Surfactant Enhanced Vapor, Sorbed, and NAPL Phase Remediation of Petroleum and Chlorinated Solvents at Brownfields

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CHALLENGES & OPPORTUNITY:

Normally hydrophobic organic chemicals (HOC), including: light (i.e. BTEX, MTBE and Gasoline), medium (i.e. Diesel, Fuel-oil, PAHs), and higher (i.e. Motor Oil, Lubricants, Bunker-C) molecular weight petroleum hydrocarbon contaminants (C6 to C50 range) exhibit limited solubility in groundwater. This is also true of chlorinated solvents. As a result, these contaminants will naturally tend to phase partition and sorb (i.e., absorb and/or adsorb) onto soil or bedrock surfaces. Then with increasing concentration they agglomerate to form thicker sorbed layers to globules (ganglia) in pore spaces, to the formation of measurable light non-aqueous phase liquids (LNAPL) and/or dense non-aqueous phase liquids (DNAPL), collectively known as NAPL.

Contaminant sorption, globule/ganglia formation, and NAPL phase partitioning, which also occurs with volatile organic carbon (VOC), collectively limit the 'Availability' of HOC for in-situ and ex-situ remediation. Their limitations can be summarized as follows:

- ➔ Less **Physically Available** – for pump and treatment (P&T), Multi-Phase Extraction (MPE), AFVR, and soil washing physical treatment methods;
- ➔ Less **Biologically Available** – for aerobic, anaerobic and/or facultative biological treatment methods; and
- ➔ Less **Chemically Available** for oxidation, reduction, or other reactions used in chemical treatment methods.

USEPA REFERENCE:

A USEPA publication evaluated 30 in-situ remediation projects involving NAPL. With n=30 (number of observations), this is of statistical importance to draw conclusions with a 95% confidence interval. The 30 sites used a variety of physical, biological, and chemical remediation methods. The in-situ soil and groundwater remediation took between 3 to 27 years, with a median of 8 years. Site remediation was generally shorter for sites with less complex hydrogeological settings, with the exception of three (3) sites with mild heterogeneity that required more than 15 years (USEPA 542-R-18-002, May 2018).

HISTORICAL REFERENCE:

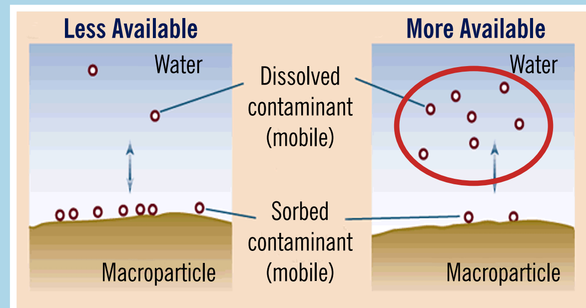
The impact of HOC phase partitioning has been well cited in literature, as demonstrated by the following quotation from 2005, which addresses how contaminant sorption limits the availability of sorbed contamination for conventional bio-remediation, with observation going back into the 1990's:

> "During the past decade, much discussion has centered on the unavailability of absorbed 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).*

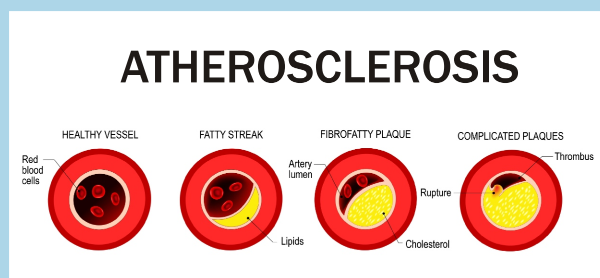
OPPORTUNITY TO ENHANCE REMEDIATION:

Generally, if we can overcome contaminant sorption, globule (ganglia), and/or NAPL (LNAPL or DNAPL) formation, we can significantly improve contaminant 'Availability' for all forms of physical, biological, and chemical remediation, including the combinations thereof.

This illustration shows how contamination, including vapors, can phase partition and sorb onto soil surfaces, within pore spaces, which limits their 'Availability' for remediation. However, if we can desorb, and breakdown globules and NAPL phases, by making them more miscible (using Ivey-sol®), they immediately become much more 'Available' for remediation.

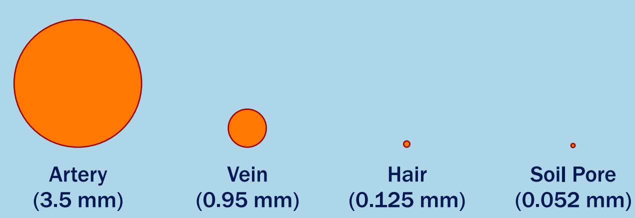


As contaminants aggregate (stick together) they will close off effective pathways, reducing porosity within the contaminated soil and groundwater regimes. This is medically analogous to atherosclerosis where plaques absorbs onto vein walls causing clogging of our arteries, reduced flow, and in worse cases cause a heart attack.

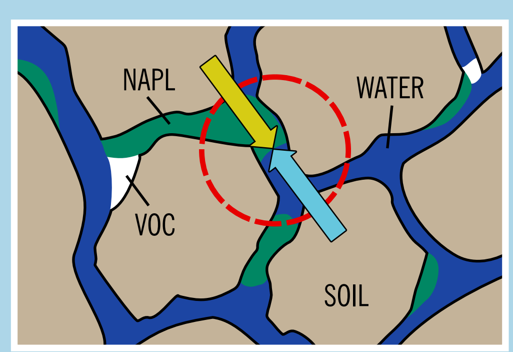


With reduced flow, within contaminated pore spaces, containing sorbed, globule and NAPL, there is corresponding reduction in access and egress, limiting the availability of phase-partitioned contaminants for effective remediation.

When you consider the average diameter of an artery to a vein, to the diameter of hair, to the average soil pore opening diameter, within soil, you quickly realize how phase partitioning can easily narrow and block pathways, causing significant pathway interference during physical, biological or chemical remediation, hindering their efficacy, leading to diminished benefits, and much longer and more costly vapor, soil and groundwater remediation.



Another overlooked factor impeding globule and NAPL remediation is Interfacial Tension. Simply put, it's the surface pressure realized at the contact plain between the groundwater and the NAPL, globule and sorbed phases within pore spaces. Water has a surface tension of 73 dynes while most contaminants are around 25 dynes, so on contact with water they are effectively trapped within the pore space, as depicted in this image.



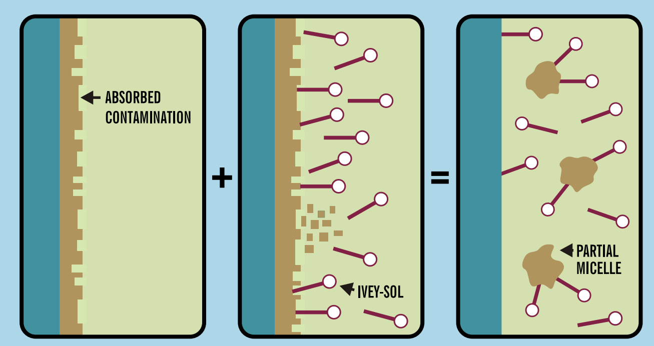
The water adhered to the soil, and where it comes in the NAPL, the NAPL does not have the force capacity (25 dynes vs. <73 dynes) to overcome the interfacial tension between the two phases, so neither can transition though the involved pore spaces, trapping the NAPL, globule, and sorbed phases to slowly back diffuse extending the site remediation period.

Entrained contamination also limits required access and egress function required for successful in-situ remediation.

IVEY-SOL® Surfactant Technology www.iveyinternational.com

To overcome contaminant phase partitioning, and interfacial tensions, the Ivey-sol® surfactant enhance remediation (SER℠) process provides a unique opportunity to improve enhanced vapor, soil and groundwater remediation, regardless of hydrogeological complexity, with consistent benefits, that are not just measured in time and cost savings.

The Ivey-sol® surfactant mechanism works below the critical micelle concentration (CMC), to selectively desorb the sorbed, globular, and/or NAPL phase mass, to increase their controlled solubility in groundwater, while lowering the surface tension of water (73 dynes to <30 dynes), to overcome interfacial tensions. In doing so Ivey-sol® increases the physical, biological and chemical availability of contaminants for remediation, with consistent and sustainable results, as shown below.



Based on hundreds of in-situ Ivey-sol® SER℠ applications globally, undertaken to enhance physical, biological or chemical remediation, over 80% of these applications have realized regulatory, and/or risk based closure, within 12 months or less. The fastest Ivey-sol® site remediation was less than 1 week, while the longest was slightly over 2 years, because the commercial site had to be remediated in sequential phases, due to the site logistics.

Brownfield Remediation - Lake Charles, LA VOC, Sorbed, and LNAPL Contamination

ATLAS ATC

OVERVIEW:

Historical commercial and industrial land-use with spills over ~35 to 40 years impacting the local soil and groundwater. Site geology was comprised of silty clay with clayey silt lenses. The groundwater was encountered at 3 to 5 ft. bgs creating a smear-zone of contamination. The site had measurable LNAPL (gasoline and diesel) at several wells on-site. The contaminants of concern (COC) included: soil VOC (TCE, DCE), sVOC (PAH-BaP), PCB (Aroclor-1026), and EPH/VPH exceeding applicable LA Department of Environmental Quality (LADEQ) Standards.

IVEY-SOL® APPLICATION:

- ➔ Baseline sampling was completed on October 8, 2021, from all IW, RW and monitoring wells locations;
- ➔ Pilot-scale scope of work completed over 5 months (November 2021 to April 2022), involved diluted injections of Ivey-sol (4%) at 4 Injection Wells (IW), with extraction at 2 Recovery Wells (RW) performing in-situ 'Push-Pull' and 'Sweep' applications;
- ➔ Total of 4 in-situ low volume applications were completed with a 50:50 blend of Ivey-sol® 103 + 106 (4%), followed by a 24 to 48 hour residence time, before commencing a Vacuum Truck extraction at the RW locations; and
- ➔ Post pilot scale sampling was undertaken at all wells on May 10, 2022.

IVEY-SOL® RESULTS:

- ➔ Recovered a total of 1,720 Gal. of COC impacted groundwater;
- ➔ Recovered ~80 gallons of free-product (LNAPL);
- ➔ VOC concentrations were reduced by 54%, but still above LADEQ limits;
- ➔ The sVOC concentrations were reduced by 46%, for compliance with LADEQ;
- ➔ The PCBs were reduced to non-detectable for compliance with LADEQ; and
- ➔ All EPH/VPH parameters were non-detected for compliance with LADEQ.
- ➔ 5 new IW plus 1 new RW will be installed within the plume area to optimize the next phase of Ivey-sol® applications.

QR Code Link To Ivey-sol® Technical Brochure (Overview, Case Studies, Testimonials)

CLIENT TESTIMONIAL:

"We were very pleased with the Ivey-sol® surfactant technology application at the Lake Charles, LA spill site. Significant reduction in VOC (54%) and SVOC (46%) were realized, with 80 Gallons of LNAPL removed in our first round of applications. Based on these encouraging results, the State has approved us to perform additional Ivey-sol® site applications".

Lee Day, PG, Senior Project Geology
ATLAS (Formerly ATC)

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