Lessons Learned PFAS Mass Removal From Soil Bedrock And Anthropogenic Surfaces For Improved Remediation And Decontamination









George (Bud) Ivey,

B.Sc., CES, CESA, P.Chem, EP

President & Senior Remediation Specialist

Ivey International Inc.

IVEY

25th REMTECH SYMPOSIUM

Interesting Projects

Beatty

11:10-11:40 CMT









IVEY-SOL Surfactant Technology

DECON-IT® Omni Surface Decontaminator

PFAS SOLS

IVEY International Inc. Global Distribution Network

An Award-Winning Environmental Remediation Company That Has Developed Innovative Patented Remediation Products and Processes To Enhance Physical - Biological - Chemical Remediation Including: Ivey-sol®, DECON-IT®, and PFAS-SOL®



IVEY-SOL Surfactant Technology

PFAS SOLS

DECON-IT® Omni Surface Decontaminator



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I'm an environmental professional with over 35 years of international experience in remediation. I have contributed to more than 3,500 remediation projects, taking me to over 70 countries. I hold in excess of 50 international patents and trademarks and have received 16 global environmental awards. My academic experience includes Synthetic Organic Chemistry, Geological Engineering, and a Master's Certification in Project Management.

IVEY-SOL Surfactant Technology

PFAS SOLS

DECON-IT® Omni Surface Decontaminator

How Old Is The Environmental Industry ?



First Earth Day April 1970



USEPA Formed December 1970



Australia Environmental Protection Act 1970



Environment and Climate Change Canada 1971



USA - Clean Water Act (CWA) 1972



Environmental Action Program (EAP) 1973-1976

>50 to <60 Years - Relatively Young - Global - Innovative Driving Change!







PER AND POLYFLUOROALKYL SUBSTANCES (PFAS) A.K.A. C8 - PFAS = PFOA + PFOS FOREVER CHEMICALS

- Per- and Polyfluoroalkyl Substances (PFAS) are a group of manufactured chemicals that have been used in industry and consumer products since the 1940s.
- Many organizations worldwide mandated the use of fire fighting foam that contains PFAS, known as Aqueous Film Forming Foam (AFFF). Plus, in many commercial products.
- However, per the Environmental Protection Agency (EPA), certain PFAS can cause serious health problems, including cancer, if people are exposed to them over a long period of time, and they can also be harmful to aquatic and terrestrial organisms.
- There are >15,000 PFAS chemicals (USEPA CompTox Database).
- 3M + DuPont + Chemours + Corteva Sued >200 Billion For PFAS Groundwater & Health Impacts In USA alone.

PFAS Solubility As Function Of Chain Length

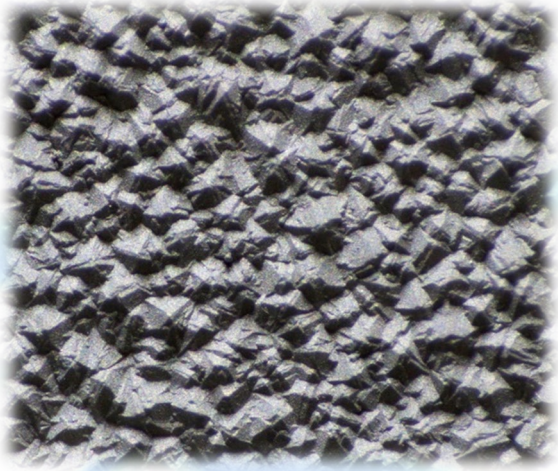
The longer The Chain Length Lower Solubility Greater Sorption

Molecular Formula	Molecular Weight	Vapor Pressure at 25 °C (Pa)	Water Solubility at 25 °C (mg/L)	Melting Point (°C)	Boiling Point (°C)	Log of Organic Carbon Partition Coefficient ($\log K_{oc}$)
C_3F_7COOH	214.0	851	562,877	−17.5	120	1.9
$C_4F_9SO_3H$	300.1	631	30,010	20.4–70.4	205–214	1.2–1.79
$C_5F_{11}COOH$	314.1	120	21,730	14	157	1.3
$C_6F_{13}SO_3H$	400.1	58.9	2302	26.7–73.2	218–238	2.4–3.1
$C_7F_{15}COOH$	414.1	4.2	771	54.3	188	1.89–2.63
$C_8F_{17}SO_3H$	500.1	6.8	60.1	15.2–73.5	219–262	2.4–3.7
$C_9F_{19}COOH$	514.1	0.2	25.2	78–88	218	2.76–2.96
$C_{10}F_{21}SO_3H$	600.1	0.7	2.4	11.6–85.2	224–284	3.53–3.66

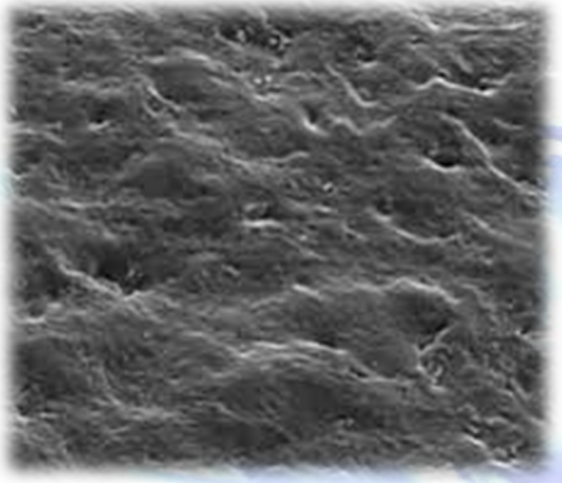
PFAS C_3 is 234,532X More Soluble The C_{10} Etc.

Reference: ResearchGate

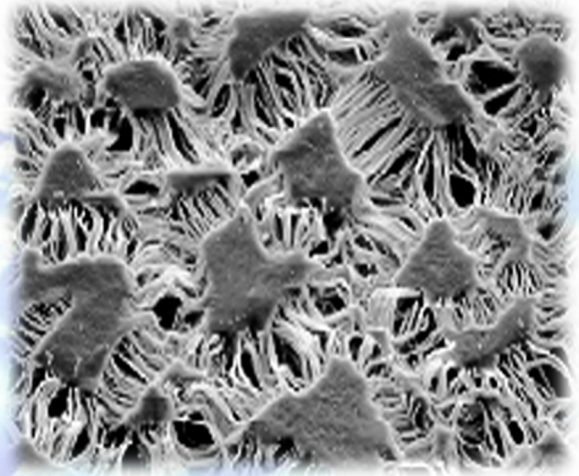
Magnified Surfaces → For Contaminant (PFAS) Sorption



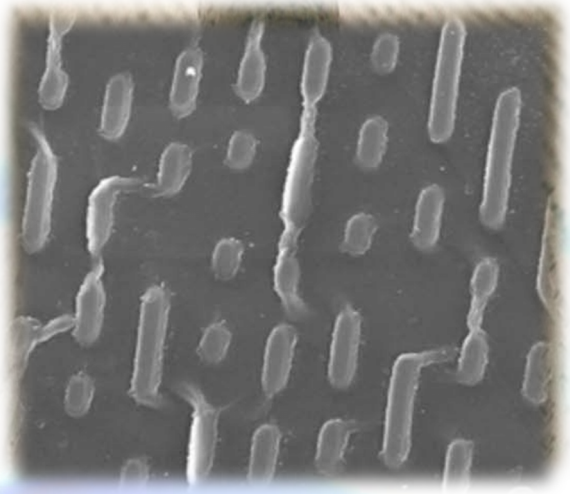
Glass Surface



Buber Flooring Surface



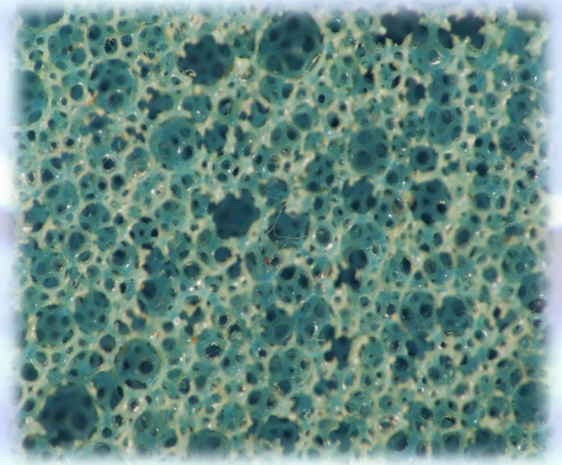
Gore-tex Surface



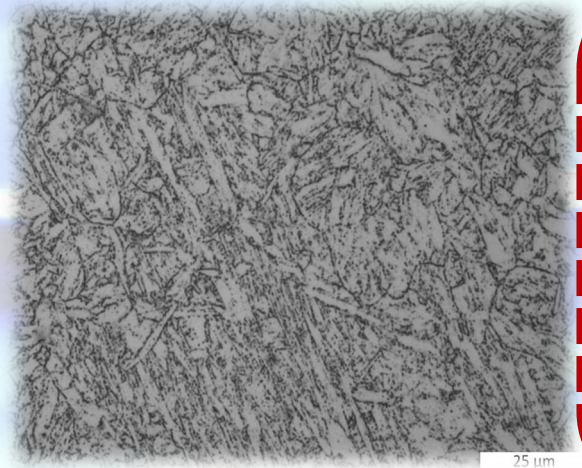
LP Record – CD Rom



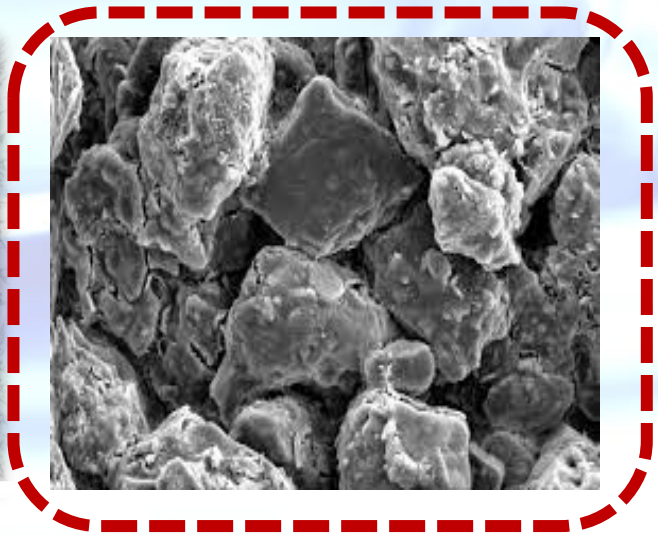
Concrete Surface



Foamed Plastic Surface



Stainless Steel Surface

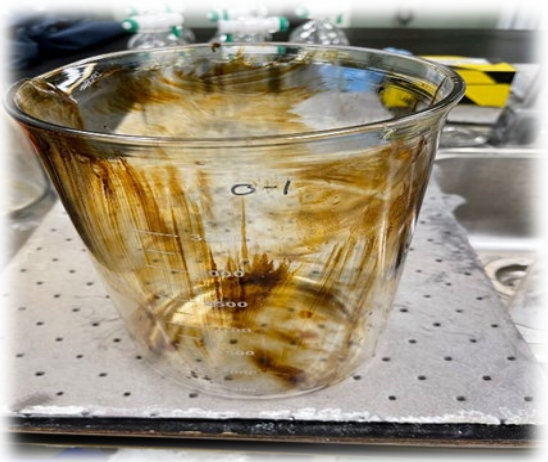


Soil Surfaces

DECONTAMINTION OF PFAS IMPACTED SURFACES

















To Comply With ASTM D5088 Decontamination Standards

Greater Surface Sorption – Lower Solubility (Greater Absorptive Coefficient)



C_1 to C_4 < C_5 to C_8 < C_9-C_{12} < C_{12}-C_{16} < C_{17}-C_∞



Greater Solubility – Lower Surface Sorption (Greater Partitioning Coefficient)

PFAS SORPTION + ABSORPTIVE COEFFICIENT + PARTITIONING COEFFICIENT

Agglomeration + Sorption + Transmissivity

Agglomeration is the 'sticking' *(cohesive or adhesive forces)* of organic molecules to one another.

(In Chemistry 'like dissolves like' and 'like attracts like')

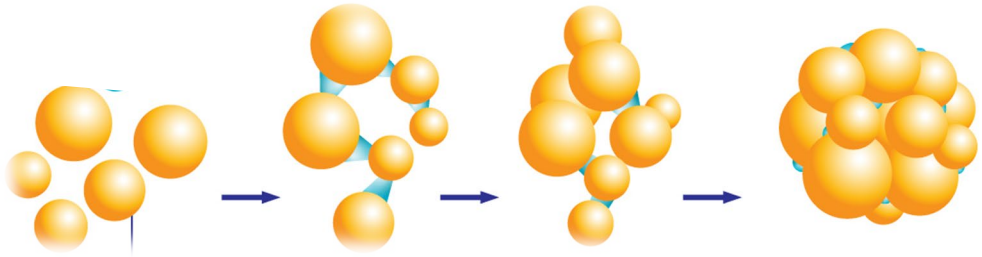
Hence, with oil Sorption onto soil surfaces, it will increase in thickness, that will amass to Globules to NAPL in soil and groundwater regimes. This can impact pore-space pathways

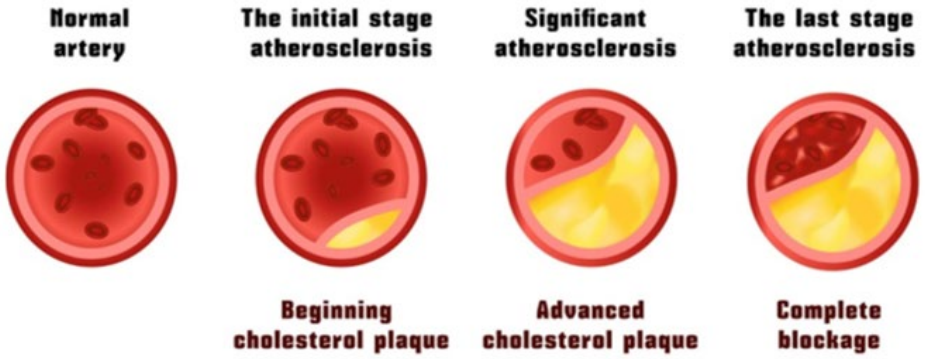
(medical analogy - clogging of arteries)

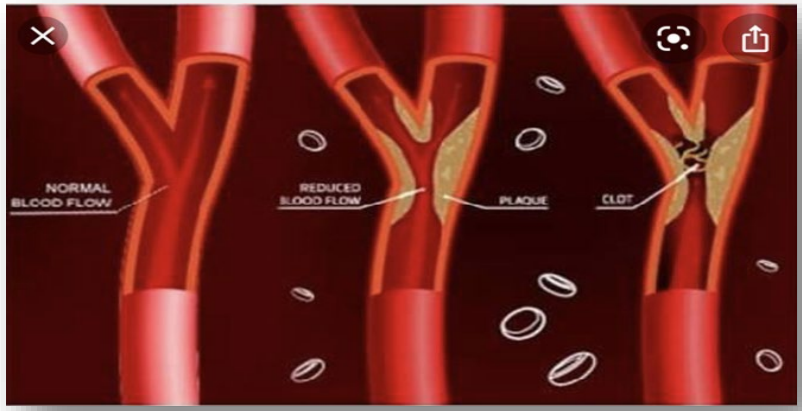
Transmissivity is a crucial hydrogeological parameter defining the rate at which groundwater flows horizontally through the entire saturated thickness of an aquifer under a unit hydraulic gradient.

Contaminated sites present reduced transmissivity often **>50% to >90% Reduction in Transmissivity**, compared to clean areas of the same site. ***Due To Pathway Blockages-Constrictions***

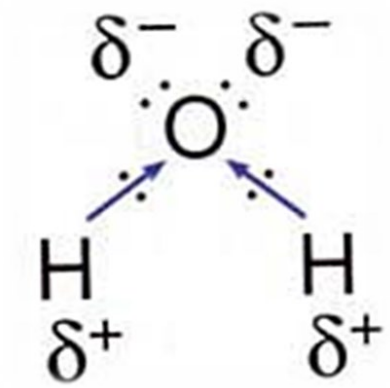
The resulting Clogging of pore pathways which '*control*' our capacity to performing Physical, Biological and Chemical Remediation…helping to explain why site remediation can be challenging, slow to costly…I will show how to over come these Hydro-Geo-Chemical challenges.



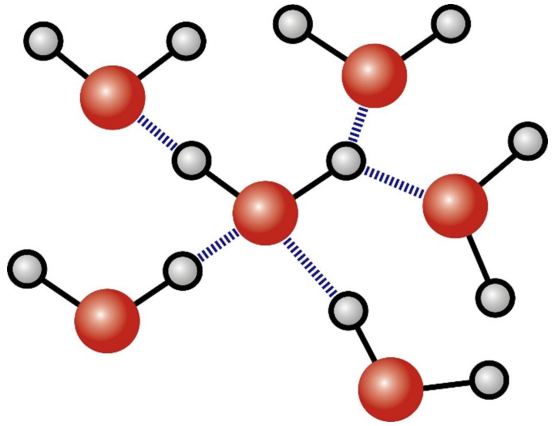




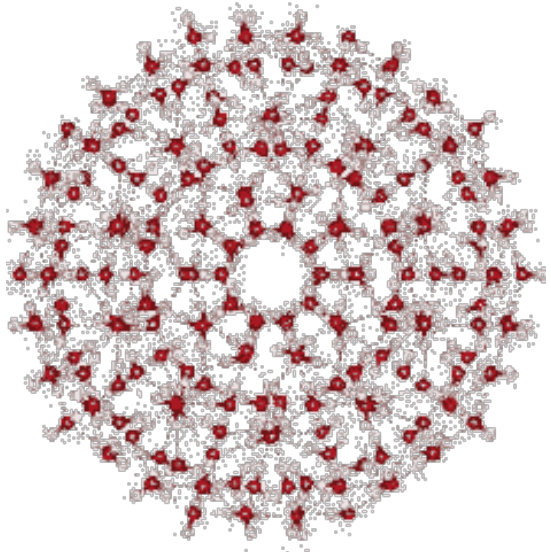
Water In Not H_2O
But A 3-Demensional Cluster



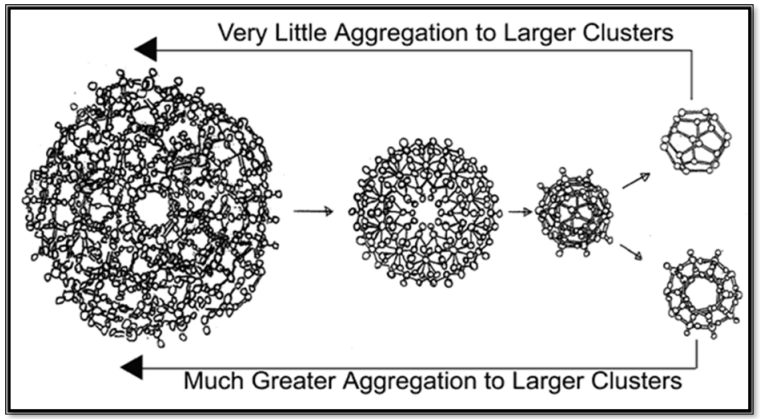


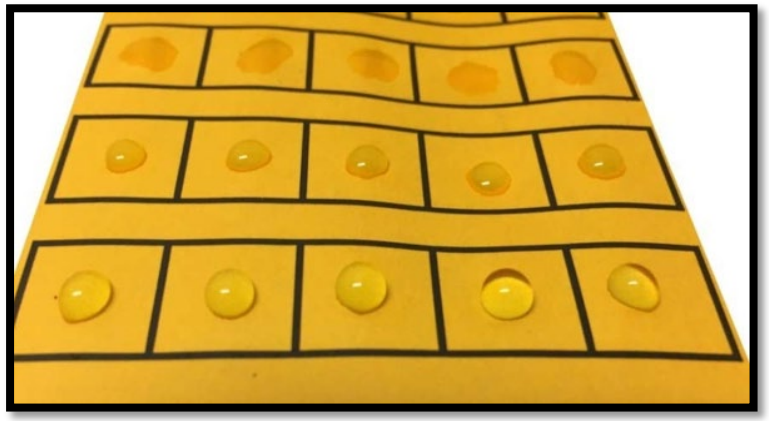


Hydrogen Bonding



Water Cluster





By Ivey International Inc.

PFAS C4 to C12

PFAS-SOL®

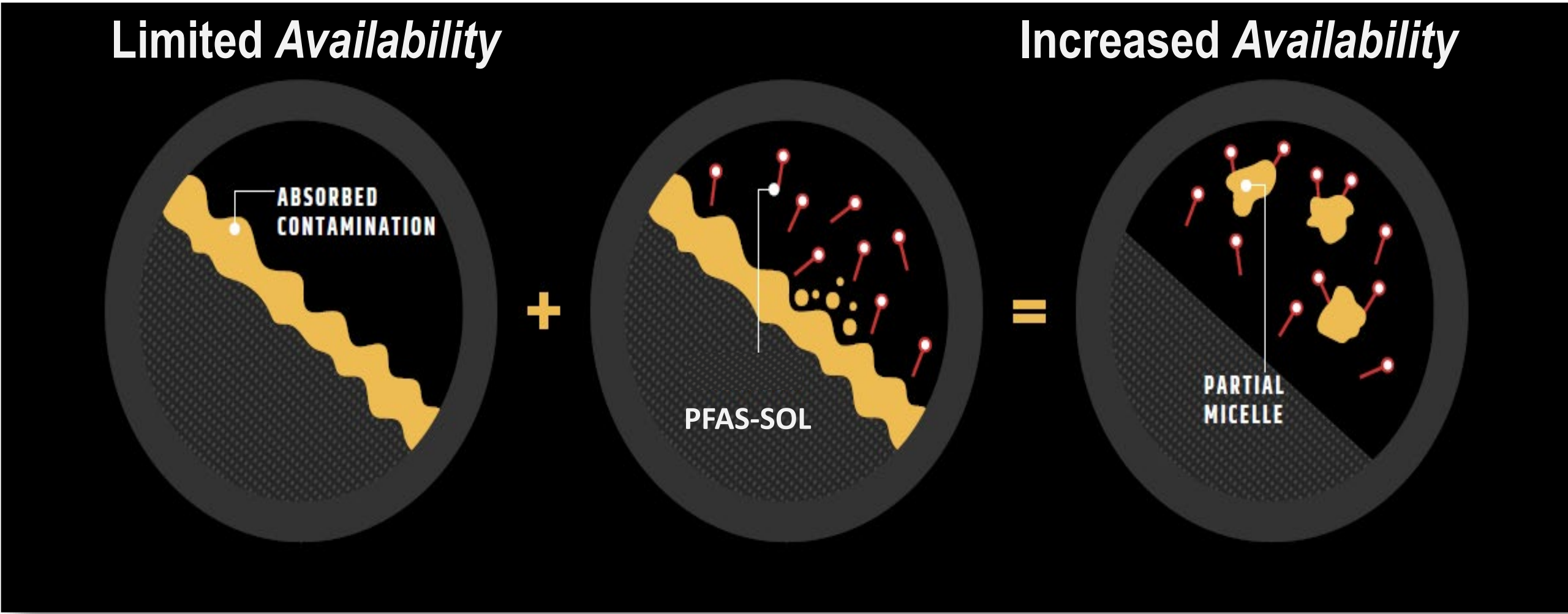
Is a patent-pending, award winning non-ionic surfactant technology developed by Ivey International Inc. for the selective removal of PFOA and PFOS (PFAS) from contaminated soil, bedrock, and groundwater, and the decontamination of anthropogenic (manmade) material surfaces.

www.iveyinternational.com

PFAS-SOL® Increases '*Availability*' of PFOA and PFAS Sorbed, Globular and NAPL Phases Below The CMC (Critical Micelle Concentration) For Improved Remediation + Decontamination

Solubility:
PFOS = 680 mg/L*
PFOA = 9600 mg/L*
MTBE=50,000 mg/L
NaCl = 357,000g/L
Sugar = 909,000 g/L

* Both Sorb to Surfaces
PFOS > PFOA



Total PFAS Mass Recovery 242% to 622% / Application

PFAS

Tests show surfactant-based technology effective in removing PFAS from soil and groundwater

By George (Bud) Ivey, David Holmes, and Cecilia MacLeod

In recent years, several major corporations, including 3M, DuPont, and Chemours (a DuPont spinoff), have reached major settlements with municipal governments and other plaintiffs, agreeing to spend billions of dollars to remove PFAS from their production processes, products and the environment.

A substantial amount of these settlement funds will go towards helping water treatment facilities to remove PFAS from drinking-water supplies. But significant dollars will also have to be spent to remediate PFAS-contaminated soil, bedrock, and groundwater.

The potential markets for PFAS remediation are numerous, ranging from chemical and other product manufacturing to electric power, wastewater treatment, real estate development, retail petroleum, landfill operations, mining, ports and harbors, federal facilities, and more (*Environmental Business Journal, Vol. XXXII, No 5/6, 2019*). All face significant future liabilities as the regulatory net and public awareness around PFAS grows and tightens. However, remediation contractors can face these future liabilities as well if their PFAS cleanup solutions prove inadequate to the task.

The traditional pump-and-treat solution has been applied to the remediation of PFAS-impacted groundwater, but it is expensive and can take decades to achieve any significant levels of removal.

Additionally, contamination in the more mobile, high-permeability groundwater zone can migrate into immobile, low-permeability subsurface zones, and pump-and-treat is not effective in removing contamination from those low-permeability zones. This can lead to future releases and back-diffusion into the high-permeability zone, and thereby failure to meet regulatory standards.



The PFAS family consists of nearly 15,000 chemicals.

Some chemical and biological removal methods are being tested, but satisfactory results have not emerged. Methanol solvent extraction is used in laboratory soil extraction, and some small-scale testing. However, regulators are not likely to look approvingly at injecting many of these impactful chemicals into the ground.

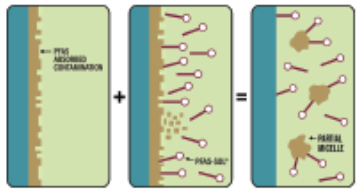
One potential solution, however, has been shown to be effective in recently completed tests. Ivey International Inc. (IVEY) has developed a new formulation from its Ivey-sol® enhanced remediation (SER) technology to address PFAS contamination in groundwater, soil, and bedrock regimes.

Tests of the PFAS-SOL® formulation conducted in the United Kingdom (UK) in collaboration with the University of Greenwich, with analysis by ALS, have shown significant PFAS mass removal rates. This formulation is non-toxic, biodegradable, and pH neutral. It is based on non-ionic formulations, with a novel additive, that can selectively desorb contaminants and render sorbed, globular and non-aqueous phase liquids (NAPL) soluble in the aqueous phase. This means it forms a non-emulsified mixture with water and can thus be more easily controlled and removed from impacted soil, fractured bedrock, groundwater, and surface water while maintaining plume control.

The PFAS-SOL surfactant structure consists of a hydrophilic head and a hydrophobic tail. The hydrophobic tail is by design, selectively attracted to the organic functional groupings on target contaminant molecules, while the hydrophilic head is attracted to groundwater.

Based on this modulated structure, these surfactants offer multiple properties that improve the effectiveness of most remediation strategies, predominantly by overcoming the limitations associated with contaminant sorption and low solubility. In addition, they lower the relative surface tension of water and overcome interfacial tension, thereby improving its wetting and associated hydraulic properties across

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PFAS-SOL can selectively remove PFAS from sorbed soil and bedrock surfaces.

broader soil textures.

PFAS-SOL can selectively remove PFAS from sorbed soil and bedrock surfaces, from globule and/or NAPL phase-partitioned layers, to make them more available for enhance physical, biological, and/or chemical remediation.

For the column tests, one metre by 14 centimetre diameter columns were filled with a mineral sand (a building sand), with 10% activated carbon to act like natural organic carbon absorptive content within the soil. The columns were then slowly saturated with water from the base and drained to a set the volume. They were next spiked with 250 mg each of PFOA and PFOS to mimic a PFAS source zone and then drained and filled, with the effluent sampled to show contaminant recovery in water.

The columns were filled again, one with methanol at a 50% concentration in water, the other with the PFAS-SOL surfactant formation at a 4% concentration. They were then drained, with the increased concentration in the effluent in the PFAS-SOL column showing a large increase in PFAS concentration. The columns were then slowly taken apart to deliver a moisture profile and obtain soil samples to measure retained PFAS.

The results showed significant mass PFAS removal from the PFAS-SOL flushes. Flushes with water alone yielded PFAS recovery of approximately 5 micrograms per liter (µg/L), whereas surfactant flushes exhibited improved recovery of up to 30.45 micrograms per liter (µg/L). This meant an average improvement in PFAS removal of 240%, with concentration spikes of up to 622%. PFOA recovery averaged 160%, with best results of 185%. PFOS recovery averaged 297%, with best results of 732%. Total PFAS recovery averaged 242%, with best results of 622%.



The two test column tubes were spiked with 250 mg each of PFOA and PFOS to mimic a PFAS source zone.

Subsequent tests have shown similarly impressive results, suggesting a bright future for this surfactant-based PFAS remediation compared with other methods that are time-consuming and costly, and don't provide assurances against future back-diffusion risks liability associated with new sportive technologies.

Ivey International Inc. won the 2023 M&A Today Global Awards "Best Environmental Technology Company" in recognition for their innovative technology developments. ■

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Dr. Cecilia MacLeod is with the University of Greenwich (UK). Email: c.macleod@greenwich.ac.uk

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Patent Pending

BREAKTHROUGH PFAS REMEDIATION TECHNOLOGY FOR PFAS MASS REMOVAL FROM SOIL, BEDROCK AND GROUNDWATER REGIMES...

PFAS-SOL® Sub CMC Selective Surfactant Desorption Technology

Our testing has shown that PFAS-SOL can reproducibly increase PFAS recovery from soil, and groundwater, several fold (>200% to >700%) when combined with in-situ soil flushing

Our R&D results confirmed the following improved capacity:

- PFOA Mass recovery of 160% to 185%
- PFOS Mass recovery of 297% to 732%
- TOTAL PFAS Mass recovery of 242% to 622%





Improves physical, biological and chemical availability of PFOA and PFAS for remediation

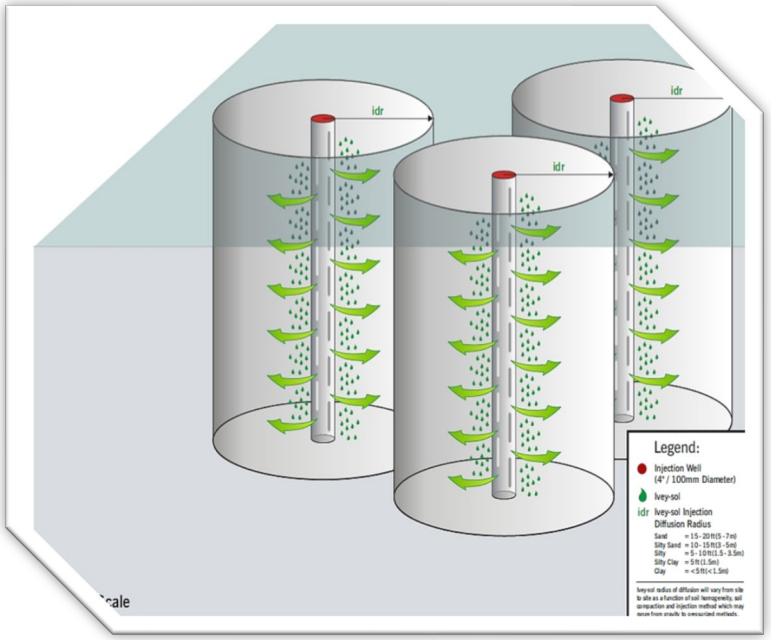
Technology overview and its capacity to resolve Forever Chemicals from the Environment

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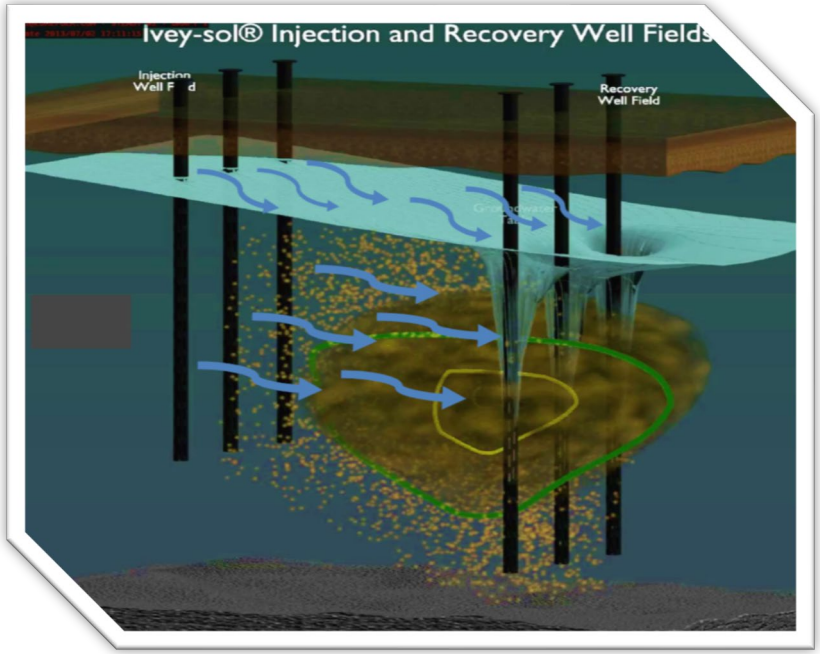
Environmental Science & Engineering - February 2024

IN-SITU PFAS-SOL® SOIL, BEDROCK & GROUNDWATER REMEDIATION METHODS

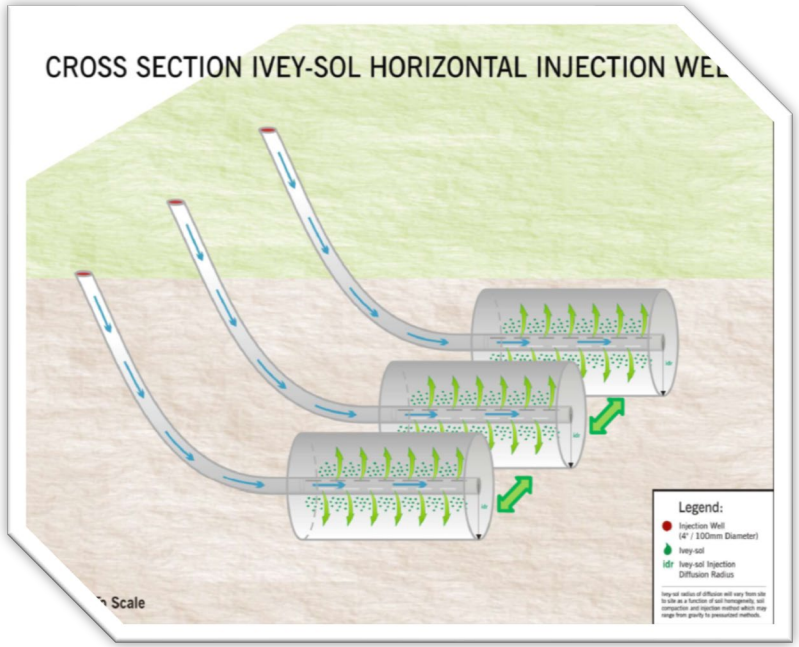
Push-Pull



Sweep



Horizontal Well



All methods designed to enable PFAS mass removal from impacted soil, bedrock and groundwater regimes.

99.99998% PFAS Mass Removal

PFAS

Decontaminating fire-fighting equipment to prevent PFAS from entering water supplies

By J. Scott Poynor

Although there is still much to learn, we know that the class of chemicals known as per- and polyfluoroalkyl substances, referred to generally as PFAS, is ubiquitous in the environment and poses risks to human health and the environment. Of utmost concern lately, PFAS in water supplies has become recognized as a special risk, and municipal water systems, or government agencies acting on their behalf, have taken the lead in suing manufacturers to phase out PFAS production and provide the funds for remediation.

Meanwhile, the development of technologies for removing PFAS from the environment is playing catch-up. These environmental endpoints include not only water and soil but surfaces of all kinds of products and equipment that present human exposure risks. Although multiple technology development efforts are underway, there remains a lack of efficient, scalable, cost-effective, and environmentally benign technologies to deal with this broad range of contamination issues.

One promising technology was recently successfully deployed at a petroleum storage facility, which faced PFAS problems associated with its fire-suppression equipment. The facility operator, recognizing the rapidly advancing tide of PFAS-related action, sought to address contamination in certain equipment, in the interest of liability and risk management and out of concern for potential employee exposures.

The equipment in question consisted of a fire-fighting system, including piping that stored aqueous film-forming foam (AFFF), a fire-fighting liquid that contains PFAS compounds.

Replacing the PFAS-contaminated equipment was not viable, due to cost considerations and, even more, to the time required for procurement and installation of new equipment. Fire-fighting systems at petroleum storage facilities are required to be operational essentially full-time, so removing the residual PFAS from the existing equipment was deemed the preferred option.



The facility operator agreed to GST's recommendation that PFAS-SOL be deployed to reduce the concentrations of PFAS residues on the fire-fighting system piping and equipment surfaces.

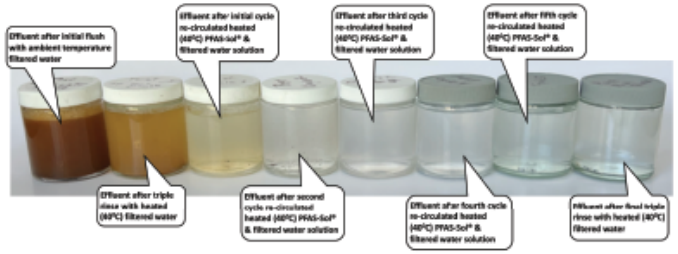
Following removal of the AFFF from the system, residual concentrations of PFAS were detected on the equipment surfaces. The facility operator performed a thorough, high-pressure flushing of the system using filtered municipal potable water, but that action left a PFAS concentration of 342,643 ng/100 cm² on the equipment's interior surface, a level deemed significant and falling short of the facility operator's decontamination goals.

The facility operator then engaged Geologic Science and Technology Group (GST), an environmental consulting firm with which the operator had frequently worked in the past, to undertake the equipment decontamination project. The objective of the project was to reduce residual concentrations of detected PFAS constituents to the maximum extent possible using currently available technology.

In initial discussions with the facility operator, GST reviewed the known available options for removing PFAS from surfaces. Flushing with an alcohol-based solvent (ethanol or methanol) has historically worked better than flushing with water, but it is known to leave PFAS concentrations in residue of about 10%, which was substantial and considered to be too high.

GST then presented a surfactant-based solution that had shown the potential to achieve substantially improved removal rates compared with alcohol-based solvents. PFAS-SOL® is a patent-pending, non-ionic surfactant developed by British Columbia based Ivey International Inc. (IVEY) that is pH neutral, non-caustic, non-corrosive, non-toxic, and biodegradable.

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The remediation project then proceeded with a series of five flush cycles using combinations of PFAS-SOL and filtered municipal potable water.

The facility operator agreed to GST's recommendation that PFAS-SOL® be deployed to reduce the concentrations of PFAS residues on the fire-fighting system piping and equipment surfaces. The equipment decontamination project was undertaken in early March 2024, with a series of sequential phases.

Tanks for blending the surfactant with municipal potable water were staged by the pipe fittings on the portion of the fire-fighting system to be decontaminated, both upstream and downstream to create a closed-loop system.

The emptied piping system was initially flushed with filtered potable water at an ambient temperature (approximately 19°C) and then flushed three times with filtered potable water heated to 40°C. Following this flushing and wipe sampling at the discharge point, laboratory analysis detected a total of 12 PFAS analytes on the piping interior surface. These analytes consisted of nine acid compounds and three sulfonate compounds.

SUMMARY OF PFAS COMPOUNDS DETECTED ON INTERIOR SURFACE OF FIREFIGHTING PIPING SYSTEM AFTER AFFF REMOVAL

DETECTED PFAS			AFTER SYSTEM AFF PURGE & WATER RINSE	AFTER HEATED PFAS-SOL® WASH and HEATED WATER RINSE	
Type	Compound	CAS	Pre-Decon	Post-Decon	% Reduction
PFCAs	Perfluorobutanoic acid (PFBA)	375-22-4	388.0 ng	<0.263 ng U	> 99.999935%
	Perfluoropentanoic acid (PFPeA)	2706-90-3	336.0 ng	<0.0434 ng U	> 99.999987%
	Perfluorohexanoic acid (PFHxA)	307-24-4	2,898.0 ng	<0.0345 ng U	> 99.999988%
	Perfluoroheptanoic acid (PFHpA)	375-85-9	311.0 ng	<0.0497 ng U	> 99.999841%
	Perfluorooctanoic acid (PFOA)	335-67-1	1,268.0 ng	<0.0312 ng U	> 99.999975%
	Perfluorononanoic acid (PFNA)	375-95-1	198.0 ng J	<0.0155 ng U	> 99.999218%
	Perfluorodecanoic acid (PFDA)	335-76-2	472.0 ng	<0.0310 ng U	> 99.999959%
	Perfluoroundecanoic acid (PFUnDA)	2058-94-8	38.8 ng J	<0.0296 ng U	> 99.992911%
	Perfluorododecanoic acid (PFDoA)	307-55-1	151.0 ng	<0.0349 ng U	> 99.999769%
Sulfonate	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	<10 ng U	0.0269 ng J	> 99.892805%
	6:2 Fluorotelomer sulfonic acid (6:2 FTS)	27619-97-2	264,000.0 ng	0.0629 ng	99.999976%
	8:2 Fluorotelomer sulfonic acid (8:2 FTS)	39108-34-4	82,000.0 ng	<0.0790 ng U	> 99.999990%
	Sum of detected PFAS		372,843 ng	0.0835 ng	99.999978%

NOTE: 1. A surrogate value = 1/2 of the reporting level was used for non-detects in calculating percent reduction; 2. J = tentatively estimated value; 3. U = not detected; 4. Laboratory analysis was performed by Eurofins Analytical Trace Testing Laboratory in Wilmington, North Carolina using a modified EPA method 1633 by adding laboratory grade PFAS standards labeled with Carbon 13 (C13) isotope, allowing lowered reporting levels and minimizing re-extraction for high concentration samples.

The remediation project then proceeded with a series of five flush cycles using combinations of PFAS-SOL® and filtered municipal potable water. In each cycle, the surfactant-water solution was heated to 40°C and recirculated for one to 1.5 hours by redundant pumps at high velocity under increased pressure. Following each cycle, the piping system was purged with filtered potable water heated to 40°C to remove all traces of the solution before applying it again in the next cycle. One final triple rinse followed cycle five.

A wipe sample was collected at the discharge point over a 100 cm² area of piping and compared with a baseline wipe sample that had been collected prior to the initial flush. The decontamination process reduced residual PFAS contamination on the equipment surfaces by an additional 99.999998%, to 0.0838 ng/100 cm², beyond what the AFFF removal and potable water flushing were able to achieve.

Another significant outcome was the fact that decontamination with the PFAS-SOL® surfactant-water solution significantly reduced residues of the longer- and shorter-chain PFAS compounds, such as C4 through C12, and not just the C8 chains that have garnered much of the attention for decontamination.

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PFAS Decontamination of Fire Pumper Trucks



- **PFAS Containing AFFF Fire Suppression Product Changes Outs Are Undertaken Globally For Many Reasons Including:**
  - Comply With Local **Regulations** (Environmental & Health Risk)
  - Response To **Worker Health & Safety** (Fire Unions) Concerns
  - Legal **Liability** Management
  - Tightening **Insurance** Pressure
  - **Stakeholder + Public** Pressures (*Social License*)
  - **Manufacturer Supply Chain** pressure to Use New Products

- **PFAS-SOL Application To Decontaminate AFFF Fire Trucks For Safer Change Outs To Non-Florinated Fire Suppression Products**
- **To Avoid Risk Of Potential Residual PFAS Cross Contamination**

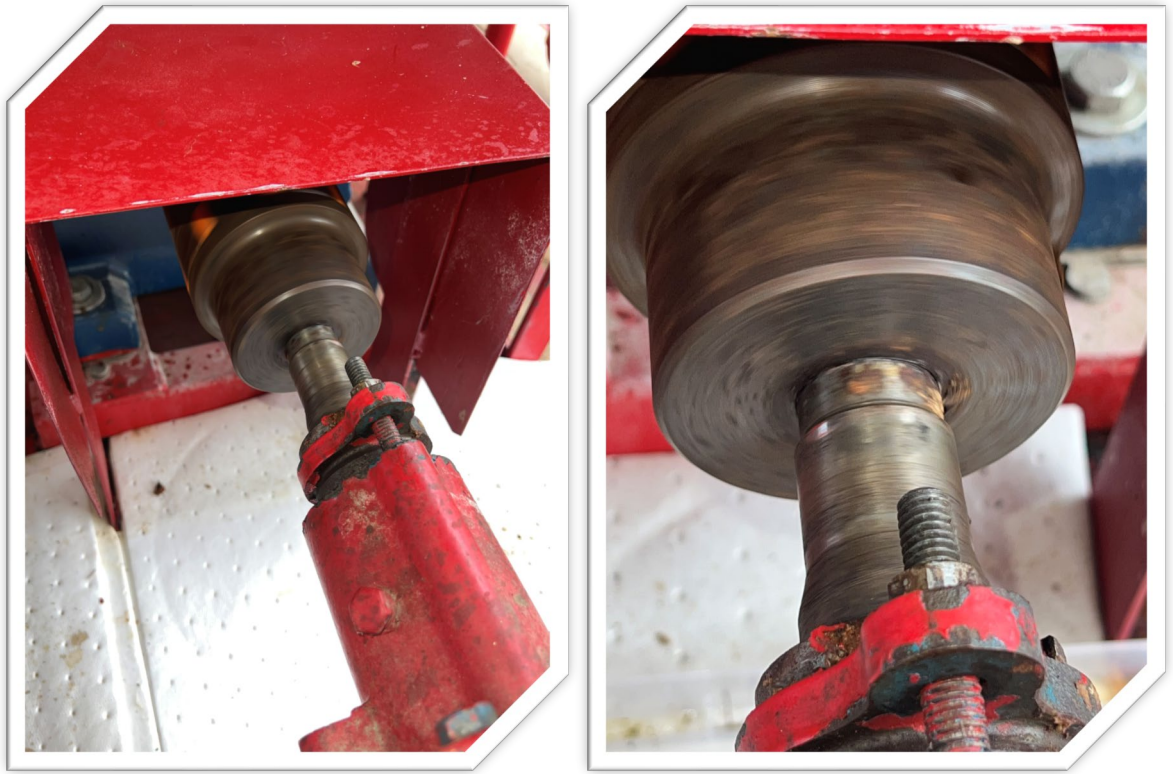
"The Use of PFAS-SOL® For Decontamination of Fire Trucks At A Refinery Site In USA Exceeded The Client's Expectations! They Are Actively Planning PFAS Decontamination Of Additional Assets In 2026, Using PFAS-SOL®."

Scott Poynor, President, GST *(Project Technical Advisor)*



Decontamination of AFFF Fire Suppression System
PFAS Contaminated Pump





Before And After
PFAS-SOL®

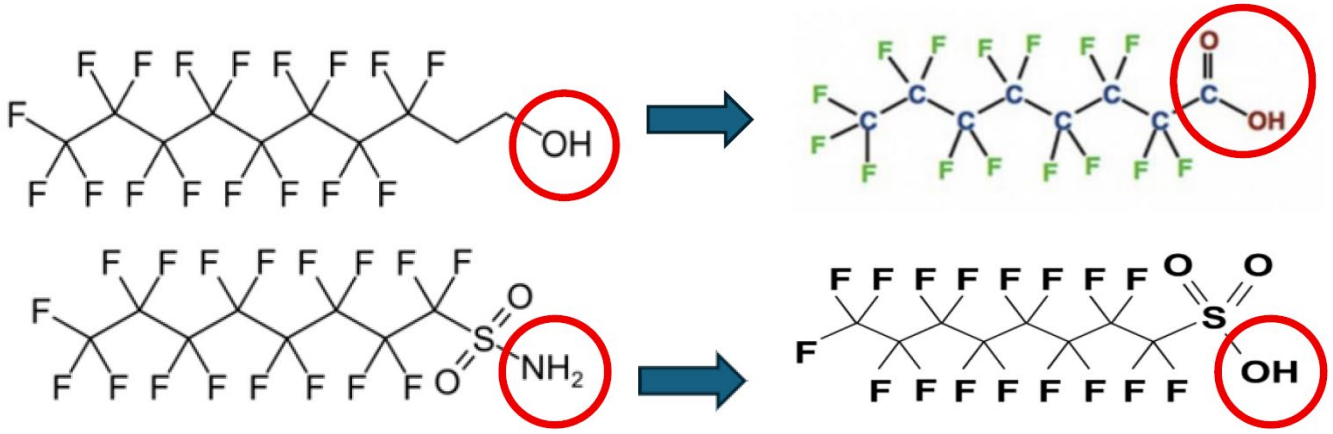
PFAS Precursors The Potentially Hidden PFAS Contaminants Exposed



PFAS precursors are intermediate chemicals that break down over time through environmental exposure or biological metabolism into highly stable, "***terminal***" PFAS end products like **PFOA** and **PFOS**. These compounds pose a hidden threat!

Unless you analyze precursors in soils, groundwater, they may remain unquantified hidden unknowns which may pose environmental risks…***as they transform become regulated*** **PFAS!**

- **Fluorotelomer alcohols** (FTOHs): Used in food packaging and stain-resistant coatings.
- **Perfluorooctane sulfonamidoethanols** (FOSEs): Found in water repellents and textiles.
- **Fluoropolymers**: Large polymeric molecules that can shed smaller precursor fragments.



UNREGULATED → REGULATED

Where Did The Ammonia Come From On my PFAS Site

SOIL WASHING FOR PFAS MASS REMOVAL

- Bench-scale PFAS-SOL soil washing simulation was undertaken on 200 g PFAS impacted soil;
- 200 ml PFAS-SOL® (4%) was used.
- This was mixed for ~1 minute, and then decanted.
- The PFAS analysis showed 5.85 mg/L (not ug/L). ***This results was near total PFAS mass recovery***
- ***"These early results indicated PFAS-SOL could be used to enhanced ex-situ PFAS Soil Washing processes, by make the PFAS contaminants more 'Physically Available' to decontaminate soils for sustainable reuse".***
- ***Pilot-Scale Applications Occurring***





PFAS DECONTAMINTION OF DREGDING SEDIMENTS

- **Undertaking Applied Research For Soil Washing OF PFAS From Sediments**

Combined Technology Applications

- **To lower In-situ PFAS Concentration Prior To In-situ Carbon Injections**
  So residual [PFAS] is stoichiometrically within the limits the Carbon mass that can be physically injected, to avoid PFAS rebound, and have improve plume control.
- **To lower In-situ PFAS Concentration Prior To In-situ Modified Clay Injections**
  So residual [PFAS] is stoichiometrically within the limits the Modified-Clay mass that can be physically injected to avoid PFAS rebound, and have improve plume control.
- **To lower In-situ PFAS Concentration Prior To In-situ ISCO Injections**
  So residual [PFAS] is stoichiometrically within the limits the ISCO that can be physically injected, for better PFAS reductions, to avoid PFAS rebound, and better plume control.
- **To lower In-situ PFAS Concentration Prior To In-situ ISCR Injections**
  So residual [PFAS] is stoichiometrically within the limits the ISCR that can be physically injected, for better PFAS reductions, to avoid PFAS rebound, and better plume control.
- **To Aid PFAS Desorption To Enhanced Physical '*Availability*' for Multi-Phase Extraction (MPE)**
  So that the MPE mass recovery does not level off (asymptotic) to maximize [PFAS] recovery and plume liability control.
- **To Aid PFAS Desorption To Enhanced Biological '*Availability*' for Remediation (In/Ex-situ)**
  So that the PFAS is more Bio-Available to the microorganisms (bacteria, fungi, algae, etc.) to maximize [PFAS] degradation rates and improve results.
- **To lower PFAS Concentrations To Risk-Based Site Remediation Closure**
  So that the PFAS concentration can be reduced to the site specific risk-based closure objectives using PFAS-SOL or combined technology approaches.
- **To lower PFAS Concentrations In Sediments During Ex-situ Physio-Chemical Remediation**



By Ivey International Inc.

IN-SITU AND EX-SITU REMEDIATION + DECONTAMINATION

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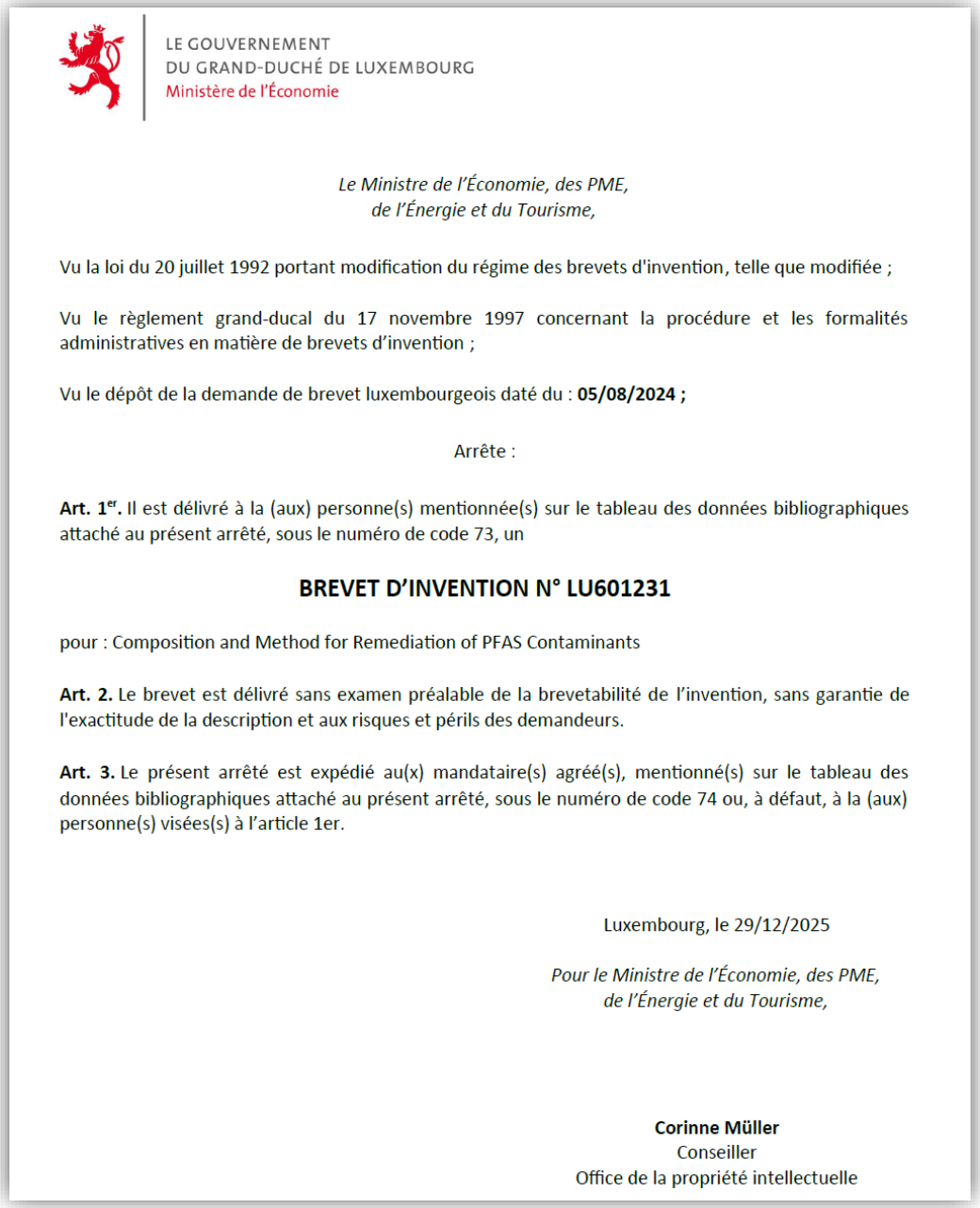
has been selected for the honor of

Technology Merit: PFAS Mass Removal

awarded by Environmental Business Journal® for outstanding business achievement in the environmental industry in 2023
San Diego, California, USA
March 25, 2024

ENVIRONMENTAL BUSINESS JOURNAL
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CEO & Editor



LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Économie

Le Ministre de l'Économie, des PME,
de l'Énergie et du Tourisme,

Vu la loi du 20 juillet 1992 portant modification du régime des brevets d'invention, telle que modifiée ;

Vu le règlement grand-ducal du 17 novembre 1997 concernant la procédure et les formalités administratives en matière de brevets d'invention ;

Vu le dépôt de la demande de brevet luxembourgeois daté du : **05/08/2024 ;**

Arrête :

Art. 1er. Il est délivré à la (aux) personne(s) mentionnée(s) sur le tableau des données bibliographiques attaché au présent arrêté, sous le numéro de code 73, un

BREVET D'INVENTION N° LU601231

pour : Composition and Method for Remediation of PFAS Contaminants

Art. 2. Le brevet est délivré sans examen préalable de la brevetabilité de l'invention, sans garantie de l'exactitude de la description et aux risques et périls des demandeurs.

Art. 3. Le présent arrêté est expédié au(x) mandataire(s) agréé(s), mentionné(s) sur le tableau des données bibliographiques attaché au présent arrêté, sous le numéro de code 74 ou, à défaut, à la (aux) personne(s) visées(s) à l'article 1er.

Luxembourg, le 29/12/2025

Pour le Ministre de l'Économie, des PME,
de l'Énergie et du Tourisme,

Corinne Müller
Conseiller
Office de la propriété intellectuelle

PATENT COOPERATION TREATY (PCT) GLOBAL PATENT APPLICATION

LUXEMBOURG APPROVAL

ON

DECEMBER 29, 2025

THE FIRST OF MANY GLOBAL (>50) PATENT APPLICATIONS

WWW.IVEYINTERNATIONAL.COM



Lessons Learned:

- Most PFAS Sorb To Soils, Bedrock + Equipment Surfaces
- The Longer The PFAS Chain The Greater The Sorption
- Sorbed PFAS Is Less "**Available**" For Remediation (Physical, Chemical, and Biological)
- Sorbed PFAS To Equipment = Risk For Cross Contamination!
- PFAS-SOL - Very Effective For PFAS Mass Removal From Impacted Soil, Bedrock, and Groundwater Total PFAS Mass Recovery 242% to 622% / Application
- PFAS-SOL - Is A Very Effective For PFAS Mass Removal From Anthropogenic Surfaces AFFF Fire Suppression System 99.99998% PFAS Mass Removal
- PFAS-SOL - Could Improve Ex-situ Soil Washing Of PFAS Impacted Soil And Sediments
- Combined Technology Application *(1 + 1 = 3!)*

IVEY

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