

Characterization of the Vadose Zone Using Partitioning Interwell Tracer Tests

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Abstract: A partitioning interwell tracer test (PITT) was conducted in the vadose zone beneath the location of a former solvent evaporation pit at the Department of Energy's Pantex Plant. The primary objective of the PITT was to establish whether or not residual Non-Aqueous Phase Liquid (NAPL) remained in the subsurface and if so, to quantify the amount. A soil vapor survey and soil sampling campaign had been conducted earlier and neither had yielded conclusive results about the presence or absence of NAPL. A divergent line-drive well field was installed and the zone of primary interest (i.e. 50 to 85 feet below ground surface) swept with a suite of conservative and partitioning gas tracers. Real-time analyses of the tracer concentrations in the injectate and from 16 extraction points were provided by two gas chromatographs installed in-line. The results of the PITT show a combined in-situ NAPL volume estimate of 850 ± 110 gallons. This data is crucial to the construction of a geosystem model that explains the mass balance of contamination and to the guidance of remediation efforts.

Column tests were performed to obtain toluene partition coefficients for 6 perfluorocarbon tracers. Toluene was selected as the primary component of the NAPL within the test zone based on EPA Method TO-14 (plus acetone and MEK) analysis of soil gas samples collected from within the test area. The NAPL/tracer partition coefficients ranged between 0 and 227.

The purpose of the PITT was to sweep tracers through the zone of interest beneath the SEP to quantify the volume of residual phase NAPL remaining in this zone. The theoretical and experimental foundation for PITT analysis for NAPL characterization in either the saturated zone or vadose zone has been previously published (Jin et al., 1995; Dwarakanath et al., 1999; and Deeds et al., 1999).

The PITT well field consists of 16 extraction wells (8 locations at 2 depth intervals), 8 tracer injection wells (4 locations at 2 depth intervals), and 4 pneumatic control wells (2 locations at 2 depth intervals). Each ¾-inch diameter well consists of a PVC riser with a 15-foot screened interval at base. The injection wells were installed in a north-south line down the central axis of the former pit. Pneumatic control wells were installed at each end of the line of injection wells. The extraction wells were installed in lines to the east and west of the line of injection wells. A cross-section of the well field is presented in Figure 1. The injection of air at the pneumatic control wells served to enhance tracer recovery at the extraction wells by minimizing lateral dispersal of the tracers injected away from the zone of interest.

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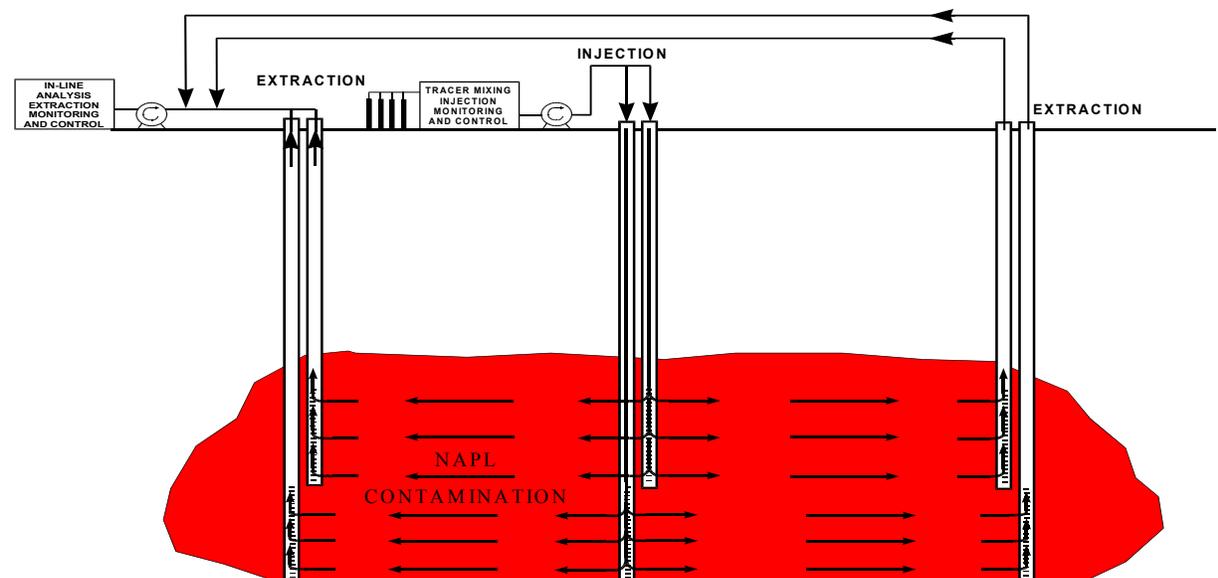


Figure 1. Schematic of Pantex PITT

Two gas chromatographs (GCs) were installed in the control trailer and plumbed to allow autonomous monitoring of tracer concentration in the injectate and at each extraction location. Both GCs were calibrated using vapor standards prepared by a third party vendor. Throughout PITT operations, analytical precision was assessed by the daily analysis of calibration check standards. Analytical recoveries for each tracer on both GCs, with the exception of one data point, were within the 70-130% data quality control limit specified.

Tracer injection began on 9/27/00 and ended on 9/28/00. The injectate pulse duration for the gas tracers (CF_2H_2 and C_4F_8) was 11.75 hours, whereas liquid perfluorocarbon tracer (C_7F_{14} , C_8F_{16} , C_9F_{18} , *c*- $\text{C}_{10}\text{F}_{18}$, and *t*- $\text{C}_{10}\text{F}_{18}$) injection continued for a total of 14.65 hours. The average injectate concentrations of the tracers ranged from a low of some 2,400 ppmw for *t*- $\text{C}_{10}\text{F}_{18}$ to a high of 10,670 ppmw for CF_2H_2 .

Injection/extraction operations continued after the tracers were injected, to move the tracers through the suspected NAPL source zone to the extraction wells. Air was injected at the injection wells as well as the pneumatic control wells. Average injection rates at individual wells varied from an average low of 86 scfm to an average high of 120 scfm. Extraction rates at individual wells varied from an average low of 58 scfm to an average high of 198 scfm. Injection/extraction operations ceased on 10/13/00. The tracers swept a pore volume of approximately 523,000 gallons.

During the PITT data analysis, tracer pairs were selected to estimate NAPL saturation and volume. Tracer pairs are chosen based on concentration measurement accuracy, tracer retardation factors and recoveries, and consistency in providing reliable and realistic measurements for each extraction location. The tracers selected from the Pantex PITT data set for NAPL saturation and volume estimation were the conservative tracer C_4F_8 and the partitioning tracer *c*- $\text{C}_{10}\text{F}_{18}$. The NAPL/tracer partition coefficients for C_4F_8 and *c*- $\text{C}_{10}\text{F}_{18}$ are 0 and 186.2 respectively.

Figure 2 shows the normalized concentration history for the NAPL partitioning tracer response (i.e., C_4F_8 and $c-C_{10}F_{18}$) at Extraction Well E8A. The normalized tracer curves exhibit separation between C_4F_8 and $c-C_{10}F_{18}$ indicating the presence of NAPL within the pore space swept. Analysis of the data indicates the presence of some 93 ± 9 gallons of NAPL in the swept pore volume between this extraction well and corresponding injection well. A systematic analysis of the data from each well pair revealed NAPL volumes ranging from a low of 27 ± 4 gallons to a high of 120 ± 16 gallons. These values represent average NAPL saturations (S_N) corrected for estimated water saturation ranging from 0.085 to 0.24 percent.

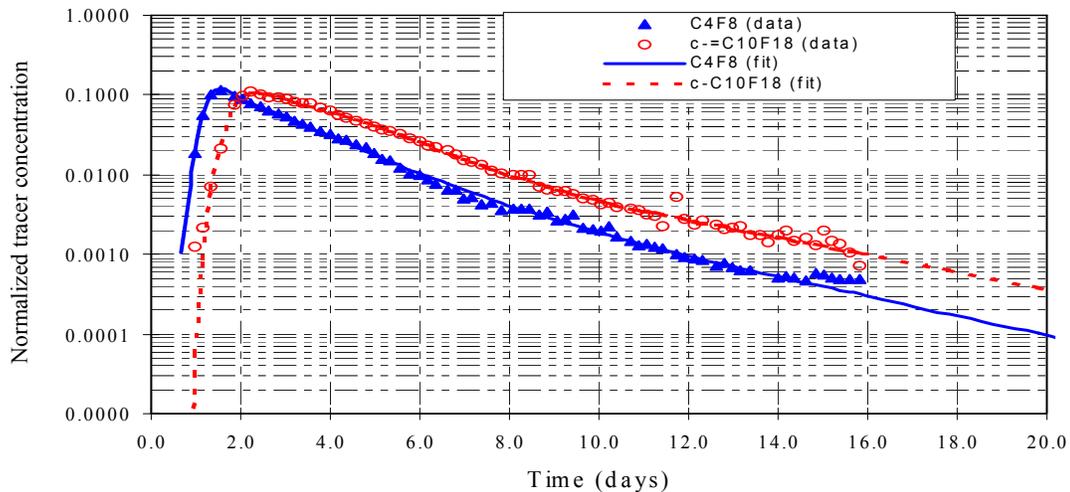


Figure 2. Extraction Well E8A: C_4F_8 and $c-C_{10}F_{18}$ Response Profiles

The results of the vadose zone PITT conducted beneath the Solvent Evaporation Pit (SEP) at the Pantex Plant burning grounds show a combined in-situ NAPL volume estimate of 850 ± 110 gallons. The test zone is situated just above a caliche layer that occurs at a depth of about 85 feet bgs. The identification of a relatively large quantity of NAPL in the test zone is logical given that the caliche layer is considered to be a partial barrier to downward migration of immiscible liquid mixtures.

References

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