Surfactant desorption is key to successful PAH bioremediation

By George A. Ivey

Formulations which are patented non-ionic surfactant mixtures used in the *in situ* and *ex situ* treatment of petroleum hydrocarbons, chlorinated solvents, heavy metals, and more recently PAHs, PCBs and MTBE type contaminated waste are involved in Surfactant Enhanced Bioremediation (SEB®) using Ivey-sol®. These surfactant formulations have the ability to enhance soil biodegradation.

During *in situ* and *ex situ* bioremediation, the effectiveness of the bioremediation process is a function of balancing several physical and chemical parameters to achieve effective bio-mineralization of the target contaminants. The addition of Ivey-sol to the substrate can aid in the controlled desorption of the contaminants making them more bio-available. As a result, the duration of hydrophobic organic chemicals (HOC) bioremediation can be reduced by as much as 30 to 60%, or more.

Normally hydrophobic organic chemicals exhibit limited bioavailability to microorganisms as the contaminants tend to partition onto the soil matrix. This partitioning can account for as much as 95% or more of the total contaminant mass. Thus this limits the concentration of HOC available to the microbial population. Hence certain HOCs such a polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCBs) and phtalates can persist in the soil matrix for long periods of time.

The use of Ivey-sol® surfactant formulations, as part of a well designed bioremediation process, will provide a mechanism to desorb and mobilize the target contaminants from the surface of soil and bed rock to make them more available to the indigenous or introduced microbial populations.

Bioavailability is governed by the substrate concentration that the cell membrane comes in contact with (i.e., what the microorganisms 'see') as well as the rate of mass transfer from potentially bioavailable (e.g., non-aqueous HOCs) phase to the directly bioavailable (e.g., surfactant-aqueous HOC) phase. Surfactant Enhanced Bioremediation affects the sorption of HOC and surfactants at the solid-liquid interface (i.e., the surface–H_2O–NAPL interface). This mechanism is in part responsible for the increased bioavailability of the HOC and surface-bound nutrients. SEB using Ivey-sol® is effective at low surfactant concentrations. It expedites bioremediation of the contaminated soil and positively affects the surfactant–soil–NAPL systems (e.g., mass transfer of HOCs, cell hydrophobicity, and cell attachment at interfaces) while averting the inhibiting and/or microbial toxic effects associated with some surfactants (i.e., catonic and anionic) which are only effective at much higher concentrations.

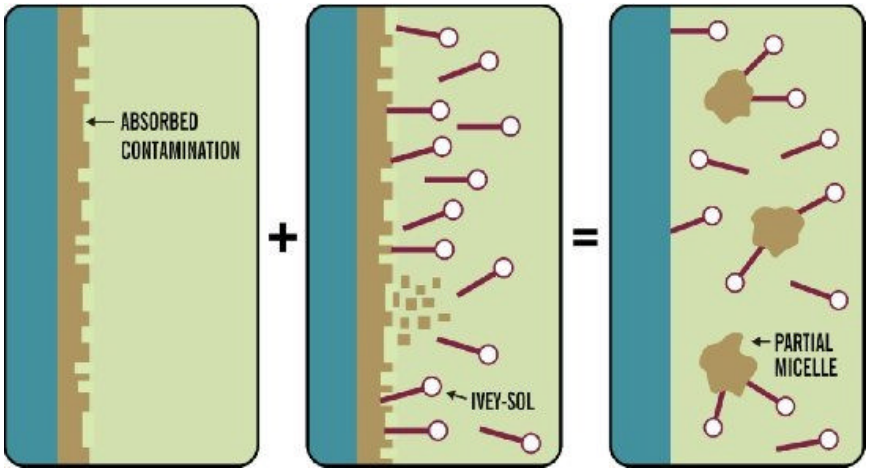


Figure 1

How Ivey-sol® technology works

An illustration of how the SEB - Ivey-sol® technology works, is shown in Figure 1. This should be used to augment one's present knowledge of bioremediation to understand the Ivey-sol surfactants' effects on a microscopic scale in improving the controlled liberation of hydrocarbons and nutrients (i.e., surfactant-aqueous HOCs and nutrients-aqueous) and their controlled availability for mineralization by the microorganisms present.

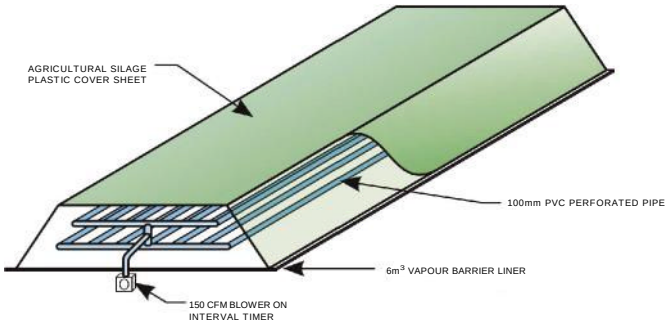
This illustration demonstrates how the technology desorbs contamination in the soil and either dissolves it for *in situ* or *ex situ* applications. In the case of *ex situ* Surfactant Enhanced Bioremediation (SEB), the surfactants desorb the contaminants, making them m ore bio-available and, as a result, expedite the biodegradation process.

This mechanism can be described as follows:

- When HOC (i.e., petroleum product) is absorbed on a soil grain, water alone will not remove it from the surface. This is a function of the hydrophobic characteristics of the HOC, which repels the water at its surface, and its inherent low water solubility.
- With the addition of SEB Ivey-sol® surfactants, the Ivey-sol® hydrophobic grouping is repelled by the water but attracted to the HOC on the surface. At the same time, the hydrophilic grouping is attracted to the water molecules.
- These opposing forces loosen the HOC from the surface of the soil matrix and suspend it in the water phase. Once dissolved, the suspended HOC is more visible to the microbial population present.
- Once liberated in low concentration in a 'surfactant-aqueous HOC' microscopic outward appearance, it is more bioavailable to the microbial population.

Range of applications

Ivey-sol® surfactant formulation can selectively dissolve a broad range of petroleum hydrocarbons from light, to medium, to heavy-end HOC type contamination. In addition, formulations have also been developed that are very effective on: chlorinated solvents,



Ex Situ Bioremediation.

PCBs, PAHs, and MTBE. It has also been shown to enhance the effectiveness of *in situ* soil and groundwater bioremediation, and *ex situ* soil (landfarm) type bioremediation processes by increasing HOC bioavailability.

Case Study (PAH & diesel soil remediation)

Ivey International Inc. was retained by Quinsam Coal Corporation to remediate over 200,000 kilograms (440,000 lbs) of diesel and PAH contaminated soil at their mining operation located near Vancouver, BC. Baseline total petroleum hydrocarbon concentrations exceeded 10,000 ppm and several of the PAH parameters exceeded the applicable Environmental Standards. Ivey International Inc. treated the contaminated soils using their new Surfactant Enhanced Bioremediatio process. After excavating and bio-piling the soil, the surfactant enhanced bioremediation 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 BC Environmental Standards and the soil was safe to re-use on-site.

Table 1

Parameters	Baseline	Ivey-sol 106	% Reduction
Hydrocarbons	*ppm*	*ppm*	*ppm*
>C10-C21 Hydrocarbons	8140	1600	80.30%
>C21-<C32 Hydrocarbons	5600	1300	76.80%
Volatile Hydrocarbons			
Benzene	0.25	0.09	64.0%
Toluene	0.63	0.14	77.8%
Ethylbenzene	0.53	0.07	86.8%
Xylene (Total)	2.2	0.3	86.4%
C6 - C10 (less BTEX)		16	
PAH'S			
1-Methylnaphthalene	130	5	96.1%
2-Methylnaphthalene	220	6	97.3%
Acenaphthene	46	6.1	86.7%
Acenaphthylene	140	6.4	95.4%
Anthracene	190	19	90.0%
Benzo(a)anthracene	100	14	86.0%
Benzo(a)pyrene	74	9	87.8%
Benzo(b)fluoranthene	54	6.3	88.3%
Benzo(ghi)perylene	21	3.3	84.3%
Benzo(k)fluoranthene	54	6.3	88.3%
Chrysene	100	13	87.0%
Dibenzo(a,h)anthracene	9.6	1.2	87.5%
Fluoranthene	230	26	88.7%
Fluorene	190	12	93.7%
Indeno(1,2,3-cd)pyrene	35	4.5	87.1%
Naphthalene	560	9.7	98.3%
Perylene	20	1.6	92.0%
Phenanthrene	420	37	91.2%
Pyrene	170	19	88.8%

Soil washed with Ivey-sol (106 Formulation)

PAH Case Study (bench scale)

During the spring of 2005, Ivey International's Research & Development Division was retained to conduct a bench-scale testing to determine the effectiveness of Ivey-sol for the desorption of PAH contaminants off silty-sand soils that had originated from an industrial brownfield site with over 100,000 tons of contaminated soil. The remediation plan involved a combination of *in situ* and *ex situ* bioremediation of said soils. The critical barrier associated with PAH bioremediation is its low bioavailability due to the fact that 90 to 95% of PAHs preferentially absorb on to surfaces versus being dissolved in the aqueous phase. If Ivey-sol could desorb and liberate the PAHs, it would in effect increase their bioavailability for microbial and mineralization.

The bench scale test involved the mixing of a 20:l volume of PAH contaminated soil from which a representative baseline sample was collected for PAH analysis. Then a 1 L volume of contaminated soil was washed and the liquid phase was decanted. A post Ivey-sol wash sample was then collected and submitted for analysis (Table 1).

As the bench scale test results demonstrate, Ivey-sol was effective at desorbing all 19 PAH compounds. On average, pre to post PAH concentrations dropped by >90%. The lowest desorption/removal was observed for benzo(ghi)perylene of 84.3%, while the highest desorption/removal was observed for 2-methylnaphthalene at 97.3%.

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