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ORS-Based Air Monitoring During an MGP Site Cleanup: A Case Study

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ABSTRACT

This paper presents results of an ambient-air monitoring program employed during a November 2004 removal action at the Shelby Street former manufactured gas plant (MGP) site in Bristol, Tennessee. The objective was to ensure that safe ambient-air conditions were maintained at all times throughout the downwind community. Because the data was available on a continual basis and in real time, a secondary objective was to support onsite decision-making concerning the implementation of mitigative measures in the event that pre-established, health-based action levels were exceeded.

An open-path, Fourier-transform infrared (FTIR) spectrometer was used to measure, in real time, a total of 14 target volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs). Continuous, meteorological monitoring was performed during all optical remote sensing (ORS) monitoring.

The cross-sector-averaging technique was used for the continual, direct assessment of offsite contaminant exposure. This involved collecting path-integrated, crosswind contaminant measurement data downwind of the source, and then dividing each 10-minute-averaged concentration by the plume width to yield a representative maximum impact along the FTIR spectrometer beam.

Excel-based input and output forms were used for each monitoring event. These forms were incorporated into a computerized data-management system which, upon entry of the requisite input data, automatically calculated the maximum fenceline and offsite (sensitive-receptor) exposure during each monitoring event using dispersion-based dilution factors, where appropriate.

To illustrate the utility of the open-path FTIR approach, results from Day 1 are examined in greater detail.

INTRODUCTION

The ambient-air monitoring program described herein was employed during a 9-day removal action in November 2004 at the Shelby Street former manufactured gas plant (MGP) site in Bristol, Tennessee. All aspects of the air monitoring program were performed in conformance with the "Ambient Air Monitoring Work Plan, Shelby Street Former MGP Site" (Work Plan), October 2004, [1] as approved by the Tennessee Department of Environment and Conservation (TDEC), Division of Superfund (DSF).

Removal-action air monitoring was performed during all emissions-affecting activities. These activities commenced on November 9 and were completed on November 18, while site restoration was completed on December 3. Background air monitoring was performed on November 7 and 8, and no site work of any type was performed on November 14.

The objective was to ensure that safe ambient-air conditions were maintained at all times throughout the downwind community. Because the data was available on a continual basis and in real time, a secondary objective was to support onsite decision-making concerning the implementation of mitigative measures in the event that pre-established, health-based action levels were exceeded.

An EDO Corporation RAM2000 open-path, Fourier-transform infrared (FTIR) spectrometer was used to measure, in real time, a total of 14 target volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) approximately 1.5 meters above grade. All open-path FTIR analyses were in conformance with procedures set forth in USEPA's Toxic Organic Compendium Method 16 (Method TO-16). [2]

The target gaseous compounds were:

Compound	CAS No.	Compound	CAS No.
ammonia	07664-41-7	phenol	00108-95-2
benzene	00071-43-2	styrene	00100-42-5
m-cresol	00108-39-4	toluene	00108-88-3
o-cresol	00095-48-7	1,2,4-trimethylbenzene	00095-63-6
p-cresol	00106-44-5	m-xylene (1,3-xylene)	00108-38-3
ethyl benzene	00100-41-4	o-xylene (1,2-xylene)	00095-47-6
naphthalene	00091-20-3	p-xylene (1,4-xylene)	00106-42-3

An additional component of the program, outside the scope of this paper, was the use of a real-time aerosol monitor to measure total inhalable particulates (PM-10, or particulate matter with an aerodynamic diameter less than 10 microns) as a proxy for benzo(a)pyrene.

Continuous, real-time meteorological monitoring was performed during all air monitoring. [3] This data was used to facilitate interpretation of the open-path FTIR data, as well as to document atmospheric transport for evidencing proper FTIR monitoring configurations. A Climatronics TACMET Weather Sensor was equipped to monitor, at a height of 3 meters, the following parameters:

- wind speed
- wind direction
- sigma-theta (standard deviation of the horizontal wind direction) -- a parameter calculated from individual, once-per-second, wind-direction measurements
- ambient temperature
- relative humidity

The decision to use open-path FTIR spectroscopy for gaseous-compound monitoring was based on the technology's capability of meeting the program objectives when used in conjunction with requisite onsite meteorological data.

Additional advantages of this technology over traditional point monitoring were: (a) facilitation of real-time, field decision-making to protect the downwind community; (b) elimination of spatial data-representativeness concerns by collecting concentration information along the entire downwind site dimension (ensuring compounds cannot leave the site undetected); (c) generation of a permanent, electronic record demonstrating maintenance of acceptable ambient-air concentrations at all times; (d) detection of target compounds of greatest concern to MGP site managers, such as naphthalene, benzene, and, where present, hydrogen cyanide; and (e) overall cost-effectiveness.

Discussion on the analytical aspects of open-path FTIR spectroscopy is not included herein, as many excellent papers exist on this subject. The interested reader is referred to a particularly comprehensive optical remote sensing (ORS) technology review by Grant and Kagann.[4]

SITE DESCRIPTION

The Shelby Street former MGP is located at 816 Shelby Street, Bristol, Tennessee. The plant operated from 1892 until 1940 as a coal gas plant. Natural gas arrived in eastern Tennessee during 1940, and the plant was converted to a center for utility construction and service crews. Atmos Energy (formerly United Cities Gas Company) purchased the property from Bristol Gas Corporation in 1966. The buildings were subsequently demolished and, in 1995, the City of Bristol leased the property from Atmos Energy for use as a parking lot.

The DSF contacted Atmos Energy in February 2002 about the historical use of the property as an MGP and associated potential environmental concerns. In February 2003, Atmos Energy proposed a source removal action to remove the coal-tar material identified in an earlier site investigation. The DSF subsequently accepted the proposal and, following a 30-day public comment period, the site was accepted into the State's Brownfields Program.

ESTABLISHMENT OF OFFSITE ACTION LEVELS

Health-based, offsite action levels applicable for this site were established during the project planning phase based on consideration of site-specific, ambient-air acceptable concentrations (AAACs) derived for all target compounds by ARCADIS, Inc.[5] For each compound, AAACs were defined for exposure durations of 1 hour and 8 hours per day over the course of the removal

action (conservatively assumed at the time to be 6 weeks). It was determined that there would be no potential adverse health impacts to the downwind community if the average ambient-air levels did not exceed these concentrations during these time periods.

A 1-hour exposure duration was applied to the general population (including children) at the site perimeter (fenceline), and addressed the exposure scenario of people parking their cars and walking to and from the nearby County Court House.

An 8-hour exposure duration was applied to the general population inside the Court House (the nearest offsite "sensitive receptor," at a distance of 30 meters from the nearest site perimeter), and addressed the exposure scenario of Court House employees or visitors being present for a normal 8-hour day inside the building. This exposure scenario was applied at all offsite locations 30 meters from the site perimeter, regardless of direction. This was a very conservative approach, as the nearest sensitive receptors other than individuals in the Court House (i.e., residences) were more than 100 meters from the site.

Action levels were established for all target compounds to ensure that the AAACs were maintained. An action-level exceedance alerted onsite personnel that implementation of some type of mitigative measure might be necessary in order to keep ambient-air concentrations within these acceptable ranges.

All action levels were defined as 10-minute-averaged values, and all "monitoring events" were precisely 10 minutes in duration. This time period was chosen based on statistical considerations in establishing representative sigma-theta values for subsequent use in the assessment of plume width (discussed later). Use of this convention ensured that, for any target compound, ambient-air concentrations could be maintained at levels less than the corresponding acceptable concentration (either 1-hour- or 8-hour-averaged).

Given that 10 minutes affords ample opportunity to initiate mitigative measures, there was no need to set the action-level concentrations any higher (i.e., more conservative) than the AAACs. For simplicity, the action-level concentrations were set equal to the AAACs.

This approach to removal-action monitoring is in contrast to programs based on typically employed, traditional point techniques -- where sample-integration times are on the order of hours or longer and adequate spatial data representativeness cannot be achieved. Further, this approach obviates the need for regulatory agencies to apply a "safety factor" (typically an order of magnitude) to account for data-quality uncertainties arising from the use of discrete monitors in an emissions environment continually changing in space and time.

Following are the 10-minute action levels based on the 1-hour (fenceline) and 8-hour (offsite, sensitive-receptor) exposure scenarios. Naphthalene was the only compound having different fenceline and sensitive-receptor concentrations, as the risk-based analysis was limiting; the American Conference of Governmental Industrial Hygienists (ACGIH) 8-hour Threshold Limit Value (TLV) was limiting for all other compounds.

Compound	Fenceline 10-Minute Action Level (mg/m3)	Sensitive-Receptor 10-Minute Action Level (mg/m3)	Compound	Fenceline 10-Minute Action Level (mg/m3)	Sensitive-Receptor 10-Minute Action Level (mg/m3)
ammonia	18.0	18.0	phenol	19.0	19.0
benzene	1.6	1.6	styrene	85.0	85.0
m-cresol	22.0	22.0	toluene	188.0	188.0
o-cresol	22.0	22.0	1,2,4-trimethylbenzene	125.0	125.0
p-cresol	22.0	22.0	m-xylene (1,3-xylene)	435.0	435.0
ethyl benzene	435.0	435.0	o-xylene (1,2-xylene)	435.0	435.0
naphthalene	0.90	0.21	p-xylene (1,4-xylene)	435.0	435.0

METHODOLOGY

Cross-Sector-Averaging Technique

The cross-sector-averaging technique was used in conjunction with open-path FTIR monitoring for the direct assessment of offsite contaminant exposure. Conceived of and employed by USEPA Region 7, [6] this technique involves collecting path-integrated, crosswind contaminant measurement data downwind of the source (concentration units of parts per million times meters, ppm-m, or milligrams per square meter, mg/m^2), and then dividing each concentration by the plume width (m) to yield a representative maximum impact along the FTIR spectrometer beam (ppm or mg/m^3). It provides a conservative methodology for assessing the maximum 10-minute-averaged concentration at any downwind location.

Unless the beam is positioned along the site perimeter, a dilution factor is applied to the maximum beam impact in order to account for the increasing amount of contaminant "loss" due to atmospheric dispersion as the plume is advected toward the downwind receptor(s). The dilution factor is based on previously performed dispersion modeling for the full range of source-beam-receptor relationships and meteorological conditions expected to occur.

The identification of an appropriate plume width depends on three factors: (a) various properties of the plume as it is transported along the mean wind direction; (b) the distance between the source and the FTIR beam; and (c) the width of the source itself (e.g., excavation area or stockpiled material). Lateral spread and lateral meander are the plume properties of concern and are functions of atmospheric stability.

Table 1 presents the key to atmospheric stability classes (after Pasquill as discussed by Turner). [7] During the daytime, atmospheric stability is greatest (less plume dispersion) with strong winds and low insolation, conditions under which buoyant turbulence is minimized. During the nighttime, stability is greatest with very light winds and clear skies, conditions under which mechanical turbulence is minimized.

Table 1. Key to Pasquill Stability Categories

Surface (10m) Wind Speed (m/s)	Insolation (Daytime)			Cloud Cover (Nighttime)	
	Strong	Moderate	Slight	Thinly Overcast or ≥ 4/8 low cloud	≤ 3/8 cloud
< 2	A	A - B	B	--	--
2 - 3	A - B	B	C	E	F
3 - 5	B	B - C	D	D	E
5 - 6	C	C - D	D	D	D
> 6	C	D	D	D	D

Table 2 presents the plume width for selected downwind distances for a 3-meter-wide source under Stability Classes B, C, and D, initially judged those most likely to be encountered during the removal action.

Table 2. Plume Width for Selected Downwind Distances for a 3-Meter-Wide Source Under Stability Classes B, C, and D

Downwind Distance (m)	Plume-Width Component (m)			Total Plume Width (m)
	Lateral Spread	Lateral Meander	Source Width	
Stability Class B				
5	6.4	7.3	3.0	16.7
10	12.8	14.6	3.0	30.4
15	19.1	21.8	3.0	43.9
Stability Class C				
5	4.4	5.4	3.0	12.8
10	8.8	10.7	3.0	22.5
15	13.2	16.1	3.0	32.3
Stability Class D				
5	3.2	3.5	3.0	9.7
10	6.4	7.1	3.0	16.5
15	9.6	10.6	3.0	23.2

For any given combination of downwind distance and stability class in Table 2, the plume width is the sum of the lateral spread, the lateral meander, and the source width (lateral dimension). Lateral plume spread and lateral plume meander are assigned in accordance with Tables 3 and 4 below. Actual plume meander was calculated based on the sigma-theta values as measured during each 10-minute monitoring event.

Table 3 presents the *lateral plume spread* [8] for selected downwind distances under Stability Classes B, C, and D.

Table 3. Lateral Plume Spread for Selected Downwind Distances Under Stability Classes B, C, and D

Downwind Distance From Point Source (m)	Lateral Plume Spread for Given Stability Class (m)		
	B	C	D
5	6.4	4.4	3.2
10	12.8	8.8	6.4
15	19.1	13.2	9.6

Following Gaussian dispersion theory, lateral plume spread may be defined as the lateral (crosswind) distance from the plume centerline beyond which the contaminant concentration drops to 2 standard deviations (about 5.0 percent) of the centerline concentration for a ground-level, point source.

For example, under Stability Class C 15 meters downwind of the source, the lateral plume spread is shown to be 13.2 meters. This means that the ground-level concentration drops to only 5 percent of its maximum value when measured at a point 6.6 meters perpendicular to the plume centerline.

Table 4 presents the *lateral plume meander* for selected combinations of sigma theta and downwind distance. Following Gaussian dispersion theory, lateral plume meander may be defined as the lateral distance the plume centerline moves given a constant mean wind direction, and is typically expressed in terms of sigma theta. Consistent with the above convention for lateral plume spread, a crosswind distance corresponding to 2 standard deviations is employed.

The lateral plume meander is calculated by multiplying the tangent of sigma theta (sigma theta was automatically calculated for each 10-minute monitoring event) by 4 times the downwind distance. For example, for a sigma theta of 15º at a downwind distance of 15 meters, the lateral plume is equal to 0.2679 (tan of 15º) times 60 meters (4 times 15 meters), or 16.1 meters.

Table 4. Lateral Plume Meander for Selected Combinations of Sigma Theta and Downwind Distance

Downwind Distance from Source (m)	Tangent of Measured Sigma Theta	Lateral Plume Meander (m)
Measured Sigma Theta of 20.0°		
5	0.3640	7.3
10	0.3640	14.6
15	0.3640	21.8
Measured Sigma Theta of 15.0°		
5	0.2679	5.4
10	0.2679	10.7
15	0.2679	16.1
Measured Sigma Theta of 10.0°		
5	0.1763	3.5
10	0.1763	7.1
15	0.1763	10.6

Treatment of Multiple Sources

The above approach was applicable even when there were two or more simultaneously emitting sources, as was generally the case. Because each measured path-integrated concentration reflected the combined impact of all sources impacting the beam, the sources furthest from the site perimeter were conservatively considered to be superimposed upon the closest source.

Application of Dilution Factors

As discussed earlier, a dilution factor was applied to the maximum beampath impact when assessing action-level exceedances for offsite, sensitive receptors.

Table 5 presents the dilution factor for selected downwind-distance combinations under Stability Classes B, C, and D. For example, under Stability Class C, if the FTIR beam is positioned 5 meters downwind of the source and the distance to the receptor(s) of concern is another 30 meters, the dilution factor is 0.036. This means that the maximum concentration at the receptor(s) of concern is 0.036 times the maximum point concentration along the beam.

Table 5. Dilution Factors for Selected Downwind-Distance Combinations Under Stability Classes B, C, and D

Source-Beam Distance (m)	Beam-Receptor Distance (m)		
	10	20	30
Stability Class B			
5	0.160	0.062	0.033
10	0.288	0.134	0.077
15	0.388	0.204	0.125
Stability Class C			
5	0.174	0.069	0.036
10	0.296	0.139	0.080
15	0.393	0.209	0.129
Stability Class D			
5	0.196	0.078	0.042
10	0.307	0.146	0.085
15	0.400	0.213	0.133

Field Data Management

Excel-based input and output forms were used for each monitoring event. These forms were incorporated into a computerized data-management system which, upon entry of the requisite data, automatically calculated the maximum fenceline and offsite (sensitive-receptor) exposure during each event using dispersion-based dilution factors, where appropriate.

Responsible field project personnel were immediately notified whenever the concentration of a given target compound exceeded its 10-minute action level. When two such exceedances occurred during any moving 1-hour period, appropriate mitigative measures were initiated. Such measures included covering the contaminated soils and coal-tar materials with tarps and odor suppressing foam, reducing the rate of lime addition, and slowing or temporarily suspending removal-action activities. Air monitoring continued while the mitigative measures were completed, and removal work was not resumed until two consecutive acceptable monitoring events occurred.

Monitoring Configurations

Wind-direction forecasting was provided throughout the duration of the program in order to facilitate onsite decision-making with respect to the open-path FTIR monitoring configurations. Optimal configurations were employed to ensure protection of any individuals who might potentially be present in the downwind direction. Based on actual winds and onsite logistical constraints arising principally from line-of-sight issues, a total of 12 different open-path FTIR monitoring configurations, ranging in distance (one-way) from 54 to 90 meters, were employed over the course of the program.

During calm conditions and when the wind was light and variable, the monitoring configurations were always protective of the occupants of the County Court House. This meant that one of the spectrometer's beampath segments was always oriented along the easternmost site perimeter. A flat mirror was employed to "bend" the FTIR beam so that two adjacent sides of the site perimeter could be monitored during a given monitoring event. A minimum wind speed of 1 mph and a maximum sigma theta of 60º were conservatively employed during such conditions.

RESULTS

Results of the removal-action monitoring clearly demonstrated that the safety of all offsite individuals was maintained at all times.

Table 6 presents an overview of the open-path FTIR monitoring program.

Table 6. Overview of the Open-Path FTIR Monitoring Program

	Monitoring Day								
Potential Emissions-Affecting Activity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
(A) excavation of overburden	●	●		●		●			
(B) removal of underground structures and debris	●	●	●	●	●				
(C) *in situ* coal-tar conditioning and stockpiling	●	●	●	●	●	●	●	●	
(D) maintenance of stockpiled materials	●	●	●	●	●	●	●	●	●
(E) truck loading for offsite disposal			●	●		●	●	●	●
Total Events	**52**	**37**	**32**	**37**	**35**	**37**	**38**	**35**	**23**

Depicted in Table 6, for each monitoring day, are the documented, potential emissions-affecting activities and the number of monitoring events performed. A total of 326 open-path FTIR monitoring events were performed over the course of the 9-day removal action. In accordance

with the Work Plan, at least four monitoring events were performed each hour of removal-action activity.

Table 7 presents a summary of the open-path FTIR monitoring results.

Table 7. Summary of the Open-Path FTIR Monitoring Results

Target Compound	Number of Monitoring Events with:					
	Non-Detects	Detects	Fenceline Action-Level Exceedances		Offsite Action-Level Exceedances	
			Number	Percentage	Number	Percentage
benzene	310	16	5	1.53	0	0.00
toluene	305	21	0	0.00	0	0.00
ethyl benzene	305	21	0	0.00	0	0.00
m-xylene	326	0	0	0.00	0	0.00
o-xylene	277	49	0	0.00	0	0.00
p-xylene	314	12	0	0.00	0	0.00
naphthalene	133	193	24	7.36	6	1.84
styrene	279	47	0	0.00	0	0.00
ammonia	169	157	0	0.00	0	0.00
1,2,4-trimethylbenzene	322	4	0	0.00	0	0.00
phenol	236	90	0	0.00	0	0.00
m-cresol	326	0	0	0.00	0	0.00
o-cresol	326	0	0	0.00	0	0.00
p-cresol	326	0	0	0.00	0	0.00
Total	**3954**	**610**	**29**	**0.64**	**6**	**0.13**

Depicted in Table 7, for each target compound, are the total number of non-detects, detects, and detects above each 10-minute action level (fenceline and offsite) observed over the course of the program. Out of a total of 4,564 individual target compound measurements, there were 3,954 non-detects, 610 detects, 29 detects above a fenceline action level (0.64 percent frequency), and 6 detects above an offsite action level (0.13 percent frequency).

Table 8 presents a summary of individual target compound detects by monitoring day.

Table 8. Summary of Target Compound Detects by Monitoring Day

Target Compound	Monitoring Day									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
benzene	10	6	0	0	0	0	0	0	0	**16**
toluene	6	4	2	8	0	0	1	0	0	**21**
ethyl benzene	0	0	0	3	0	0	11	7	0	**21**
m-xylene	0	0	0	0	0	0	0	0	0	**0**
o-xylene	37	1	0	0	0	11	0	0	0	**49**
p-xylene	1	2	0	0	0	0	9	0	0	**12**
naphthalene	45	31	23	14	22	17	24	12	5	**193**
styrene	22	15	9	0	0	1	0	0	0	**47**
ammonia	37	19	7	14	23	14	26	16	1	**157**
1,2,4-trimethylbenzene	0	0	1	0	0	3	0	0	0	**4**
phenol	0	12	13	3	6	3	24	29	0	**90**
m-cresol	0	0	0	0	0	0	0	0	0	**0**
o-cresol	0	0	0	0	0	0	0	0	0	**0**
p-cresol	0	0	0	0	0	0	0	0	0	**0**
Total	**158**	**90**	**55**	**42**	**51**	**49**	**95**	**64**	**6**	**610**

As shown in Table 8, the greatest number of detects occurred on Day 1 (158), the start of removal activities, followed by Day 7 (95) and Day 2 (90). Naphthalene was the most frequently detected target compound (193) followed by ammonia (157). Benzene was detected a total of 16 times.

Table 9 and **Table 10** present the number of action-level exceedances by emissions-affecting activity for naphthalene and benzene, respectively. Action-level exceedances were observed for no other target compounds.

Table 9. Naphthalene Action-Level Exceedances as a Function of Observed Emissions-Affecting Activity

Exposure Scenario	Emissions-Affecting Activity					Total
	A	B	C	D	E	
Day 1						
Fenceline	0	0	9	1	NA	10
Offsite	0	0	4	0	NA	4
Day 2						
Fenceline	0	0	2	0	NA	2
Offsite	0	0	0	0	NA	0
Day 3						
Fenceline	NA	0	1	0	4	5
Offsite	NA	0	0	0	1	1
Day 4						
Fenceline	0	0	1	3	2	6
Offsite	0	0	0	1	0	1
Day 6						
Fenceline	0	NA	0	1	0	1
Offsite	0	NA	0	0	0	0

Key to Emissions-Affecting Activity (Tables 9 and 10)

A excavation of overburden
B removal of underground structures and debris
C *in situ* coal-tar conditioning and stockpiling
D maintenance of stockpiled materials
E truck loading for offsite disposal

Table 10. Benzene Action-Level Exceedances as a Function of Observed Emissions-Affecting Activity

Exposure Scenario	Emissions-Affecting Activity					Total
	A	B	C	D	E	
Day 1						
Fenceline	0	NA	5	0	0	5
Offsite	0	NA	0	0	0	0

For naphthalene (Table 9), there were a total of 24 fenceline and 6 offsite action-level exceedances. Most of these exceedances occurred during *in situ* coal-tar conditioning and stockpiling, with other exceedances during truck loading for offsite disposal and during maintenance of stockpiled materials. There were no action-level exceedances of either type during excavation of overburden or during removal of underground structures and debris.

Day 1 had the greatest number of combined action-level exceedances for naphthalene (14), followed by Day 4 (7), Day 3 (6), Day 2 (2), and Day 6 (1). There were no naphthalene exceedances of either type on Days 5, 7, 8, or 9.

For benzene (Table 10), there were a total of 5 fenceline action-level exceedances and no offsite exceedances. All fenceline exceedances occurred during *in situ* coal-tar conditioning and stockpiling on Day 1.

Figure 1 presents a recreated daily FTIR event summary form for Day 1 (the day having the most action-level exceedances) for selected compounds and monitoring events. This information is presented to illustrate the utility of the open-path FTIR approach in terms of its inherent capability to facilitate reconstruction of emissions-affecting activities and associated analysis of offsite impacts. In-depth results as presented herein are limited to Day 1 in the interest of space.

Each daily summary form was generated automatically from that day's FTIR event output forms and presents the maximum measured concentration (impact), in milligrams per cubic meter (mg/m^3), anywhere along the site perimeter (fenceline) and at any offsite sensitive receptor. Maximum measured concentrations in parentheses are calculated based on a minimum detection level (MDL) "default" approach, in which the measured FTIR concentration is assumed equal to the instrument MDL for a given non-detect.

Figure 1. Recreated Daily FTIR Event Summary Form for Day 1 for Selected Compounds and Events

Date	11/09/04
Monitoring Day #	1

Event #	Start Time	Config #	Wind Dir. (º)	Maximum Measured Concentration / Action Level (mg/m3)											
				Benzene		Toluene		m-Xylene		o-Xylene		p-Xylene		Naphthalene	
				Fence 1.6	Offsite 1.6	Fence 188.0	Offsite 188.0	Fence 435.0	Offsite 435.0	Fence 435.0	Offsite 435.0	Fence 435.0	Offsite 435.0	Fence 0.90	Offsite 0.23
34	14:00	3	159	(0.04)	(0.01)	0.11	0.02	(0.08)	(0.02)	0.22	0.05	(0.07)	(0.02)	0.27	0.06
35	14:10	3	064	(0.10)	(0.02)	0.35	0.08	(0.20)	(0.04)	0.62	0.13	(0.19)	(0.04)	**0.94**	0.20
36	14:20	3	187	0.30	0.07	0.25	0.05	(0.08)	(0.02)	(0.02)	(0.00)	(0.08)	(0.02)	0.74	0.16
37	14:30	3	123	(0.05)	(0.01)	(0.10)	(0.02)	(0.09)	(0.02)	0.26	0.06	(0.09)	(0.02)	0.18	0.04
38	14:40	3	150	0.10	0.02	(0.07)	(0.01)	(0.06)	(0.01)	0.18	0.04	(0.06)	(0.01)	0.24	0.05
39	14:50	3	232	(0.04)	(0.01)	(0.07)	(0.02)	(0.07)	(0.02)	0.20	0.04	(0.07)	(0.01)	0.21	0.04
40	15:00	3	226	(0.05)	(0.01)	(0.11)	(0.02)	(0.10)	(0.02)	0.27	0.06	(0.10)	(0.02)	0.33	0.07
41	15:10	3	084	(0.02)	(0.00)	(0.04)	(0.01)	(0.04)	(0.01)	0.09	0.02	(0.03)	(0.01)	0.12	0.03
42	15:30	3	230	**1.72**	0.19	(0.27)	(0.03)	(0.25)	(0.03)	0.62	0.07	(0.25)	(0.03)	**1.45**	0.16
43	15:40	3	209	**1.65**	0.18	(0.33)	(0.04)	(0.32)	(0.03)	0.68	0.07	(0.31)	(0.03)	**1.80**	0.20
44	15:50	3	208	0.32	0.04	(0.18)	(0.02)	(0.17)	(0.02)	0.32	0.04	(0.16)	(0.02)	0.79	0.09
45	16:20	3	179	(0.14)	(0.02)	(0.30)	(0.04)	(0.29)	(0.03)	0.52	0.06	(0.28)	(0.03)	**0.99**	0.12
46	16:30	1	145	1.33	0.16	0.53	0.06	(0.25)	(0.03)	0.55	0.07	(0.25)	(0.03)	**1.61**	0.19
47	16:40	1	171	**4.62**	0.63	2.12	0.29	(0.44)	(0.06)	(0.10)	(0.01)	(0.43)	(0.06)	**4.50**	**0.61**
48	16:50	1	231	**3.12**	0.43	(0.49)	(0.07)	(0.46)	(0.06)	1.11	0.15	(0.45)	(0.06)	**2.49**	**0.34**

Table 11 presents a summary of the target compounds detected on Day 1, in order of occurrence frequency. Naphthalene, ammonia, and o-xylene were detected during more than half of the 52 monitoring events for that day.

Table 11. Summary of Target Compound Detects on Day 1

Detected Target Compound	Frequency of Event Occurrence	
	Number	Percent
naphthalene	45	86.5
ammonia	37	71.2
o-xylene	37	71.2
styrene	22	42.3
benzene	10	19.2
toluene	6	11.5
p-xylene	1	1.9

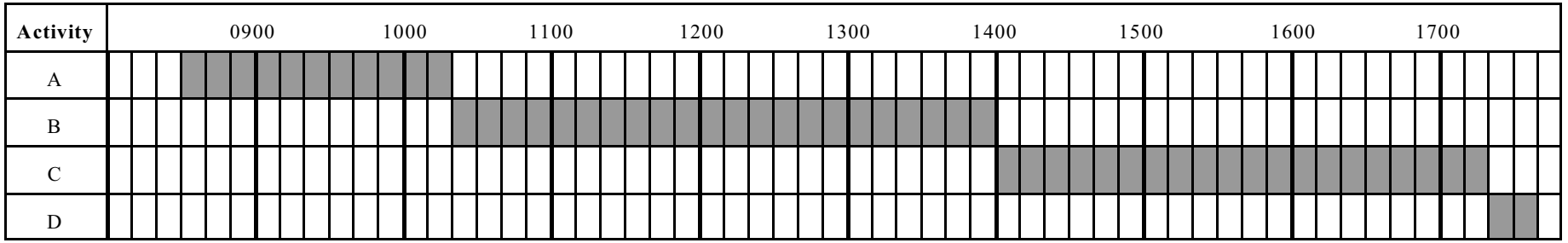
Figure 2 depicts the times of each potential emissions-affecting activity on Day 1. In the final report,[9] similar chronological depictions of potential emissions-affecting activities are presented during each monitoring day, and are used to support detailed reconstruction of such activities as well as analyses of offsite impacts.

QUALITY CONTROL

Precision and accuracy were assessed for all open-path FTIR data collected. For each monitoring event, carbon tetrafluoride (CF_4) was introduced into the spectrometer's flow-through cell from a NIST-traceable cylinder and measured for precision. Accuracy was assessed at the beginning and end of each day by measuring sulfur hexafluoride (SF_6), also introduced into the flow-through cell from a NIST-traceable cylinder.

Excellent precision and accuracy were noted -- well within the project measurement quality objectives (MQOs) -- during each monitoring day. The average precision achieved for all of the FTIR data was ±1.56 percent, and the average accuracy was – 5.72 percent.

Figure 2. Depiction of Potential Emissions-Affecting Activities: Day 1



Key to Potential Emissions-Affecting Activities

- **A** excavation of overburden
- **B** removal of underground structures and debris
- **C** *in situ* coal-tar conditioning and stockpiling
- **D** maintenance of stockpiled materials

CONCLUSIONS

The main objective of ensuring that safe ambient-air conditions were maintained throughout the downwind community was achieved, as was the secondary objective of supporting onsite mitigative decision-making. Application of the cross-sector-averaging technique proved to be an unobtrusive and particularly straightforward approach for meeting these objectives.

The monitoring program design enabled the AAACs to be directly assessed, without applying "safety factors" to account for data-quality uncertainties.

All measurement quality objectives as set forth in the project Work Plan were achieved or exceeded. The average *precision* for all FTIR data was ±1.56 percent (objective of ±5 percent) , and the average *accuracy* was −5.72 percent (objective of ±25 percent). All concerns with data *representativeness* were eliminated, as concentration information was collected along the entire downwind site dimension. A high degree of data *comparability* was achieved due to the excellent event-to-event correlation between the reported target compounds and the observed emissions-affecting activity. Finally, the inherent reliability of the open-path FTIR technology together with the simplicity of the cross-sector-averaging technique enabled the data *completeness* objective (four monitoring events for each hour of removal-action activity) to be equalled or exceeded during each day.

Offsite contaminant transport during calm conditions or when the wind was light and variable -- typically problematic with more traditional approaches -- was effectively addressed, as conservative meteorological defaults were employed and the entire site perimeter segment between the emission sources and the nearest receptors was monitored during such times.

Naphthalene was the gaseous target compound which "drove" the removal action, occurring in measurable quantities 59 percent of the time, and was responsible for 30 of the 35 action-level exceedances (both fenceline and offsite) which occurred during the 9-day program.

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