Soil Vapor Migration Through Subsurface Utilities

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ABSTRACT

A soil vapor pathway field investigation was conducted in an area north of Buffalo Avenue in Niagara Falls, New York (the Investigation Area). The state environmental regulatory agency requested one of the industrial facilities in the area to conduct a study to further investigate soil vapor results produced by the agency's prior field investigation of a much broader area. The agency's investigation yielded sporadic detections of petroleum and chlorinated solvents, which were inconsistent with soil vapor from a "conventional" ground water plume.

The field investigation consisted of soil vapor and sewer sampling designed to evaluate a conceptual model (CM) that soil vapor detected by the state agency was not a result of a "conventional" groundwater plume in the overburden which extends from industrial areas south of Buffalo Avenue beneath the Investigation Area to the north. Instead the CM proposed that the soil vapor in the Investigation Area comes from: 1) soil vapors present and/or migrating horizontally along significant subsurface utility corridors which extend into the Investigation Area and/or 2) from vapors within the sewers themselves.

Six series of soil vapor samples were collected to examine these CM concepts. Each series had three sample points with the first point located immediately adjacent to a utility corridor (representing utility corridor vapors), while the other two points were at increasing distances from the corridor (representing the distances that buildings were setback away from the corridors). Sewer vapor samples were also collected to evaluate sewer vapors as a potential source of soil vapor.

The investigation results show that soil vapor found in the Investigation Area are attributable to soil vapor migration in utility corridors.

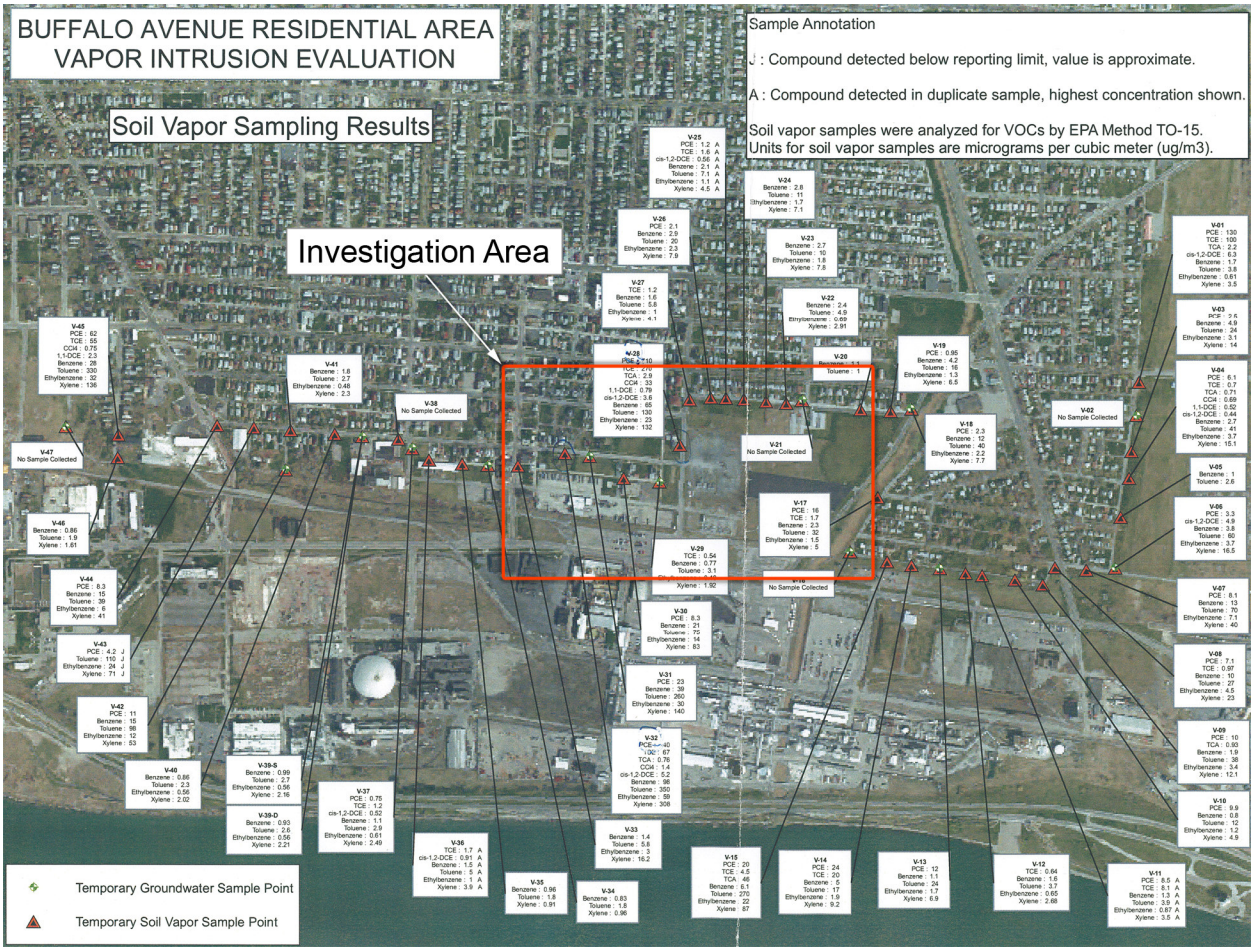
INTRODUCTION

In 2008, a soil vapor pathway field investigation (Investigation) was conducted north of Buffalo Avenue in Niagara Falls, New York. The investigation was undertaken with the oversight of the New York State Department of Environmental Conservation (NYSDEC), in consultation with the New York State Department of Health (NYSDOH).

The Investigation was the second investigation in the area. The first investigation, conducted by NYSDEC in 2007, involved groundwater and soil vapor sampling at more than 40 locations throughout an area they referred to as the Buffalo Avenue Residential Area.[1] The first investigation yielded sporadic detections in soil vapor samples without associated detections in

shallow groundwater. There were several active and former industrial facilities located south of Buffalo Avenue that had documented releases of chemicals to the subsurface. The NYSDEC requested one active facility to further investigate soil vapor near two of its soil vapor sampling locations, one along MacKenna Avenue (V-32) and the other along 27th Street (V-28), herein referred to as the Investigation Area, shown in Figure 1.

Figure 1. Investigation Area



The purpose of the Investigation was to develop a site-specific conceptual model (CM) for the soil vapor pathway in the Investigation Area, given that the results of NYSDEC's investigation suggested that soil vapor they detected was not a result of a "conventional" groundwater plume. Because the vadose zone was comprised of clay and subsurface utilities (primarily sewer pipes), an alternative CM was suspected that soil vapor was present in the Investigation Area due to soil vapors within the bedding of the utility corridors and/or from sewer vapors themselves. A work plan proposed soil vapor and sewer vapor sampling to verify this conceptual model.

This paper describes the Investigation Area and the investigation and discusses the results and conclusions, which have since been accepted by NYSDEC.

INVESTIGATION AREA

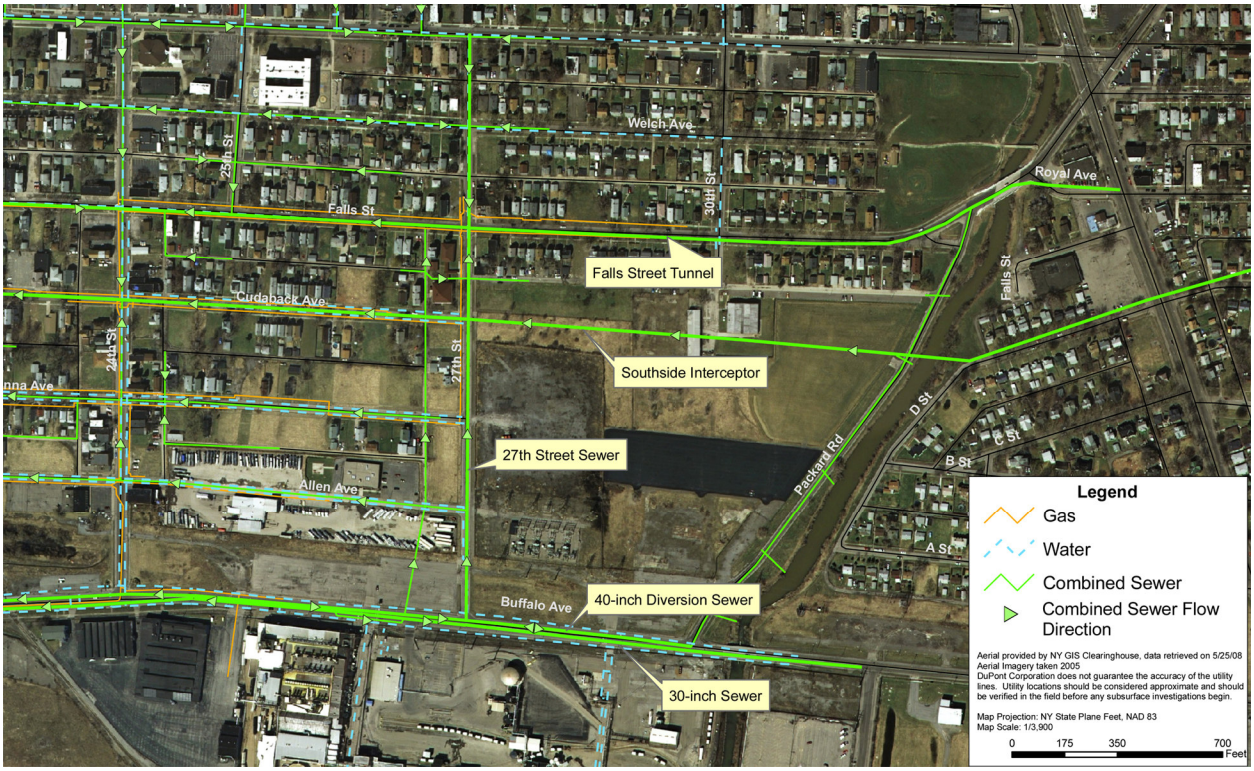
Soil

Based on a review of soil and well boring data, overburden geology in the Investigation Area consists of approximately 4 to 10 feet of glaciolacustrine clays and glacial till on top of bedrock. The depth to bedrock is the shallowest along Buffalo Avenue and deepens to the north and east. Soil boring logs from the NYSDEC 2007 investigation also supported this understood geology of the Investigation Area. Sewer drawings obtained from the City of Niagara Falls engineering department also indicate a shallow bedrock setting with a number of larger sewers installed into bedrock, as discussed below.

Subsurface Utilities

Subsurface utilities exist under most of the roadways as shown in Figure 2. The direction of sewer flow is also indicated on Figure 2. A review of utility drawings obtained from the City of Niagara Falls engineering department indicates that many of the larger sewers within the Investigation Area are constructed into bedrock. The drawings indicate that the combined sewers beneath Buffalo Avenue and 27th Street were constructed into bedrock at depths of 8 and 13 feet, respectively.

Figure 2. Subsurface Utilities

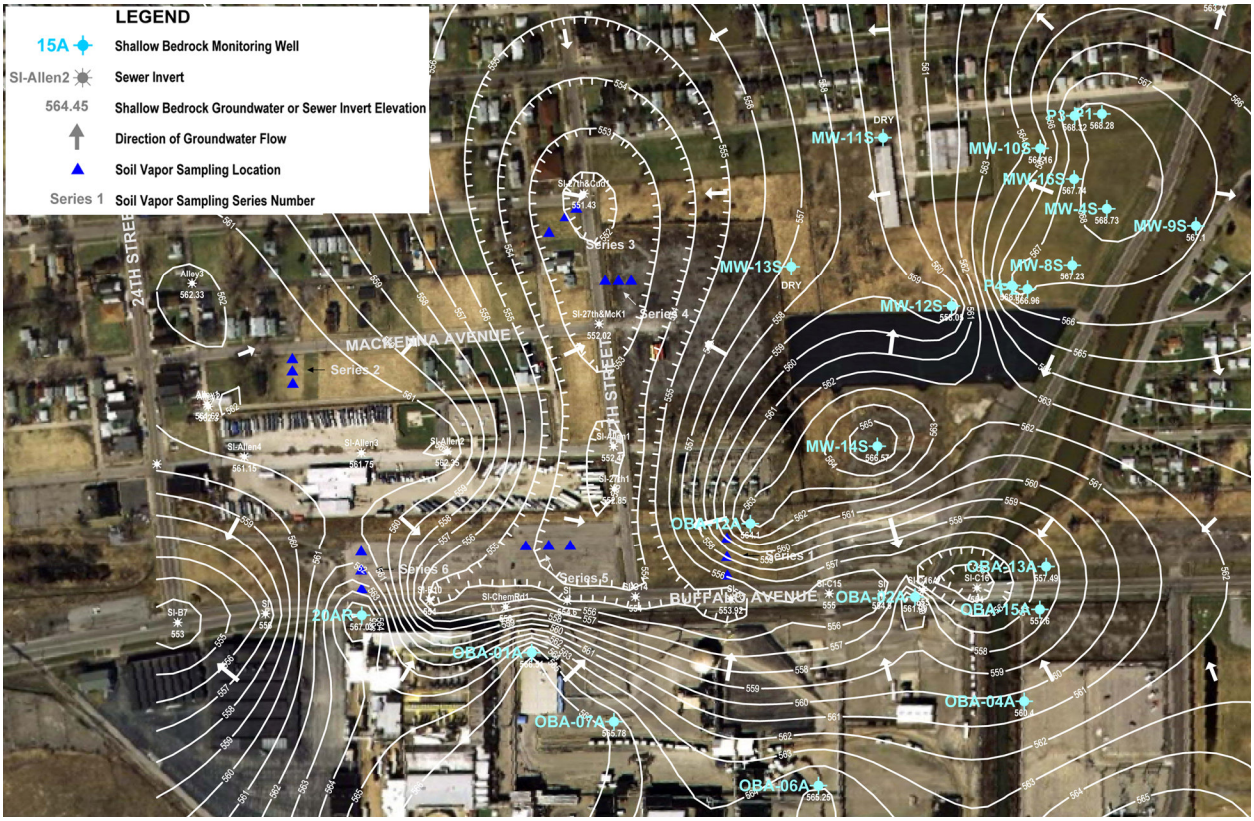


Groundwater

Shallow groundwater is present in some areas of the Investigation Area at a depth 2 and 6 feet below ground surface (bgs). Extensive hydrogeologic studies in the vicinity of the Investigation Area indicate that the predominant groundwater flow direction in the overburden is vertically downward to the bedrock. Locally, it is expected that overburden groundwater flow is influenced by the presence of sewer corridors, particularly those that fully penetrate the overburden and are incised into bedrock. Wells installed in the shallow overburden near or within the Investigation Area indicate little to no groundwater in the overburden, particularly those installed nearly adjacent to these sewers.

Overburden and shallow bedrock groundwater flow in the study area, conceptually, are dominated locally by the sewers incised into the top of bedrock (e.g., the Buffalo Avenue Sewer). Generally, the major sewer lines (Buffalo Avenue, 27th Street sewers) are installed well below the top of bedrock. These sewers create a very large and interconnected manmade preferential pathway for shallow bedrock groundwater flow. An idealized plot of potentiometric groundwater flow of the study area is presented in Figure 3. This conceptual model of shallow groundwater flow exhibits the expected general flow direction, where data is available, toward incised sewer lines.

Figure 3. Conceptual Shallow Groundwater Flow



Deep bedrock groundwater flow is influenced by a combination of the Niagara River, a production well, the Falls Street Tunnel, and the NYPA Conduits, depending on the depth of the groundwater and geographic location.

With the exception of two shallow bedrock wells, groundwater sample results for overburden and top-of-bedrock wells indicate very low concentrations of a few volatile organic compounds. Monitoring well locations are shown on Figure 3. Groundwater containing VOCs is presumed to be intercepted by the Buffalo Avenue sewer.

Historic Land Use

The historic land use of the Investigation Area was researched to identify land uses in the vicinity of the sampling locations that have a potential to contribute to the area's soil vapor. In general, the land use has not changed much since 1950. However, there were four junkyards along MacKenna Avenue that were present in 1950 but removed by 1965.

INVESTIGATION

In its summary report, NYSDEC identified four soil vapor sampling locations where tetrachloroethene (PCE) and trichloroethene (TCE) were detected at concentrations above soil vapor screening levels of 100 and 50 micrograms per cubic meter ($\mu g/m^3$), respectively, required by NYSDEC. NYSDEC requested that further investigation be focused on two of the locations, identified below:

- along MacKenna Avenue, near NYSDEC soil vapor sample V-32
- along 27th Street, near NYSDEC soil vapor sample V-28

These locations are shown on Figure 4.

The sampling program developed to assess if:

- vapors migrate horizontally within or around subsurface utilities (primarily sewer lines),
- vapors are present due to a "conventional" groundwater plume,
- vapors migrate from the utilities into the clay overburden where buildings are located,
- vapors migrate from the utilities through sewer lateral connections to building, and
- vapors in the sewer pipes can contribute to soil vapor.

Sampling Locations and Methodology

Soil Vapors

Soil vapor sample points were installed in six series of three sample points per series plus one additional soil vapor point near a sewer lateral (a total of 19 soil vapor points). The location of each series and soil vapor point is presented in Figure 4 and described below:

- Series 1 - North of Buffalo Avenue east of the intersection of Buffalo Avenue and 27th Street
- Series 2 - South of MacKenna Avenue near NYSDEC soil vapor sample point V-32
- Series 3 - West of 27th Street near the intersection with Cudaback Avenue
- Series 4 - East of 27th Street and across the street from NYSDEC soil vapor sample point V-28
- Series 5 - West of the combined sewer located to the west and parallel with 27th street

- Series 6 - North of Buffalo Avenue between 24th and 27th Streets
- Sewer Lateral - West of 27th Street next to NYSDEC soil vapor sample point V-28

Figure 4. Sampling Locations

In general, the siting for each series was chosen to evaluate the potential for soil vapor migration away from subsurface utilities and into the clay overburden away from those utilities. To prove that hypothesis, three soil vapor points within each series were selected at progressively increasing distances away from the adjacent utility corridor. The first soil vapor point in each series, Point 1, was placed closest to the utility corridor, and the second and third soil vapor points, Points 2 and 3, respectively, were placed at increasing distances from the utility corridor. In addition, for Series 2, 3, and 4, Points 2 and 3 in each series represent average setback distances, respectively, to the front and back of receptor homes along the adjacent street. The sewer lateral soil vapor site was chosen to characterize soil vapors near an adjacent sewer lateral to a house along 27th Street and near NYSDEC's sampling point V-28.

Soil vapor samples were collected using dedicated temporary soil vapor sampling points installed at depths no closer than one foot above the water table. Soil vapor sampling points were installed using a Geoprobe to create a bore hole into which Teflon™ sample tubing was placed to the desired depth. Most points were installed at a depth of 4 feet bgs, although all points, with one exception, were installed between 3 and 6 feet bgs. After sample collection, the temporary tubing/probes were removed from the soil borings. For soil vapor point DSV6-1, the tubing was found to be only 1.3 feet bgs rather than the field reported 3 feet.

After completion of the probe installation, the probe was purged 2 to 3 probe volumes. Some of the probes could not be purged because the bore holes were filled with water and there was no soil vapor to sample. Alternative locations and/or depths were attempted to be installed and sampled. In some cases, acceptable installations were achieved. However for the following sample points, acceptable alternative locations and depths could not be achieved, and therefore no soil vapor samples were collected:

- Series 4, Points 1 and 2
- Series 5, Points 2 and 3

The probe installation was allowed to stand for at least 24 hours before soil vapor sampling was initiated. Helium tracer gas screening was conducted before and after sample collection to confirm there was no sample probe leak or entrainment of ambient air into the bore hole. All tracer gas screenings yielded helium levels at or below 1 percent before and after each sample collection, thereby indicating that soil vapor probes did not leak and ambient air was not entrained into the bore hole.

Sewer Vapors

To determine the chemical content of the vapors from permitted discharges into the active sewer lines (not the bedding) combined sewer vapor (CSV) samples were taken at four locations as shown on Figure 4. The locations were chosen to characterize sewer vapors near soil vapor series along Buffalo Avenue, 27th Street and MacKenna Avenue. One sample (CSV-1A) was collected from the primary industrial discharge sewer. The other sample (CSV-1B) was collected from a diversion sewer. CSV-2 was collected from a manhole near Series 2. CSV-3 was collected from a primary industrial discharge sewer manhole near Series 4, and is downstream of CSV-1A. Note that according to municipal drawings, the sewer along MacKenna does not connect with the primary industrial sewer that flows west under Buffalo Avenue and north under 27th Street.

Sampling tubing was inserted down through a manhole at a height just above, but not in contact with, the liquid sewer contents. Sample depths were as follows:

- CSV-1a: 12 feet bgs
- CSV-1b: 9 feet bgs
- CSV-2: 9 feet bgs
- CSV-3: 15 feet bgs

Sample Analysis

After sample collection, all soil vapor and sewer vapor sample canisters were shipped under routine chain-of-custody to a subcontracted laboratory where they were analyzed by USEPA Method TO-15 for the standard list of analytes. The laboratory was certified under the Environmental Laboratory Approval Program (ELAP) and by NYSDOH for TO-15 analyses.

Quality Control

One field duplicate soil vapor sample was collected as part of this sampling program (duplicate to LSV-1 11/3/08). There were no field duplicates of sewer vapor samples, and no equipment or trip blanks.

Additionally, a Data Usability Summary Report (DUSR) was prepared for this sampling program to compare sample data with validation criteria prescribed by the United States Environmental Protection Agency's (USEPA) data validation guidance[2].

RESULTS AND EVALUATION

Vapor Sampling Results

Soil vapor samples were successfully collected at 15 of the 19 points (as discussed above, samples could not be collected at four soil vapor points). Sewer vapor samples were successfully collected at all 4 locations.

Results for TCE and PCE are depicted in Figure 5 for each sample point.

Figure 5. Sample Results

Data Evaluation

The sample results were evaluated to:

- define the CM of the soil vapor pathway within the Investigation Area, and
- assess if soil vapor levels warrant further investigation.

Soil Vapor Pathway Conceptual Model
This subsection draws conclusions from the sampling data and presents such conclusions as CM concepts. The numbering of the CM concepts is for discussion purposes only and not correlated with any other information contained in this paper.

Together with the sporadic and limited detections of TCE and PCE in shallow ground water, soil vapor results reveal that both TCE and PCE concentrations were highest at Points 1 of Series 1, 2, and 3,[a] and were either below detection or significantly lower (5 to 50 times) at Points 2 and 3 than the respective Point 1 concentration. Since the highest levels of soil vapor are alongside the utility corridors, and sharply decline with increasing distance from the utility corridor into the clay overburden, it appears that:

CM Concept #1: TCE and PCE soil vapor is present and/or migrating horizontally within the utility corridor, and their presence in soil vapor is not a result of a "conventional" ground water plume in the overburden extending beneath the Investigation Area.

CM Concept #2: Soil vapor diffusion into the clay dominated overburden is limited.

TCE and PCE soil vapor concentrations for Points 1 at Series 1 and 3 are quite similar. Sewer vapor concentrations associated with Series 1 and 3 (CSV-1A and CSV-3) are similar as well. Sewer vapor concentrations in the diversion sewer (CSV-1B) were significantly less than in the primary industrial sewer (CSV-1A). Therefore, it appears that:

CM Concept #3: The primary industrial discharge sewer that runs west along Buffalo Avenue then north along 27th Street may be contributing to soil vapor migration within the utility corridor.

TCE and PCE concentrations from Point 1 at Series 2 are approximately 35% lower for both compounds than the other two series. Sewer vapor associated with Series 2 (CSV-2) is approximately 88% lower for both compounds than the other two CSV samples. Therefore, it appears that:

CM Concept #4: Soil and sewer vapor from the primary industrial discharge sewer along 27th Street may be diffusing west along MacKenna Avenue. However, since the 27th Street sewer is not directly connected to the MacKenna sewer, the possibility of other sources for these compounds is not eliminated.

TCE and PCE concentrations of all three points at Series 6 are essentially below background. Therefore, it appears that:

[a] Evaluation of Series 4 and 5 sample results is not possible since only one of the three samples in each series could be collected.

CM Concept #5: Soil vapor does not appear to be migrating in the utility corridor along Buffalo Avenue and west of 27th Street, and soil vapor is not present as a result of a "conventional" groundwater plume in the overburden beneath the Investigation Area.

TCE and PCE soil vapor at Point 1 of Series 5 were not detectable, and therefore, it appears that:

CM Concept #6: Soil vapor is not migrating in the sewer corridor located to the west and parallel with 27th Street, and soil vapor is not present as a result of a "conventional" groundwater plume in the overburden beneath the Investigation Area.

Since the sewer lateral soil vapor sample (LSV-1) point was installed only four feet from the curb and since its results are similar to both Points 1 of Series 1 and 3, LSV-1 is more representative of a utility corridor sample rather than a sewer lateral sample. Therefore, any conclusion regarding vapor migration through lateral sewer connections cannot be drawn.

Soil Vapor Levels

Soil vapor sample Points 2 and 3 of Series 2, 3, and 4 represent soil vapor concentrations over the typical residence setback distance along each adjacent street. Points 2 and 3 represent the front and back edge of the house, respectively. Therefore, the average concentration of the two sample points provides insight into the potential soil vapor concentration under those residences. Average concentrations of TCE and PCE between Points 2 and 3 at each series are as follows:

- Series 2 – TCE: 17 $\mu g/m^3$; PCE: 96 $\mu g/m^3$
- Series 3 – TCE: <5 $\mu g/m^3$; PCE: 15 $\mu g/m^3$
- Series 4 – TCE: <11 $\mu g/m^3$; PCE: <14 $\mu g/m^3$ [b]

CONCLUSIONS

Conclusions drawn from the sample results are as follows:

- TCE and PCE soil vapors detected by NYSDEC in its 2007 sampling program are related to vapor migration in the utility corridors along Buffalo Avenue east of 27th Street, along 27th Street, and along MacKenna Avenue, and not due to vapor migration from a "conventional" groundwater plume in the overburden beneath structures in the Investigation Area.
- The source of TCE and PCE soil vapors appear to be associated with current or historic permitted sewer use from a large number of industrial, commercial, and other users.
- TCE and PCE soil vapors do not exist above detectable levels in the utility corridor along Buffalo Avenue west of 27th Street and in the sewer corridor that runs west and parallel to 27th Street.
- TCE and PCE soil vapor diffusion from the utility corridors into the clay overburden where buildings are located is limited.

[b] Based on Point 3 only. The Point 2 in this series could not be collected.

REFERENCES

1. New York State Department of Environmental Conservation; *Summary Report for Buffalo Avenue Residential Area Niagara Falls, New York*; August 2007.
2. United States Environmental Protection Agency, Region II; *Validating Canisters of Volatile Organics in Ambient Air, HW-18, Revision 0*; New York, New York; 1994.

KEY WORDS

Soil vapor migration
Soil vapor pathway conceptual model