# Remediation of PCE Impacted Soil Beneath Former Dry Cleaner: Using Pilot Test Data for the Design and Operation of an Active Sub-Slab Vapor Mitigation System for Site Closure - Case Study

Bob Roth P.E. Terracon – Wheat Ridge, Colorado Andy Safulko E.I.T. - Terracon – Wheat Ridge, Colorado



## Site History

- One story multi-tenant commercial building constructed in 1973
- 270' x 200' (54,000 sf).
- Dry cleaning business used dry cleaning machine used from 1998 to 2014.
- Other tenants included, food storage/distribution, refrigeration service, wood door manufacturer, siding distributor, and paint/varnish vendor.
- Phase 1 Environmental Site Assessment (ESA) September 2016. Dry cleaning machine considered REC.
- Phase 2 ESA September 2016. Sub-slab soil gas sampling and analyses.
- Limited Phase 2 ESA March 2017. Indoor air sampling and analysis.

#### lerracon



0 20' 40' 50'

#### Results of Sub-Slab Vapor Sampling and Analyses (September 2016)











llerracon

#### **Results of Sub-Slab Vapor Sampling and Analyses (August 2017)**







PILOT TEST EQUIPMENT

	DISTANCE	FLOW (CFM)				
	(FT)	95	135	132		
		VACUUM (INCHES WATER)				
BLOWER	0	46	48	48		
VMP-1	10	0.480	0.512	0.516		
VMP-2	20	0.058	0.065	0.065		
VMP-3	30	0.030	0.024	0.024		
BLOWER	0	46	48	48		
VMP-4	20	0.084	0.076	0.077		
VMP-5	40	0.016	0.003	0.005		
VMP-6	50	0.011	0.008	0.005		
VOCs (ppm)		ND	ND	ND		
LEL (%)		0	0	0		





## Vacuum vs. Distance (VMPs at 10, 20, and 30 feet)





## Vacuum vs. Distance (VMPs at 20, 40, 50 feet)



## **VOCs in Vapors Extracted During Pilot Test**

		EXTRACTED VAPORS - PILOT TEST
		8/16/17
ANALYTE	TARGET SUB-SLAB SOIL GAS CONC.	RESULT
	(ug/m3)	(ug/m3)
ACETONE	4,500,000	9.2
CHLOROMETHANE	13,000	0.493
CYCLOHEXANE	150,000	0.661
ETHANOL	NR	7.35
TRICHLOROFLUOROMETHANE	NR	2.27
DICHLORODIFLUOROMETHANE	NR	0.895
HEPTANE	NR	0.74
N-HEXANE	3,100	3.49
METHYLENE CHLORIDE	41,000	0.401
2-BUTANONE (MEK)	730,000	12.8
TETRACHLOROETHENE	1,600	48.9
TETRAHYDROFURAN	290,000	3.62
TOLUENE	15	0.609
TRICHLOROETHENE	100	5.43
2,2,4-TRIMETHYLPENTANE	NR	1.41
	TOTAL	98

TO-15 ANALYSIS FOR 66 VOCS ONLY VOCS DETECTED ARE SHOWN - 15 VOCS DETECTED NR = NOT REPORTED





#### Selection of ROI to Address Impacted Vapors in Area of Concern

#### Use of Pilot Test Data to Select Blower Flower Rate to Achieve ROI of 50 feet









# **VMS Monitoring Data**

DATE	NOTE	DURATION OF OPERATING PERIOD	SYSTEM OFF	TOTAL OPERATING TIME	BLOWER VACUUM	VAPOR FLOW RATE	TOTAL VOCS IN EXTRACTED VAPORS	PCE/TCE IN EXTRACTED VAPORS	PCE/TCE EXTRACTION RATE DURING PERIOD	MASS OF PCE/TCE EXTRACTED DURING PERIOD	TOTAL MASS OF PCE/TCE EXTRACTED
		(DAYS)	(DAYS)	(DAYS)	(INCHES WATER)	(CFM)	UG/M3	UG/M3	(GRAM/DAY)	(GRAM)	(GRAM)
10/11/2017	START	0		0	77	82	98	54	0.1806	0	0
10/25/2017		14		14	77	82	NI	NI	0.1806	2.53	2.53
11/10/2017		16		30	68	150	681	0	0.0000	2.71	5.24
11/20/2017	SHUT OFF	10		40	68	150	NI	0	0.0000	0.00	5.24
11/27/2017	STARTUP	7	7	40	68	150	989	52	0.1591	3.18	8.42
12/12/2017	SHUT OFF	15		55	68	150	NI	0	0.1591	8.75	17.17

NOTE:

PCE/TCE CONCENTRATION ON 10/11/17 BASED ON PILOT TEST 8/16/17

NI = NO INFORMATION (NOT ANALYZED)

### Concentration of VOCs in Extracted Vapors – Pilot to 11/10/17

TO-15 ANALYSIS FOR 66 VOCS ONLY VOCS DETECTED ARE SHOWN - 26 VOCS DETECTED NR = NOT REPORTED INCREASE IN VOC CONCENTRATION

		EXTRACTED VAPORS - PILOT TEST	EXTRACTED VAPORS - VMS
		8/16/17	11/10/17
ANALYTE	TARGET SUB-SLAB SOIL GAS CONC.	RESULT	RESULT
	(ug/m3)	(ug/m3)	(ug/m3)
ACETONE	4,500,000	9.2	59.1
BENZENE	52	ND	5.05
CARBON DISULFIDE	10,000	ND	2.93
CHLOROMETHANE	13,000	0.493	0.997
CYCLOHEXANE	150,000	0.661	8
ETHANOL	NR	7.35	347
ETHYLBENZENE	5	ND	3.09
TRICHLOROFLUOROMETHANE	NR	2.27	3.31
DICHLORODIFLUOROMETHANE	NR	0.895	2.25
HEPTANE	NR	0.74	10.1
N-HEXANE	3,100	3.49	15.7
METHYLENE CHLORIDE	41,000	0.401	2.53
2-BUTANONE (MEK)	730,000	12.8	9.69
4-METHYL-2-PENTANONE (MIBK)	440,000	ND	ND
METHYL METHACRYLATE	100,000	ND	2.53
2-PROPANOL	NR	ND	124
PROPENE	440,000	ND	8.92
TETRACHLOROETHENE	1,600	48.9	ND
TETRAHYDROFURAN	290,000	3.62	ND
TOLUENE	15	0.609	48
TRICHLOROETHENE	100	5.43	ND
1,2,4-TRIMETHYLBENZENE	8,800	ND	5.43
1,3,5-TRIMETHYLBENZENE	NR	ND	2.67
2,2,4-TRIMETHYLPENTANE	NR	1.41	6.12
M&P-XYLENE	15,000	ND	9.43
O-XYLENE	15,000	ND	3.74
	TOTAL	98	681



### Concentration of VOCs in Extracted Vapors – Pilot to 11/27/17

EXTRACTED EXTRACTED VAPORS -VAPORS -VAPORS -START UP PILOT TEST VMS SPIKE 8/16/17 11/10/17 11/27/17 VISL TARGET ANALYTE SUB-SLAB RESULT RESULT RESULT SOIL GAS CONC. (ug/m3) (ug/m3) (ug/m3) (ug/m3) ACETONE 4,500,000 230 9.2 59.1 BENZENE 52 ND 5.05 4.35 CARBON DISULFIDE 10,000 2.93 2.51 ND CHLOROETHANE NR ND 1.32 ND CHLOROMETHANE 13,000 0.493 0.997 5.8 CYCLOHEXANE 150,000 0.661 2.42 8 1.4-DIOXANE 1.62 82 ND ND ETHANOL NR 7.35 347 129 ETHYLBENZENE 5 ND 3.09 4.26 4-ETHYLTOLUENE NR ND ND 3.17 TRICHLOROFLUOROMETHANE 2.27 NR 3.31 44.2 DICHLORODIFLUOROMETHANE NR 0.895 2.25 13.1 HEPTANE NR 0.74 3.31 10.1 N-HEXANE 3,100 3.49 15.7 6.59 METHYLENE CHLORIDE 41,000 0.401 2.53 2.63 METHYL BUTYL KETONE NR ND ND 34.9 730,000 2-BUTANONE (MEK) 12.8 9.69 70.3 4-METHYL-2-PENTANONE (MIBK) 440,000 ND ND 37.1 METHYL METHACRYLATE 100,000 ND 2.53 14 2-PROPANOL NR ND 124 56.4 PROPENE 440,000 ND 8.92 34.2 STYRENE 155,000 ND 4.65 ND TETRACHLOROETHENE 1,600 48.9 ND 51.5 4.64 TETRAHYDROFURAN 290,000 3.62 ND TOLUENE 15 0.609 48 201 TRICHLOROETHENE 100 5.43 ND ND 1.2.4-TRIMETHYLBENZENE 8.800 ND 5.43 4.04 1,3,5-TRIMETHYLBENZENE ND 2.67 ND NR 2,2,4-TRIMETHYLPENTANE NR 1.41 6.12 2.39 M&P-XYLENE 15,000 ND 9.43 14.5 O-XYLENE 15,000 ND 3.74 5 TOTAL 989 98 681

EXTRACTED



TO-15 ANALYSIS FOR 66 VOCS ONLY VOCS DETECTED ARE SHOWN - 36 VOCS DETECTED NR = NOT REPORTED INCREASE IN VOC CONCENTRATION

# Why increase in concentration over time and more VOCs? Is the zone of influence increasing with time?



## Detection of VOCs not associated with dry cleaning

- Ethyl benzene, 4-ethyl toluene, o-xylene, and m,p-xylene associated with gasoline and not dry cleaning fluids. Detection possibly due to incidental leakage of fuel from equipment used during the construction of the building or from use by occupants in adjacent units.
- Trichlorofluoromethane, dichlorodifluoromethane, 1,1,2trichlorotrifluoroethane, and 1,2-dichlorotetrafluoroethane are typically used as refrigerants and propellants for floor wax, paints, cosmetics, and perfumes. Detection possibly due to incidental leaks of refrigerants by the adjacent refrigeration repair business. Detection of VOCs associated with paints possibly due to incidental leaks of paints by the adjacent paint and varnish business and/or the use of paints on the floor.
- Acetone, methyl butyl ketone, 2-butanone, and 4-methy-2-pentanone are common industrial solvents and sometimes used in cleaning fluids. Detection of these VOCs possibly due to incidental leaks of spot removers used by the former dry cleaning business.



### Total Volume of Sub-Slab Vapors Extracted by VMS

DATE	NOTE	DURATION OF OPERATING PERIOD	SYSTEM OFF	TOTAL OPERATING TIME	BLOWER VACUUM	VAPOR FLOW RATE	VOLUME VAPOR EXTRACTED DURING PERIOD	CUMULATIVE VOLUME
		(DAYS)	(DAYS)	(DAYS)	(INCHES WATER)	(CFM)	FT3	FT3
10/11/2017	START	0		0	77	82	0	0
10/25/2017		14		14	77	82	1,653,120	1,653,120
11/10/2017		16		30	68	150	2,672,640	4,325,760
11/20/2017	SHUT OFF	10		40	68	150	2,160,000	6,485,760
11/27/2017	STARTUP	7	7	40	68	150	1,512,000	7,997,760
12/12/2017	SHUT OFF	15		55	68	150	3,240,000	11,237,760



## **COST COMPARISON**

#### (Roughly the same cost but using 0.25 hp fan prolongs mitigation)

ITEM	TERRACON	OTHER CONSULTANT	NOTE
PILOT TEST/CONCEPT DESIGN	2,500		
INSTALLATION	6,000	8,000	
MONITORING	1,000	2,500	
ELECTRIC (TERRACON 5 HP BLOWER)	591		55 DAY AT \$10.74/DAY
ELECTRIC (OTHER 0.25 HP FAN)		140	260 DAY AT \$0.54/DAY
TOTAL	10,091	10,640	

# Conclusions

- The pilot study data provided the rationale to design a VMS that addressed the sub-slab vapors in the area of concern, reduced the concentrations below the VISLs, and enabled the site to attain regulatory closure in two months after startup of the VMS.
- The concentration of VOCs in the extracted vapors could increase over time due to extraction of sub-slab vapors outside of the ROI where there are residual VOCs not associated with the area of concern. If concentrations are above VISLs, mitigation could be prolonged.
- Operation of a VMS could potentially capture VOCs not associated with the area of concern. If concentrations are above VISLs, mitigation could be prolonged.



## Recommendations

- Never underestimate the value of a VMS pilot test. It will give you building-specific information that can be used to design the VMS.
- Without a design rationale, one might under design the VMS which could prolong vapor mitigation or not extract vapors whose concentrations exceed VISLs.
- Without a design rationale, one might over design the VMS which could increase the cost for equipment as well as increased costs for electric service.



# **Thank You!**

# **Questions?**

Bob Roth, P.E Terracon 10625 W I-70 Frontage Road North – Suite 3 Wheat Ridge, Colorado 80033 <u>bob.roth@terracon.com</u> Office: 303-454-5278

