# Bridgeton Landfill Air and Landfill Gas Sampling August 2012: Summary of Findings

Bridgeton Landfill, LLC
13570 St. Charles Rock Road
Bridgeton, MO 63044

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Stantec

## Sign-Off Sheet

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# Executive Summary

On Thursday, August 16 and Friday, August 17, 2012, Stantec Consulting Services Inc. (Stantec) conducted an extensive study of airborne and landfill gases and vapors on and around the Bridgeton Landfill, 13570 St. Charles Rock Road, Bridgeton, Missouri (the landfill). The study was conducted to determine and document the presence and concentration of a large number of chemical compounds which may be present from landfill decomposition and related biological and chemical phenomena occurring or potentially occurring in the landfill. These chemical compounds may potentially contribute to odors reportedly detected by residential, commercial and industrial neighbors of the landfill property, and were also evaluated for their potential contribution to occupational and community health.

In advance of the air sampling event, Stantec and Bridgeton Landfill, LLC coordinated with the Missouri Department of Natural Resources (MDNR) to develop a sampling plan to thoroughly characterize the ambient air and landfill gas/vapor; and to answer questions posed by the interested stakeholders and members of the public. The final "Air Sampling Work Plan" (the "Work Plan"), approved by MDNR was issued August 14, 2012 and served as the basis for the sampling event.

As requested and approved by MDNR in the Work Plan, samples of air and landfill gas were analyzed for the following individual constituents and analytical groupings that are of potential concern for occupational and community health, some of which may contribute to the odor. Analytical methods selected and utilized were specified by US EPA, the Occupational Safety and Health Administration (OSHA), the National Institute of Occupational Safety and Health (NIOSH), the American Society for Testing and Materials (ASTM), and methods developed by Columbia Analytical Laboratories (AQL) specifically for odor investigations. All methods were presented in the Work Plan and approved by MDNR.

- Fixed Gases: EPA 3C (hydrogen, oxygen + argon, nitrogen, carbon monoxide, carbon dioxide, methane)
- Ammonia: OSHA ID-188
- Mercury` and Compounds: NIOSH 6009
- Hydrogen Cyanide: NIOSH 6010
- Reduced Sulfur Compounds: ASTM D5504
- Volatile Organic Compounds and Tentatively Identified Compounds: EPA TO-15
- Aldehydes (Carbonyl Compounds): EPA TO-11A
- Amines (Aliphatic): AQL 101

- Carboxylic Acids: AQL 102
- Polycyclic Aromatic Hydrocarbons (PAHs): EPA TO-13A
- Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans (Dioxins/Dibenzofurans): EPA TO-9

Samples of gas from under the flexible membrane liner (FML) in the Amphitheater, Second Tier, and East Face were found to contain numerous VOCs and TICs, aldehydes, reduced sulfur compounds, carboxylic acids (none detected in the sample from the second tier), naphthalene and coal-tar pitch volatile PAHs, and PCDD/PCDF. The variability in the concentrations of specific compounds found in gas from the three FML locations may help to explain the perceptible differences in odors across the landfill.

Samples of ambient air obtained from various locations on or adjacent the landfill were found to have detectable levels of several target compounds present, but at concentrations significantly below those detected under the FML.

The analytical results for ambient air were compared to occupational standards promulgated by OSHA and guidelines developed by NIOSH and ACGIH. No constituent detected in samples of ambient air from locations on the active areas of the landfill and downwind at the fence line exceeded or even approached applicable occupational standards or guidelines.

Analytical results for the ambient air samples were also compared to risk-based US EPA Regional Screening Level (RSL) concentrations for industrial and residential exposure. Of the compounds detected in samples of ambient air from locations on the active areas of the landfill and downwind at the fence line, only benzene and formaldehyde were present at concentrations exceeding the respective risk-based US EPA Regional Screening Levels (RSLs) for industrial and residential exposure. The RSLs for both of these compounds are very close to the laboratory method reporting limits. Formaldehyde was not found in landfill gas and is consistent with ambient background as evidenced by similar concentrations found in the upwind samples. Although benzene was not detected in the upwind samples, it is a common constituent in ambient air from urban/industrial areas.

The likely contributors to the odor observed at off-site locations are reduced sulfur compounds (e.g., dimethyl sulfide and mercaptans) and carboxylic acids (e.g., butyric acid and valeric acid) that have extremely low odor thresholds. It should be recognized that the odors of many of the reduced sulfur compounds and carboxylic acids are perceptible to the human nose at concentrations that are well below levels that present a health risk.

The results of the extensive sampling conducted in August support the conclusion that although some landfill emissions have resulted and may result in a perceptible odor, there were no compounds at concentrations of health concern to members of the surrounding community or to the people working on the landfill.

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# 1.0 Introduction

On Thursday, August 16 and Friday, August 17, 2012, Stantec Consulting Services Inc. (Stantec) conducted an extensive study of airborne and landfill gases and vapors on and around the Bridgeton Landfill, 13570 St. Charles Rock Road, Bridgeton, Missouri (the landfill). The study was conducted to determine and document the presence and concentration of a large number of chemical compounds which may be present from landfill decomposition and related biological and chemical phenomena occurring or potentially occurring in the landfill. These chemical compounds may potentially contribute to odors reportedly detected by residential, commercial and industrial neighbors of the landfill property, and were also evaluated for their potential contribution to occupational and community health.

The study was planned, developed, scheduled, and directed by professional Stantec personnel from Columbus, Ohio and Mequon and Green Bay, Wisconsin, and included the expertise of a Ph.D., Board Certified Toxicologist (DABT) and a Board Certified (ABIH) Industrial Hygienist (CIH). In advance of the air sampling event, Stantec and Bridgeton Landfill, LLC coordinated with the Missouri Department of Natural Resources (MDNR) to develop a sampling plan to thoroughly characterize constituents in the ambient air and landfill gas/vapor, and answer questions posed by the interested stakeholders and members of the public. The final Air Sampling Work Plan (the “Work Plan”), as approved by MDNR was issued on August 14, 2012 and served as the basis for the sampling event.

Once the Work Plan was approved by Bridgeton Landfill, LLC and MDNR, the onsite air and landfill gas sampling tasks were conducted on August 16 and 17 by the Stantec professionals, field staff and appropriate senior staff, in cooperation with landfill management and employees, MDNR personnel, and onsite landfill contractors.

## 2.0 Constituents of Interest in Landfill Gas and Air

As requested and approved by MDNR in the Work Plan samples of air and landfill gas were analyzed for the following individual constituents and analytical groupings that are of potential concern for occupational and community health, some of which may contribute to the odor. The protocols for collecting samples for the analyses listed below are found in Table 1. Analytical methods selected and utilized were specified by US EPA, the Occupational Safety and Health Administration (OSHA), the National Institute of Occupational Safety and Health (NIOSH), the American Society for Testing and Materials (ASTM), and methods developed by Columbia Analytical Laboratories (AQL) specifically for odor investigations. All methods were presented in the Work Plan and approved by MDNR.

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# 3.0 Sampling Methodology

## 3.1 COLLECTION OF LANDFILL GAS SAMPLES

The major objective of collecting samples from beneath the flexible membrane liner (FML) was to characterize the chemical constituents in the gas being produced from the landfill at various locations, and to evaluate that gas without interference from other sources of the same constituents, especially the motor vehicles and diesel powered equipment operating on and near the landfill. As described below, air-tight sampling ports were designed and utilized to ensure only gas from below the FML was collected.

With the exception of samples for quantification of PAHs and Dioxins/Dibenzofurans, very small volumes of gas were required and could be easily acquired through a small air-tight sampling port inserted through the FML fabric. For these “under FML” samples, the sample apparatus was connected directly to these small, barbed, air-tight ports. In order to make certain that adequate volumes of gas would be present for sample collection, “chambers” were created beneath the FML at the selected locations. The methods used to construct the chambers reflected the differences in materials underlying the FML in the three locations and accounted for the volume of air required for the analytical methods. For example, the gravel and rock beneath the FML in the Amphitheater allowed rapid accumulation and movement of gas; whereas the other two areas had less porous surfaces beneath the FML. Photograph 1 shows Stantec and MDNR personnel collecting VOC samples from one of the sampling ports. Photographs 2, 3, and 4 show high volume sampling of source gas from under the FML on the amphitheater, second tier, and East face, respectively.

Characterization of PAHs and Dioxins/Dibenzofurans require large quantities of air (or gas) that are drawn through special Polyurethane Foam (PUF) filters using a high-volume sampling pump over (generally) a 24-hour period. In order to ensure a continuous supply of gas beneath the FML for the high-volume samplers, box-like structures were constructed beneath the FML and fitted with a manifold allowing two samplers to operate simultaneously. Manifolds were fabricated in the landfill shop to facilitate the movement of gas from under the FML directly to the intake ports of the high-volume samplers. These tubing structures provided a means to draw gas directly from under the FML into the sampler with minimum interference or influence from ambient air.

The high-volume samplers require an uninterrupted AC power supply to run the pumps. Electrical power was accessible for the locations on the landfill and along the fence line. A gasoline powered generator positioned approximately 50 feet away, and downwind of the sample intake, was used to supply power to the high-volume sampler in the upwind/background locations. The generator was tended throughout the 24-hour sample period to make certain that air collection was not interrupted. Photographs 5, 6, and 7 show the apparatus used to collect ambient air or source gas for PAH and Dioxin/Dibenzofuran analysis.

## 3.2 COLLECTION OF AMBIENT AIR SAMPLES

Ambient air samples were collected at “breathing zone” height by mounting the sampling apparatus and SUMMA canisters on a tower constructed of plastic milk crates so that the sample collection intake ports were approximately 3 to 6 feet above the ground surface. Photographs 8, 9, and 10 show the sample collection structures and pump assemblies. Each set of ambient air samples at each location included instruments and collection media for collection of fixed gases (hydrogen, oxygen + argon, nitrogen, carbon monoxide, carbon dioxide, methane), ammonia, mercury, hydrogen cyanide, reduced sulfur compounds, volatile organic compounds, aldehydes, amines, and carboxylic acids. All of the samples in each set were collected for approximately 3 to 5 hours, with the exception of the set of samples collected at the Amphitheater location of the landfill where the concentration of the sampled compounds was expected to be potentially greater than other ambient locations. This set of air samples from the Amphitheater was collected for approximately 2 hours. It should also be noted that air was drawn into the Tedlar™ Bags for 15-20 minutes to avoid over-inflating the bags and subsequent rupture prior to being shipped to the laboratory. In all instances, sample flow rates and sample durations were optimally selected for best analytical detection and reporting limits. Also, durations were intentionally long to provide some assurance that if the presence of compound(s) was sporadic the sample would be collecting, or running, when the compound(s) appeared.

## 3.3 QUALITY ASSURANCE PROCEDURES FOR SAMPLE COLLECTION

Sample quality assurance encompasses procedures used for pre-sample calibration of sampling pumps, handling of samples before, during, and after collection, post-calibration of sampling pumps; elimination of potential cross contamination, elimination of collection of interfering compounds or materials.

All sampling pumps were pre-calibrated using a BIOS Defender Model 510-M revC1 (*BIOS International, Mesa Labs, Butler, New Jersey*) mechanical/digital calibration device traceable to the National Bureau of Standards (NTIS) with representative sampling media in place for each type of sample. After sample collection, and prior to collecting the next set of samples, the pumps were post-calibrated using the same calibration device, and with the actual sample in place. Where discrepancies between pre- and post-samples were noted, the change was assumed to be linear over time, and the sample volume provided to the analytical lab and used in determining concentration was the arithmetic average of the pre- and post-calibration values (consistent with industry standard methods).

Contemporary sampling media provides little opportunity for cross-contamination or external contamination. Media does not off-gas materials that could be collected in another sample and interfere with accurate analysis or reporting. Similarly, media is well protected by its manufactured configuration at all times so that external dirt, debris, or other materials cannot be readily introduced. All media, including Tedlar™ sample bags, were virgin materials. SUMMA™ canisters were cleaned and prepared by the analytical laboratory in a manner consistent and appropriate for re-use. After sampling, samples were capped and air-tightly secured, labeled with sample location identifier letter (A through N and A/U through C/U) and pump ID letter, and placed in a plastic sealable bag which was also labeled with the sample location identifier letter. Sets of samples in sealable bags were stored in the landfill office refrigerator until shipped to the laboratory for analysis to reduce volatilization or de-adsorption from the media. In addition, all samples were shipped following laboratory guidance using overnight delivery to ensure maximum holding times were not exceeded. Proper chain-of-custody forms were used for all shipped samples.

# 4.0 Sampling Locations

Figure 1 shows an aerial view of the Bridgeton Landfill and immediately adjacent properties. Locations where air and landfill gas samples were collected are indicated – and were located using the GPS coordinates provided by MDNR at the time the samples were collected. All sample locations were mutually agreed upon by MDNR, Bridgeton Landfill, LLC, Stantec and on the days that the samples were collected. The sample locations on Figure 1 correspond to the GPS coordinates provided by MDNR.

## 4.1 LOCATIONS UNDER FML

At the request of MNDR, three areas of the landfill were investigated to characterize constituents in the gas being generated in those specific locations. The three representative locations selected jointly by MDNR, landfill personnel, and Stantec, were previously, and remain, covered with FML. As shown on Figure 1, the locations where samples of gas were collected from under the FML are designated as:

- the “Amphitheater” a relatively level area on the northwest of the landfill near the concrete batch plant;
- the “Second Tier” which is at a slightly higher elevation on the landfill than the Amphitheater; and
- the “East Face” which is a large area on the eastern slope of the landfill.

## 4.2 LOCATIONS ON THE LANDFILL AND DOWNWIND AT THE FENCE LINE

The three ambient air sample locations designated as “the Amphitheater”, the “Summit”, and “Summit Valley”, were selected as representative of the active remediation area where people were working and where the odor was present. The air sample from the Amphitheater was collected at breathing zone height at the same location as the sample from under the FML also designated as Amphitheater. It was postulated that constituents present in the air at those locations would likely reflect both the air moving across the landfill property from upwind and from fugitive gas emissions from the landfill.

Six ambient air sample locations along the facility fence line were selected to capture constituents in air moving from the landfill towards off-site receptors. The odor was present at the fence line locations at the time sampling was initiated.

Ambient air sample locations designated as “Pond Center”, “Pond West” and “Pond East” were along the chain-link fence that separates the landfill from the adjacent Republic Services and other commercial properties to the north north/east of the landfill that are along the southwest side of St. Charles Rock Road. The flare for the landfill gas collection system is approximately 100 feet to the north of the Pond West sampling location.

It had been reported that odors were frequently observed in the topographically low area in the southeast corner of the landfill property. Two sampling locations designated “East Fence #1” and “East Fence #2,” across the construction road from the east face of the landfill where FML was being installed were selected with the concurrence of MDNR.. These two ambient air sample locations were along the chain link fence that forms the boundary between the landfill property and the Boenker Farm property to the southeast. The FML sample designated as East Face was collected approximately 500 feet to the north of East Fence #2. The ambient air sample location designated as “South Fence” was along the chain link fence in a low lying area adjacent to Boenker Lane.

## 4.3 UPWIND/BACKGROUND LOCATIONS

Ambient air samples designated as “Grassy Knoll Center”, “Grassy Knoll West”, and “Grassy Knoll North” were collected in an open grassy field in the northern portion of the landfill property. This area is on a slight rise or knoll. No odor was present on the days that the samples were collected. Air was moving from off-site across the grassy knoll towards the active areas of the landfill where construction was occurring

# 5.0 Analytical Results

## 5.1 LANDFILL GAS FROM UNDER THE FML

Table 2 presents a summary of the analytical results for all compounds detected in samples of gas from the three locations under the FML.

### 5.1.1 Analytes Not Detected in Any Sample

The following analytes were not detected in any of the gas samples collected from the three locations under the FML: carbon monoxide; ammonia; hydrogen cyanide; mercury; and amines. Benzo(a)pyrene and the related carcinogenic PAHs associated with incomplete combustion of organic matter were also not found in any of the gas samples.

### 5.1.2 Fixed Gases

The gas from under the FML in the Amphitheater was found to contain: oxygen + argon (7.68%); nitrogen (35.7%); methane (9.94%); and carbon dioxide (46.7%). Gas from under the FML on the Second Tier was found to contain: hydrogen (1.29%); oxygen + argon (7.92%); nitrogen (47.0%); methane (8.70%); and carbon dioxide (35.0%). Gas from under the FML on the East Face was found to contain: hydrogen (2.03%); oxygen + argon (8.04%); nitrogen (47.7%); methane (10.7%); and carbon dioxide (31.4%).

### 5.1.3 Volatile Organic Compounds

Thirty five (35) target analytes and twenty eight (28) Tentatively Identified Compounds (TICs) were found in at least one of the three samples taken from under the FML. As summarized in Table 2, it is apparent that the three FML locations had somewhat different profiles with respect to the specific compounds that were detected and the concentrations of those compounds. The following VOCs were found in all three locations: propene; tetrahydrofuran; benzene; n-heptane; toluene; n-octane; ethylbenzene; m, p- and o-xylenes; n-nonane; cumene; alpha-pinene; and d-limonene. The following TICs were found in all three locations: furan; dimethyl sulfide; and 2-methylfuran.

### 5.1.4 Aldehydes

Formaldehyde was not found in any of the samples collected under the FML. Acetaldehyde, propionaldehyde, butyraldehyde, o-tolualdehyde, and 2,5-dimethylbenzaldehyde were found in two samples; and isovaleraldehyde, and valeraldehyde were found in one sample.

### 5.1.5 Reduced Sulfur Compounds

Hydrogen sulfide was detected in the sample from under the FML on the Second Tier, and was undetected in the other two “under FML” locations. The following reduced sulfur compounds were detected in all three under FML samples: dimethyl sulfide; methyl mercaptan; ethyl mercaptan; carbon disulfide; ethyl methyl sulfide; thiophene; dimethyl disulfide; and 3-methyl thiophene. The following compounds were detected in one or two of the samples: carbonyl sulfide; isopropyl mercaptan; t-butyl mercaptan; isobutyl mercaptan; 3-methyl thiophene; 2,5-

dimethyl thiophene; and 2-ethyl thiophene. Dimethyl sulfide and dimethyl disulfide were the reduced sulfur compounds detected at the highest concentrations.

### 5.1.6 Carboxylic Acids

No carboxylic acid compounds were detected in the gas from under the FML on the Second Tier. All carboxylic acid target analytes were found in gas from under the FML on the Amphitheater: acetic acid; propionic acid; 2-methylpropionic acid; butanoic acid; 2-methylbutanoic acid; pentanoic acid; 3-methylpentanoic acid; 4-methylpentanoic acid; hexanoic acid; heptanoic acid; 2-ethylhexanoic acid; and octanoic acid. All of the same analytes were found in gas from under the FML on the East Face except: acetic acid; 3-methylpentanoic acid; 4-methylpentanoic acid; and octanoic acid.

### 5.1.7 PAHs

With the exception of fluoranthene and pyrene which were not found in gas from under the FML in the Amphitheater, the following PAHs were found in gas from under the FML in all three locations: naphthalene; acenaphthene; fluorine; phenanthrene; anthracene; fluoranthene; and pyrene. It is significant to note that benzo(a)pyrene and related carcinogenic PAHs associated with incomplete combustion of organic matter were not found in any of the samples of gas from under the FML.

### 5.1.8 Dioxins/Dibenzofurans

Table 3 presents the concentrations of individual PCDD and PCDF isomers measured in samples of gas from the three locations under the FML. Consistent with US EPA guidance, the detected concentrations of the individual dioxin and dibenzofuran isomers were converted to a 2,3,7,8-TCDD Toxicity Equivalent Concentration (TEQ) using the Toxicity Equivalence Factors (TEFs) recommended by US EPA (December 2010). The TCDD TEQ concentrations for the individual isomers were added to yield a single TCDD TEQ concentration for the sample. The TCDD TEQs for gas from each of the under FML samples were: Amphitheater (1.28E-08 $\mu g/m^3$); Second Tier (1.03E-08 $\mu g/m^3$); and East Face (3.00E-08 $\mu g/m^3$).

## 5.2 AMBIENT AIR FROM LOCATIONS ON THE LANDFILL AND DOWNWIND AT THE FENCE LINE

As described in Section 4, (shown on Figure 1), ambient air samples were collected from three locations within the active remediation area on the landfill where a strong odor was evident. These three locations are designated as the Amphitheater, the Summit and the Summit Valley. Samples were collected at six locations along the fence line that were downwind of the active areas of the landfill and where the odor was present at the time the samples were taken. Table 4 presents a summary of the analytical results for locations on the landfill and downwind at the fence line.

### 5.2.1 Analytes Not Detected in Any Sample

The following analytes were not detected in any samples of air from locations on the landfill or downwind at the fence line: ammonia, hydrogen cyanide; mercury; amines; carboxylic acids;

and reduced sulfur compounds with the exception of dimethyl sulfide. Benzo(a)pyrene and the related carcinogenic PAHs associated with incomplete combustion of organic matter were also not found in any of the air samples from locations on the landfill and downwind at the fence line.

#### 5.2.2 Fixed Gases

The sample bags for the Pond East and Pond West locations were deflated when they arrived at the analytical laboratory and consequently there are no results for these two locations. For all of the other locations on the landfill where samples for fixed gases were collected, the percentage of oxygen + argon was 21.5% and the percentage of nitrogen was 78.4 to 78.5%. Hydrogen, carbon monoxide, methane and carbon dioxide were not detected in measurable concentrations.

#### 5.2.3 Volatile Organic Compounds

Twenty (20) Target Analyte VOCs and sixteen (16) TICs were found in low $\mu g/m^3$ concentrations in one or more of the downwind locations on the landfill. The Target Analytes detected were: propene; dichlorodifluoromethane; ethanol; acetonitrile; acetone; trichlorofluoromethane; methylene chloride; 2-butanone (methyl ethyl ketone); ethyl acetate; tetrahydrofuran; benzene; toluene; n-octane; tetrachloroethene; ethylbenzene; m,p-xylenes; o-xylene; n-nonane; alpha-pinene and d-limonene. The TICs were: furan; dimethyl sulfide; methyl acetate; 2-methylfuran; methylpropionate; ethylpropionate; methylbutyrate; ethyl butyrate; isobutene; hexamethylcyclotrisiloxane; 2-ethyl-1-hexanol; acetic acid; 2-butoxyethanol; isopentane and a C6-H10 alkene. No VOC or TIC was found at concentrations exceeding occupational exposure standards. Only benzene was present at concentrations exceeding the very conservative US EPA risk-based RSLs for residential and industrial exposure. Table 4 presents the concentrations of VOCs and TICs detected in air samples from the six downwind locations and on the landfill. US EPA RSLs, OSHA PELs, and ACGIH TLVs are presented for comparison.

It should be noted that two SUMMA™ canisters were collected from the South Fence line location because the first canister South Fence #1 lost vacuum within the first hour and was considered potentially unreliable. A second canister, designated as South Fence #2 was activated and collected air for a duration of 4 hours. The analytical results from both canisters are presented in Table 4.

#### 5.2.4 Aldehydes

Acetaldehyde was detected in all of the samples, and was the only aldehyde detected in air samples from the Amphitheater and East Fence line locations 1 & 2. As shown on the tables, acetaldehyde was detected in the landfill and downwind samples at concentrations similar to those found in upwind samples. Acetaldehyde, formaldehyde, valeraldehyde and 2,5-dimethylbenzaldehyde were found in a number of locations at concentrations similar to those detected in the upwind samples (except valeraldehyde which was not found in the upwind samples).

### 5.2.5 Reduced Sulfur Compounds

Dimethyl sulfide was the only reduced sulfur compound found in air from locations on the landfill and downwind along the fence line. As noted in the discussion of fixed gases (Section 5.2.2), the sample bags for the Pond East and Pond West locations were deflated when they arrived at the analytical laboratory and consequently there are no results for these two locations.

### 5.2.6 PAHs

High volume samples for determination of PAHs were taken from the Summit and the downwind location designated as East Fence #1. The following PAH compounds were detected in these samples: naphthalene; acenaphthene; fluorine; phenanthrene; and pyrene (summit only). Benzo(a)pyrene and other related carcinogenic PAHs were not detected in any sample.

### 5.2.7 Dioxins/Dibenzofurans

High volume samples for determination of dioxins/dibenzofurans were also collected from the Summit and East Fence #1. Table 5 shows the concentrations of the individual polychlorinated dibenzo-p-dioxins and dibenzofuran (dioxins/dibenzofurans) isomers that were detected. Concsitent with the US EPA guidance, the detected concentrations of the individual dioxins and dibenzofuran isomers were converted to 2, 3, 7, 8-TCDD TEQs. The total TCDD TEQ calculated for dioxins in the sample collected at the summit was 1.49E-08 $\mu g/m^3$; and the total TCDD TEQ calculated for dioxins in the sample collected at the east fence #1 was 7.88E-09 $\mu g/m^3$.

## 5.3 AMBIENT AIR FROM UPWIND/BACKGROUND LOCATIONS

As described previously, background samples were collected from three specific locations in an area on the northwestern portion of the landfill property referred to as the Grassy Knoll. This area was upwind of the active remediation areas of the landfill on both August 16 and 17; and no discernible odor was present. Samples were collected for all analytical suites except for PAHs. One of the high-volume sampling units arrived from the vendor in a non-functional condition and could not be repaired until the next day when repair parts were received. Given the aggressive schedule for collecting samples and the desirable 24-hour collection time required for both the PAH and Dioxin/Dibenzofuran analytical methods, it was decided to sacrifice the PAH analysis of background air. Table 6 presents a summary of analytical results for all compounds detected in at least one upwind/background sample.

### 5.3.1 Analytes Not Detected in Any Sample

The following analytes were not detected in any of the samples collected from the upwind locations on the Grassy Knoll: ammonia; hydrogen cyanide; mercury; amines; carboxylic acids; and reduced sulfur compounds.

### 5.3.2 Fixed Gases

The sample bag from the Grassy Knoll Center collected on August 16, 2012 was deflated upon arrival at the laboratory, thus the sample was not valid. All other sample bags arrived intact and were analyzed. Hydrogen, carbon monoxide and methane were not detected in any of the upwind samples. A low concentration of carbon dioxide was reported in the August 17, 2012 sample from the Grassy Knoll West. The percentage of oxygen + argon was 21.5% in all samples; and the percentage of nitrogen was 78.4 to 78.5%.

### 5.3.3 Volatile Organic Compounds

Seven (7) Target Analyte VOCs were detected in one or more of the upwind samples: acetone; acetonitrile; dichlorodifluoromethane; ethyl acetate; tetrachloroethene; trichlorofluoromethane; and toluene. Six (6) TICs were detected in one or more of the upwind samples: acetic acid; ethyl butyrate; ethyl propionate; hexamethycyclotrisiloxane; and an unidentified compound with retention time of 9.41 minutes. The concentrations of all VOCs and TICs are presented by location along with corresponding US EPA RSL and occupational standard/guideline concentrations. All reported concentrations of VOCs were below US EPA RSL concentrations for both residential and industrial air.

### 5.3.4 Aldehydes

Three common aldehyde compounds were reported at low µg/m$^3$ concentrations in one or more of the upwind samples: acetaldehyde; formaldehyde; and 2, 5-dimethylbenzaldehyde. Both acetaldehyde and formaldehyde were reported at concentrations higher than the US EPA RSL concentrations for residential and industrial air. As will be further discussed in section 6.2.2, the conservative risk-based RSLs are very close to, and in some cases less than, standard laboratory method reporting limits. Consequently, it is common for detected concentrations of these two compounds to exceed screening levels.

### 5.3.5 Dioxins/Dibenzofurans

One high-volume sample was collected from the Grassy Knoll Center to characterize upwind/background concentrations of the polychlorinated dioxins and dibenzofurans. Consistent with US EPA guidance, the concentrations of the individual dioxin and dibenzofuran isomers were converted to 2,3,7,8-TCDD TEQs and evaluated as a single concentration of the index compound. As can be seen from Table 7, a number of Dioxin and Dibenzofuran isomers were found to be present at extremely low concentrations in the upwind sample. The TCDD TEQ concentration of 1.94E-08 µg/m$^3$ was consistent with the US EPA RSL for residential air (6.4E-08 µg/m$^3$) and less than the RSL for industrial air (3.2E-07 µg/m$^3$).

# 6.0 Discussion of Sampling Results

## 6.1 COMPARISON OF COMPOUNDS DETECTED BY LOCATION

### 6.1.1 Downwind on Landfill Compared to Gas from Under FML

The following compounds were detected in the gas samples from under the FML and the ambient air from locations on the landfill and at the downwind fence line locations, but not in the upwind samples: propene; ethanol; 2-butanone (MEK); tetrahydrofuran; benzene; n-octane; ethylbenzene; xylenes; n-nonane; alpha-pinene; d-limonene; furan; dimethyl sulfide; methyl acetate; 2-methyl furan; methyl propionate; methyl butyrate; isobutene; C7-H12 alkene; ethyl propionate; and isopentane.

### 6.1.2 Downwind on Landfill Compared to Upwind/Background

The compounds that were detected in both upwind air and landfill/downwind fence line locations were: dichlorodifluoromethane; acetonitrile; acetone; trichlorofluoromethane; ethyl acetate; toluene; tetrachloroethene; acetaldehyde and formaldehyde. The concentrations of each detected compound were similar among all samples. The two chlorofluorocarbon compounds (Freons), tetrachloroethene, acetaldehyde, and formaldehyde appear to be constituents in the regional air mass moving across the landfill during the times that the samples were collected.

## 6.2 APPLICABLE OCCUPATIONAL AND PUBLIC HEALTH STANDARDS

### 6.2.1 Occupational Exposure Standards

Occupational Exposure Limits (OELs) published as OSHA PELs (Permissible Exposure Limits) and ACGIH TLVs (Threshold Limit Values) are presented on Tables 4 and 6 for all constituents for which occupational exposure standards or guidelines were available. In a few instances where OSHA PELs and ACGIH TLVs have not been developed, AIHA Workplace Environmental Exposure Levels (WEEL) were applied. Note that gas from under the FML is not an exposure environment, thus no comparison is made to occupational or risk-based concentrations.

ACGIH TLVs are health-based values, and refer to concentrations of chemical substances and represent conditions under which it is believed nearly all workers may be repeatedly exposed, day after day, over a working lifetime, without adverse health effects. OSHA PELs are based on 1969 TLVs with the exception that some have been updated as substance specific standards to reflect more current toxicological data and research. AIHA WEELs are also similar to TVLs and have been developed for compounds for which there are no TLVs or PELs but for which AIHA believes there is significant potential workplace exposure.

The concentrations of all detected compounds in ambient air on the landfill, downwind at the fence line and upwind were low, well below occupational exposure limits. In fact, no constituent detected in samples of ambient air from locations on the active areas of the landfill and downwind at the fence line exceeded or even approached applicable occupational standards or guidelines. The highest concentration of compounds compared to their respective OELs were benzene in the Pond West sample, dimethyl sulfide in the Summit Valley sample, and formaldehyde in the Pond Center, Pond East, Pond West, and Summit samples. These compounds were detected in concentrations less than 2% of their OEL Most detected sample concentrations were below 0.01% of their OELs.

As a special case, a unique TLV for VOCs that may cause similar toxicological effects was developed. It is an additive TLV based on the sum of all of the detected concentrations divided by its respective TVL; this sum is compared to one (1). The highest VOC mixture exposure was 1% of the mixture TLV, in the Pond West sample. This is well below the mixture TLV even with a 20% addition to account for detected compounds that may cause similar toxicological effects as the other detected VOCs, but that have no OELs.

It is clear that detected concentrations of the significant number and variety of compounds collected in ambient air samples on and around the landfill are well below applicable occupational exposure limits. In addition, concentrations and exposures to mixtures of the detected volatile organic compounds (presumed additive synergist relationship) are well below the mixture TLV. Total adjusted concentrations of dioxin and furan compounds are also well below the OEL and RSLs.

### 6.2.2 Risk-Based Screening Levels

US EPA risk-based Regional Screening Level (RSL) concentrations for exposure to constituents in air in residential and industrial settings are presented on Tables 4 and 6. RSLs for carcinogenic chemicals are derived to correspond to an excess lifetime cancer risk of 1 in 1,000,000 (1 in 1 million or 1E-06) for a person (receptor) who is assumed to be exposed to that concentration on an ongoing basis over an extended period of time (25 years for industrial and 30 years for residential). RSLs for chemicals that produce adverse non-cancer effects are concentrations that are very unlikely to produce health effects in people who are exposed over many years. Concentrations of constituents below applicable RSL concentrations are generally not considered to be of concern for public health. Concentrations above RSLs do not necessarily mean that adverse health effects will occur, but do indicate that additional evaluation may be appropriate.

The vast majority of detections were much lower than the RSL concentrations. However, the concentrations of benzene found in air from all three of the downwind fence line locations along the Pond, East Fence line #1, and South Fence line #1 and 2; and on the landfill at the Amphitheater and Summit Valley locations were higher than the conservative RSL for residential exposure (0.31 µg/m$^3$), with detected concentrations ranging from 1.5 up to 16 µg/m$^3$ The highest concentrations of benzene were found in the three Pond West, Pond Center and Pond east samples. Benzene was not detected in the air at the Summit or at the downwind East Fence line #2 location. The concentrations of benzene found in the air on the Amphitheater (1.1 µg/m$^3$) and the downwind East Fence line #1 location (1.5 µg/m$^3$ ) were similar to the RSL for industrial exposure (1.6 µg/m$^3$). It is not uncommon to find concentrations of benzene exceeding the conservative RSLs in air samples in urban/industrial settings.

All concentrations of formaldehyde found in upwind locations and in samples from locations on the landfill and the downwind fence line locations were greater than the RSL concentrations; as were the majority of the acetaldehyde concentrations, As indicated previously, the residential and industrial RSLs for formaldehyde (0.19 and 0.94 µg/$m^3$ ) and acetaldehyde (1.1 and 5.6 µg/$m^3$ ) µg/$m^3$ ), are close to the laboratory MRLs for these compounds in ambient air (0.32 – 0.70 µg/$m^3$). Acetaldehyde and formaldehyde have a number of common sources such as motor vehicle emissions and are frequently found in ambient air in urban settings.

## 6.3 ODOR THRESHOLDS

Table 8 presents the lowest published odor threshold for constituents found in gas from under the FML in comparison to the range of concentrations found in ambient air from locations on the landfill and downwind at the fence line. The odor threshold concentrations were obtained from US EPA (1992), Ruth (1986), and AIHA (1997). The characterization of the odor for each individual compound is the description used in the source reference for the odor concentration. The range of concentrations at which people can begin to recognize the distinctive odor of a chemical are frequently associated with occupational environments. For the majority of chemicals, most people can recognize a characteristic odor at concentrations well below concentrations that are of concern for health. The odor descriptions for the individual compounds are not intended to describe the odor associated with Bridgeton Landfill.

As indicated on Table 8, the lowest published odor threshold is near or below the laboratory Method Reporting Limits for the ambient air samples for the following compounds present in gas from under the FML: ethyl acetate; acetaldehyde; hydrogen sulfide; dimethyl sulfide; dimethyl disulfide; methyl mercaptan; ethyl mercaptan; isopropyl mercaptan; t-butyl mercaptan; isobutyl mercaptan; n-butyl mercaptan; thiophene; butanoic (butyric) acid; and pentanoic (valeric) acid.

The reduced sulfur compounds as a group have odors that are commonly described as “rotten eggs”, “decayed cabbage”, “sulfide-like”, and “disagreeable”. Mercaptans can be perceived at such low concentrations that they are added to natural gas as odorants to warn of gas-leaks.

As mentioned previously, the majority of the Tedlar™ bags for the ambient samples were deflated upon arrival at the analytical laboratory, although they were intact when shipped from the landfill office. Consequently, there is little data for reduced sulfur compounds. Dimethyl sulfide was the only sulfur compound detected in the usable ambient air samples from locations on the landfill. Dimethyl sulfide and dimethyl disulfide were the two sulfur compounds found at the highest concentrations in the samples of gas from under the FML. Because the odor thresholds for many of the reduced sulfur compounds are below laboratory MRLs, it is not unreasonable to assume that other reduced sulfur compounds found in gas samples from under the FML may also be present in ambient air. It is very likely that reduced sulfur compounds were significant contributors to the odor.

The carboxylic acids as a group have odors that are commonly described as “sour”, “perspiration”, “body odor”, and “cheesy”. A number of carboxylic acids were found in gas from under the FML from the amphitheater and the east face, but not the second tier, with the greatest number of individual compounds and highest concentrations detected in the sample from the amphitheater. Although no carboxylic acids were detected in the air samples from locations on the landfill and the downwind fence line, it is reasonable to assume that low concentrations of some of these compounds may have been presented and contributed to the odor.

The concentrations of the individual VOCs found in ambient air samples from locations on the landfill and downwind at the fence line are lower than the range of corresponding odor thresholds. However, the aggregate of VOCs present in the downwind locations may have contributed to the perception of odor.

The very low concentrations of naphthalene, related coal-tar pitch volatile PAHs, and Dioxins/Dibenzofurans found in the ambient air samples are not contributors to the odor. The low concentrations of aldehydes are consistent with background and are not related to the odor.

# 7.0 Summary and Conclusions

Samples of gas from under the FML in the Amphitheater, Second Tier, and East Face were found to contain numerous VOCs and TICs, aldehydes, reduced sulfur compounds, carboxylic acids (none detected in the sample from the second tier), naphthalene and coal-tar pitch volatile PAHs, and Dioxins/Dibenzofurans. The differences in the concentrations of specific compounds found in gas from the three FML locations may help to explain the perceptible differences in odors across the landfill.

It is not appropriate to compare the concentrations of constituents found in samples of gas from under the FML with occupational exposure standards or risk-based screening levels because the area below FML is not an exposure environment.

No constituent detected in samples of ambient air from locations on the active areas of the landfill and downwind at the fence line exceeded or even approached applicable occupational standards or guidelines established by the Occupational Safety and Health Administration (OSHA), the National Institutes for Occupational Safety and Health (NIOSH), or the American Council of Governmental and Industrial Hygienists (ACGIH).

Of those compounds detected in samples of ambient air from locations on the active areas of the landfill and downwind at the fence line, only benzene, acetaldehdye ,and formaldehyde were present at concentrations exceeding the respective risk-based US EPA RSLs for industrial and residential exposure. The RSLs for these compounds are very close to the laboratory method reporting limits. Formaldehyde was not found in landfill gas and is consistent with ambient background as evidenced by the presence of this compound in the upwind air samples. The concentrations of acetaldehyde found in samples from locations on the landfill and downwind at the fence line were similar to the concentrations found in the upwind samples. Benzene, formaldehyde and acetaldehyde are frequently detected at low concentrations in ambient air in urban/industrial areas. These compounds have a number of common sources such as motor vehicle emissions.

The downwind fence line sample locations were very close to the areas of the landfill where FML was being installed to control gas emissions. Thus the downwind fence line samples represent the maximum concentrations of constituents moving from the landfill towards off-site receptors at the time the samples were collected. The concentrations of potentially landfill-related constituents in air at the Boenker Farm and in the surrounding neighborhood are not known, but are expected to decrease with increasing distance from the landfill.

The likely contributors to the odor observed at off-site locations are reduced sulfur compounds (e.g., dimethyl sulfide and mercaptans) and carboxylic acids (e.g., butyric acid and valeric acid) that have extremely low odor thresholds. As discussed in section 6.3, the individual members of these two groups of compounds have been described as having odors that many people find objectionable. However, the majority of these odorous compounds are of low order of toxicity.

The results of the extensive sampling conducted in August support the conclusion that although there was an odor, there are no compounds in the fugitive emissions from the landfill at concentrations of health concern to members of the surrounding community or to the people working on the landfill.

## 8.0 Tables, Figures, Photographs

Table 1. Sample collection protocols

Table 2. Summary of analytical results for all compounds detected under the FML

Table 3. Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF) detected under the FML

Table 4. Summary of analytical results for all compounds detected in ambient air samples from the downwind locations and on the landfill

Table 5. Individual polychlorinated dibenzo-p-dioxin and dibenzofurans (PCDD/PCDF) isomers and conversion to 2,3,7,8-TCDD toxicity equivalents (TEQs); on landfill and downwind

Table 6. Summary of analytical results for all compounds detected in at least one upwind/background sample

Table 7. Individual polychlorinated dibenzo-p-dioxin and dibenzofurans (PCDD/PCDF) isomers and conversion to 2,3,7,8-TCDD toxicity equivalents (TEQs); in upwind samples

Table 8. Summary of compounds detected under the FML with associated odor thresholds, and concentrations detected in downwind and landfill ambient air samples

Figure1. Air Sampling Locations

Photographs

## 9.0 References

American Industrial Hygiene Association, *Odor Thresholds for Chemicals with Established Occupational Health Standards, 1997 edition.*

Ruth, J.H., *Odor Thresholds and Irritation Levels of Several Chemical Substances: A Review,* Am. Ind. Hyg. J., 47: A-142 through A-151, March 1986.

US EPA, *Reference Guide to Odor Thresholds for Hazardous Air Pollutants Listed in the Clean Air Act Amendments of 1990, EPA/600/R-92/047, March 1992.*

US EPA Regional Screening Levels Summary Table, April/May 2012 on-line

Occupational Safety and Health Administration (OSHA), *29CFR1910.1000, Occupational Safety and Health Standards, Subpart Z – Toxic and Hazardous Substances, Table Z-1 Limits for Air Contaminants* (also includes Table Z-1-A, Z-2, and Z-3)

American Conference of Governmental Industrial Hygienists (ACGIH), *TLVs® and BEIs® Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices,* 2012 & 2013 edition

American Industrial Hygiene Association (AIHA), *Workplace Environmental Exposure Limits (WEELs),* 2012 edition

TOXNET, *Toxicology Data Network*, US National Library of Medicine, Sep 2012 on-line

# Tables

## *Table 1*

Sample collection protocols

Bridgeton Landfill

| *Analyte group* | *Sample location* | *Analytical method* | *Collection method* | *Sample duration and flow rate* | *Link to methodology* |
|---|---|---|---|---|---|
| Volatile organic compounds | Source and under FML[1] | EPA[3] TO-15 | 1 Liter Summa canisters | <30 sec, <30 sec total evacuation time by regulator | http://www.cdc.gov/niosh/docs/2003-154/pdfs/2549.pdf |
| | Ambient[2] on landfill and off landfill | EPA TO-15 | 6 Liter Summa canisters | 240 min, 240 minute total evacuation time by regulator | http://www.epa.gov/ttnamti1/files/ambient/airtox/to-15r.pdf |
| Reduced sulfur compounds | Source and under FML | ASTM[4] D5504 | 1 liter Tedlar[5] bag, partial fill | Low flow sampling pump; max. 10-15 min @ 0.050 lpm[6] | http://www.astm.org/Standards/D5504.htm |
| | Ambient on landfill and off landfill | ASTM D5504 | 20 liter Tedlar bag, partial fill | Low flow sampling pump; 240 min @ 0.050 lpm | http://www.caslab.com/Forms-Downloads/Flyers/REDUCED_SULFUR_BROCHURE.pdf |
| Carboxylic acids | Source and under FML | Columbia Analytical AQL Method 102 | Treated silica gel sorbent tube | Low flow sampling pump; max. 15 min @ 1.0 lpm | http://www.caslab.com/Forms-Downloads/Flyers/CARBOXYLIC_SAMPLING_FLYER.pdf |
| | Ambient on landfill and off landfill | Columbia Analytical AQL Method 102 | Treated silica gel sorbent tube | Low flow sampling pump; 240 min @ 0.40 lpm | |
| Amines | Source and under FML | Columbia Analytical AQL Method 101 | Specially treated sorbent tube | Low flow sampling pump; max. 15 min @ 1.0 lpm | http://www.caslab.com/Forms-Downloads/Flyers/AMINES_METHOD_101_FLYER.pdf |
| | Ambient on landfill and off landfill | Columbia Analytical AQL Method 101 | Specially treated sorbent tube | Low flow sampling pump; 240 min @ 0.40 lpm | |
| Ammonia | Source and under FML | OSHA[7] ID-188 | Carbon beads | Low flow sampling pump; max. 15 min @ 0.50 lpm | http://www.osha.gov/dts/sltc/methods/inorganic/id188/id188.html |
| | Ambient on landfill and off landfill | OSHA ID-188 | Carbon beads | Low flow sampling pump; 240 min @ 0.50 lpm | |
| Aldehydes | Source and under FML | EPA TO-11A | 2,4-DNPH[8] coated sorbent tube | Low flow sampling pump; max. 30 min @ 1.2 lpm | http://www.epa.gov/ttnamti1/files/ambient/airtox/to-11ar.pdf |
| | Ambient on landfill and off landfill | EPA TO-11A | 2,4-DNPH coated sorbent tube | Low flow sampling pump; 240 min @ 1.2 lpm | |
| Dioxins and furans | Source and under FML | EPA TO-9 | High volume sample, PUF[9] sorbent | High volume pump; 24 hours @ >200 LPM | http://www.epa.gov/ttnamti1/files/ambient/airtox/to-9arr.pdf |
| | Ambient on landfill and off landfill | EPA TO-9 | High volume sample, PUF sorbent | High volume pump; 24 hours @ >200 LPM | |
| Polynuclear aromatic hydrocarbons | Source and under FML | EPA TO-13A | High volume sample, PUF sorbent | High volume pump; 24 hours @ >200 LPM | http://www.epa.gov/ttnamti1/files/ambient/airtox/to-13arr.pdf |
| | Ambient on landfill and off landfill | EPA TO-13A | High volume sample, PUF sorbent | High volume pump; 24 hours @ >200 LPM | |

## *Table 1*

Sample collection protocols

Bridgeton Landfill

| *Analyte group* | *Sample location* | *Analytical method* | *Collection method* | *Sample duration and flow rate* | *Link to methodology* |
|---|---|---|---|---|---|
| Hydrogen cyanide | Source and under FML | NIOSH[10] 6010 | Soda lime sorbent tube | Low flow sampling pump; max. 15 min @ 0.05 lpm | http://www.cdc.gov/niosh/docs/2003-154/pdfs/6010.pdf |
| | Ambient on landfill and off landfill | NIOSH 6010 | Soda lime sorbent tube | Low flow sampling pump; 240 min @ 0.04 lpm | |
| Mercury compounds | Source and under FML | NIOSH 6009 | Anasorb sorbent tube | Low flow sampling pump; max. 30 min @ 0.20 lpm | http://www.cdc.gov/niosh/docs/2003-154/pdfs/6009.pdf |
| | Ambient on landfill and off landfill | NIOSH 6009 | Anasorb sorbent tube | Low flow sampling pump; 240 min @ 0.20 lpm | |
| Fixed gases (hydrogen, methane, carbon monoxide, carbon dioxide) | Source and under FML | EPA Method 3C | 1 liter Tedlar bag, partial fill | Low flow sampling pump; max. 10-15 min @ 0.050 lpm | http://www.epa.gov/ttn/emc/promgate/m-03c.pdf |
| | Ambient on landfill and off landfill | EPA Method 3C | 20 liter Tedlar bag, partial fill | Low flow sampling pump; 240 min @ 0.050 lpm | |

**Footnotes**

**1)** FML - flexible membrane liner covering specific areas of the surface of the landfill

**2)** Ambient - ambient air samples are collected in open air, as opposed to from sources such as under the FML

**3)** EPA - U.S. Environmental Protection Agency

**4)** ASTM - American Society for Testing Materials

**5)** Tedlar - trademarked flexible material used for sample collection bags; impervious to small molecular weight gases and vapors for known periods of time (holding times)

**6)** LPM - liters per minute

**7)** OSHA - U.S. Occupational Safety and Health Administration

**8)** 2,4-DNPH - 2,4-dinitrophenylhydrazine

**9)** PUF - polyurethane foam

**10)** NIOSH - U.S. National Institute of Occupational Safety and Health

## *Table 2*

Summary of analytical results for all compounds detected under the FML[1]
Bridgeton Landfill

| Compounds/analytes | Concentrations in µg/m$^{3}$[2] | | | | | |
|---|---|---|---|---|---|---|
| | *Amphitheater* | | *Second Tier* | | *East Face* | |
| | *Stantec* | *MDNR*[3] | *Stantec* | *MDNR* | *Stantec* | *MDNR* |
| ***Volatile Organic Compounds*** | | | | | | |
| Propene | 27,000 | 22,546 | 95,000 | 168,919 | 37,000 | 74,332 |
| Chloromethane | ND[4] | | ND | | 2,700 | |
| 1,3-Butadiene | 590 | | ND | | ND | |
| Chloroethane | ND | | 5600 | | ND | |
| Ethanol | 99,000 | | ND | | ND | |
| Acetone | 500,000 | 672,255 | ND | 91,455 | 72,000 | 124,712 |
| 2-Propanol | 60,000 | | ND | | ND | |
| 2-Butanone (MEK) | 340,000 | | ND | | 89,000 | |
| Ethyl acetate | 4,800 | | ND | | ND | |
| n-Hexane | 2,100 | | ND | | 2,900 | |
| Tetrahydrofuran | 170,000 | 180,816 | 39,000 | ND | 70,000 | 62,828 |
| Benzene | 120,000 | 130,663 | 620,000 | 837,007 | 390,000 | 450,450 |
| Cyclohexane | 1,100 | | ND | | ND | |
| 1,4-Dioxane | 4,100 | | ND | | ND | |
| n-Heptane | 3,200 | | 8,000 | | 3,300 | |
| 4-methyl-2-pentanone | 30,000 | 20,565 | ND | ND | 16,000 | 16,181 |
| Toluene | 43,000 | 44,845 | 100,000 | 128,129 | 48,000 | 73,109 |
| 2-Hexanone | 11,000 | | ND | | 3,100 | |
| n-Butyl acetate | 12,000 | | ND | | ND | |
| n-Octane | 9,500 | | 17,000 | | 13,000 | |
| Chlorobenzene | 3,000 | | ND | | ND | |
| Ethylbenzene | 27,000 | 38,700 | 32,000 | 42,942 | 22,000 | 29,699 |

## *Table 2*

Summary of analytical results for all compounds detected under the FML[1]

Bridgeton Landfill

| Compounds/analytes | Amphitheater | | Second Tier | | East Face | |
|---|---|---|---|---|---|---|
| | ***Concentrations in µg/m*** $^{3(2)}$ | | | | | |
| | *Stantec* | *MDNR* [3] | *Stantec* | *MDNR* | *Stantec* | *MDNR* |
| m,p-Xylenes | 57,000 | 39,511 | 37,000 | 31,566 | 40,000 | 34,475 |
| 0-Xylene | 20,000 | 13,460 | 12,000 | 18,106 | 16,000 | 24,836 |
| Styrene | 1,200 | | ND | | ND | |
| n-Nonane | 16,000 | | 17,000 | | 9,000 | |
| Cumene | 6,000 | | 5,200 | | 4,300 | |
| Alpha-Pinene | 12,000 | | 53,000 | | 16,000 | |
| n-Propylbenzene | 3,800 | | ND | | 2,200 | |
| 4-Ethyltoluene | 4,900 | | ND | | 2,900 | |
| 1,3,5-Trimethylbenzene | 6,700 | | ND | | 3,500 | |
| 1,2,4-Trimethylbenzene | 19,000 | 23,989 | ND | ND | 8,300 | 19,466 |
| 1,4-Dichlorobenzene | 10,000 | | ND | | 3,200 | |
| d-Limonene | 22,000 | | 22,000 | | 21,000 | |
| Naphthalene | 510 | | ND | | ND | |
| ***Tentatively Identified Compounds*** | | | | | | |
| Furan | 46,000 | | 120,000 | | 300,000 | |
| Dimethyl sulfide | 68,000 | | 83,000 | | 280,000 | |
| Methyl acetate | 44,000 | | ND | | ND | |
| 2-Methylfuran | 68,000 | | 380,000 | | 240,000 | |
| Methyl propionate | 45,000 | | ND | | ND | |
| 1-Butanol | 73,000 | | ND | | ND | |
| 2-Pentanone | 59,000 | | ND | | ND | |
| Methyl butyrate | 110,000 | | ND | | ND | |
| Dimethyl disulfide | 70,000 | | ND | | 42,000 | |

## *Table 2*

Summary of analytical results for all compounds detected under the FML[1]

Bridgeton Landfill

| Compounds/analytes | Amphitheater | | Second Tier | | East Face | |
|---|---|---|---|---|---|---|
| | ***Concentrations in µg/m³[2]*** | | | | | |
| | *Stantec* | *MDNR* [3] | *Stantec* | *MDNR* | *Stantec* | *MDNR* |
| 2-Methyl cyclopentanone | 51,000 | | ND | | ND | |
| Methyl hexanoate | 43,000 | | ND | | ND | |
| 2-Ethyl cyclopentanone | 41,000 | | ND | | ND | |
| n-Decane | 40,000 | | ND | | ND | |
| p-Isopropyltoluene | 120,000 | | ND | | 42,000 | |
| n-Undecane | 46,000 | | ND | | ND | |
| Dimethyl ether | ND | | 120,000 | | ND | |
| Isobutene | ND | | 140,000 | | 85,000 | |
| n-Butane | ND | | 41,000 | | 35,000 | |
| C4-H8 Alkene (5.51 RT) | ND | | 83,000 | | 33,000 | |
| C4-H8 Alkene (5.80 RT) | ND | | 90,000 | | 34,000 | |
| Isopentene | ND | | 42,000 | | ND | |
| Cyclopentene | ND | | 41,000 | | 33,000 | |
| C6-H10 Alkene (13.0 RT) | ND | | 110,000 | | 74,000 | |
| C10-H12 Alkene (14.58 RT) | ND | | 92,000 | | 71,000 | |
| C10-H12 Alkene (14.63 RT) | ND | | 110,000 | | 93,000 | |
| 3-Methyl-3-heptene | ND | | 27,000 | | 29,000 | |
| C8-H14 Alkene (16.96 RT) | ND | | 22,000 | | ND | |
| C8-H14 Alkene (16.89 RT) | ND | | ND | | 31,000 | |
| ***Aldehydes*** | | | | | | |
| Formaldehyde | ND | | ND | | ND | |
| Acetaldehyde | 1,200 | | ND | | 350 | |
| Propionaldehyde | 660 | | ND | | 140 | |

## *Table 2*

Summary of analytical results for all compounds detected under the FML[1]
Bridgeton Landfill

| Compounds/analytes | Amphitheater | | Second Tier | | East Face | |
|---|---|---|---|---|---|---|
| | ***Concentrations in μg/m³*** [2] | | | | | |
| | *Stantec* | *MDNR* [3] | *Stantec* | *MDNR* | *Stantec* | *MDNR* |
| Butyraldehyde | 3,000 | | ND | | 1,500 | |
| Benzaldehyde | 2,300 | | 140 | | 990 | |
| Isovaleraldehyde | ND | | 120 | | ND | |
| Valeraldehyde | ND | | 1,200 | | ND | |
| o-Tolualdehyde | ND | | 340 | | 92 | |
| 2,5-Dimethyl-benzaldehyde | 720 | | ND | | 960 | |
| ***Reduced Sulfur Compounds*** | | | | | | |
| Hydrogen sulfide | ND | | 27 | | ND | |
| Carbonyl sulfide | ND | | 150 | | 150 | |
| Methyl mercaptan | 490 | | 4,000 | | 260 | |
| Ethyl mercaptan | 460 | | 130 | | 17 | |
| Dimethyl sulfide | 240,000 | | 600,000 | | 570,000 | |
| Carbon disulfide | 190 | | 180 | | 2,300 | |
| Isopropyl mercaptan | 210 | | 170 | | ND | |
| t-Butyl mercaptan | 380 | | 29 | | ND | |
| Ethyl methyl sulfide | 12,000 | | 4,000 | | 5,100 | |
| Thiophene | 11,000 | | 5,000 | | 19,000 | |
| Isobutyl mercaptan | ND | | 420 | | ND | |
| n-Butyl mercaptan | 2,100 | | 710 | | 1,400 | |
| Dimethyl disulfide | 4,100 | | 20,000 | | 54,000 | |
| 3-Methylthiophene | 840 | | 330 | | 900 | |
| Tetrahydrothiophene | ND | | 210 | | 380 | |
| 2,5-Dimethylthiophene | ND | | ND | | 800 | |

## *Table 2*

Summary of analytical results for all compounds detected under the FML[1]
Bridgeton Landfill

| Compounds/analytes | Amphitheater | | Second Tier | | East Face | |
|---|---|---|---|---|---|---|
| | *Concentrations in µg/m³* [(2)] | | | | | |
| | *Stantec* | *MDNR* [(3)] | *Stantec* | *MDNR* | *Stantec* | *MDNR* |
| 2-Ethylthiophene | ND | | ND | | 840 | |
| ***Carboxylic Acids*** | | | | | | |
| Acetic Acid | 11,000 | | ND | | ND | |
| Propionic Acid | 13,000 | | ND | | 9,200 | |
| 2-Methylpropionic Acid | 12,000 | | ND | | 13,000 | |
| Butanoic Acid | 56,000 | | ND | | 41,000 | |
| 3-Methylbutanoic Acid | 11,000 | | ND | | 9,000 | |
| Pentanoic Acid | 23,000 | | ND | | 3,800 | |
| 3-Methylpentanoic Acid | 610 | | ND | | ND | |
| 4-Methylpentanoic Acid | 1,100 | | ND | | ND | |
| Hexanoic Acid | 53,000 | | ND | | 1,200 | |
| Heptanoic Acid | 2,900 | | ND | | ND | |
| 2-Ethylhexanoic Acid | 4,800 | | ND | | 1,800 | |
| Octanoic Acid | 690 | | ND | | ND | |
| ***PAHs*** | | | | | | |
| Naphthalene | 35 | | 7.9 | | 13 | |
| Acenaphthene | 4.5 | | 0.23 | | 0.22 | |
| Fluorene | 3.4 | | 0.2 | | 0.18 | |
| Phenanthrene | 0.21 | | 0.44 | | 0.19 | |
| Anthracene | 0.19 | | 0.022 | | 0.041 | |
| Fluoranthene | ND | | 0.019 | | 0.026 | |
| Pyrene | ND | | 0.021 | | 0.016 | |

## *Table 2*

Summary of analytical results for all compounds detected under the FML[1]
Bridgeton Landfill

| Compounds/analytes | Concentrations in µg/m³[(2)] Amphitheater | | Second Tier | | East Face | |
|---|---|---|---|---|---|---|
| | *Stantec* | *MDNR* [(3)] | *Stantec* | *MDNR* | *Stantec* | *MDNR* |
| ***TCDD TEQ*** | 1.52E-08 | | 1.03E-08 | | 3.00E-08 | |

**Footnotes**

**1)** FML - flexible membrane liner covering specific areas of the surface of the landfill

**2)** µg/m³ - micrograms per cubic meter

**3)** Missouri Department of Natural Resources

**4)** ND - not detected

**5)** Refer to Figure 1, Location of Samples, for location descriptions

## *Table 3*

Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF) detected under the FML[1]

Bridgeton Landfill

| *ID [2]* | *Sample #* | *Date collected* | *Location/description* | *2,3,7,8-TCDD (µg/m3)* | *1,2,3,7,8-PeCDD (µg/m3)* | *1,2,3,4,7,8-HxCDD (µg/m3)* | *1,2,3,6,7,8-HxCDD (µg/m3)* | *1,2,3,7,8,9-HxCDD (µg/m3)* | *1,2,3,4,6,7,8-HpCDD (µg/m3)* | *OCDD (µg/m3)* | *2,3,7,8-TCDF (µg/m3)* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A/U | 1425 | 8/17/2012 | Amphitheater, under FML | ND[3] | ND | ND | ND | 8.74E-09 | 8.14E-08 | 5.07E-07 | 2.34E-08 |
| B/U | 1422 | 8/17/2012 | Second Tier of LF, under FML | ND | ND | ND | ND | ND | 4.58E-08 | 1.61E-07 | ND |
| C/U | 1423 | 8/17/2012 | East Face of Landfill, under FML | 1.76E-08 | ND | ND | ND | 3.49E-08 | 6.11E-08 | ND | 1.53E-08 |

| *ID* | *Sample #* | *Date collected* | *Location/description* | *2,3,4,7,8-PeCDF (µg/m3)* | *1,2,3,4,7,8-HxCDF )µg/m3)* | *1,2,3,6,7,8-HxCDF (µg/m3)* | *1,2,3,7,8,9-HxCDF (µg/m3)* | *2,3,4,6,7,8-HxCDF (µg/m3)* | *1,2,3,4,6,7,8-HpCDF (µg/m3)* | *1,2,3,4,7,8,9-HpCDF (µg/m3)* | *OCDF* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A/U | 1425 | 8/17/2012 | Amphitheater, under FML | 1.41E-08 | 3.56E-08 | 1.53E-08 | ND | ND | 1.21E-07 | ND | 3.65E-07 |
| B/U | 1422 | 8/17/2012 | Second Tier of LF, under FML | 1.22E-08 | 3.41E-08 | 1.19E-08 | ND | ND | 9.90E-08 | ND | 4.23E-07 |
| C/U | 1423 | 8/17/2012 | East Face of Landfill, under FML | ND | 2.98E-08 | 1.57E-08 | ND | ND | 1.44E-07 | ND | 1.25E-06 |

| *ID* | *Sample #* | *Date collected* | *Location/description* | *Total Tetra-dioxins* | *Total Penta-dioxins* | *Total Hexa-dioxins* | *Total Hepta-dioxins* | *Total Tetra-furans* | *Total Penta-furans* | *Total Hexa-furans* | *Total Hepta-furans* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A/U | 1425 | 8/17/2012 | Amphitheater, under FML | ND | 8.57E-09 | 1.93E-08 | 8.14E-08 | ND | 3.76E-08 | 5.66E-08 | 1.21E-07 |
| B/U | 1422 | 8/17/2012 | Second Tier of LF, under FML | ND | ND | ND | 1.34E-07 | ND | 2.94E-08 | 6.16E-08 | 1.47E-07 |
| C/U | 1423 | 8/17/2012 | East Face of Landfill, under FML | ND | ND | 3.49E-08 | 1.22E-07 | 2.93E-08 | 3.18E-08 | 5.87E-08 | ND |

**Footnotes**

**1)** FML - flexible membrane liner covering specific areas of the surface of the landfill

**2)** ID is common location identifier. Each sample location is assigned a unique letter or combinaton of letters

**3)** ND - not detected

## *Table 3*

Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF) detected under the FML[1]

Bridgeton Landfill

| ***ID*** [2] | ***Sample #*** | ***Date collected*** | ***Location/description*** | ***1,2,3,7,8-PeCDF (µg/m3)*** |
|---|---|---|---|---|
| A/U | 1425 | 8/17/2012 | Amphitheater, under FML | 1.43E-08 |
| B/U | 1422 | 8/17/2012 | Second Tier of LF, under FML | 1.54E-08 |
| C/U | 1423 | 8/17/2012 | East Face of Landfill, under FML | 1.29E-08 |

| ***ID*** | ***Sample #*** | ***Date collected*** | ***Location/description*** |
|---|---|---|---|
| A/U | 1425 | 8/17/2012 | Amphitheater, under FML |
| B/U | 1422 | 8/17/2012 | Second Tier of LF, under FML |
| C/U | 1423 | 8/17/2012 | East Face of Landfill, under FML |

| ***ID*** | ***Sample #*** | ***Date collected*** | ***Location/description*** |
|---|---|---|---|
| A/U | 1425 | 8/17/2012 | Amphitheater, under FML |
| B/U | 1422 | 8/17/2012 | Second Tier of LF, under FML |
| C/U | 1423 | 8/17/2012 | East Face of Landfill, under FML |

**Footnotes**

**1)** FML - flexible membrane liner covering spe

**2)** ID is common location identifier. Each sam

**3)** ND - not detected

## *Table 4*

Summary of analytical results for all compounds detected in ambient air [1] samples from the downwind locations and on the landfill
Bridgeton Landfill

| | | | | | Concentrations in µg/m3 [6] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Compounds/analytes*** | ***RSL ind.*** [2] | ***RSL Res.*** [3] | ***OSHA PEL*** [4] | ***ACGIH TLV*** [5] | ***Pond Center*** | ***Pond East*** | ***Pond West*** | ***Summit*** | ***Amphi-theater*** | ***East Fenceline #1*** | ***East Fenceline #2*** | ***South Fenceline #1*** | ***South Fenceline #2*** | ***Summit valley*** |
| ***Volatile organic compounds*** | | | | | | | | | | | | | | |
| Propene | 13,000 | 3,100 | —— | 8.61E+05 | 1.6 | 1.8 | 2 | ND[7] | ND | 1.8 | 1.1 | 0.86 | 2.2 | 1.8 |
| Dichlorofluoromethane | 440 | 100 | 4.21E+06 | 4.21E+04 | 2.2 | 2.7 | 2.3 | 2.2 | 2.1 | 2.2 | 2.2 | 0.86 | 2.2 | 1.8 |
| Ethanol | 140,000 | 32,000 | 1.88E+06 | 1.88E+06 | ND | ND | ND | ND | 16 | ND | 12 | ND | ND | 8.5 |
| Acetonitrile | 260 | 63 | 6.72E+04 | 3.36E+04 | 0.82 | ND | ND | ND | 0.76 | 0.88 | 14 | ND | 1.9 | ND |
| Acetone | 140,000 | 32,000 | 2.38E+06 | 1.19E+06 | 17 | 18 | 13 | 13 | 14 | 11 | ND | 8.9 | 21 | ND |
| Trichlorofluoromethane | 3,100 | 730 | 5.62E+06 | 5.62E+06 | 1.2 | 1.4 | 1.3 | 1.3 | 1.1 | 1.1 | 1.1 | 1.1 | ND | 1.1 |
| Methylene chloride | 1,200 | 96 | 8.68E+04 | 1.74E+05 | ND | ND | ND | ND | ND | 0.94 | 0.79 | ND | 2.1 | 0.88 |
| 2-Butanone (MEK) | 22,000 | 5,200 | 5.90E+05 | 5.90E+05 | ND | ND | ND | ND | ND | ND | ND | ND | ND | 11 |
| Ethyl acetate | NA | NA | 1.44E+06 | 1.44E+06 | 17 | 5 | 8.7 | 8 | 3.1 | ND | ND | ND | ND | 1.6 |
| Tetrahydrofuran | 8,800 | 2,100 | 5.90E+05 | 1.47E+05 | 2.7 | 2.6 | 3 | ND | ND | 2.5 | 1.2 | ND | 2 | 4.7 |
| Benzene | 1.6 | 0.31 | 3.19E+03 | 1.60E+03 | 10 | 10 | 16 | ND | 1.1 | 11 | ND | 1.5 | 6.1 | 6.2 |
| Toluene | 22,000 | 5,200 | 7.54E+05 | 7.54E+04 | 3.7 | 3.3 | 3.4 | 1.7 | 1.6 | 2 | ND | 1.1 | 2.6 | 1.6 |
| n-Octane | NA | NA | 2.34E+06 | 1.40E+06 | ND | ND | 0.98 | ND | ND | ND | ND | ND | ND | ND |
| Tetrachloroethene | 47 | 9.4 | 6.78E+05 | 1.70E+05 | ND | ND | ND | ND | ND | ND | 2.1 | ND | ND | ND |
| Ethylbenzene | 4.9 | 0.97 | 4.34E+05 | 8.68E+04 | 0.72 | 0.83 | 0.91 | ND | ND | ND | ND | ND | ND | ND |
| m,p-Xylenes | 440 | 100 | 4.34E+05 | 4.34E+05 | 1.5 | 1.7 | 3.2 | ND | ND | ND | ND | ND | ND | ND |
| 0-Xylene | 440 | 100 | 4.34E+05 | 4.34E+05 | ND | ND | 1.1 | ND | ND | ND | ND | ND | ND | ND |
| n-Nonane | 880 | 210 | 1.05E+06 | 1.05E+06 | ND | ND | 0.87 | ND | ND | ND | ND | ND | ND | ND |
| Alpha-Pinene | NA | NA | 5.57E+05 | 1.11E+05 | ND | ND | ND | ND | ND | 1.1 | ND | ND | ND | ND |
| d-Limonene | NA | NA | 1.67E+05 (AIHA WEEL[8]) | | 0.99 | ND | ND | ND | ND | ND | ND | ND | ND | ND |

## *Table 4*

Summary of analytical results for all compounds detected in ambient air [1] samples from the downwind locations and on the landfill
Bridgeton Landfill

| Compounds/analytes | RSL ind. [2] | RSL Res. [3] | OSHA PEL [4] | ACGIH TLV [5] | Concentrations in µg/m³ [6] Pond Center | Pond East | Pond West | Summit | Amphi-theater | East Fenceline #1 | East Fenceline #2 | South Fenceline #1 | South Fenceline #2 | Summit valley |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Tentatively Identified Compounds*** | | | | | | | | | | | | | | |
| Furan | NA | NA | —— | —— | 3.4 | 4.7 | ND | ND | ND | 3.5 | ND | ND | ND | 13 |
| Dimethyl sulfide | NA | NA | —— | 2.54E+04 | 4.5 | 4.4 | 2.8 | ND | ND | 5.2 | ND | ND | ND | 12 |
| Methyl acetate | NA | NA | 6.06E+05 | 6.06E+05 | ND | ND | ND | ND | ND | ND | ND | ND | ND | 10 |
| 2-Methylfuran | NA | NA | —— | —— | 3.7 | 5.4 | ND | ND | ND | 3.9 | ND | ND | ND | 14 |
| Methyl propionate | NA | NA | —— | —— | ND | ND | ND | ND | ND | ND | ND | ND | ND | 5.5 |
| Methyl butyrate | NA | NA | —— | —— | ND | ND | ND | ND | ND | ND | ND | ND | ND | 12 |
| Isobutene | NA | NA | —— | —— | ND | 2.9 | ND | ND | ND | ND | ND | ND | ND | ND |
| C6-H10 Alkene (13.0 RT) | NA | NA | —— | —— | ND | ND | ND | ND | ND | ND | ND | ND | ND | 4.6 |
| Unidentified (9.41 RT) | NA | NA | —— | —— | 4.1 | 4 | 3.3 | ND | ND | 3.1 | ND | ND | ND | ND |
| Ethyl propionate | NA | NA | —— | —— | 14 | 7.1 | 11 | 9.9 | 4.1 | ND | ND | ND | ND | ND |
| Ethyl butyrate | NA | NA | —— | —— | 14 | 8.4 | 11` | 9.7 | 5.9 | 3.9 | ND | 4.9 | ND | 4.5 |
| Hexamethylcyclotrisiloxane | NA | NA | —— | —— | 12 | 3.5 | 3.4 | ND | ND | 15 | ND | ND | ND | ND |
| 2-Ethyl-1-hexanol | NA | NA | —— | —— | 3.2 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Acetic acid | NA | NA | 2.46E+04 | 3.68E+04 | ND | 4.7 | ND | ND | ND | ND | ND | ND | ND | ND |
| 2-Butoxyethanol | NA | NA | 2.42E+05 | 9.60E+04 | ND | ND | ND | 2.8 | ND | ND | ND | ND | ND | ND |
| Isopentane | NA | NA | —— | —— | ND | ND | ND | ND | 4.9 | ND | ND | ND | ND | ND |
| ***Aldehydes*** | | | | | | | | | | | | | | |
| Formaldehyde | 0.94 | 0.19 | 9.21E+02 | 3.68E+02 | 6.3 | 6.2 | 6.2 | 6.1 | ND | ND | ND | 1.5 | 1.7 | NS |
| Acetaldehyde | 5.6 | 1.1 | 3.31E+04 | 4.50E+04 | 1.7 | 1.5 | 1.6 | 1.5 | 19 | 10 | 8.3 | 1.1 | 1.5 | NS |
| Valeraldehyde | NA | NA | —— | 1.76E+05 | 0.47 | 0.62 | 0.46 | ND | ND | ND | ND | ND | 0.47 | NS |

## *Table 4*

Summary of analytical results for all compounds detected in ambient air [1] samples from the downwind locations and on the landfill
Bridgeton Landfill

***Concentrations in µg/m³ [6]***

| *Compounds/analytes* | *RSL ind.* [2] | *RSL Res.* [3] | *OSHA PEL* [4] | *ACGIH TLV* [5] | *Pond Center* | *Pond East* | *Pond West* | *Summit* | *Amphi-theater* | *East Fenceline #1* | *East Fenceline #2* | *South Fenceline #1* | *South Fenceline #2* | *Summit valley* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,5-Dimethylbenzaldehyde | NA | NA | —— | —— | 0.94 | 0.91 | 0.86 | 0.9 | ND | ND | ND | ND | 0.94 | NS |
| ***Reduced sulfur compounds*** | | | | | | | | | | | | | | |
| Dimethyl sulfide | NA | NA | —— | 1.93E+03 | NS | NS | NS | NS | NS | 19 | NS | NS | 33 | NS |
| ***PAHs*** | | | | | | | | | | | | | | |
| Naphthalene | 0.36 | 0.072 | 5.24E+04 | 5.24E+04 | NS | NS | NS | 0.089 | NS | 0.029 | NS | NS | NS | NS |
| Acenaphthene | NA | NA | —— | —— | NS | NS | NS | 0.0076 | NS | 0.004 | NS | NS | NS | NS |
| Fluorene | NA | NA | —— | —— | NS | NS | NS | 0.0089 | NS | 0.0038 | NS | NS | NS | NS |
| Phenanthrene | NA | NA | 2.00E+02 | 2.00E+02 | NS | NS | NS | 0.023 | NS | 0.011 | NS | NS | NS | NS |
| Fluoranthene | NA | NA | 2.00E+02 | 2.00E+02 | NS | NS | NS | 0.004 | NS | 0.0021 | NS | NS | NS | NS |
| Pyrene | NA | NA | 2.00E+02 | 2.00E+02 | NS | NS | NS | 0.002 | NS | ND | NS | NS | NS | NS |
| ***TCDD TEQ*** [9] | 3.20E-07 | 6.40E-08 | 2.0E-04 (Leung HW[10]) | | -- | -- | -- | 1.49E-08 | -- | 7.88E-09 | -- | -- | -- | -- |

**Footnotes**

**1)** Ambient air samples are collected in open air, as opposed to from sources such as under the FML

**2)** RSL Ind. U.S. Regional Risk-based Screening Level for industrial/commercial reference

**3)** RSL Res. U.S. Regional Risk-based Screening Level for residential reference

**4)** U.S. Occupational Safety and Health Administration Permissible Exposure Limit

**5)** American Conference of Governmenta Industrial Hygienists Threshold Limit Value

**6)** µg/m³ - micrograms per cubic meter

**7)** ND - not detected

**8)** American Industrial Hygiene Association Workplace Environmental Exposure Level

## *Table 4*

Summary of analytical results for all compounds detected in ambient air [(1)] samples from the downwind locations and on the landfill
Bridgeton Landfill

| | | | | | ***Concentrations in µg/m$^{3}$ (6)*** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Compounds/analytes*** | ***RSL ind.*** [(2)] | ***RSL Res.*** [(3)] | ***OSHA PEL*** [(4)] | ***ACGIH TLV*** [(5)] | ***Pond Center*** | ***Pond East*** | ***Pond West*** | ***Summit*** | ***Amphi-theater*** | ***East Fenceline #1*** | ***East Fenceline #2*** | ***South Fenceline #1*** | ***South Fenceline #2*** | ***Summit valley*** |

**9)** U.S. EPA recommended 2,3,7,8-TCDD Toxicity Equivalent Concentration (TEQ) using the Toxicity Equivalence Factors (TEFs) (U.S. EPA, December 2010), see also Table 5

**10)** Lueng HW et al, Am Ind Hyg Assoc J, 1988

## *Table 5*

Individual polychlorinated dibenzo-p-dioxin and dibenzofuran (PCDD/PCDF) isomers and conversion to 2, 3, 7, 8-TCDD toxicity equivalents (TEQs); on landfill and downwind

Bridgeton Landfill

| *Analyte* | *TEF [3]* | *Concentrations in ambient air [1] on Landfill, in µg/m³ [2]* | | | |
|---|---|---|---|---|---|
| | | *Summit* | | *East Fenceline #1* | |
| | | *Measured* | *TEQ [4]* | *Measured* | *TEQ* |
| 2378-TCDD | 1 | 3.58E-09 | 3.58E-09 | ND | NA |
| 12378-PeCDD | 1 | 5.2E-09 | 5.2E-09 | 3.62E-09 | 3.62E-09 |
| 123478-HxCDD | 0.1 | ND | NA | 2.66E-09 | 2.66E-10 |
| 123678-HxCDD | 0.1 | 3.98E-09 | 3.98E-10 | 6.07E-09 | 6.07E-10 |
| 123789-HxCDD | 0.1 | 6.35E-09 | 6.35E-10 | 8.4E-09 | 8.4E-10 |
| 1234678-HpCDD | 0.01 | 3.87E-08 | 3.87E-10 | 3.84E-08 | 3.84E-10 |
| OCDD | 0.0003 | 1.96E-07 | 5.88E-11 | 1.57E-07 | 4.71E-11 |
| 2378-TCDF | 0.1 | 1.80E-08 | 1.8E-09 | 6.64E-09 | 6.64E-10 |
| 12378-PeCDF | 0.03 | 4.19E-09 | 1.257E-10 | ND | NA |
| 23478-PeCDF | 0.3 | 4.14E-09 | 1.242E-09 | ND | NA |
| 123478-HxCDF | 0.1 | 6.60E-09 | 6.6E-10 | 8.64E-09 | 8.64E-10 |
| 123678-HxCDF | 0.1 | 4.89E-09 | 4.89E-10 | 2.88E-09 | 2.88E-10 |
| 123789-HxCDF | 0.1 | ND | NA | ND | NA |
| 234678-HxCDF | 0.1 | ND | NA | ND | NA |
| 1234678-HpCDF | 0.01 | 2.70E-08 | 2.7E-10 | 2.71E-08 | 2.71E-10 |
| 1234789-HpCDF | 0.01 | ND | NA | ND | NA |
| OCDF | 0.0003 | 1.09E-07 | 3.27E-11 | 8.70E-08 | 2.61E-11 |
| **Total TEQ** | | | **1.49E-08** | | **7.88E-09** |

US EPA, Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8-Tetrachlorodibenzo-p-dioxin and Dioxin-Like Compounds, EPA/100/R 10/005. December 2010

**Footnotes**

**1)** Ambient air samples are collected in open air, as opposed to from sources such as under the FML

**2)** µg/m³ - micrograms per cubic meter

**3)** TEF - Toxicity Equivalence Factor

**4)** TEQ - Toxicity Equivalent Concentration

*Table 6*

Summary of analytical results for all compounds detected in at least one upwind/background sample

Bridgeton Landfill

| Compounds/analytes | *RSL ind.* (2) | *RSL Res.* (3) | *OSHA PEL* (4) | *ACGIH TLV* (5) | Concentrations in µg/m³ (1) Grassy Knoll Center (1) | Grassy Knoll Center (2) | Grassy Knoll West (1) | Grassy Knoll West (2) | Grassy Knoll North (1) | Grassy Knoll North (2) |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Volatile organic compounds*** | | | | | | | | | | |
| Dichlorofluoromethane | 440 | 100 | 4.21E+06 | 4.21E+06 | 2.1 | 2.1 | 2.2 | 2.2 | 2.2 | 2.2 |
| Acetonitrile | 260 | 63 | 6.72E+04 | 3.36E+04 | ND(6) | 0.78 | ND | ND | ND | 0.88 |
| Acetone | 140,000 | 32,000 | 2.86E+06 | 1.19E+06 | 12 | ND | 13 | ND | 21 | ND |
| Trichlorofluoromethane | 3,100 | 730 | 5.62E+06 | 5.62E+06 | 1.1 | 1.1 | 1.2 | 1.1 | 1.1 | 1.1 |
| Ethyl acetate | NA | NA | 1.44E+06 | 1.44E+06 | 2.6 | ND | 3 | ND | 2.7 | ND |
| Toluene | 22,000 | 5,200 | 7.54E+-5 | 7.54E+04 | 1 | ND | 1.4 | ND | 1.1 | ND |
| Tetrachloroethene | 47 | 9.4 | 6.78E+05 | 1.70E+05 | 1.4 | ND | ND | 1.8 | ND | ND |
| ***Tentatively Identified Compounds*** | | | | | | | | | | |
| Unidentified (9.41 RT) | NA | NA | —— | —— | 3.3 | ND | ND | ND | 4.6 | ND |
| Ethyl propionate | NA | NA | —— | —— | 5 | ND | 4.7 | ND | 5.2 | ND |
| Ethyl butyrate | NA | NA | —— | —— | 7.6 | 5.4 | 6.5 | ND | 7.9 | ND |
| Hexamethylcyclotrisiloxane | NA | NA | —— | —— | 3.3 | ND | ND | ND | 12 | ND |
| Acetic acid | NA | NA | 2.46E+-4 | 3.68E+04 | ND | ND | 3.7 | ND | ND | ND |
| ***Aldehydes*** | | | | | | | | | | |
| Benzaldehyde | NA | NA | 8.69E+03 | | ND | ND | ND | ND | 3.4 | ND |
| Formaldehyde | 0.94 | 0.19 | 9.21E+02 | 3.68E+02 | ND | 2.9 | ND | 3.1 | ND | 3.2 |
| Acetaldehyde | 5.6 | 1.1 | 3.31E+04 | 4.50E+04 | 17 | 1.3 | 19 | 1.2 | 18 | 1.2 |
| 2,5-Dimethylbenzaldehyde | NA | NA | —— | 1.76E+05 | ND | 0.41 | ND | 0.51 | ND | 0.81 |
| ***TCDD TEQ*** | 3.20E-07 | 6.40E-08 | 2.0E-04 (Leung HW(7)) | | 1.94E-08 | -- | -- | -- | -- | -- |

**Footnotes**

**1)** µg/m³ - micrograms per cubic meter

**2)** RSL Ind. U.S. Regional Risk-based Screening Level for industrial/commercial reference

**3)** RSL Res. U.S. Regional Risk-based Screening Level for residential reference

**4)** U.S. Occupational Safety and Health Administration Permissible Exposure Limit

**5)** American Conference of Governmenta Industrial Hygienists Threshold Limit Value

**6)** ND - not detected

**7)** U.S. EPA recommended 2,3,7,8-TCDD Toxicity Equivalent Concentration (TEQ) using the Toxicity Equivalence Factors (TEFs) (U.S. EPA, December 2010), see also Table 5

**8)** Lueng HW et al, Am Ind Hyg Assoc J, 1988

## *Table 7*

Individual polychlorinated dibenzo-p-dioxin and dibenzofuran (PCDD/PCDF) isomers and conversion to 2, 3, 7, 8-TCDD toxicity equivalents (TEQs); in upwind samples
Bridgeton Landfill

| *Analyte* | *TEF* | *Concentrations in ambient air [(1)] on Landfill, in µg/m [3 (2)]* <br> *Grassy Knoll Center* <br> *Measured* | <br><br> *TEQ* |
|---|---|---|---|
| 2378-TCDD | 1 | ND | NA |
| 12378-PeCDD | 1 | 7.51E-09 | 7.51E-09 |
| 123478-HxCDD | 0.1 | 4.85E-09 | 4.85E-10 |
| 123678-HxCDD | 0.1 | 4.33E-09 | 4.33E-10 |
| 123789-HxCDD | 0.1 | 1.08E-08 | 1.08E-09 |
| 1234678-HpCDD | 0.01 | 4.11E-08 | 4.11E-10 |
| OCDD | 0.0003 | 1.39E-07 | 4.17E-11 |
| 2378-TCDF | 0.1 | 2.65E-08 | 2.65E-09 |
| 12378-PeCDF | 0.03 | 8.53E-09 | 2.559E-10 |
| 23478-PeCDF | 0.3 | 9.90E-09 | 2.97E-09 |
| 123478-HxCDF | 0.1 | 1.64E-08 | 1.64E-09 |
| 123678-HxCDF | 0.1 | 9.18E-09 | 9.18E-10 |
| 123789-HxCDF | 0.1 | ND | NA |
| 234678-HxCDF | 0.1 | 6.52E-09 | 6.52E-10 |
| 1234678-HpCDF | 0.01 | 3.02E-08 | 3.02E-10 |
| 1234789-HpCDF | 0.01 | ND | NA |
| OCDF | 0.0003 | 1.16E-07 | 3.48E-11 |
| **Total TEQ** | | | **1.94E-08** |

**Footnotes**

**1)** Ambient air samples are collected in open air, as opposed to from sources such as under the FML

**2)** µg/$m^3$ - micrograms per cubic meter

**3)** TEF - Toxicity Equivalence Factor

***Table 7***

Individual polychlorinated dibenzo-p-dioxin and dibenzofuran (PCDD/PCDF) isomers and conversion to 2, 3, 7, 8-TCDD toxicity equivalents (TEQs); in upwind samples
Bridgeton Landfill

**4)** TEQ - Toxicity Equivalent Concentration

## *Table 8*

Summary of compounds detected under the FML with associated odor thresholds, and concentrations detected in downwind and landfill ambient air samples

Bridgeton Landfill

| | | ***Contentration, in µg/m³ (8)*** | | |
|---|---|---|---|---|
| ***Compounds/analytes*** | ***Odor Threshold*** | ***Laboratory MRL (7) (range)*** | ***Concentration detected in landfill and downwind ambient air samples (range) 6*** | ***Characterization of Odor*** |
| ***Volatile Organic Compounds*** | | | | |
| Propene | 39,584(3) | 0.69 - 1.4 | 1.1 - 2.2 | Grassy, aromatic |
| Chloromethane | NP(4) | 0.69 - 1.4 | ND(5) | Ether |
| 1,3-Butadiene | 220(1) | 0.69 - 1.4 | ND | Aromatic, rubber |
| Chloroethane | NP | 0.69 - 1.4 | ND | |
| Ethanol | 342(2) | 0.69 - 1.4 | 8.5 - 16 | Sweet alcohol |
| Acetone | 47,500(2) | 0.69 - 1.4 | 8.9 - 21 | Sweet minty, chemical |
| 2-Propanol | 105,697(3) | 0.69 - 1.4 | ND | Rubbing alcohol |
| 2-Butanone (MEK) | 750(1) | 0.69 - 1.4 | 11 | Sweet |
| Ethyl acetate | 1.0(1) | 1.4 - 2.8 | 1.6 - 17 | Fruity, pleasant |
| n-Hexane | NP(3) | 0.69 - 1.4 | ND | Gasoline |
| Tetrahydrofuran | 7,375(2) | 0.69 - 1.4 | 1.2 - 4.7 | Ether-like |
| Benzene | 4,500(2) | 0.69 - 1.4 | 1.1 - 16 | Sweet solvent |
| Cyclohexane | 1,435(2) | 1.4 - 2.8 | ND | Sweet aromatic |
| 1,4-Dioxane | 10.8(2) | 0.69 - 1.4 | ND | Ether-like |
| n-Heptane | 200,000(2) | 0.69 - 1.4 | ND | Gasoline |
| 4-methyl-2-pentanone | 410(2) | 0.69 - 1.4 | ND | Sweet, sharp |
| Toluene | 1,000(1) | 0.69 - 1.4 | 1.1 - 3.7 | Rubbery mothballs |
| 2-Hexanone | NP | 0.69 - 1.4 | ND | Sweet, paint |
| n-Butyl acetate | 2,993(3) | 0.69 - 1.4 | ND | Sweet banana |
| n-Octane | 725,000(2) | 0.69 - 1.4 | 0.98 | Gasoline |
| Chlorobenzene | 980(2) | 0.69 - 1.4 | ND | Almond-like, shoe polish |
| Ethylbenzene | 400(1) | 0.69 - 1.4 | 0.72 - 091 | Oily solvent |
| m,p-Xylenes | 1,000(1) | 0.69 - 1.4 | 1.5 - 3.2 | |
| O-Xylene | 1,000(1) | 0.69 - 1.4 | 1.1 | |
| Styrene | 430(2) | 0.69 - 1.4 | ND | Solvent, rubbery |
| n-Nonane | 3,412,500(2) | 0.69 - 1.4 | 0.87 | |
| Cumene | 39.2(2) | 0.69 - 1.4 | ND | Sharp |
| Alpha-Pinene | NP | 0.69 - 1.4 | 1.1 | |
| n-Propylbenzene | NP | 0.69 - 1.4 | ND | |
| 4-Ethyltoluene | NP | 0.69 - 1.4 | ND | |
| 1,3,5-Trimethylbenzene | 10,815(3) | 0.69 - 1.4 | ND | |
| 1,2,4-Trimethylbenzene | 11,798(3) | 0.69 - 1.4 | ND | |
| 1,4-Dichlorobenzene | 722(3) | 0.69 - 1.4 | ND | Mothballs |
| d-Limonene | NP | 0.69 - 1.4 | 0.99 | Citrus |

## *Table 8*

Summary of compounds detected under the FML with associated odor thresholds, and concentrations detected in downwind and landfill ambient air samples
Bridgeton Landfill

| | ***Contentration, in µg/m*** $^{3\,(8)}$ | | | |
|---|---|---|---|---|
| ***Compounds/analytes*** | ***Odor Threshold*** | ***Laboratory MRL*** [(7)] ***(range)*** | ***Concentration detected in landfill and downwind ambient air samples (range)*** [6] | ***Characterization of Odor*** |
| Naphthalene | 50[(1)] | 0.69 - 1.4 | ND | Mothballs |
| ***Tentatively Identified Compounds*** | | | | |
| Furan | NP | NA | 3.4 - 13 | |
| Dimethyl sulfide | 2.5[(2)] | NA | 2.8 - 12 | Decayed cabbage |
| Methyl acetate | 412[(2)] | NA | 10 | Sweet ester |
| 2-Methylfuran | 90,450[(2)] | NA | 3.7 - 14 | |
| Methyl propionate | NP | NA | 5.5 | |
| 1-Butanol | 2,638[(3)] | NA | ND | Sweet alcohol |
| 2-Pentanone | 27,125[(3)] | NA | ND | |
| Methyl butyrate | 52.8[(2)] | NA | 12 | Body odor |
| Dimethyl disulfide | 0.1[(2)] | 5.2 - 7.5 | ND | |
| 2-Methyl cyclopentanone | NP | NA | ND | |
| Methyl hexanoate | NP | NA | ND | |
| 2-Ethyl cyclopentanone | NP | NA | ND | |
| n-Decane | NP | NA | ND | |
| p-Isopropyltoluene | NP | NA | ND | |
| n-Undecane | NP | NA | ND | |
| Dimethyl ether | NP | NA | ND | |
| Isobutene | NP | NA | 2.9 | |
| n-Butane | NP | NA | ND | |
| C4-H8 Alkene (5.51 RT) | NP | NA | ND | |
| C4-H8 Alkene (5.80 RT) | NP | NA | ND | |
| Isopentene | NP | NA | ND | |
| Cyclopentene | NP | NA | ND | |
| C6-H10 Alkene (13.0 RT) | NP | NA | 4.6 | |
| C10-H12 Alkene (14.58 RT) | NP | NA | ND | |
| C10-H12 Alkene (14.63 RT) | NP | NA | ND | |
| 3-Methyl-3-heptene | NP | NA | ND | |
| C8-H14 Alkene (16.96 RT) | NP | NA | ND | |
| C8-H14 Alkene (16.89 RT) | NP | NA | ND | |
| **Aldehydes** | | | | |
| Acetaldehyde | 0.2[(2)] | 0.32 - 0.70 | 1.1 - 19 | |
| Propionaldehyde | 10[(1)] | 0.32 - 0.70 | ND | |

## *Table 8*

Summary of compounds detected under the FML with associated odor thresholds, and concentrations detected in downwind and landfill ambient air samples

Bridgeton Landfill

| | ***Contentration, in µg/m*** $^{3\,(8)}$ | | | |
|---|---|---|---|---|
| ***Compounds/analytes*** | ***Odor Threshold*** | ***Laboratory MRL*** [(7)] ***(range)*** | ***Concentration detected in landfill and downwind ambient air samples (range)*** [6] | ***Characterization of Odor*** |
| Butyraldehyde | 13.6[(2)] | 0.32 - 0.70 | ND | |
| Benzaldehyde | 8[(2)] | 0.32 - 0.70 | ND | |
| Isovaleraldehyde | NP | 0.32 - 0.70 | ND | |
| Valeraldehyde | NP | 0.32 - 0.70 | 0.47 - 0.62 | Decayed, rancid |
| o-Tolualdehyde | NP | 0.65 - 1.4 | ND | |
| 2,5-Dimethylbenzaldehyde | NP | 0.32 - 0.70 | 0.86 - 0.94 | |
| **Reduced Sulfur Compounds** | | | | |
| Hydrogen sulfide | 0.7[(2)] | 7 | ND | Rotten eggs |
| Carbonyl sulfide | 24.3[(2)] | 12 | ND | |
| Methyl mercaptan | 0.04[(2)] | 9.8 | ND | Sulfide-like |
| Ethyl mercaptan | 0.0032[(2)] | 13 | ND | Garlic |
| Dimethyl sulfide | 2.5[(2)] | 13 | 19 - 33 | Decayed cabbage |
| Carbon disulfide | 24.3[(2)] | 7.8 | ND | Disagreeable |
| Isopropyl mercaptan | 0.2[(2)] | 16 | ND | |
| t-Butyl mercaptan | 1.6[(2)] | 18 | ND | |
| Ethyl methyl sulfide | 48.7[(2)] | 16 | ND | |
| Thiophene | 2.6[(2)] | 17 | ND | Aromatic |
| Isobutyl mercaptan | 2.0[(2)] | 18 | ND | |
| n-Butyl mercaptan | 1.6[(2)] | 18 | ND | |
| Dimethyl disulfide | 0.1[(2)] | 9.6 | ND | |
| 3-Methylthiophene | NP | 20 | ND | |
| Tetrahydrothiophene | NP | 18 | ND | |
| 2,5-Dimethylthiophene | NP | 23 | ND | |
| 2-Ethylthiophene | NP | 23 | ND | |
| **Carboxylic Acid Compounds** | | | | |
| Acetic Acid | 2,500[(2)] | 20 | ND | Sour, vinegar |
| Propionic Acid | 200[(3)] | 2.4 | ND | Sour |
| 2-Methylpropionic Acid | NP | 2.5 | ND | |
| Butanoic Acid | 1.0[(2)] | 2.4 | ND | Sour, perspiration |
| 3-Methylbutanoic Acid | 52.8[(2)] | 2.4 | ND | Body odor |
| Pentanoic (Valeric) Acid | 2.6[(2)] | 2.5 | ND | |
| 3-Methylpentanoic Acid | NP | 2.5 | ND | |
| 4-Methylpentanoic Acid | NP | 2.5 | ND | |
| Hexanoic (Caproic) Acid | NP | 2.5 | ND | |

## *Table 8*

Summary of compounds detected under the FML with associated odor thresholds, and concentrations detected in downwind and landfill ambient air samples

Bridgeton Landfill

| | | ***Contentration, in µg/m $^{3}$ (8)*** | | |
|---|---|---|---|---|
| ***Compounds/analytes*** | ***Odor Threshold*** | ***Laboratory MRL (7) (range)*** | ***Concentration detected in landfill and downwind ambient air samples (range) 6*** | ***Characterization of Odor*** |
| Heptanoic Acid | NP | 2.4 | ND | |
| 2-Ethylhexanoic Acid | NP | 2.5 | ND | |
| Octanoic (Caprylic) Acid | NP | 2.4 | ND | |
| **PAHs** | | | | |
| Naphthalene | 50(1) | 0.011 - 0.015 | 0.029 - 0.089 | Mothballs |
| Acenaphthene | 505(2) | 0.011 - 0.015 | 0.004 - 0.0076 | |
| Fluorene | 6,000(2) | 0.011 - 0.015 | 0.0038- 0.0089 | |
| Phenanthrene | NP | 0.011 - 0.015 | 0.011 - 0.023 | |
| Anthracene | NP | 0.011 - 0.015 | ND | |
| Fluoranthene | NP | 0.011 - 0.015 | 0.0021 - 0.004 | |
| Pyrene | NP | 0.011 - 0.015 | 0.002 | |
| **TCDD TEQ(10)** | NP | NA(9) | 7.88E-09 - 1.49E-08 | |

**Footnotes**

**1)** US EPA, Reference Guide to Odor Thresholds for Hazardous Air Pollutants Listed in the Clean Air Act Amendments of 1990, EPA/600/R-92/047, March 1992

**2)** Ruth, J.H., Odor Thresholds and Irritation Levels of Several Chemical Substances: A Review, Am. Ind. Hyg. Assoc. J. 47:A-142 through A-151, March 1986

**3)** American Industrial Hygiene Association, Odor Thresholds for Chemicals with Established Occupational Health Standards, 1997 edition

**4)** NP - not published

**5)** ND - not detected

**6)** Does not include samples where the comound was undetected (ND)

**7)** MRL - Minimum Reporting Limit

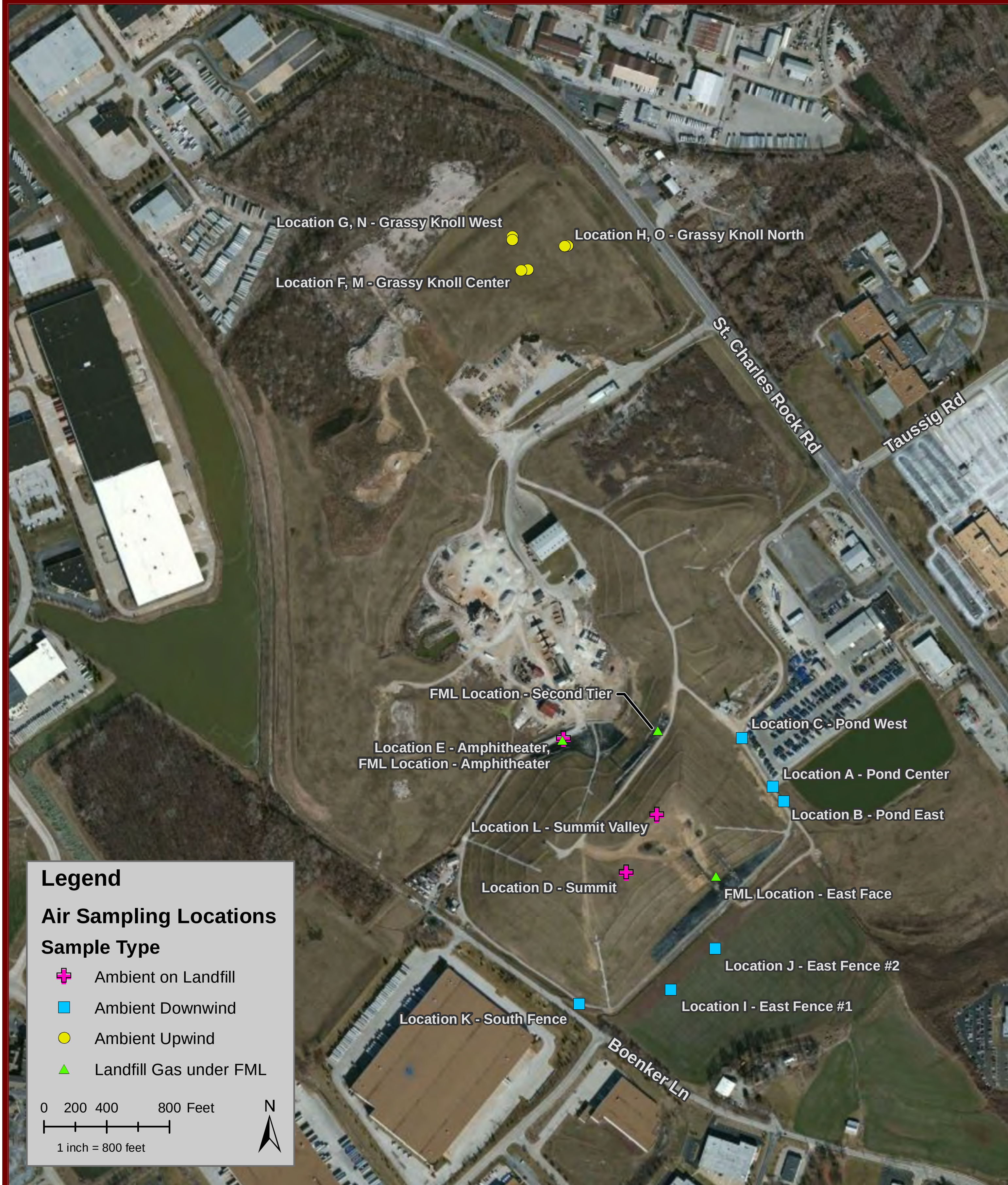
**8)** µg/m$^3$ - micrograms per cubic meter

**9)** NA - not available

**10)** U.S. EPA recommended 2,3,7,8-TCDD Toxicity Equivalent Concentration (TEQ) using the Toxicity Equivalence Factors (TEFs) (U.S. EPA, December 2010), see also Table 5

**11)** Odor descriptions for the individual compounds as given in the source reference

# Figures




Stantec

**Bridgeton Landfill, LLC**
**13570 St. Charles Rock Road, Bridgeton, MO 63044**

**Air and Landfill Gas Sampling Locations, August 2012 — J/N 182608005**

# Photographs

# Bridgeton Landfill Air and Landfill Gas Sampling
# August 2012

# PHOTOGRAPHS

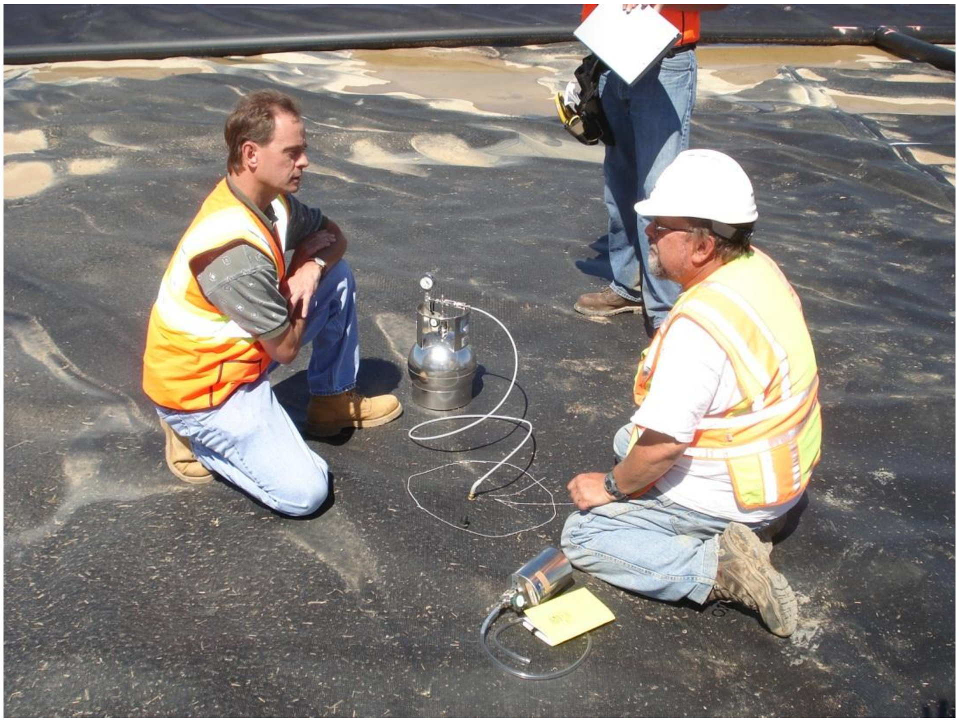


**Figure 1**
Stantec and MDNR personnel collecting VOC samples from one of the sampling ports beneath the FML.

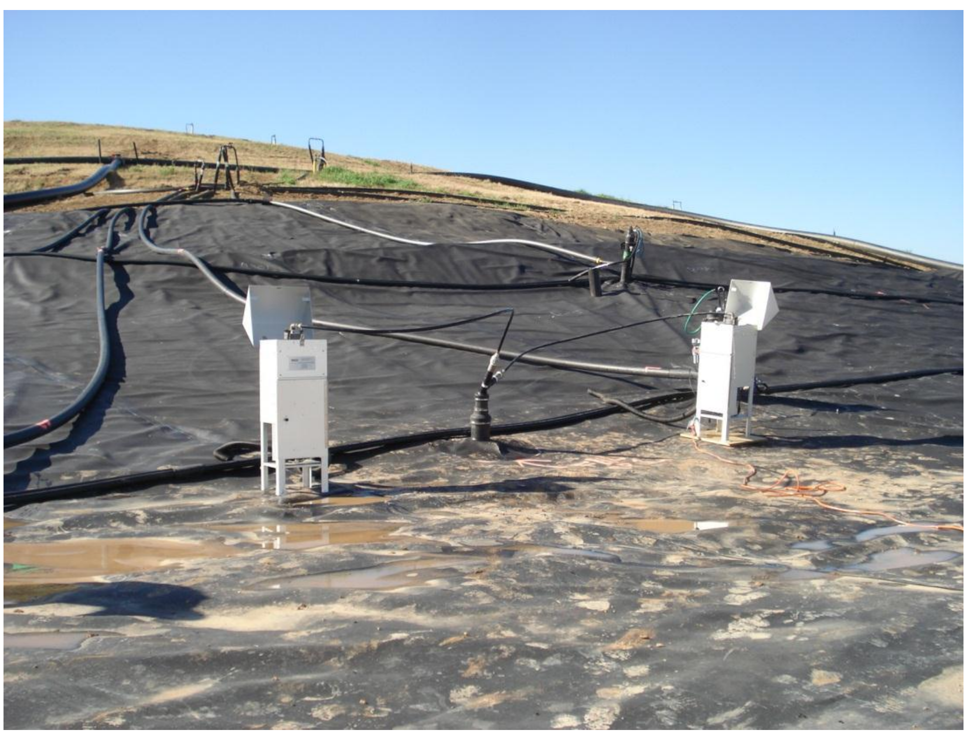


Figure 2
High volume sampling of source gas from under the FML on the amphitheater, second tier, and east face

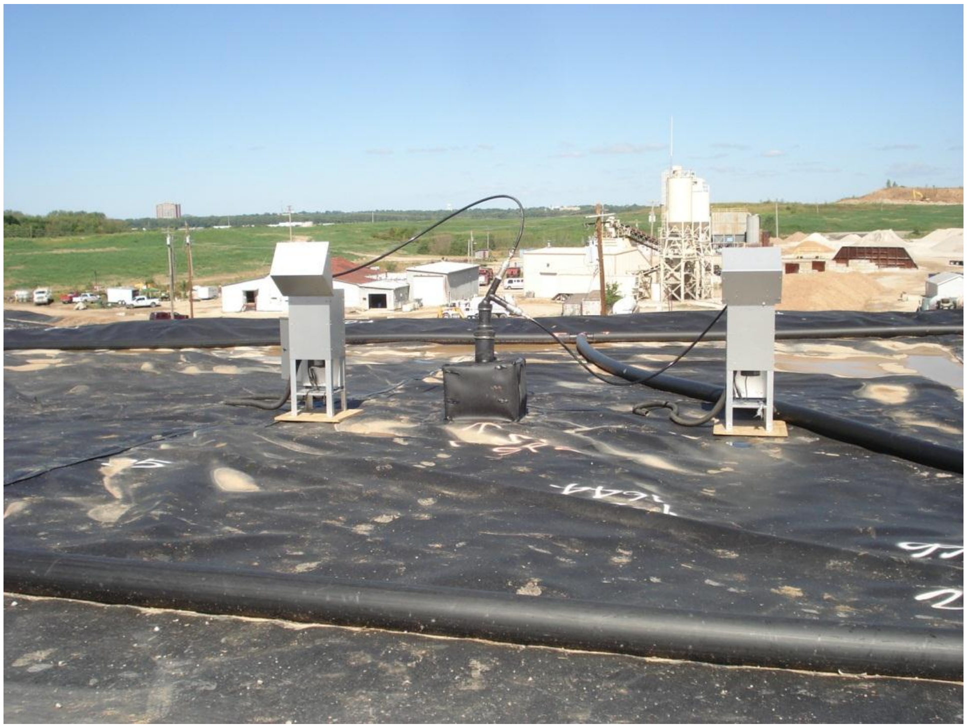


**Figure 3**
High volume sampling of source gas from under the FML on the second tier

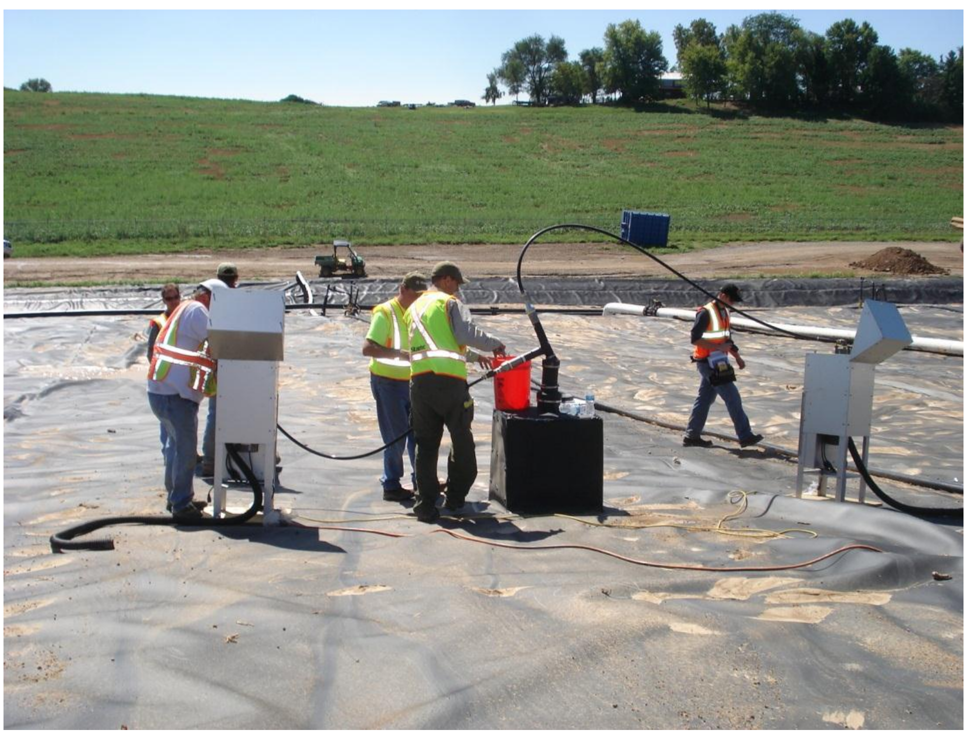


**Figure 4**
High volume sampling of source gas from under the FML on the east face

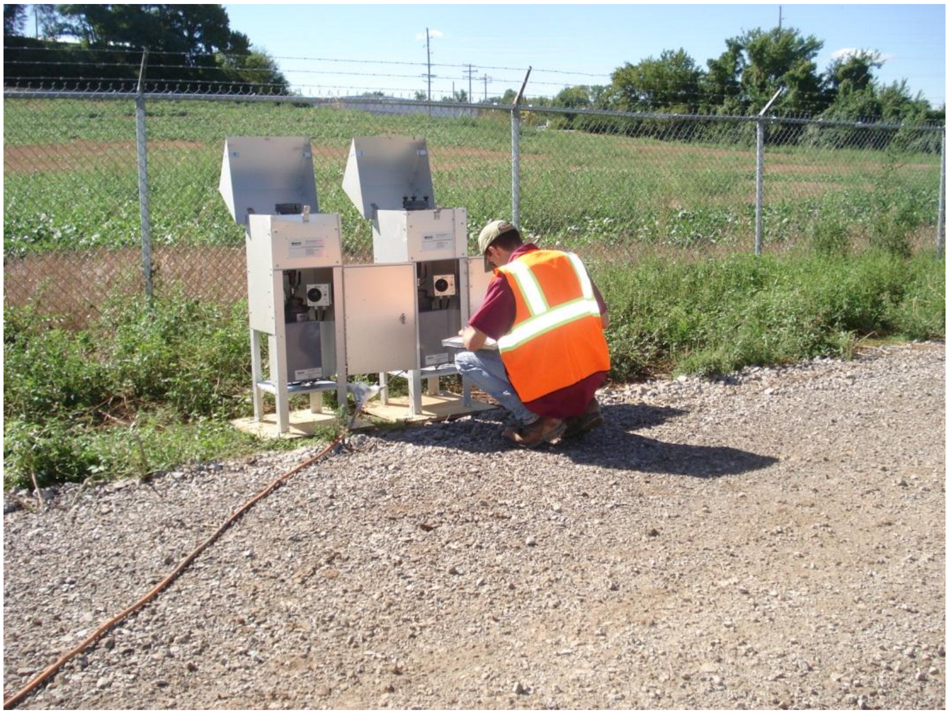


**Figure 5**
Apparatus used to collect ambient air or source gas for PAH and Dioxin/Dibenzofuran analysis

**Figure 6**
Apparatus used to collect ambient air or source gas for PAH and Dioxin/Dibenzofuran analysis

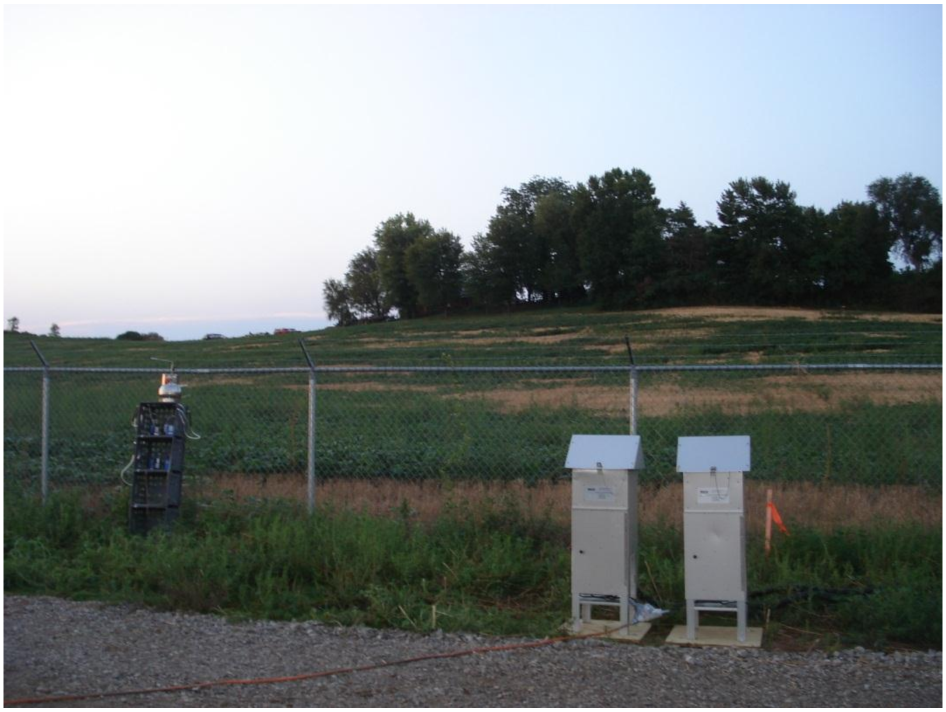


**Figure 7**
Apparatus used to collect ambient air or source gas for PAH and Dioxin/Dibenzofuran analysis

**Figure 8**
Ambient air sample collection structures and pump assemblies

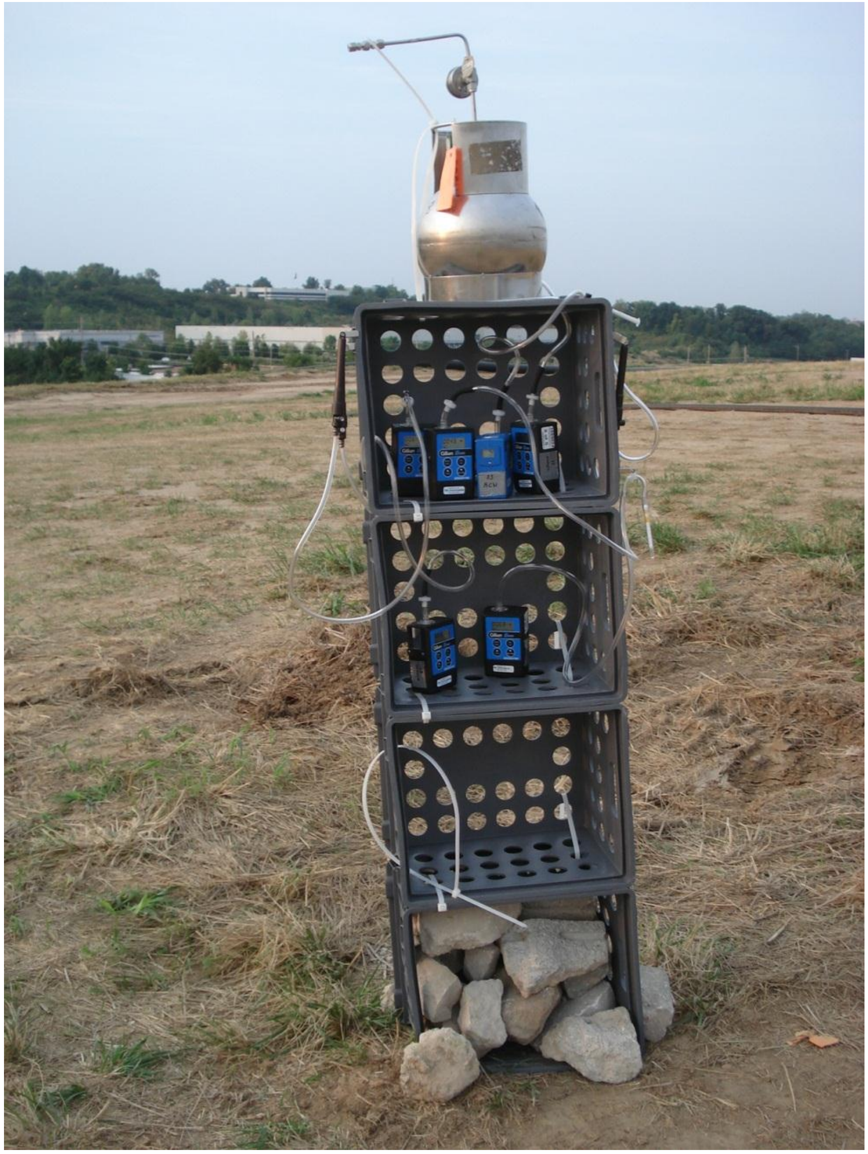


**Figure 9**
Ambient air sample collection structures and pump assemblies

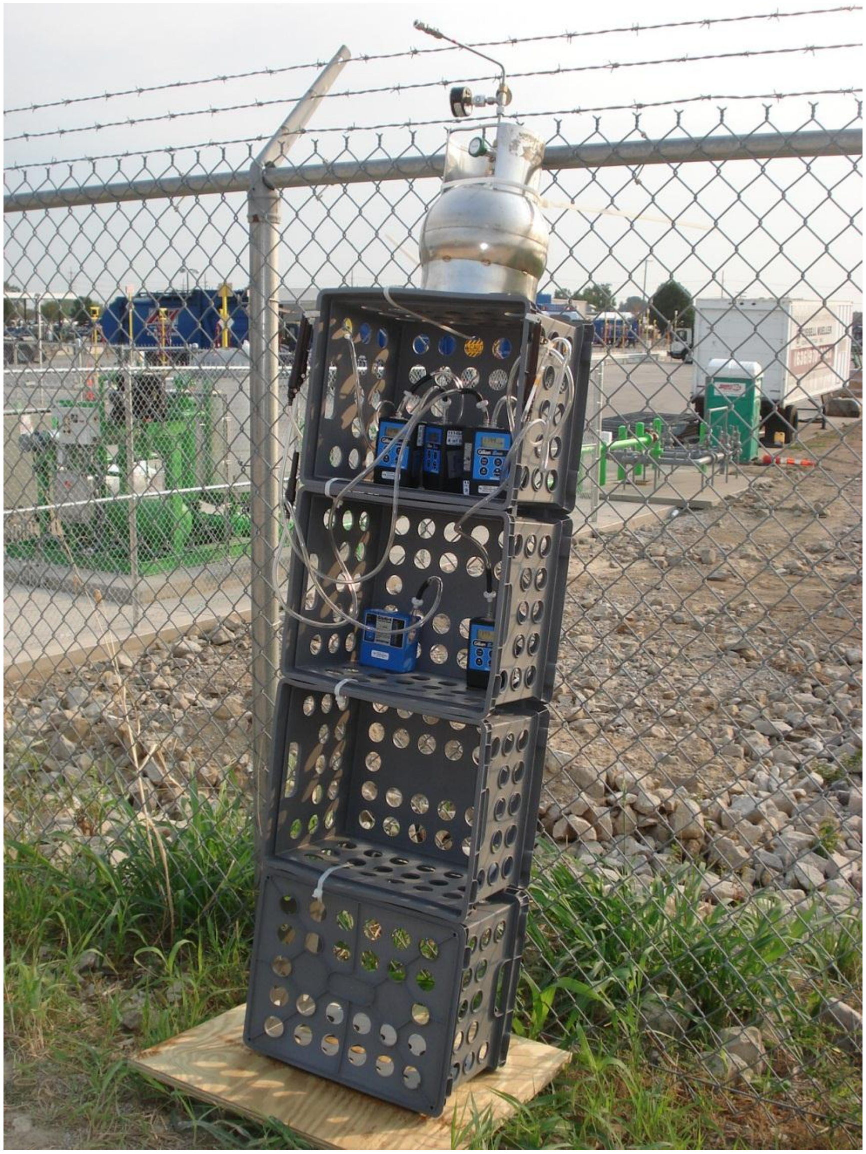


**Figure 10**
Ambient air sample collection structures and pump assemblies