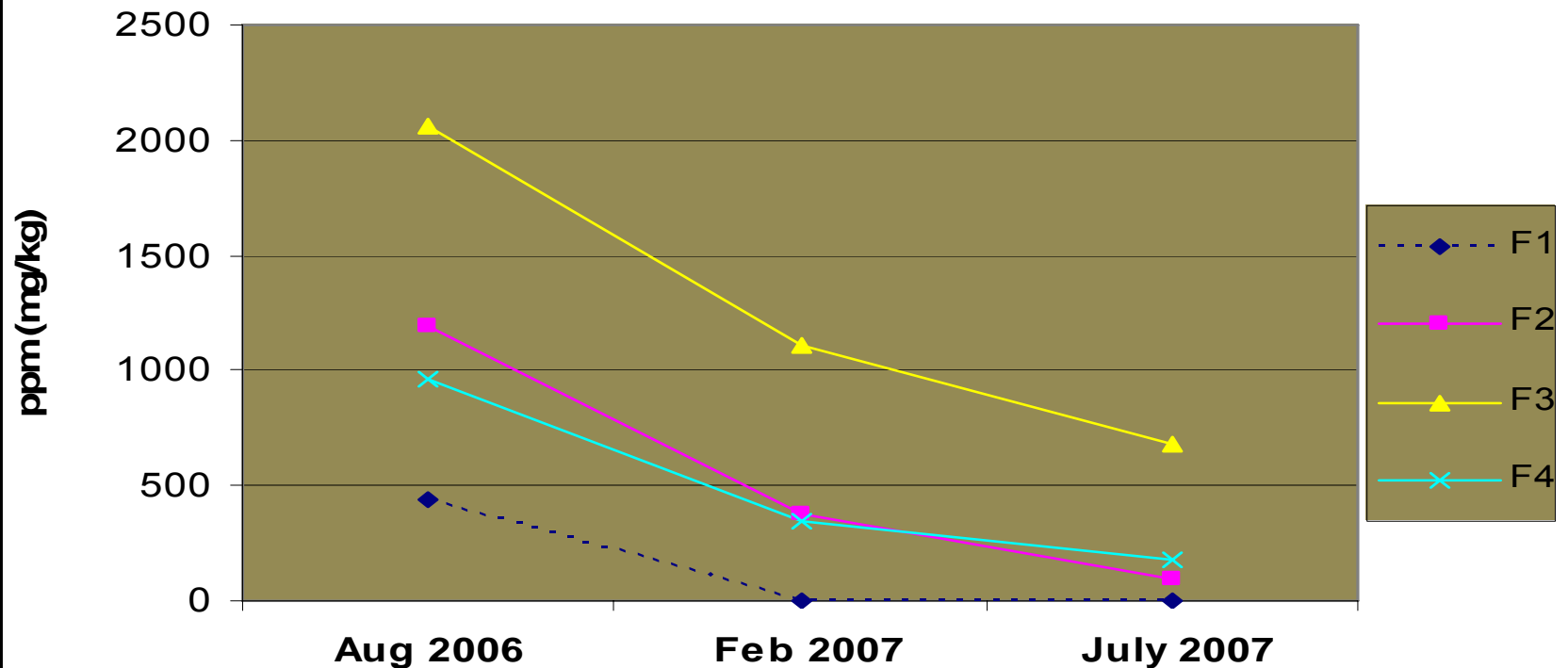
CASE STUDY #1

Surfactant Enhanced Bioremediation (SEB) of F2, F3 and F4 Contaminated Soils Northern Alberta

- ▶ Ivey International Inc. was retained to apply their SEB technology to treat >2000 tons of F2, F3, and F4 fine grained contaminated soil at a remote site in Northern, Alberta, Canada.
- ▶ The project was commenced in late August 2006, just prior to the on-set of colder northern weather in an area know for minus 30 °C to minus 40°C winter temperatures.
- ▶ The soils had some Salinity and EC levels issues.

RESULTS

Ex-situ Surfactant Enhanced Bioremediation(SEB) of F2, F3, F4 Soil Contamination



	F1	F2	F3	F4
August 2006	441 ppm	1,189 ppm	2,064 ppm	965 ppm
February 2007	2 ppm	376 ppm	1,107.5 ppm	347.5 ppm
July 2007	N.D.	98.25 ppm	347.5 ppm	180 ppm

CONCLUSIONS

► The SEB process was effective in achieving the soil remediation goals in <11 months, commencing with average baseline hydrocarbon concentration of ***F1 441 ppm, F2 1,189 ppm, F3 2,064 and F4 965.***

► The total % reduction in each hydrocarbon fractions were: ***F1 (100%), F2 (92%), F3 (83%), and F4 (81%),*** achieving the applicable Alberta Environment Soil Remediation Guidelines (ABENV, June 2007).

CASE STUDY #2

Quebec Canada

- ▶ 6,000 ton Soil Bioremediation treated in May 2006 using Ivey-sol SEB Process.
- ▶ Client was having difficulty lowering their PAH concentration in soils at their soil bioremediation facility.
- ▶ Surfactant Enhanced Bioremediation treatment was undertaken and within four months significant reductions in total PAH levels were realized.
- ▶ The subject company had a good ex-situ bioremediation system design application in place, their main problem was not being able to overcome the strong sorption of the PAH compounds to the soils.

Ivey-sol • SPTT



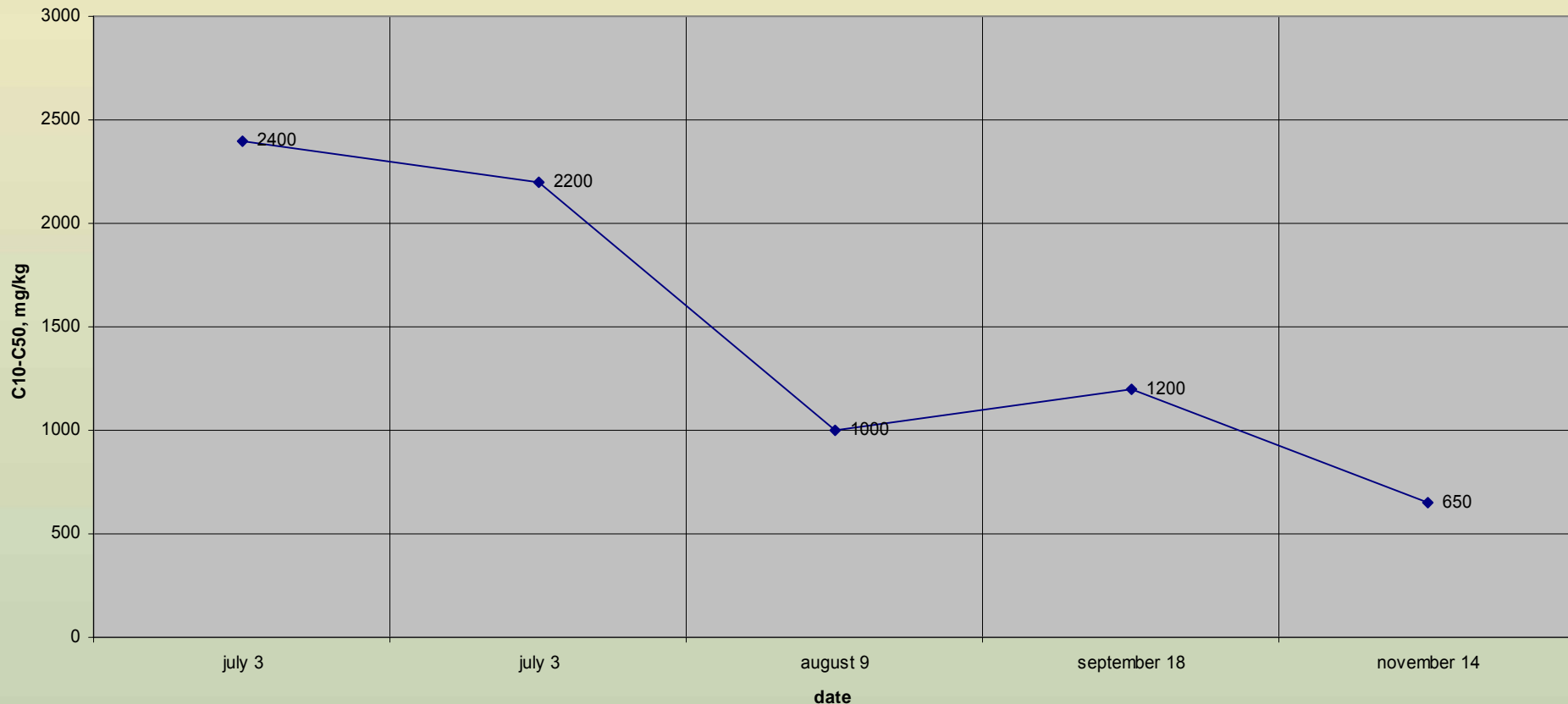
Ivey-sol • SPTT



SEB Diesel Contaminated Soil

SEB Ex-situ Soil Remediation Project Quebec, Canada

Andain A-1



CASE STUDY #3

Mine Site

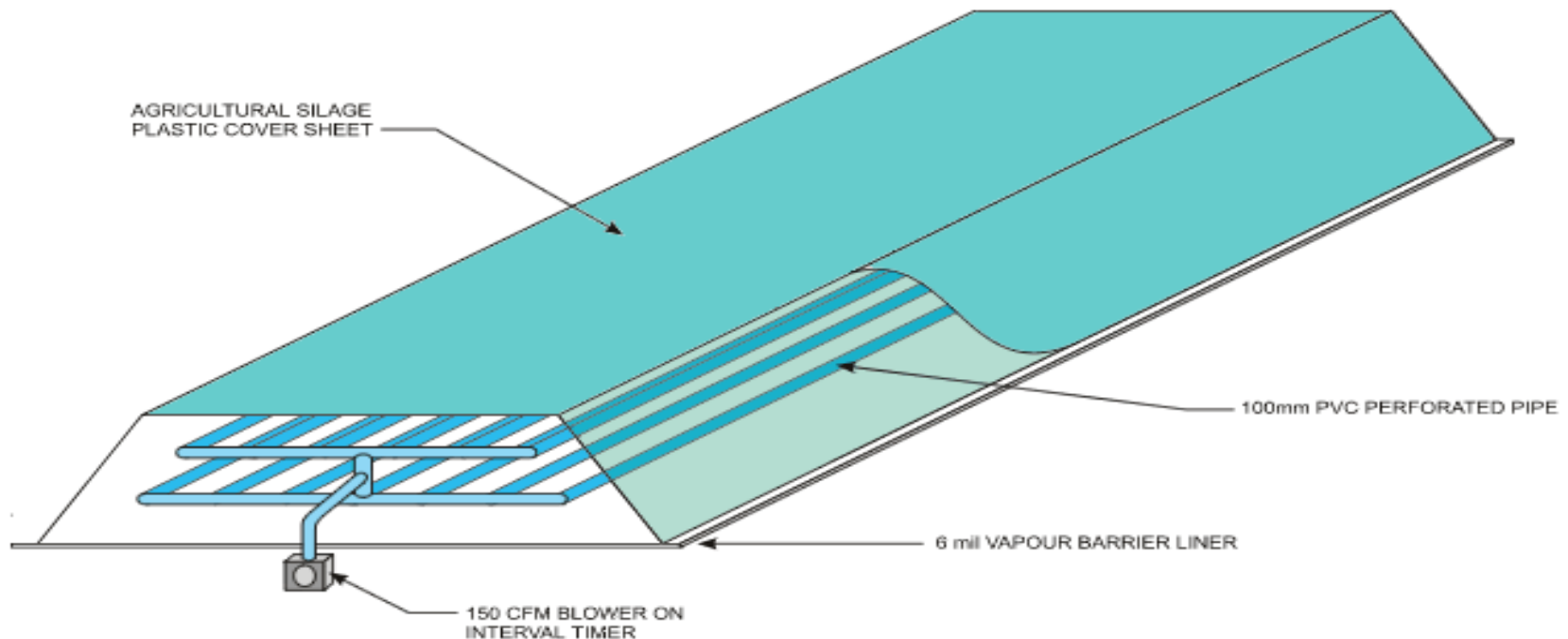
Western Canada

- ▶ Approximately 1000 ton Soil Bioremediation treated in July 2005 using Ivey-sol SEB Process.
- ▶ Silty, clay and sandy soil impacted with Fuel oil and Diesel >5000ppm to 10,000 ppm.
- ▶ Surfactant Enhanced Bioremediation treatment was undertaken and within 12 to 14 weeks the soil was remediated to the BC Ministry of Environment Soil Clean Up Commercial Standard.

Ex-Situ SEB

Surfactant Enhanced Bioremediation (F3 &F4)

EX-SITU BIOREMEDIATION



Client Quote

“After excavating and bio-piling the soil, the surfactant enhanced bioremediation (SEB) treatment was applied and the bio-pile was then covered. Daily aeration was done during the treatment period. After only 12 weeks samples taken from the pile showed that the remediation of the Fuel-oil/Diesel and PAH contamination was completed to the applicable BC Environmental Standards and the soils were safe to re-use on-site.”

Reference: Tony Robson, Director,
Mining Plant & Equipment-Quinsam Coal Corp.
Tel: (250) 286 3224 (ext 224); E-mail: tonyr@oberon.ark.com

Environmental Science & Engineering Magazine Ca. 2005

CASE STUDY #4

Research Project (SER-SEB)

Madrid Spain

- ▶ In 2007 Ivey international Inc. conducted a joint Research and Development project with CIEMAT in Madrid Spain.
- ▶ Purpose was to evaluate the ability of Surfactant (Ivey-sol) to Desorb Sorbed PAH compounds in column tests. If effective; to evaluate potential for increasing the Bio-Availability of PAH for biodegradation using the SEB process.
- ▶ Results were that the Ivey-sol Surfactants were very effective at desorbing the PAH compounds making them more Available for remediation; including increased Bio-Availability for Bioremediation.

METHODOLOGY



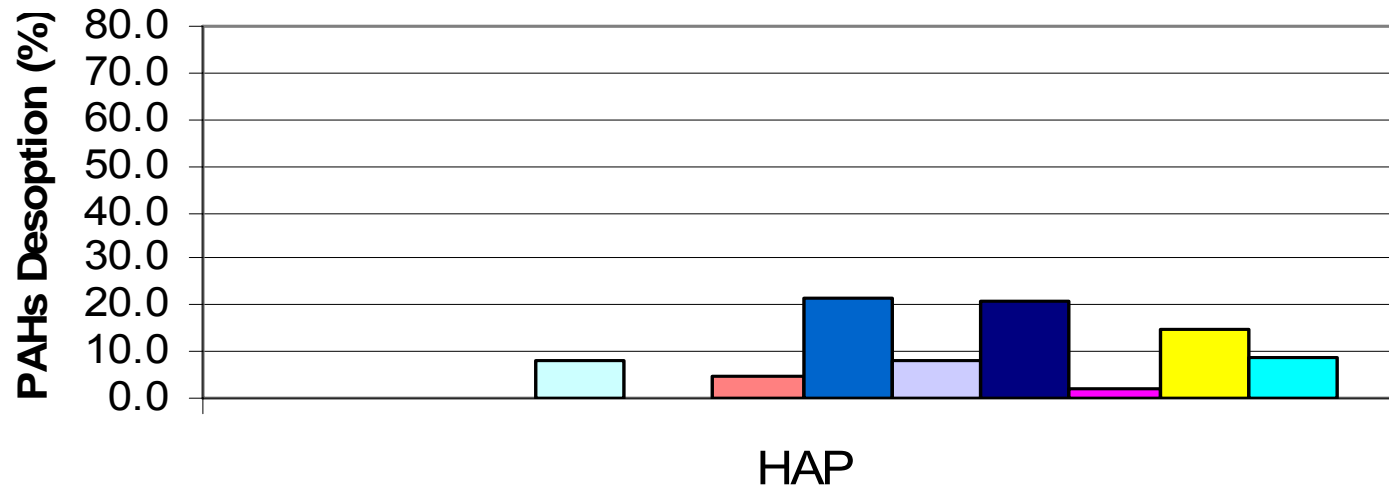
Free desorption



Induced desorption

RESULTS

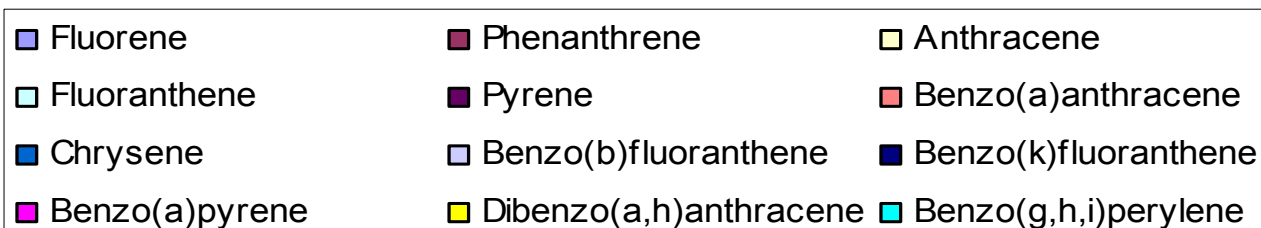
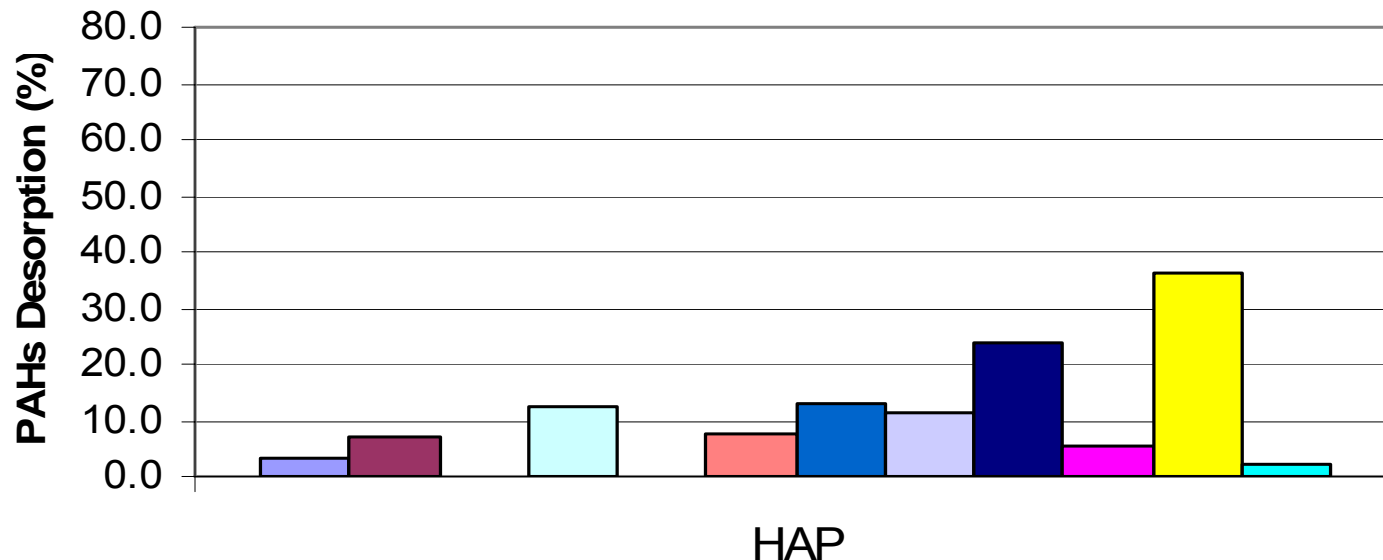
Free desorption



PAHs desorption in free desorption test

RESULTS

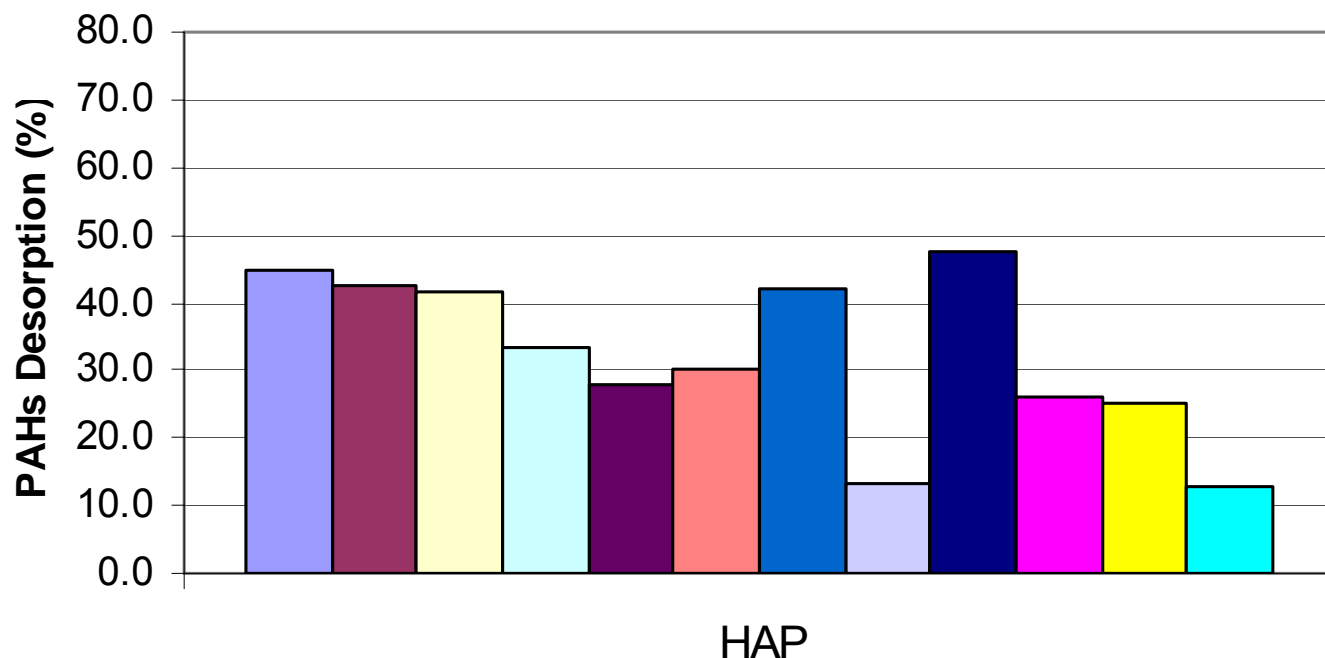
Induced desorption with resin (XAD-2)



PAHs desorption in induced desorption test

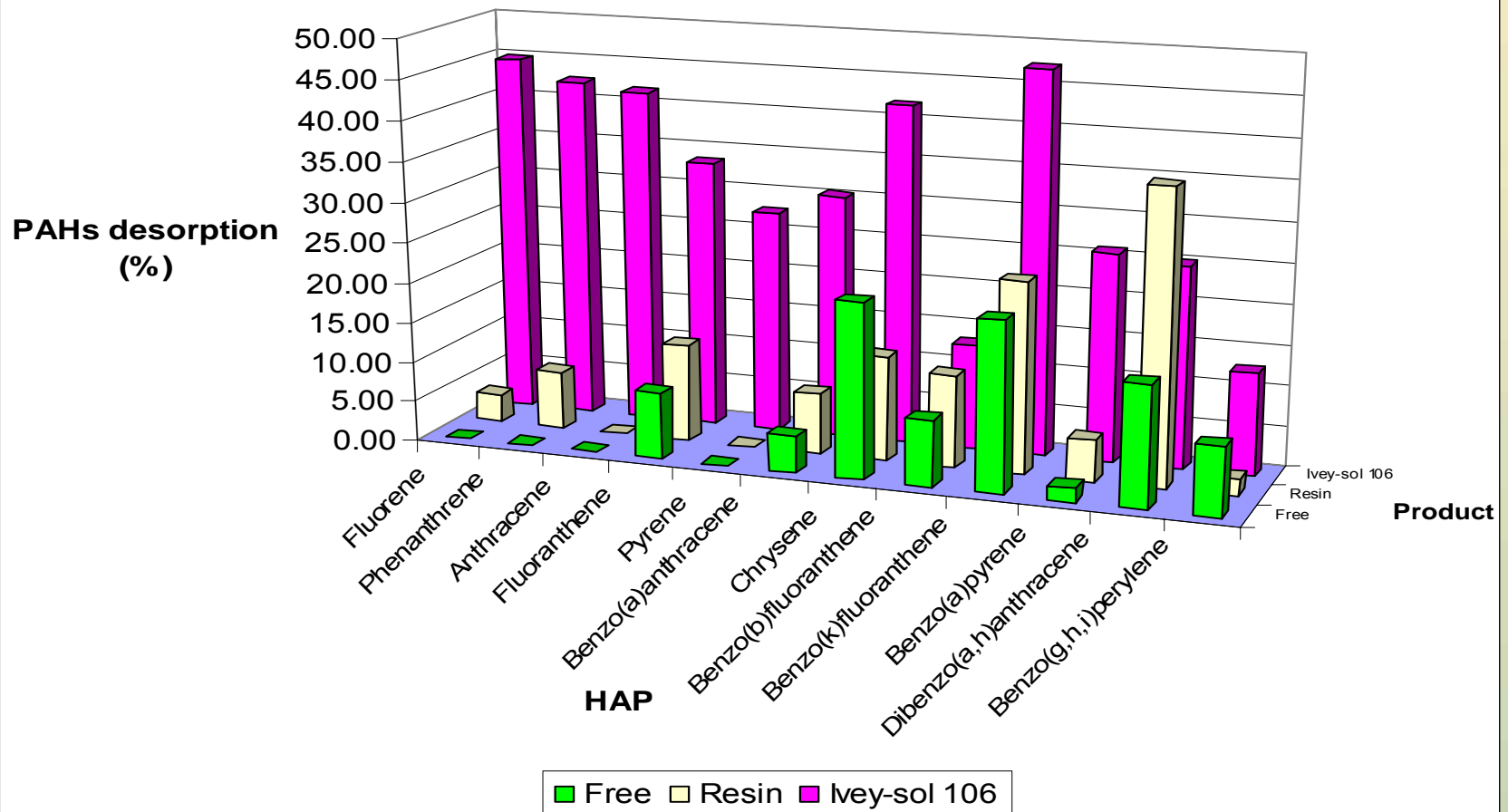
RESULTS

Surfactant desorption (Ivey sol 106)



PAHs desorption in surfactant aided desorption test

RESULTS



Comparative PAHs desorption (%) for all tests

Ivey-sol • SPTT

Waste Water Treatment Surfactant Enhanced Bioremediation

The image shows the interior of a mobile bioreactor unit. It features several large, yellow, cylindrical tanks arranged in a row. Each tank has a black lid with a central opening. A network of black and white hoses is connected to the tanks, with some hoses running vertically and others horizontally. The unit is constructed with light-colored wood paneling on the walls and floor. A person's arm and shoulder are visible on the right side of the frame. The background shows a bright outdoor area with trees and a building.

**Multi-Stage Bioreactor
TPH Treatment**

Packing Material (Growth Substrate)



**Bacterial Growth
on substrate to
treat the water**



***Pre & Post (24 Hour) Ivey-sol Addition
Outperforming Other Surfactant***



Duration of Bioremediation Treatment

Ex-situ: Typically 3 to 4 months or less.

In-situ: Typically 12-18 months or less.

*Duration of bioremediation is a function of contaminant type,
its concentration, and the soil geology.*

For Additional Information Contact:

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