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Increasing Bio-Availability of Contaminants In Groundwater Using Surfactant Enhanced Bioremediation (SEB)

Water Technologies Symposium 2009
April 29, 30 & May 1, 2009
Fairmont Banff Springs
Banff, Alberta

Presentation Outline

i)Definition of bio-availability;
ii)Facts affecting bio-availability;
iii)Bio-availability of F1, F2, F3 and F4;
iv)Contaminant sorption explained;
v)How sorption affects bio-availability;
vi)Surfactants explained;
vii)How Surfactants can improve desorption & increase bio-availability;
viii)Case studies;
ix)Questions & Answers Period

Bio-availability & Sorption

'…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…'

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

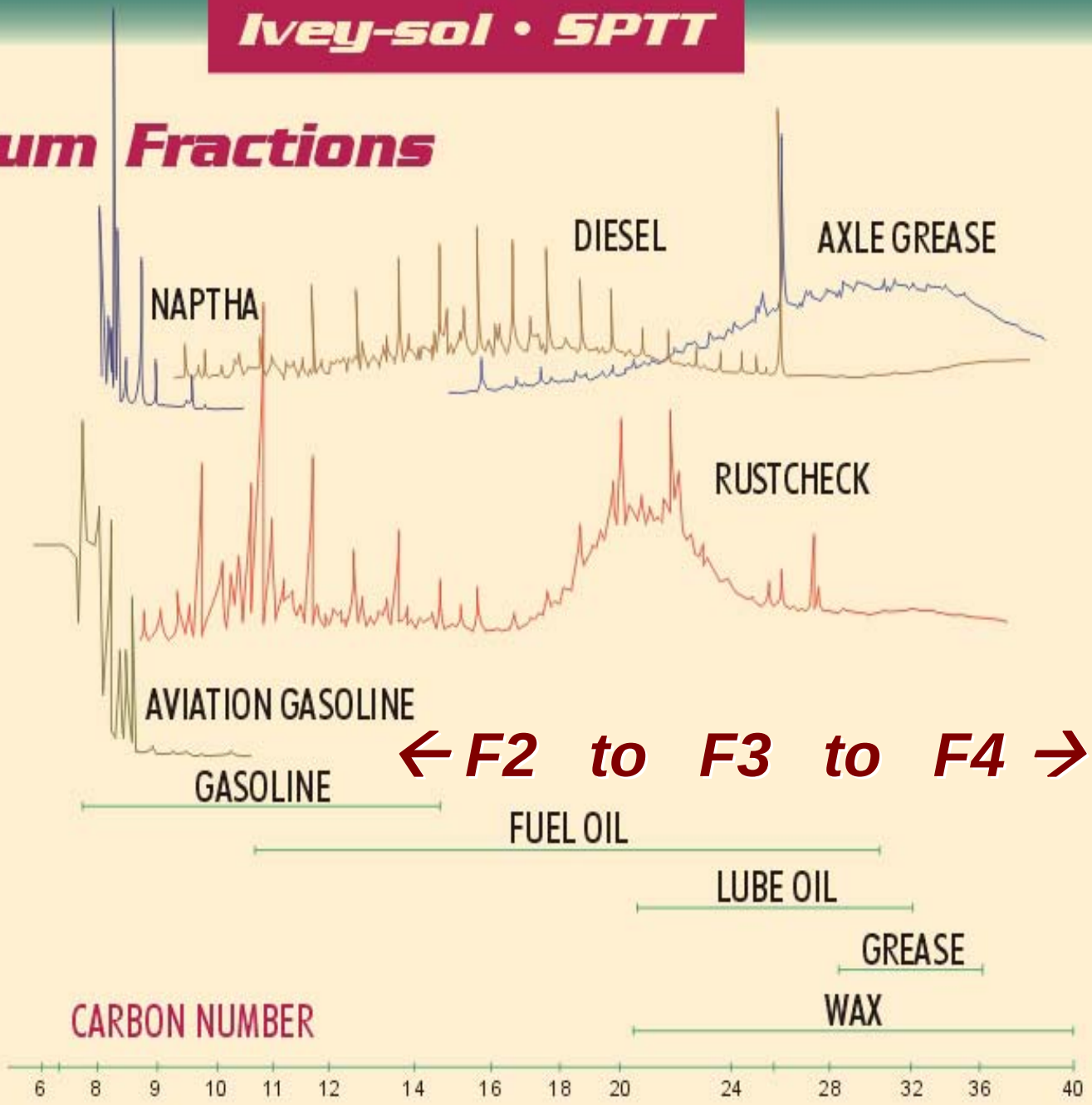
Definition Of Bio-Availability

The degree to which, or rate at which, a contaminant that may be dissolved or sorbed, becomes available at the site of biological activity for uptake and mineralization.

FACT

90 to 95 % of all petroleum hydrocarbon contaminants will absorb or adsorb to particles In soil, sediments, bedrock and groundwater aquifers

Petroleum Fractions



FACT

Sorption is one of the most significant factors behind why remediation can be costly, slow, and sometimes fail

Hydrocarbon Sorption Potentials

F4 >F3 >F2 >F1

FACT

Contaminant Sorption Limits the '*Availability*' of Many Contaminants For Biological Remediation!

Contaminants Must Be '*Bio-Available*' For Biodegradation To Be Realized

FACT

Low '*Bio-Availability*' Will Limit Contaminant Bioremediation Rate In Groundwater & Soil

Hydrocarbon Bio-Availability

F1 >F2 >F3 >F4

Sorption (i.e. absorption or adsorption) of Contamination in Soil Matrix

Soil & Groundwater Bioremediation Must Address This To Be Successful.

Adsorption vs. Absorption

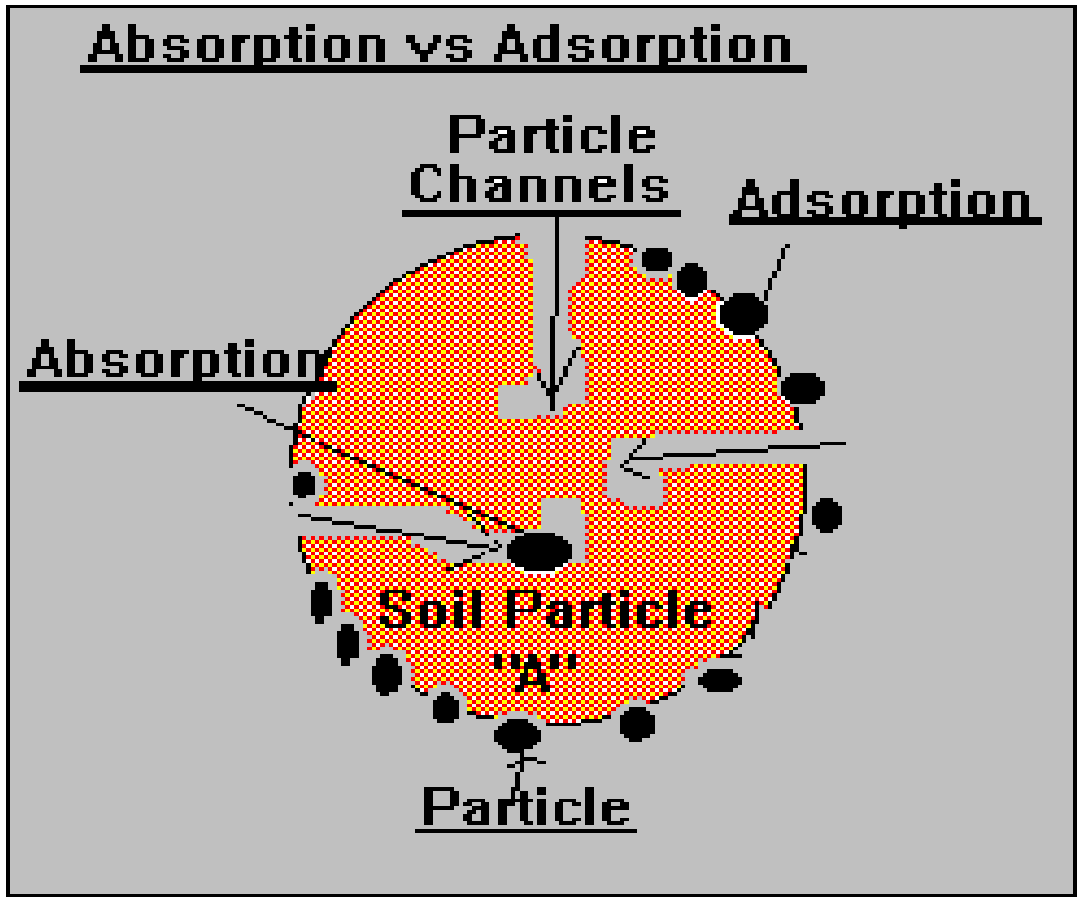
►Sorption reactions generally occur over a short period of time, however if the ***adsorbed*** contaminant begins to be incorporated into the structure of the sorbent , a slow occurring reaction, known as ***absorption***, begins to take place.

►To be more precise , the ***difference between adsorption and absorption*** is that adsorption is the attraction between the outer surface of a solid particle and a contaminant, whereas absorption is the uptake of the contaminant into the physical structure of the solid.

►The ***next figure shows the differences*** between intra-particle absorption versus surface adsorption.

►The ***main difference*** being that some contaminant particles are attracted to the outer surface of the soil particle, while others are incorporated into the particle's structure.

Adsorption vs. Absorption



Fine Grain Soil From Central Alberta
Lots of surface area for contaminant sorption

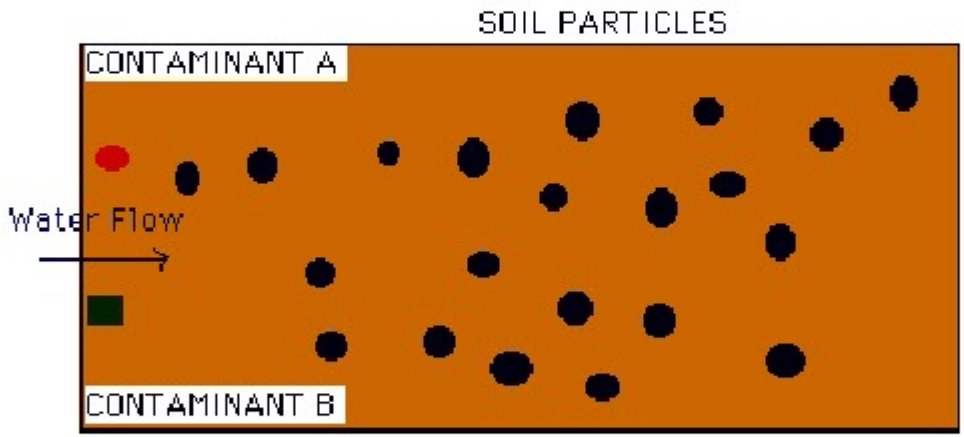
Sorption Demonstration
(Animation)

The following animation sequence displays how sorption can affect two separate particles' velocities and movement in an aquifer.

The more they exhibit sorption, the less 'available' they are for bioremediation.

The animation shows a vertical cut from a soil column, interspersed particles of organic matter, and two contaminants that are moving through the soil /water matrix.

THE VELOCITIES OF TWO CONTAMINANTS
ONE IS SORBING---ONE IS NOT



‘Availability of Contamination’

Contaminant ‘availability’ is quickly becoming a new driving force for the evaluation of *in-situ* and *ex-situ* remediation options for air, soil and groundwater remediation.

Examples:

‘Bio-Availability’	***Bioremediation***
‘Chemical Availability’	***Oxidation/Reduction***
‘Physical-Availability’	***P&T, Soil Washing, etc.***

Generally Speaking

Contaminant Sorption Is Inversely Proportional To Contaminant Bio-Availability For Soil and Groundwater Bioremediation

Hence:

Hydrocarbon Sorption Potentials
F4 >F3 >F2 >F1

Hydrocarbon Bio-Availability
F1 >F2 >F3 >F4

Hydrocarbon Degradation Rates
F1 >F2 >F3 >F4

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 biodegraded 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. *Hydrocarbon Bioremediation is an aerobic biodegradation process.*

Anaerobic

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

BIOSTIMULATION

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

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 Bio-stimulation or Bio-augmentation.

'Newest Innovative Form of Bioremediation'

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For Effective Bioremediation of Petroleum Contaminated Groundwater & Soil

YOU MUST ADDRESS SORPTION

Sorption = Limited Bio-Availability

Contaminant sorption is a major limiting factor negatively affecting all *in-situ* & *ex-situ* remediation of F2, F3, and F4 contaminants

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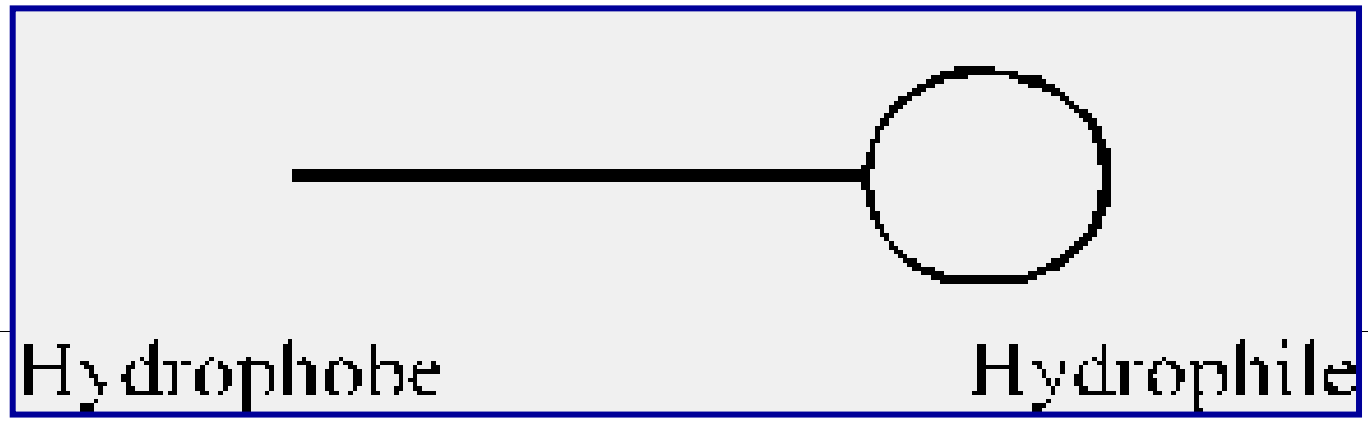
SURFACTANT ENHANCED BIOREMEDIATION (SEB)

New Innovative Process to Desorb F2, F3, and F4 Contaminants Making Them Bio-Available For Bioremediation In Groundwater & Soils

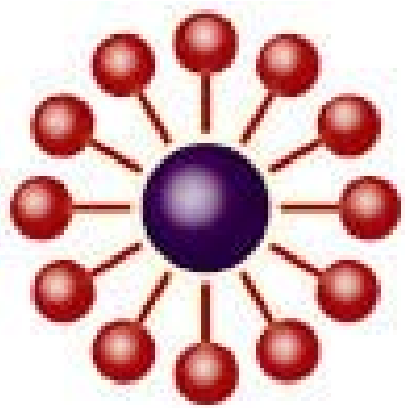
Overview of Surfactants & SEB
Case Studies

Structure & Definition



Surface Active Agent (SAA) with Hydrophilic (water loving) and Lipophilic(oil-liking) ends

- Surface Active Agent
- **Anionic** - negatively charged groupings (laundry detergent)
- **Cationic** - positively charged groupings (germicides, emulsifiers)
- **Amphoteric** have both anionic and cationic groupings (i.e. Hair shampoo, skin cleaner, and carpet shampoo)
- **Non-Ionic** - no ionic constituents. Selectively dissolve LNAPL, DNAPL, PAHs, DCE, TCE, PCE, etc.

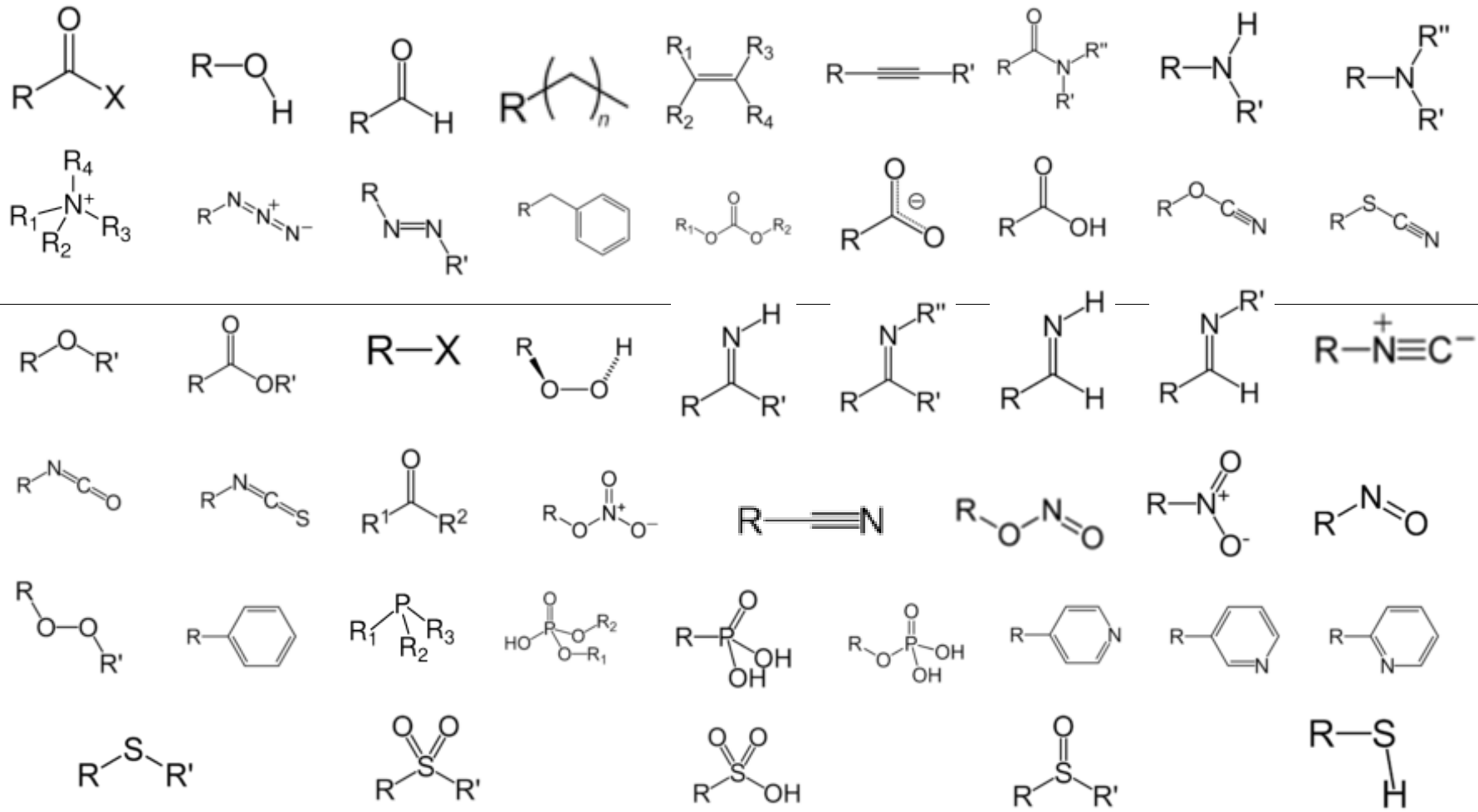


Surfactants Can Lower Water Surface Tension (From 73 dynes to <50 dynes) & Desorb Sorbed Contaminants From Soil Surfaces

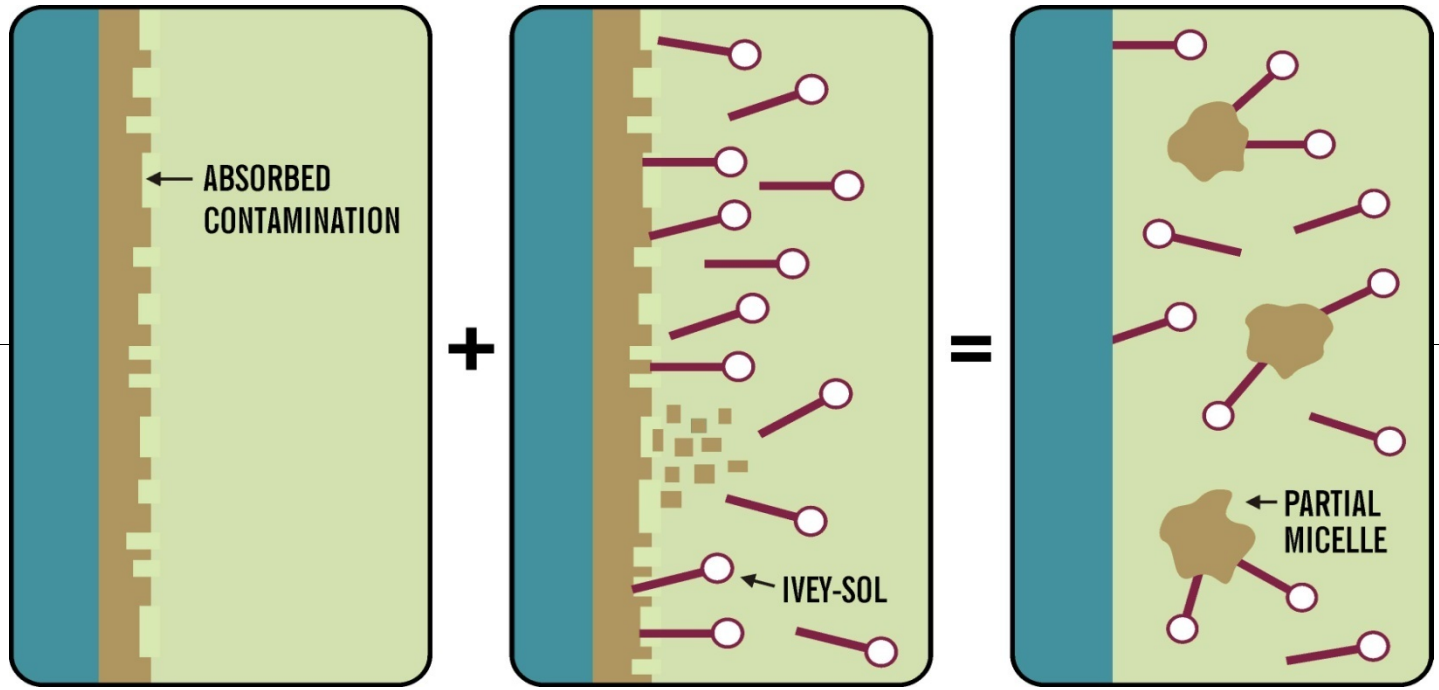
This can increase the wetting ability of the water when present, making surfactant application possible in fine grain soils by improving water Permeability (K).

They can improve desorption in finer grain soils aiding bioremediation by increasing bio-availability

Functional Groups



Mechanism

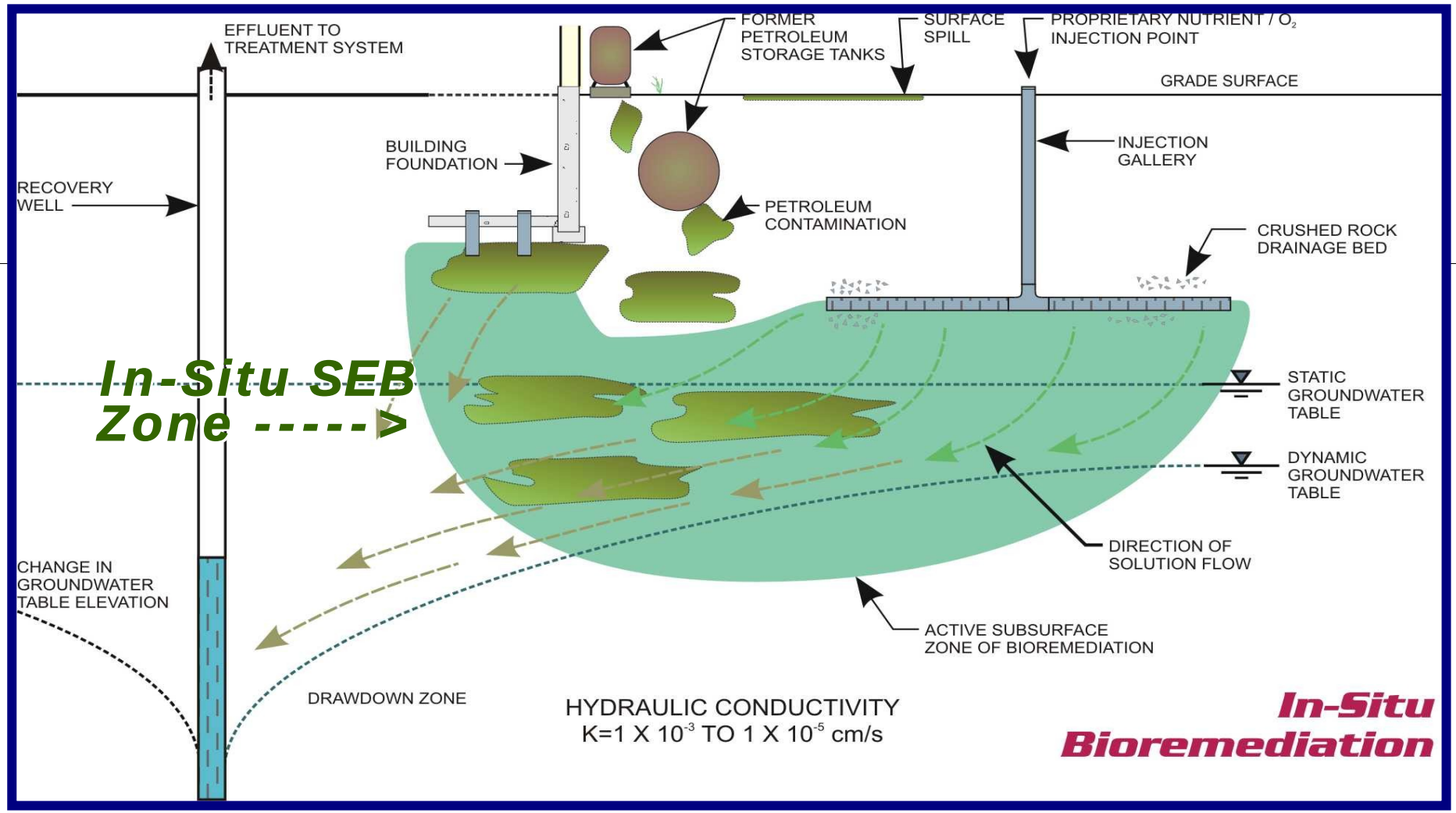


Surfactant Interaction With Organic (NAPL) On A Surface With Partial Micelle of F2, F3, or F4

In-situ & Ex-situ SEB

Applications
&
Case Studies

In-Situ SEB
Surfactant Enhanced Bioremediation



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

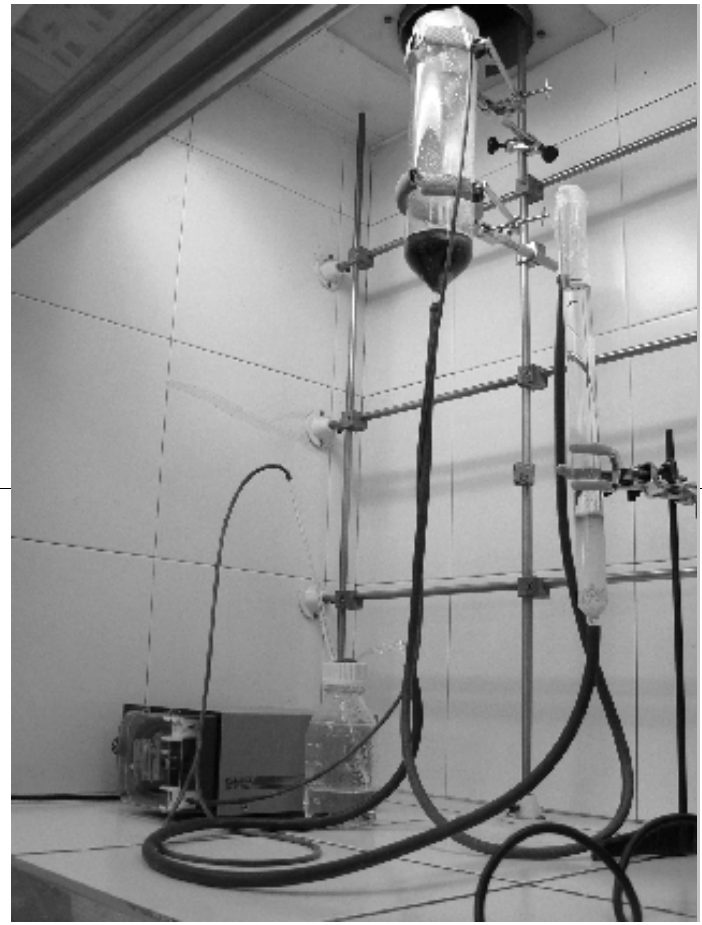
SEB Applications
Case Studies

CASE STUDY #1
Research Project (SEB)
Madrid Spain

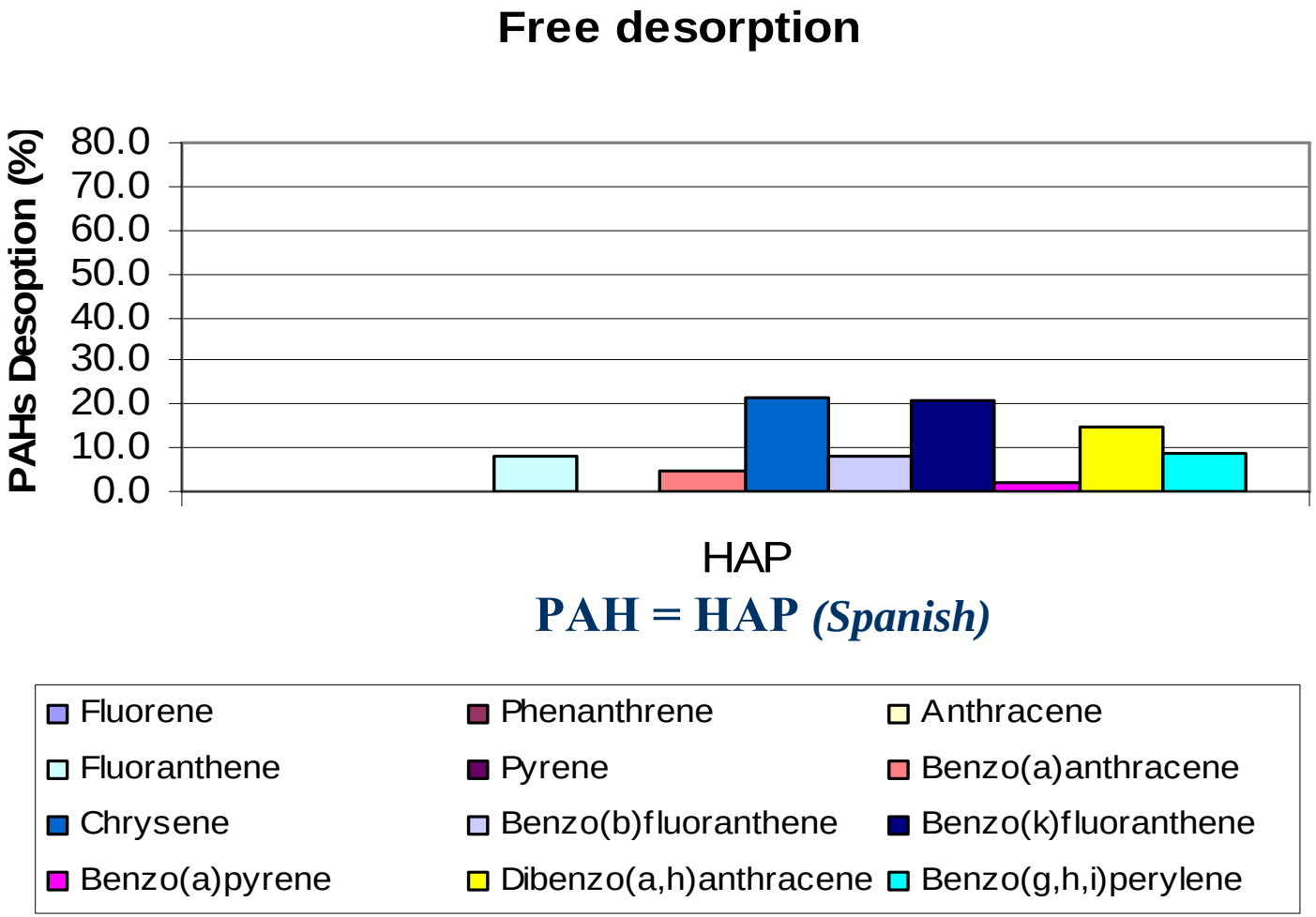
In 2007-2008, Ivey international Inc. conducted a joint Research and Development project with CIEMAT in Madrid Spain.

Purpose was to evaluate the ability of Surfactant (Ivey-sol 106) 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.

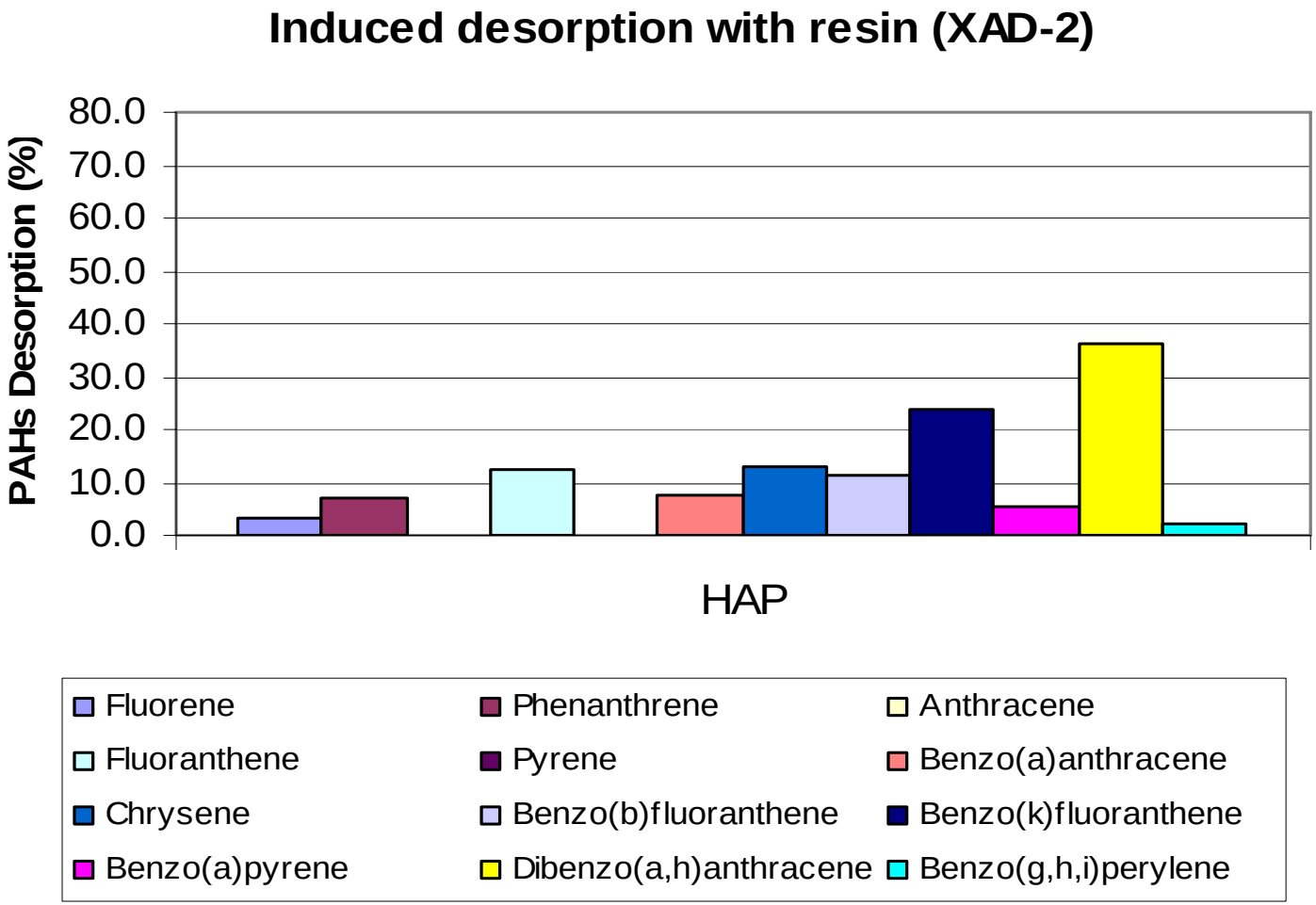


Images of column test laboratory set up

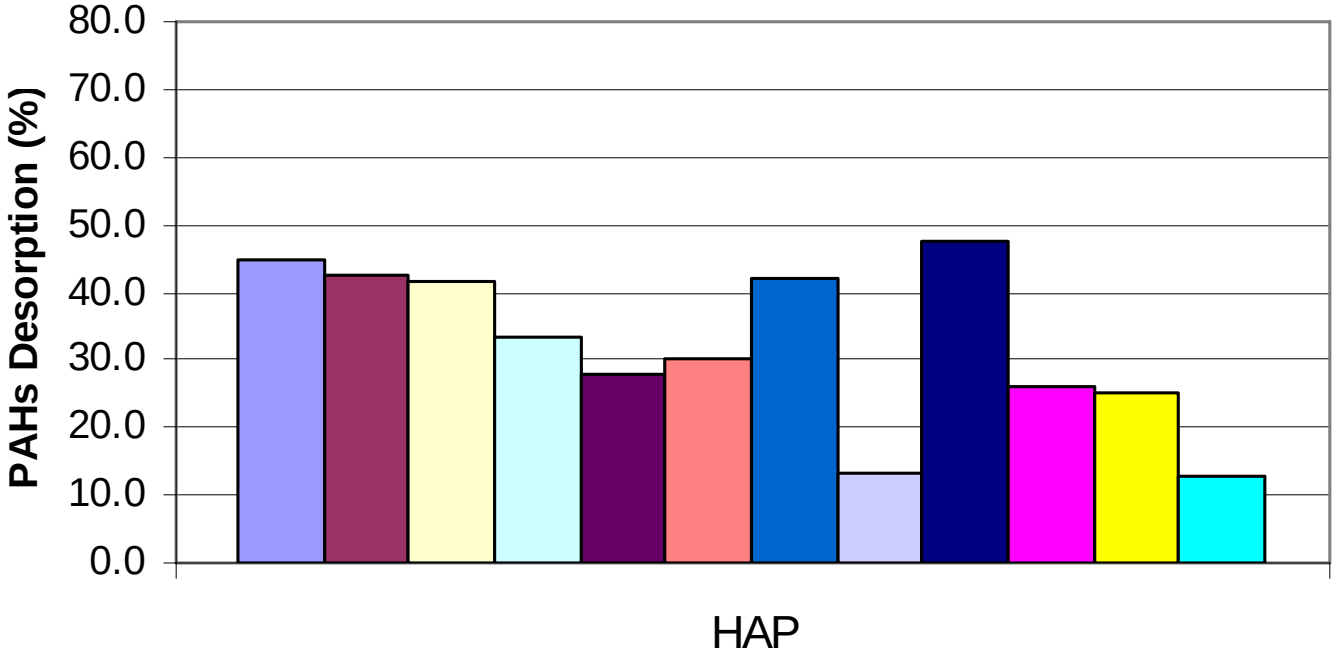


PAH = HAP *(Spanish)*

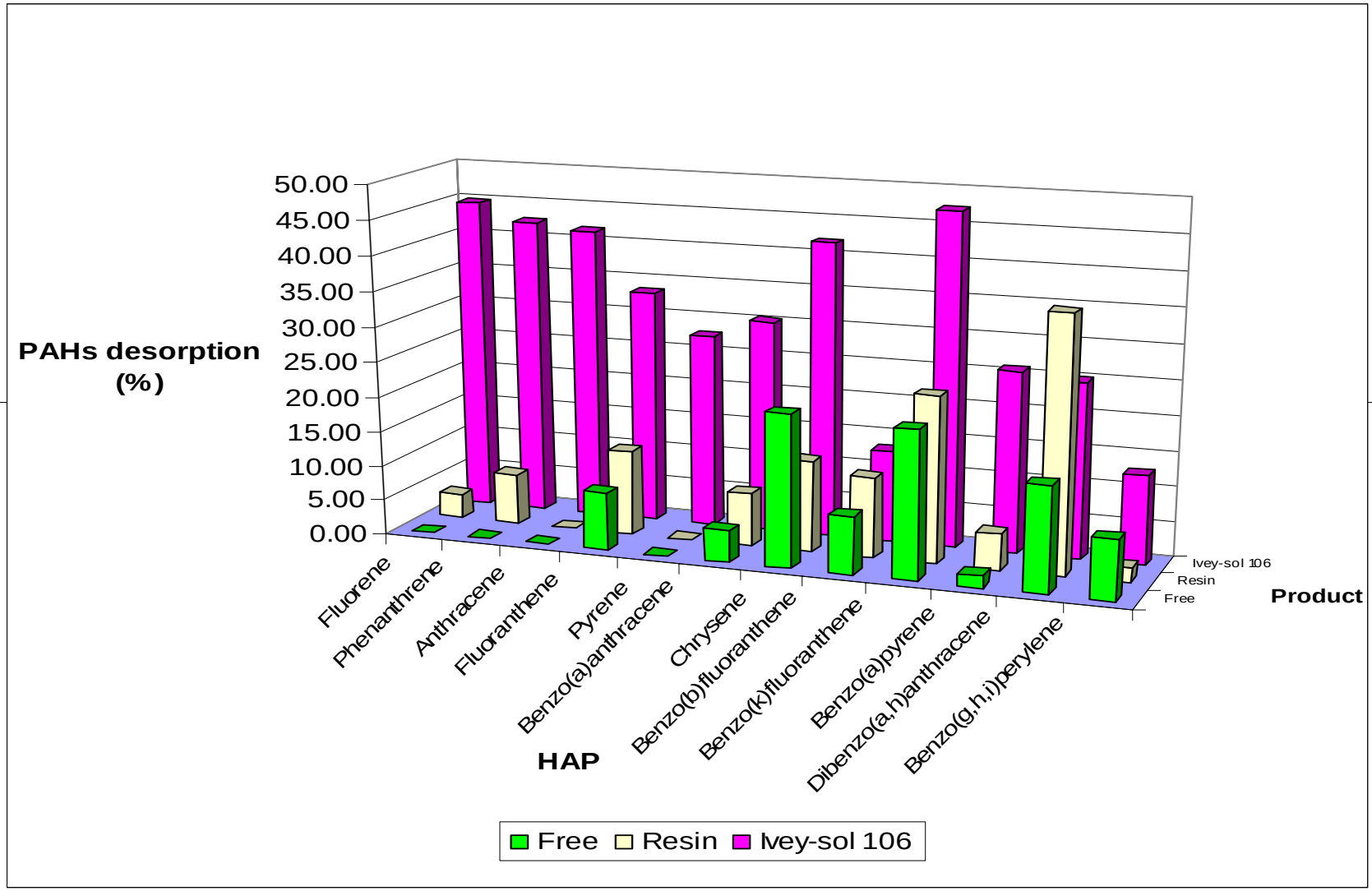
PAHs desorption in free desorption test water only.



PAHs desorption in induced desorption test (with a resin)



PAHs desorption with Ivey-sol 106 aided desorption test

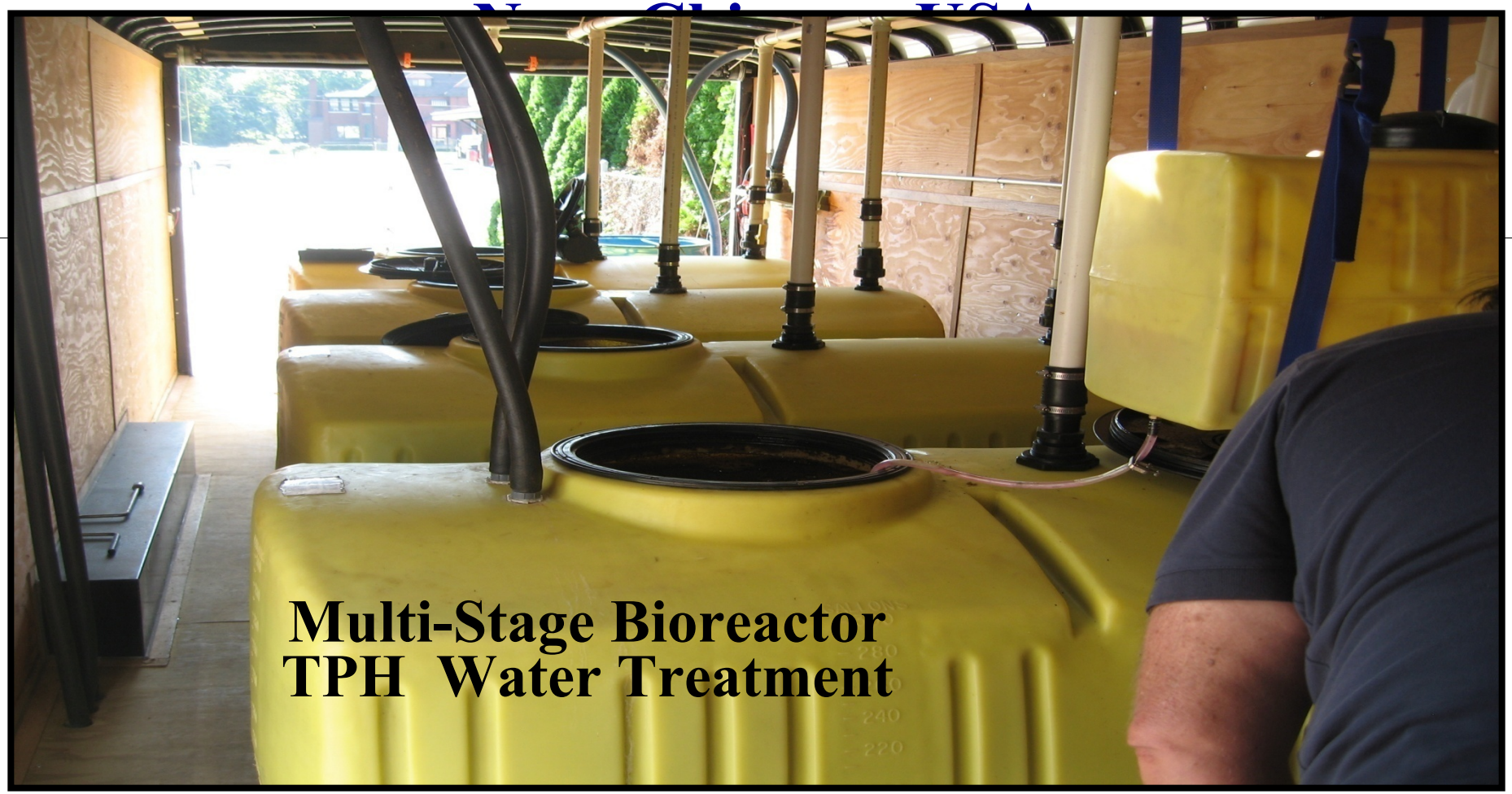


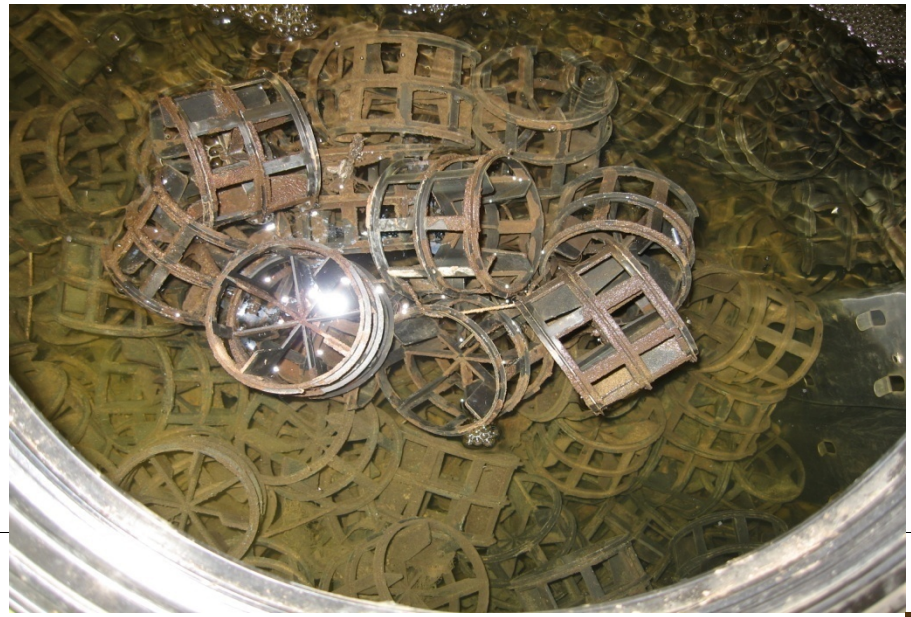
Comparative PAHs desorption (%) for all tests

Conclusions

- Ivey-sol 106 surfactants were very effective at desorbing the PAH compounds making them more ‘Available’ for all forms of remediation
- The potential for Ivey-sol surfactant to desorb and increase the bio-availability of PAH compounds for bioremediation was established.
- The findings of this study are to be published in an international journal in 2009
- Continued joint research and development projects, stemming from this work, are planned in 2009.

Case Study #2: SEB Groundwater Treatment (Bioreactor)





Packing Material (Growth Substrate)

Typical Bacterial Growth on substrate to treat the water

(No Ivey-sol)

A bio-reactor post (24 Hour) following Ivey-sol Addition

Conclusions

- The addition of Ivey-sol as an in-line automated feed to the bio-reactor water treatment system, significantly increased the rate and extent of biological growth on the packing substrate.
- According to the subject client, who also tested competing products, he stated that Ivey-sol out performed all other surfactants.
- The Ivey-sol made the dissolved contaminants more bio-available to the bacteria within the bio-reactors as was evidenced by visual bacterial growth in <24 to <48 hours.

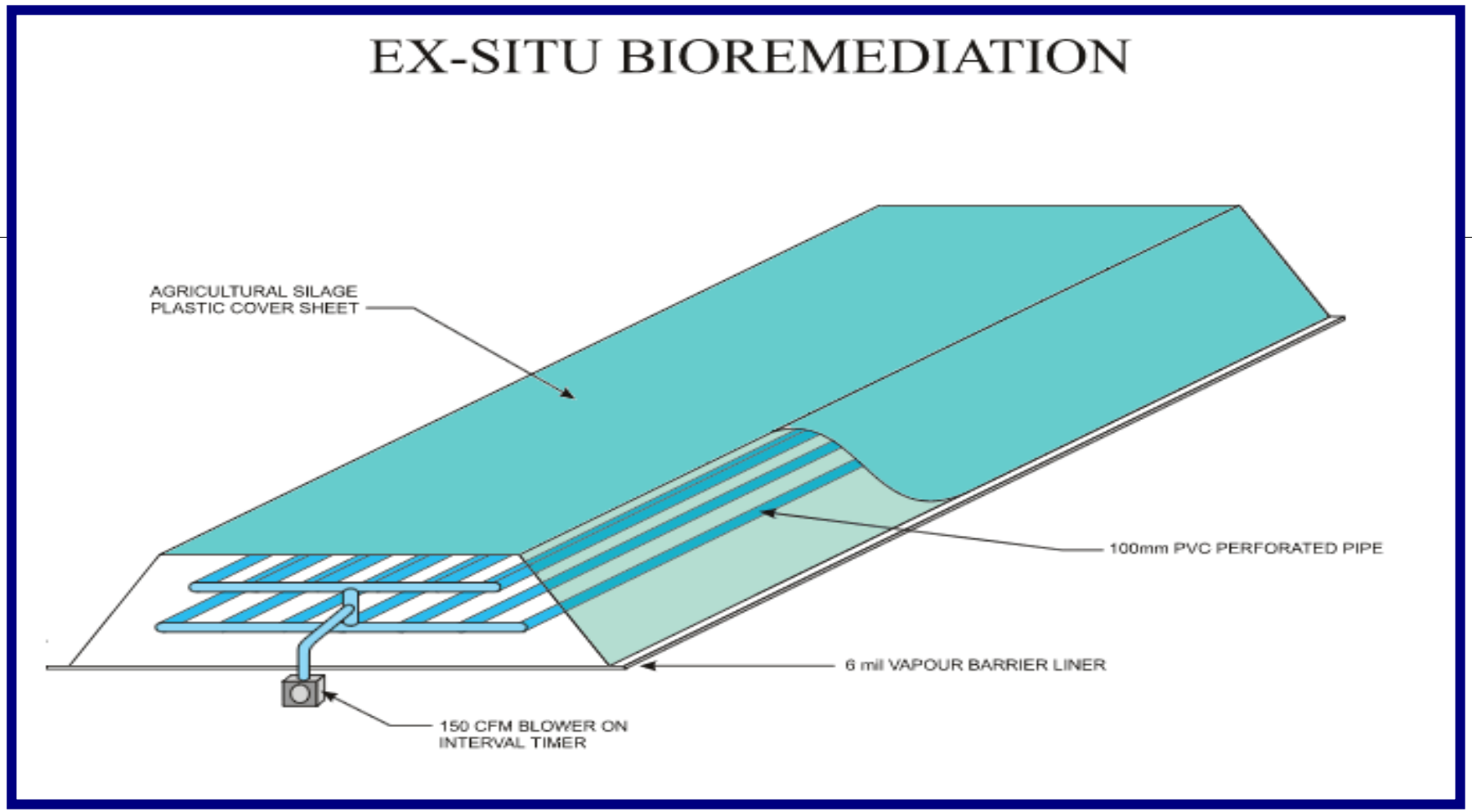
CASE STUDY #3

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 commenced in late August 2006, just prior to the onset of colder northern weather in an area known for -30 ^{o}C to -40^{o}C winter temperatures.

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



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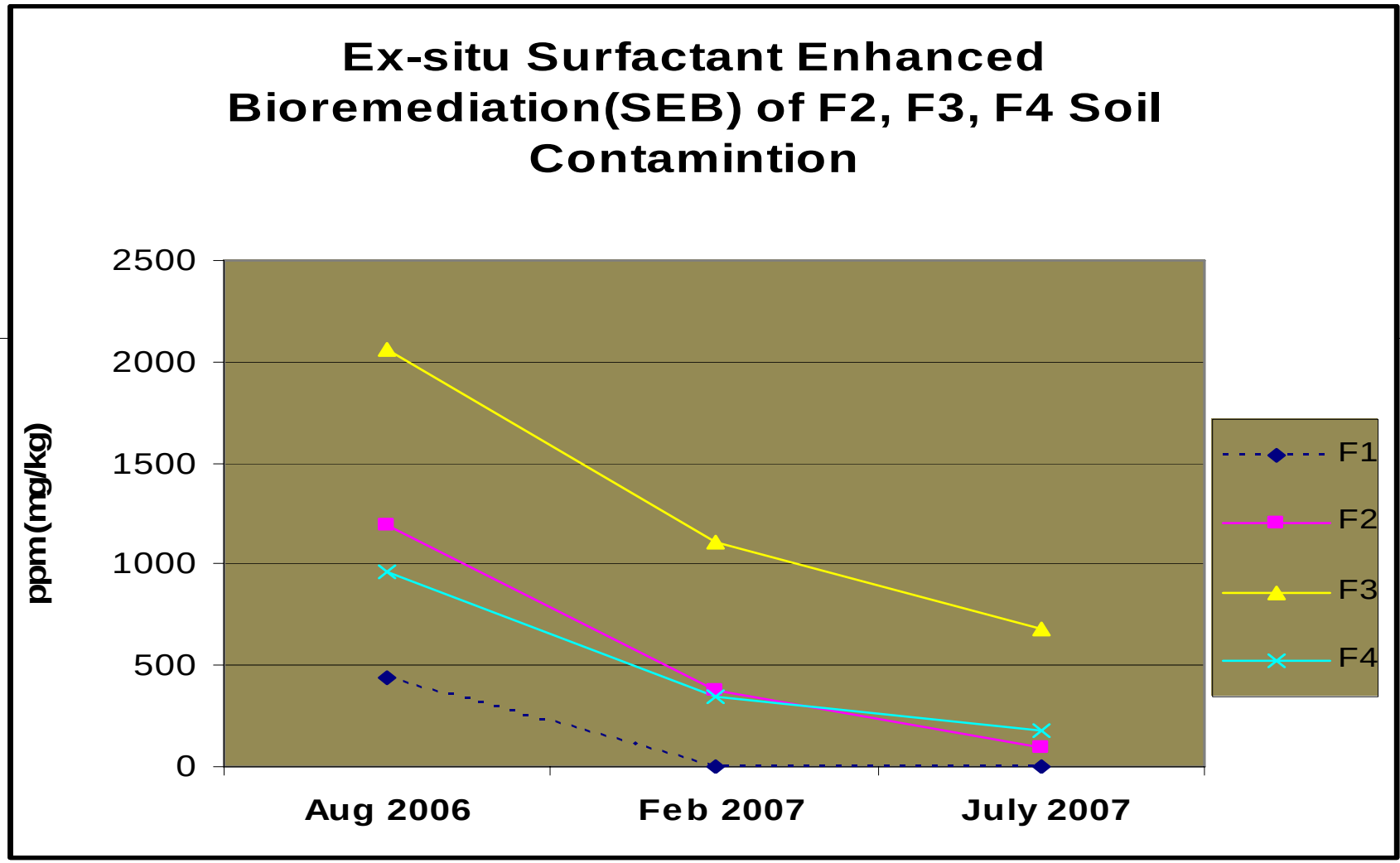
RESULTS


Ex-situ Surfactant Enhanced Bioremediation(SEB) of F2, F3, F4 Soil Contamintion
ppm(mg/kg)
2500
2000
1500
1000
500
0
Aug 2006
Feb 2007
July 2007
F1
F2
F3
F4

	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%),*** meeting the applicable Alberta Environment Soil Remediation Guidelines (ABENV, June 2007).

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