

PC10) Performace Evaluation of Passive Soil-Vapor
Survey from Comparisons with Laboratory
Analysis for Chlorinated Solvents

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1. Introduction

In 2002 and 2003, environmental soil investigations were performed at two active dry-cleaning facilities located in the State of Illinois in the United States of America (USA). The purpose of these investigations was to determine the presence of subsurface contamination induced from approximately 35 to 50 years of on-site drycleaning operations at the subject sites. The constituents of concern (COC) from drycleaning operations are tetrachloroethylene (i.e., perc of PCE) and its daughter products such as trichloroethylene (TCE), cis-1,2-dichloroethylene (cDCE), trans-1,2-dichloroethylene (tDCE), 1,1-dichloroethylene (1DCE), and vinyl chloride (VC). Laboratory analytical results of 22 hydrophobic adsorbents coils (i.e., soil-vapor sampling device) exposed to the interior and exterior surface soils of the subject sites and laboratory analytical results of 44 soil samples collected using intrusive soil investigation by direct push technique (GeoProbe) from the soil-vapor sampling locations were compared to evaluate the performance of the passive soil-vapor survey.

2. Site Characterization

According to the historical documentation (i.e., the Phase I Environmental Site Assessment Reports) prepared for the subject sites, the Site A is a 2,500 square feet (sq ft) active drycleaning facility and has operated drycleaning operations since approximately 1972. silty clay or clay is predominant beneath the Site A and the depths to water are ranged from 13 to 15 feet below the land surface (ft bls). A total of 10 soil-vapor sampling locations were advanced to approximately one to two ft bls followed by 10 soil borings at the same locations down to a maximum depth of one to two ft bls followed by 10 soil borings at the same locations down to a maximum depth of 32 ft bls at the Site A. The site map showing the soil-vapor sampling and boring locations is provided in Figure 1.

Table 1. Tier Soil Remediation Objectives Groundwater Remediation Objectives for Chlorinated Solvents (35 IAC Part 742)

VOCs	Residential		Industrial/ Commercial		Construction Workers		SCGIER		GCGIER	
	Ingestion (mg/kg)	Inhalation (mg/kg)	Ingestion (mg/kg)	Inhalation (mg/kg)	Ingestion (mg/kg)	Inhalation (mg/kg)	Ingestion (mg/kg)	Inhalation (mg/kg)	Ingestion (mg/kg)	Inhalation (mg/kg)
PCE	12	11	110	20	2400	28	0.06	0.3	0.005	0.025
TCE	58	5	520	8.9	1200	12	0.06	0.3	0.005	0.025
1DCE	700	1,500	18,000	1500	1800	300	0.06	0.3	0.007	0.035
cDCE	780	1,200	20,000	1200	20000	1200	0.4	1.1	0.07	0.02
tDCE	1,600	3,100	41,000	3100	41000	3100	0.7	3.4	0.1	0.5
VC	0.46	0.28	7.9	1.1	170	1.1	0.01	0.07	0.002	0.01

NOTES: VOCs = volatile organic compounds

SCGIER = soil component of groundwater ingestion exposure route

GCGIER = groundwater component of groundwater ingestion exposure route

Ingestion = soil ingestion

Class I = Class I groundwater categorized by Title 35 IAC Part 620
Groundwater Quality

PCE = tetrachloroethylene

TCE = tetrachloroethylene

1DCE = 1,1-dichloroethylene

cDCE = cis-1,2-dichloroethylene

tDCE = trans-1,2-dichloroethylene

VC = vinyl chloride

mg/kg = milligrams per kilogram

mg/L = milligrams per liter

The Site B is a 4,000 sq ft active drycleaning facility and the drycleaning operation has been performed at the site since 1956. Fine sand with a trace of gravel is predominant beneath the Site B and the depths to water are ranged from 6 to 8 ft bls. At the site, 12 soil-vapor sampling locations were drilled and 12 soil borings at the same locations to a maximum depth of 28 ft bls. The site map showing the soil-vapor sampling and boring locations is provided in Figure 2.

2.1. Passive Soil-Gas Sampling and Laboratory Analyses

A soil-gas sampling device consists of a glass vial containing hydrophobic adsorbent cartridges with a length of wire attached to the vial for retrieval as seen in the Figure 3. Prior to installing the soil-gas sampling device, the overlying concrete slab, asphalt, or topsoil layer was removed. Surface fills were then continuously removed until natural

soil was encountered. AT least three-inch diameter hole is desirable to install the soil-vapor sampling device. Upon replacing a solid plastic cap from the soil-gas sampling device with a sampling cap (a plastic cap with a hole covered by screen meshing), the soil-gas sampling device was installed into the hole, with the sampling cap end facing down. The device was then covered with local soils or aluminum foil and a concrete patch. The device's locations, times and dates of emplacement, and other relevant information were recorded.

Approximately 48 to 72 hours after deployment, the soil-gas sampling devices were retrieved from the boreholes and were decontaminated using gauze cloth. Then the sampling caps were replaced with solid plastic caps. The soil-gas sampling devices (i.e., vials) were labeled and delivered to the analytical laboratory.

The soil-gas sampling devices were analyzed using the United States Environmental Protection Agency (US EPA) Method 8021 as described in the Solid Waste Manual (SW-846) for screening purposes. This method, which is modified to accommodate thermal desorption screening of the adsorbent cartridges, uses a capillary gas chromatograph (GC) with a photoionization detector (PID) in series with a flame ionization detector (FID) and a dry electrolytic conductivity detector (DELCD). The laboratory did not target VC with the Method 8021 because the laboratory did not use a focusing trap. Now the laboratory analyzes samples by the Method 8260 and targets VC. More detailed analysis procedures are available upon the request.

2.2. Intrusive Soil Sampling and Laboratory Analyses

Soil borings were advanced using direct-push techniques. Interior soil borings were advanced using a track-mounted GeoProbe equipment. Prior to conducting soil sampling, a 4.0-inch diameter electric core machine was used to remove the overlying concrete. Soils were then continuously sampled using a 1"-diameter sampling tube with disposable sample liners at 4.0-foot intervals to depths ranged from 12 to 16 ft bls.

Exterior soil boring were advanced using a truck-mounted rig equipped with hydraulically powered direct-push technology and a hollow stem auger. Prior to conduction soil sampling, the overlying asphalt or topsoil layer was removed. Soils were the n continuously sampled at 4-foot intervals to the maximum depths mentioned above.

Soil samples were examined for visual and olfactory evidence of contamination and screened for the presence of organic vapors with a photo-ionization detector (PID). Within less than one or two minutes after opening sample liners, the PID readings were measured over the sample liners. The PID was equipped with a 10.6 electron volt (eV) lamp. Measurements of headspace vapors are approximately proportional to the concentration of volatile organic compounds (VOCs) and can be indicative of the presence of VOC impacts. PID screening samples were collected at approximately two foot depth in-

tervals and each soil sample was split into two equal sections. One section was placed using TerraCore into laboratory prepared sample containers consisting of one 40 milliliter (ml)-glass vial with methanol preservative, two 40 ml-glass vials with sodium bisulfate preservative, and two 40 ml-glass vials with deionized water if the soil rigorously reacts with sodium bisulfate, and one four-ounce (oz.) glass jar, labeled, and placed into a cooler with ice. It approximately takes less than five minutes from opening sample liners to completing sample collection during the soil boring installation activities to minimize the evaporation of constituents of potential concern (COPC).

Evidence of contamination was noted based on the PID readings, and a log soil conditions was prepared. Upon completion of the sampling activities, the soil boring holes were grouted with saturated bentonite and concrete- or asphalt-patched to grade. Disposable nitrile gloves were worn during sampling activities to prevent cross-contamination between sample intervals.

The soil samples from each boring were submitted to a laboratory for quantitative analysis. Samples were analyzed for VOCs using the US EPA Method 8260B (EPA Target Compound List). The use of full-scan VOC analysis ensures the detection of the targeted contaminants, PCE, TCE, cDCE, and VC.

2.3. Passive Soil-Gas Laboratory Results

The soil-vapor survey results are the mass collected from the vapor-phase emanation from the source. Since the vapor-phase is merely a fractional trace of the actual source, the units (i.e., nanograms) used in the report are smaller than those employed for intrusive soil sample analytical results (milligrams per kilogram). Also, the quantitative level for each COC provides a reliable basis for comparing the relative strength of any detection of that compound from various sampling locations. All 22 sampling locations at Site A and Site B were covered by asphalt for exterior and concrete slab for interior for the sites.

As presented in Table 1, the maximum detections in soil-vapor samples collected from Site A were 7,400 from E-3, 1,300 from E-2, 1,900 from E-8, and 540 nanograms (ng) from E-8 for indicated the source of contamination was originated from the vicinity of drycleaning machine and is migrating off-site.

For Site B, the maximum detections were 2,100 from E-8 and E-11, 1,00 from E-11, 320 from E-11, and 94 ng from E-11 for PCE, TCE, cDCE, and tDCE, respectively. The laboratory analytical results of the soil-vapor devices and soil samples collected from Site B are summarized in Table 2. The PCE distribution map from the soil-vapor survey is presented in Figure 5. The soil-gas laboratory results revealed the presence of highest PCE contamination in soil in the drycleaning equipment on-site area.

2.4. Intrusive Soil Laboratory Results

Table 1 and Table 2 also present the laboratory analytical results of 44 soil samples (22 from the intervals showing the highest physical impact such as PID readings and 22 from deep soil each boring) collected from Site A and Site B. The intrusive soil sampling locations could be different from the soil-vapor sampling locations by maximum six inches.

The maximum detected concentrations or highest laboratory detection limits of PCE, TCE, cDCE, and VC at Site A were 660, 5.7, 9.6 < 2.7 and <2.4 mg/kg, respectively, in the sample collected from 3 to 4.5 ft bls at boring location B-3. The highest PCE concentration was above the soil saturation limit of PCE (i.e., 240 mg/kg pursuant to *the Title 35 Illinois Administrative Code Part 742 Tiered Approach to Corrective Action Objects*).

As Site B, the maximum detected concentrations were 3,700, 15, 4.8, 2.9 and 0.19 mg/kg for PCE, TCE, cDCE, tDCE, and VC, respectively. The highest PCE and TCE were detected in the soil sample collected from 10 to 12 ft bls at boring location B-12. The highest PCE concentration detected at Site B was also above the soil saturation limit of PCE.

3. Discussion

Laboratory analytical results of PCE in the soil samples and the soil-vapor samples collected from Site A and Site B are compared in Figure 6 and Figure 7, respectively. The figures show the relative detections of PCE and relative values of PCE concentrations in surface soil, in subsurface (i.e. deeper) soil, and sum of the surface and subsurface soil each sample. Each detection or concentration was divided by the highest detection or concentration of corresponding compound in either surface soil or subsurface soil to determine the relative value.

For Site A, considering the results for the shallow soil samples, the soil-vapor survey effectively screened the site to identify the location reporting the highest soil concentration of PCE and TCE as presented in Figure 6. While the second highest soil-vapor detection did not correlate with the second highest soil concentration, it did represent the fourth highest soil concentration of PCE identified. In general, the 5 highest soil-vapor detections, which were all greater than 1,000 ng, identified the 5 locations reporting the highest soil concentration of PCE. It is quite possible that at the soil-vapor sampling location E-1, the contaminants may be present at a depth less than 3 ft bls but at a lower concentration, which could provide a higher soil-vapor measurement because the source is closer to the soil-vapor sampling device.

At Site B, the highest PCE soil-gas was measured at E-8 and E-11. In contrast, the

maximum concentration of PCE in soil was detected at B-12 as shown in Table 2. It is difficult to define the correlation between the relative detections of soil-vapor and the relative concentrations of PCE in soil at Site B as presented in Figure 7. Note that at boring location B-12 the soil sample the maximum PCE was detected was taken at a depth interval from 10 to 12 ft bls, at which the contamination is from the soil-gas sampling device affects the amount of compounds that will be present in the soil-vapor, it might be acceptable to state that the soil-vapor survey at this site was failed to identify the extent of subsurface contamination due to the relatively long distance between the soil-vapor samplers and the location of actual contamination.

The distance from the samplers to the actual contamination, which is the most valuable factor to determine the effectiveness of soil-vapor survey, mainly depend on the history of contaminant-generating operations and geologic formation at a site. Longer drycleaning operation history (i.e., 50 years) and presence of fine sand at the beneath Site B allow the contaminants to migrate farther and deeper over a fixed time compared to Site A (i.e., 35 years and silty clay) so that the soil-vapor survey is not likely the most effective investigation.

It is also important to note that when soil-vapor sample locations are covered with asphalt or concrete, sample measurements are often increased significantly caps tends to reach equilibrium underneath the cap. Thus, a reading taken below or near an impermeable surface is much higher than it would be in the absence of such a cap.

Another critical fact is that, whatever the relative concentrations of source and associated soil gas, best results are achieved when the ratio of soil-gas measurements to actual subsurface concentrations remains as close to constant. It is the reliability and consistency of this ratio, not the particular units of mass (i.e., nanograms in this study) that determine usefulness. Thus, it is necessary to conduct following intrusive sampling at one or two points which show relatively high soil-gas vapor values to obtain corresponding concentrations of soil and ground-water contaminants. These correspondent values furnish the basis for approximating the required ratio. Once that ratio is established, it can be used in conjunction with the soil-gas measurements (regardless of the units adopted) to estimate subsurface contaminant concentrations across the survey field.

Conclusively, it is important to keep in mind that specific conditions at individual sample points, including soil porosity and permeability, depth to contamination, geologic information, and perched ground water, can have significant impact on soil-gas measurements at those locations. When soil-gas survey is handled in this way, the data provide information that can yield substantial savings in drilling costs and in time. They furnish, among other things, a checklist of compounds expected at each survey location and help to determine how and where drilling budgets can most effectively be spent.

Conclusion

Laboratory analytical results of hydrophobic adsorbent coils containing surface soil-vapor and corresponding soil samples collected by conventional intrusive method from two active drycleaning facilities in the State of Illinois, U.S.A, were presented to evaluate the performance of soil-gas survey.

The most critical factor to determine the effectiveness of soil-gas survey is the distance from the soil-vapor sampling device to the actual contamination, which is a function of soil porosity, permeability, primary lithology, and other geological and hydrogeological site-specific parameters. Also this factor can be affected by the history of contaminant-generation operations.

The laboratory analytical results in this study showed longer drycleaning operation history (i.e., 50 years) and presence of fine sand at the beneath Site B allow the contaminants to migrate farther and deeper over a fixed time compared to Site A (i.e., 35 years and silty clay) so that the soil-vapor survey is not likely the most effective environmental site investigation method alone for Site B. However, for Site A, the soil-vapor survey successfully screened the site to identify the location reporting the highest soil concentration of chlorinated solvents.

Since the best soil-vapor survey results are achieved when the ratio of soil-vapor measurements to actual subsurface concentrations remains as close to constant a minimum intrusive soil and groundwater investigation should be followed to determine the reliability and consistency of the ratio. When soil-gas survey is handled with this precautionary understanding, the data provide information that can yield substantial savings in drilling costs and in time.

References

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