### BURNS MEDONNELL.

### Surfactant Enhanced Extraction to Expedite Remediation of Carbon Tetrachloride Source Zone at an Active Grain Elevator Facility

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April 2018 2018 Chlorinated Conference Palm Springs, CA

### SITE REMEDIATION PRESENTATION OVERVIEW

- Active Grain Elevator Facility Kansas City, Kansas
- ▶ 80/20 Fumigant Mixture Carbon Tetrachloride and Carbon Disulfide Used in 70s and 80s
- Leaks from AST Discovered in 90s Groundwater and Soil Impacts
- Site Enters KDHE Voluntary Cleanup Program: 2000
- ▶ DPVE System Installation & Operation: Dec. 2007 to Current
- Surfactant Enhanced Extraction (SEE) Pilot Study: Spring 2015
- ► SEE Full-Scale: Fall 2016
- Observations Continue into 2018

### **SITE LAYOUT**



# SITE CHALLENGES

 Limited vehicle access led to creative equipment placement



# SITE CHALLENGES

 DPVE system installed by crane



# SITE CHALLENGES

 DPVE system situated adjacent to substation, railroad tracks, and elevator infrastructure







### **DPVE PERFORMANCE – HYDRAULIC CONTROL AND CAPTURE**



### DPVE PERFORMANCE – SUMMARY (2007 – 2014)



### DPVE PERFORMANCE – SUMMARY (2007 – 2014)

- Plume size and concentration reduction
  - Vapor-Phase Removal:
    - 9,100 pounds (690 gal. as CT)
  - Dissolved-Phase Removal:
    - 33 pounds (as CT)
  - Groundwater
    Recovered/Treated:
    - 7.5 million gallons



### SOURCE AREA CONDITIONS (2006 – 2014)

- Continued variability and persistence in source area DPVE wells
- Could significant mass remain in the soil?

CT – Carbon Tetrachloride



CL - Chloroform



### DPVE PERFORMANCE – SUMMARY (2007 – 2014)



## 2014 INVESTIGATION SOIL RESULTS

Sample Name	SB-1/SS-1	SB-1/SS-2	SB-2/SS-1	SB-2/SS-2	SB-3/SS-1	SB-3/SS-2	SB-4/SS-1	SB-4/SS-2					
Sampling Date	07/21/14	07/21/14	07/21/14	07/21/14	07/21/14	07/21/14	07/21/14	07/21/14					
Sample Depth	10-13	24-26	10-13	23-28	10-13	23-28	10-13	23-28					
COCs													
Carbon Tetrachloride (µg/Kg)	1,300,000	7,700	31,000 J*	16,000	3,000,000	180,000	7,000,000	1,100					
Chloroform (µg/Kg)	11,000	15,000	350 J*	4,400	30,000	21,000	19,000	150					
Methylene Chloride (µg/Kg)	ND (1,100)	ND (350)	ND (270) UJ	ND (340)	ND (2,700)	220 J*	ND (2,600)	ND (550)					
Chloromethane (µg/Kg)	ND (430)	ND (140)	ND (110) UJ	ND (140)	ND (1,100)	ND (140)	ND (1,100)	ND (220)					
Carbon Disulfide (µg/Kg)	790 J*	ND (350)	96 J*	480	180,000	28,000	42,000	ND (550)					
Degradation Parameters													
Total Organic Carbon (mg/Kg)	4,600	3,400	2,200	3,800	3,400	10,000	2,600	3,800					
AVS (µmol/g)	0.036	ND (0.028)	ND (0.019)	0.72	ND (0.020)	1.11	ND (0.020)	ND (0.022)					
Bioavailable Iron (mg/Kg) <sup>(1)</sup>	NS	NS	75	239	295	538	308	412					
Miscellaneous Inorganic Parameters													
Manganese (mg/Kg)	8.3	420	11	390	20	290	260	94					

### **2014 SOIL INVESTIGATION RESULTS**



### WHY DOES SIGNIFICANT MASS REMAIN?

- CT discontinued in the 1980s
  - Contact time increases sorption
  - Desorption rate is < adsorption rate
  - Koc (CT soil organic carbon-water partitioning coefficient): 251 L/Kg
    - Compare to vinyl chloride: 8.5 L/Kg
- Elevated organic carbon concentrations in sand zone
- Elevated CT discovered in LNAPL
- Source zone periphery rapidly remediated by DPVE
  - Minimal contact time in these areas

# SURFACTANT ENHANCED DPVE

### **How It Works**

- Surfactants are structured with a hydrophilic head and hydrophobic tail
- Hydrophobic tail attracts and attaches to organic portion of CT (carbon molecule)
- Hydrophilic head attracted to groundwater making CT miscible
- Lowers surface tension by reducing H20 cluster size (73 to < 30 Dynes) improves 'apparent' K



# SEE PILOT STUDY OVERVIEW

# SEE Pilot Limited To:

- ► DPVE-3
- ► DPVE-4
- ► K-MW-120S
- ► K-MW-121S



# SEE PILOT STUDY OVERVIEW

- Mixing 5 gal
  Ivey-sol into
  250 gal of
  Water
- 1:50 Ratio For Application
- Installed temporary GAC





# SEE PILOT STUDY OVERVIEW

- SEE Pilot Test Begins Spring 2015 - Approx. 30 days
- Tests conducted at K-MW-120s, K-MW-121s, DPVE-3 and DPVE-4
- 1 Drum (55 Gal.) Surfactant Used



### REAL – TIME FIELD SURFACTANT TEST

Real-time field surfactant testing - measuring water surface tension



# **PILOT STUDY RESULTS**

### Test 1 and 2

- Push-Pull Tests at shallow monitoring wells
- Modest increase in mass removal observed



# **PILOT STUDY RESULTS**

### Test 3 and 4

- Point-To-Point Tests
- Influent groundwater concentrations (8,100 ug/L) highest ever recorded by over 50-percent
- Influent groundwater concentrations 4x greater than average



# **PILOT STUDY RESULTS**

- Highly elevated and highly variable influent concentrations
- Recovery of high concentration "slugs" over short periods of time

	Sample	Sample		Carbon		Methylene	Carbon	Total			
	Collection	Collection		Disulfide	Chloroform (µg/L)	Chloride	Tetrachloride	VOC			
	Date	Time	Sample Location	(µg/L)		(µg/L)	(µg/L)	(µg/L)			
Pilot Test #2: K-MW-121S Push-Pull											
	04/15/15	1027	Baseline Treatment Influent	12	200	ND (10)	390	602			
		1345	Treatment Influent	45 J	140	ND (50)	4,400	4,585			
		1535	Treatment Influent	ND (10)	510	ND (10)	960	1,470			
		1645 Treatment Influent		29	280	ND (25)	570	879			
		1450	AS Effluent	ND (5.0)	17	ND (5.0)	10	27			
		1452	GAC Effluent	ND (5.0)	ND (1.0)	ND (5.0)	ND (1.0)	ND (12.0)			
+ [	04/16/15	0825	Treatment Influent	63	480	ND (25)	1,500	2,043			
-		0827	AS Effluent	25	420	ND (25)	1,200	1,645			
		0830	GAC Effluent NA <sup>1</sup>								

August through November 2016

275 Gallons Ivey-sol 106 Surfactant Formulation

- Mixed with conservative tracer for distribution observation
- Applied Push-Pull and Point-to-Point Flushing Techniques
- Monitored recovery progress via real-time tracer testing and using the lvey-sol field surfactant test sheets



Aquafluor Meter: Measures intensity of fluorescence



Diluted Ivey-sol in water with tracer added – pre-injection mixing.

- Three additional wells K-MW-122 through 124 – Installed to facilitate surfactant delivery to the northern portion of the source area
- A total of 5 SEE phases were conducted to target the most heavily impacted portion of the source area







Influent samples indicative of LNAPL which was heavily concentrated with COCs. Note: 119 was downgradient, lack of tracer confirmed hydraulic control of SEE area.







DPVE-2, located in the southern portion of the source area, demonstrated 2 order of magnitude COC reduction following the SEE pilot scale

### **Full-Scale SEE**





### FULL-SCALE SEE RESULTS

98% CT Reduction in Source Area Shallow Monitoring Wells
 K-MW-120S, 121S, 122 through 124

▶ 92% CT Reduction in Source Area DPVE wells

- DPVE-3 and 4
- Significant reductions in LNAPL thickness
  - No measurable LNAPL in March 2018

### **GET IN TOUCH WITH US**

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