RemTech 2024

October 16 to 18, 2024 Banff, AB, Canada The 23rd REMTECH

technologies symposium







USEPA 542-R-18-002, May 2018

- > This USEPA publication evaluated 30 in-situ remediation projects involving NAPL;
- With n=30 (number of observation), this is of statistical importance to draw conclusions with a 95% Confidence Level;
- > The 30 sites used a variety of physical, biological and chemical remediation methods;
- The in-situ soil and groundwater remediation took between 3 and 27 years, with a median of 8 years; and
- Site remediation was generally shorter for sites with less complex hydrogeological settings, with the exception of 3 sites with mild heterogeneity that were >15 years for remediation.

≥ 8 Years For Site Remediation...<u>Why</u>?....Let Me Share Some Insights As To Why.

Observations of contamination in soil, bedrock and groundwater following a spill is your observing <u>SYMPTOMS</u>

Confirmed Presence of <u>Dissolved</u>, <u>Sorbed</u>, <u>NAPL</u> and <u>VOC</u> are the <u>DISEASE</u>

Remediation Practitioners have to correctly diagnose the <u>DISEASE</u>, causing the <u>SYMPTOMS</u> at your Sites ---> Your <u>'PATIENTS'</u>

Failure to fully comprehend the <u>SYMPTOMS & DISEASE</u>, can lead to <u>Incomplete</u> <u>Diagnosis</u> (Missed Data), <u>Incorrect Treatments</u> (Wrong Remediation Strategy), and Results in Many Years of Poor Results <u>Slower Recovery</u>, and <u>Complication</u> (High Costs/Liability) for your <u>PATIENTS</u> (Your Sites)

- A gasoline pipeline developed a leak resulting in pooled petroleum at the surface
- The leak was repaired and affected soil was excavated down to 12 feet (3.66 m) below ground surface (bgs)
- Released gasoline percolated through complex stratigraphy consisting of alternating sand, silt, clay, and sandstone lenses before reaching groundwater at approximately 60 feet (18.3 m) bgs
 The leak site was placed under a Judicial Agreed Order

Contamination was delineated, and the following <u>Legal Judicial Order</u> remedial goals were established:

Permanently remove all measurable Non-Aqueous Phase Liquids (LNAPL) to <0.01 ft. or <0.3 cm</p>

■ Reduce benzene groundwater concentrations to ≤0.050 mg/L

Reduce TPH groundwater concentrations to ≤25.0 mg/L

Five (5) Remedial Technologies Were Applied Over A 13-Year Period = \$,\$\$\$,\$\$\$!!!



- Belt skimmers were installed in each well that had measurable LNAPL
- Each skimmer consistently recovered LNAPL during operation
- Near original LNAPL thickness returned as soon as skimmer is turned off. This repeated for <u>over 4 years of operation</u> (8)

Five remedial technologies were applied over a 13-year period



- Soil Vapor Extraction (SVE) system was installed across the groundwater plume
- Contaminant concentrations decreased during <u>several years of operation</u> but rebounded immediately upon system shutdown
- Rebounded concentrations were near original levels

Five remedial technologies were applied over a 13-year period



- Air Sparging was added to the SVE system
- Contaminant concentrations again decreased during <u>several additional</u> <u>years of operation</u> but rebounded immediately upon system shutdown
- Rebounded concentrations were again near original levels (8)

Five remedial technologies were applied over a 13-year period



- In-Situ Chemical Oxidation was attempted following previous remedial failures
- Contaminant concentrations significantly decreased immediately upon ISCO completion
- Dissolved phase concentrations rebounded to ~65% of original levels within 30 days
- LNAPL returned to each well within
 60 days following injection (8)

Five remedial technologies were applied over a 13-year period



- As a last ditch effort, absorbent socks were placed in all wells with LNAPL
- Absorbent socks produced no sustained measurable reduction in LNAPL
- Absorbent socks did temporarily placate the regulator...resulting in another year and a half of billing with no resulting progress toward remedial goals

Millions In Remediation Costs For The Property Owner With On-going Liability Plume Spread Expanded Over the 13 Years → This Patient Ended Up In Critical Condition

After >13 years of remediation, the presiding Judge in an Administrative Hearing stated: "Effort does not equal progress" The Judge demanded progress toward the remedial goal within a reasonable time frame

The client had spent Millions by this point (>13 years) following five (5) failed remediation strategies of without substantial resolution of the environmental liability

A NEW SITE CONCEPTUAL MODEL WAS DEVELOPED USING HIGH RESOLUTION SITE CHARACTERIZATION





A NEW SITE CONCEPTUAL MODEL WAS DEVELOPED USING HIGH RESOLUTION SITE CHARACTERIZATION



3-D Illustration of Subsurface Petroleum Distribution at approx. Concentrations Exceeding Action Levels **3-D Illustration of approximate NAPL Distribution Within Petroleum Affected Strata**

1st Phase: Non-Ionic Surfactant Technology (Ivey-sol[®]) was used to Remediate NAPL in Vadose Zone before Remediating the Groundwater Saturated Zone



Phase Partitioning (PP): Sorption - Globule - NAPL - VOC

Petroleum & Halogenated Organics have limited water solubility. Hence they will PP to <u>Sorb</u> onto Soil Surfaces, <u>Agglomerate</u> to form <u>Layers</u>, <u>Globules</u>, <u>NAPL</u>, or **VOC** = Reducing their '*Availability*' for Remediation.

Sorbed Contamination Expressing Limited 'Availability' For Remediation



Agglomeration

Contaminant <u>agglomeration</u> is the 'sticking' (cohesive or adhesive forces) of organic molecules to one another, onto surfaces (Sorption), can increase in thickness....its a very a natural phenomenon.

(like dissolves like & like attracts like)

Agglomeration may be viewed as unwanted surface Sorption, that amasses to Globules or Ganglia, to NAPL and/or VOC layers in formations. (medical analogy - clogging of arteries)

Within geology, this causes caking, bridging, and/or blockage of effective pathways = 'Pathway Interference' (hence delivery or extraction issues!)

Diameter of Soil Pore Openings « Diameter of Hair « Veins « Arteries



Phase Behavior: Sorbed - Globule - NAPL- VOC Lets Take A Closer Look



Interfacial Tension (Limits Mobility)

Soil

] Vapor

Water

Contamination



Ivey-sol Reduces The Size of Water Clusters Improving (Lower Surface Tension from 73 Dynes to < 30 dynes) Access & Regress within Fine Grain Soil Textures ~ Improving K









How >95% of surfactants work by encapsulating contaminants hindering their 'Availability' for remediation, and impeding O/W separation, and waste water treatment .

Ivey-sol® <u>selectively</u> desorbs, Sorbed, NAPL, VOC <u>below the CMC</u> Increasing Physical, Biological and/or Chemical <u>Availability</u> For Enhanced Remediation

Surfactant Desorption Increased NAPL Accumulating in Monitor Wells



LNAPL in Source Area Monitor Well Prior to Initial Surfactant Desorption of Vadose Zone (1st Phase)

0.02 ft (0.61 cm) thick (<0.3 cm goal)



LNAPL in Same Source Area Monitor Well 48 hours after completing 1st Phase of LNAPL Desorption. Approximately 0.24 ft (7.32 cm) thick in same Monitor Well as pictured to left. Extractable LNAPL was recovered prior to starting 2nd Phase

Increased 'Availability' Overcame Sorption, Agglomeration, Interfacial Tension, etc.

Unremoved NAPL is source of the multi-year NAPL rebound = \$,\$\$\$,\$\$\$.00 lvey-sol[®] resolved NAPL!





4th Phase: In-Situ Chemical Oxidation Technology Applied in the Groundwater Saturated Zone Treating Remaining Residuals (Post SER[®])



By eliminating the ongoing vadose zone secondary sources prior to dissolved phase remediation, contaminant reduction efficiencies were drastically improved. Within 45 days of surfactant treatment, all measurable NAPL (<0.01 ft) was eliminated from all monitoring wells without rebound. Approximately <u>45 days after initiating ISCO</u>, Benzene and TPH groundwater concentrations were reduced below their regulatory goals.

Rebound was statistically insignificant to non-existent at 30 days, 60 days, 90 days and 120 days post-remediation large due to surfactant desorption prior to ISCO. NAPL never recurred. Not even a sheen was observed during all postremedial groundwater monitoring. Reductions were sustained in throughout extended postremedial groundwater monitoring. In a subsequent hearing for the Agreed Order, the presidin Judge agreed with the Regulator's recommendation and issued No Further Action Status!

BEFORE THE CORPORATION COMMISSION OF THE STATE OF OKLAHOMA

APPLICANT:	PIPELINE, INC.)
RESPONDENT:		
RELIEF REQUESTED: C	DRDER NO	
REQUIRED, AND	SHALL	CAUSE PD NO.
PROCEED WITH SITE R PLUGGING AND ABAN	ESTORATION, AND DONING WELLS ON)
THE SUBJECT SITE.		
LEGAL DESCRIPTION:		ORDER NO.
)
OKLAHOMA.))

FINAL ORDER OF THE COMMISSION

This cause came on for hearing before Keith Thomas, Administrative Law Judge for the Corporation Commission of the State of Oklahoma in the Commission's courtrooms, Oklahoma City, Oklahoma, pursuant to notice given as required by law and the rules of the Commission for the purpose of taking testimony and reporting to the Commission.

In a subsequent hearing for the Agreed Order, the presiding Judge agreed with the Regulator's recommendation, and issued 'No Further Action Status'.

Summary

- During the first 13 years of active remediation, effort and money was split between remediation, managing annual cash flow, and avoiding enforcement. This resulted in considerable time, cost and effort spent trying different technologies with little progress for ≥ 13 years! <u>Spent Millions</u>.
- The presiding Judge in an Administrative Hearing stated "Effort does not equal progress". The Judge demanded progress toward the remedial goal within a reasonable time frame.
- A revised CSM prompted a change in remediation tactics and an aggressive, <u>a</u> more thoughtful remedial strategy was employed.

Summary

- Development, permitting, implementation and validation was achieved in under two years.
- Although <u>annual</u> allocated expenditure increased, overall project costs were substantially reduced from the projected budget (estimated >67% savings on a net present value basis).
- More importantly, a significant liability was quickly mitigated, <u>rather</u> <u>than perpetuated for several decades</u>.

Client said to me at Battelle; "You saved me millions"

What is the Paradigm Shift for Managing Environmental Liabilities?

- Take time and reasonable effort to know the Site (The Patient) before launching into remediation actions!
- Design mitigation focused on a total project basis (in terms of cost and schedule) rather than a sole focus on annual expenditure.
- Execute an aggressive remedial strategy using a thoughtful approach.
 <u>Do not engage in intentionally slow mitigation over decades, just</u> <u>because the regulator will allow.</u>

Just tossing remediation methods at sites will open Consultants to potential litigation.

What is the Paradigm Shift for Managing Environmental Liabilities?

- Achieving <u>No Further Action Status</u> in a timely manner should be the <u>primary focus</u> of all project tasks; from initial assessment through post-remedial monitoring;
- Look before you Leap Develop a <u>thoughtful</u> mitigation strategy based on ample data. This is usually beyond the regulatory required minimum site assessment

CONTACT INFORMATION

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