Bridgeton Landfill Ambient Air and Landfill Source Gas Sampling-July 2014

Summary of Findings from the
July 2014 Comprehensive
Sampling Event

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Sign-off Sheet

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Executive Summary

This report describes the methodology and presents the findings from the comprehensive sampling event conducted by Stantec Consulting Services Inc. (Stantec) on July 29, 30 and 31, 2014 on and around the Bridgeton Landfill, LLC (Bridgeton) facility located at 13570 St. Charles Rock Road, Bridgeton, Missouri (the landfill). The purpose of this comprehensive sampling event was to fulfill the requirements of the June 19, 2014 Second Amendment to Order of Preliminary Injunction (Second Amended Order or Order) issued by the State of Missouri Attorney General and the Missouri Department of Natural Resources (MDNR). The Order required Bridgeton Landfill to “undertake three air sampling events, initiating the first within 45 days of the entry of this Second Amendment, the second seven months following entry of this Second Amendment, and the third thirteen months from entry of this Second Amendment. These air sampling events will include all parameters included in the August 2012 Stantec sampling event. The sampling event will sample from the inlet prior to the flare, and from agreed locations…using under liner collection ports to sample the South Quarry, neck area and North Quarry.”

The July 2014 sampling is the third comprehensive air sampling event to be conducted at the landfill. Stantec conducted two previous comprehensive sampling events at the request of Bridgeton; the first event was conducted in August 2012 (as referenced in the Order), and the second event was conducted in April/May 2013. Stantec’s strategy for collecting samples of landfill source gas and ambient air representing upwind (background), on-landfill locations and downwind fence-line locations where an odor was noted was similar in 2014 and 2012. The strategy for collecting samples during the April/May 2013 sampling event was determined by MDNR’s consultant Soil Water Air Protection Enterprise (SWAPE).

The July 2014 sampling event differs from the previous events in that samples were collected from the Inlet to the Flare in addition to locations under the ethylene vinyl alcohol (EVOH) cover. The gas collection system is located deep within the waste mass. Samples of source gas from the North Quarry, Neck and South Quarry represent source gas that has migrated upwards from deeper in the waste mass and accumulated under the EVOH. Consistent with the first comprehensive event conducted in August 2012, samples of landfill source gas and ambient air were analyzed for the following parameters or constituents of concern during the July 2014 sampling event. All analyses were performed by ALS Laboratories (formerly Columbia Analytical). Stantec’s analytical chemist reviewed and validated all of the Level III data packages from the laboratory and determined that the data were usable.

Consistent with previous sampling event s in 2012 and 2013, ambient air and source gas samples collected during the July 2014 sampling event were analyzed for the following list of parameters by the Methods indicated below.

- Fixed Gases: EPA Method 3C (hydrogen, oxygen + argon, nitrogen, carbon monoxide, carbon dioxide, methane)
- Ammonia: OSHA Method ID-188
- Mercury and Compounds: NIOSH Method 6009
- Hydrogen Cyanide: NIOSH Method 6010
- Reduced Sulfur Compounds: ASTM Method D5504
- Volatile Organic Compounds and Tentatively Identified Compounds: EPA Method TO-15
- Aldehydes (Carbonyl Compounds): EPA Method TO-11A
- Amines (Aliphatic): (ALS Laboratory in-house method) AQL 101
- Carboxylic Acids: (ALS Laboratory in-house method) AQL 102
- Polycyclic Aromatic Hydrocarbons (PAHs): EPA Method TO-13A
- Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans (Dioxins/Dibenzofurans): EPA Method TO-9

Although the Order specifies only sampling of the landfill source gas at designated locations, ambient air samples were also analyzed for the same groups of constituents in 2012, 2013 and 2014.

The comprehensive sampling characterizes chemical constituents of concern present in the landfill source gas and ambient air that may contribute to the odors and/or are of potential concern for public health.

Conclusions

The following conclusions are based on the findings of the three comprehensive sampling events conducted in August 2012, April/May 2013 and July 2014.

- Odors from the landfill are not continuously present and are not at the same intensity at any given location in the community.
    - The major contributors of the odors are believed to be carboxylic acid and reduced sulfur compounds. Although they are the main contributors for the detectable odors, their concentrations are below toxicity thresholds and not a concern for public health.

- Low concentrations of aldehydes, PAHs and dioxins/dibenzofurans were detected in ambient air. The following evidence indicates that the landfill is not the source of these compounds.
    - Concentrations of aldehydes, PAHs and dioxins/dibenzofurans in ambient air on the landfill and at downwind fence-line locations were similar to the concentrations in upwind ambient air for all samples collected in 2012, 2013 and 2014.
    - The concentrations of aldehydes detected in ambient air are within the background range for urban areas, including St. Louis and are not a concern for public health.
    - Benzo[a]pyrene and related carcinogenic PAHs (cPAHs) associated with incomplete combustion of organic matter have not been detected in any sample of source gas or ambient air collected in 2012, 2013, or 2014.
    - The concentrations of dioxins/dibenzofurans in landfill source gas were similar to ambient background in 2012, 2013 and 2014.
    - The concentrations of dioxins/dibenzofurans detected in ambient air are within the background range for urban areas and are not a concern for public health.
- The landfill is not a source of ammonia or hydrogen cyanide.
    - Ammonia was detected in ambient air at the Flare Station in 2014, but not in any other sample of ambient air. Ammonia has not been detected in any landfill source gas sample from 2012, 2013 or 2014.
    - Hydrogen cyanide has not been detected in any sample of ambient air or in any landfill source gas sample from 2012, 2013, or 2014.
- Mercury has not been detected in any sample of ambient air. Mercury was detected in source gas from the Flare Inlet in 2014, but has not been detected in any other landfill source gas sample from 2012, 2013 or 2014.
- Concentrations of benzene detected in ambient air from locations on the landfill and downwind locations had decreased significantly in 2014 as compared to 2012 and 2013.
    - In 2014, the concentrations of benzene detected in ambient air were consistent with average annual background in the St. Louis area.
- Benzene concentrations were below occupational exposure standards in all samples of ambient air from locations on the landfill and downwind in 2012, 2013 and 2014.

  - The highest benzene concentration detected in any 4-hour (2012 and 2013) or 8-hour (2014) ambient air sample from locations on the landfill or downwind locations was 27 µg/m³ at the Amphitheater on April 16, 2013. All other detected concentrations were lower. This concentration was orders of magnitude lower than the OSHA PEL (32,000 µg/m³) and the ACGIH TLV (32,000 µg/m³).

- Benzene concentrations were at or below the conservative US EPA risk-based Regional Screening Level (RSL) of 1.6 µg/m³ (or 0.0005 Parts Per Million) in all 8-hour samples of ambient air from locations on the landfill and downwind fence-line locations in 2014. The RSL was derived to correspond to a cancer risk of 1 in 1 million (1E-06) for long-term exposure to an industrial worker (8 hours per day for 250 days per year for 25 years).

  - In 2012 and 2013, concentrations of benzene exceeding the risk-based industrial RSL, but 100 to 1,000 times lower than the OSHA PEL and ACGIH TLV were detected in ambient air from locations on the landfill and downwind locations.

- Higher concentrations of benzene and other VOCs may be present for brief periods (minutes) in locations where intrusive activities into the landfill cause the release of source gas and strong odors.

  - Benzene was detected at 370 µg/m³ in an "instantaneous grab sample" collected on July 29, 2014 during a period of intense odor. The sample was collected within 500 feet downwind of an open excavation on the east face of the landfill.

  - The concentration of benzene detected in the grab sample was lower than the OSHA PEL and the ACGIH TLV for 8-hour workplace exposures.

  - The concentrations of benzene detected in 8-hour samples in the same general location downwind of the open excavation on July 29 and July 30, 2014 were 1.7 µg/m³ in the Southeast Corner and 1.6 µg/m³ on the East Fence, respectively.

  - The results of these particular samples support the conclusion that even in a location close to the source where intermittent intense odors were present, the time weighted exposure to benzene over 8-hours was comparable to the conservative risk-based RSL for long-term exposures.

- The concentrations of constituents of concern detected in source gas from the Neck in July 2014 were significantly less than what was detected in samples from this general area, previously referred to as the Second Tier in 2012 and 2013.

  - The concentrations and specific groups of constituents of concern in source gas from the Neck resemble source gas from the North Quarry where the subsurface reaction is not occurring.

- The concentrations of VOCs, reduced sulfur compounds and carboxylic acids detected in source gas from the South Quarry in July 2014 were similar to the concentrations of these same groups of constituents detected in source gas from reaction areas in the Amphitheater and East Face locations in 2013.
- Based on the constituents of concern detected in source gas from the South Quarry and the gas entering the Flare, the major groups of compounds contributing to the occasional odors are VOCs, reduced sulfur compounds (e.g. dimethyl sulfide and mercaptans), and carboxylic acids (e.g. butanoic and hexanoic acids).
- The constituents of concern contributing to occasional odors in the community are of low order of toxicity and do not pose a health threat to members of the community.

Recommendations

The findings from the three comprehensive sampling events conducted in August 2012, April/May 2013 and July 2014 support the following recommendations.

The two additional sampling events mandated by the Second Amended Order (June 19, 2014) should focus on the following constituents of concern present in the landfill source gas that are likely to be associated with the odor and are of greatest potential concern for public health:

- VOCs and TICs (particularly benzene)
- Reduced sulfur compounds, and
- Carboxylic acids

Continued sampling for those constituents of concern that have never been detected in landfill source gas and/or those constituents that are frequently detected in ambient air as a result of local and regional sources will not provide useful information about potential exposures to the surrounding community that can be attributed (at least in part) to releases of reaction gas from the landfill. Sampling for the following constituents should be discontinued:

- Fixed Gases
- Ammonia
- Mercury and Compounds
- Hydrogen Cyanide
- Aldehydes
- Amines

- Polycyclic Aromatic Hydrocarbons (PAHs)
- Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans (Dioxins/Dibenzofurans)

Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienist
cPAHs	Carcinogenic Polycyclic Aromatic Hydrocarbons
CIH	Certified Industrial Hygienist
EVOH Cap	Ethylene Vinyl Alcohol Cap
FML	Flexible Membrane Liner
MDNR	Missouri Department of Natural Resources
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic Aromatic Hydrocarbon
PEL	Permissible Exposure Limit
SWAPE	Soil Water Air Protection Enterprise
TCDD	2, 3, 7, 8-Tetrachlorodibenzo-p-dioxin
TEQ	2, 3, 7, 8-TCDD Toxicity Equivalent Concentration
TICs	Tentatively Identified Compounds
TLV	Threshold Limit Value
USEPA	United States Environmental Protection Agency
USEPA RSL	U.S. EPA Regional Screening Levels
VOC	Volatile Organic Compound

1.0 INTRODUCTION

This report describes the methodology and presents the findings from the comprehensive sampling event conducted by Stantec Consulting Services Inc. (Stantec) on July 29, 30 and 31, 2014 on and around the Bridgeton Landfill, LLC (Bridgeton) facility located at 13570 St. Charles Rock Road, Bridgeton, Missouri (the landfill). The purpose of this comprehensive sampling event was to fulfill the requirements of the June 19, 2014 Second Amendment to Order of Preliminary Injunction (Second Amended Order or Order) issued by the State of Missouri Attorney General and the Missouri Department of Natural Resources (MDNR). The Order required Bridgeton Landfill to "undertake three air sampling events, initiating the first within 45 days of the entry of this Second Amendment, the second seven months following entry of this Second Amendment, and the third thirteen months from entry of this Second Amendment. These air sampling events will include all parameters included in the August 2012 Stantec sampling event. The sampling event will sample from the inlet prior to the flare, and from agreed locations…using under liner collection ports to sample the South Quarry, neck area and North Quarry."

The Bridgeton Landfill website (www.bridgetonlandfill.com) provides a detailed history of the Landfill along with numerous reports and documents. A subsurface reaction or subsurface smoldering event in the landfill waste was first identified in December 2010; and Bridgeton began implementing corrective actions at that time.

The July 2014 sampling is the third comprehensive air sampling event to be conducted at the landfill. Stantec conducted two previous comprehensive sampling events at the request of Bridgeton; the first event was conducted in August 2012 (as referenced in the Order), and the second event was conducted in April/May 2013. Stantec's strategy for collecting samples of landfill source gas and ambient air representing upwind (background), on-landfill locations and downwind fence-line locations where the odor was present was similar in 2014 and 2012. Locations for ambient air samples collected in 2013 were selected by MDNR's consultant Soil Water Air Protection Enterprise (SWAPE).

The purpose of the comprehensive sampling is to characterize chemical constituents of concern present in the landfill source gas and ambient air that may contribute to the odors and/or are of potential concern for public health. In addition to the comprehensive sampling described in this report, MDNR instituted a community air monitoring program in May 2013. This program, which is ongoing as of the date of this report, consists of fixed monitors (AreaRAEs) that continuously record total VOCs, sulfur dioxide (SO_2), carbon monoxide (CO), hydrogen sulfide (H_2S), oxygen (O_2), % Lower Explosive Limit (%LEL), and gamma radiation. The data from the AreaRAE monitors is supplemented by an individual who traverses a prescribed path around the exterior of the landfill recording odors, and taking real-time measurements of benzene (UltraRAE benzene monitor) and H_2S (Jerome J-605 monitor). MDNR also collects 8-hour ambient air samples for laboratory analysis of volatile organic compounds on a weekly basis. The results of

MDNR's monitoring can be on the Agency website along with weekly interpretations of the results from the Missouri Department of Health and Senior Services (DHSS).

Both the MDNR website and the Bridgeton Landfill website (www.bridgetonlandfill.com) provide access to all air sampling reports and reports and updates for the corrective measures being implemented at the landfill. As can be seen from these reports, conditions on the landfill have changed dramatically since the first comprehensive sampling event was conducted in August 2012. Although the Order specifies only sampling of the landfill source gas at designated locations, ambient air samples were analyzed for the same groups of constituents in 2012, 2013 and 2014. Members of the surrounding community are not directly exposed to landfill source gas, but could potentially be exposed to constituents in the source gas that are released to the ambient air and move off of the landfill boundaries. The primary objective of the sampling is to characterize the composition of ambient air leaving the landfill boundary relative to the composition of the source gas.

This report presents the findings of the comprehensive sampling conducted in July 2014 and discusses changes in composition of the source gas and ambient air based on comparable data from 2012, 2013 and 2014.

2.0 CONSTITUENTS OF CONCERN IN LANDFILL SOURCE GAS AND AMBIENT AIR

As specified by the Order, the July 2014 comprehensive sampling event addressed the same analytical groupings as the August 2012 sampling event. The 2013 comprehensive sampling event included all of the same analytical groupings as 2012, but also included sulfur dioxide and hydrogen chloride. Landfill source gas and ambient air samples were analyzed for constituents that are commonly associated with odors and/or are of concern to public health at low concentrations in ambient air, and for which there are well-accepted laboratory analytical methods. For example, amines, carboxylic acids, reduced sulfur compounds and ammonia are frequently associated with objectionable odors. Some individual aldehyde compounds (e.g. formaldehyde), individual volatile organic compounds or VOCs (e.g. benzene), mercury, hydrogen cyanide, polycyclic aromatic hydrocarbons or PAHs (e.g. benzo[a]pyrene], and the polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (dioxins/dibenzofurans) are of potential concern for public health at low concentrations.

Consistent with previous sampling events in 2012 and 2013, ambient air and landfill source gas were analyzed for the following constituents of concern (referred to as the full suite of analytes) in July 2014.

- Fixed Gases: hydrogen, oxygen + argon, nitrogen, carbon monoxide, carbon dioxide, methane

- Ammonia
- Mercury and Compounds
- Hydrogen Cyanide
- Reduced Sulfur Compounds
- Volatile Organic Compounds and Tentatively Identified Compounds (TICs)
- Aldehydes (Carbonyl Compounds)
- Amines
- Carboxylic Acids
- Polycyclic Aromatic Hydrocarbons (PAHs)
- Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans (Dioxins/Dibenzofurans)

3.0 SAMPLING METHODOLGY

Sample collection protocols were consistent with the analytical methods as 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 ALS Environmental (formerly Columbia Analytical Services) specifically for odor investigations. Note that Silonite® canisters, rather than standard Summa™ canisters were used to collect samples for analysis of VOCs, reduced sulfur compounds and fixed gases. Silonite® canisters have an inert ceramic lining that allows for the stability of reduced sulfur compounds.

The following table summarizes the methods and sample collection media and also provides links to the analytical methods.

Analytical Methods and Collection Media

Constituents of Concern	Analytical Method	Collection Media & Apparatus
Fixed Gases	EPA 3C http://www.epa.gov/ttn/emc/promgate/m-03c.pdf	1 Liter or 6 Liter Silonite® Canister

Ammonia	OSHA ID-188F http://www.osha.gov/dts/sitc/methods/inorganic/id188/id188.html	Sorbent Tube; low flow sampling pump
Mercury and Compounds	NIOSH 6009 http://www.cdc.gov/niosh/docs/2003-154/pdfs/6009.pdf	Sorbent Tube; low flow sampling pump
Hydrogen Cyanide	NIOSH 6010 http://www.cdc.gov/niosh/docs/2003-154/pdfs/6010.pdf	Sorbent Tube; low flow sampling pump
Reduced Sulfur Compounds	ASTM D5504 http://www.astm.org/Standards/D5504.htm	1 Liter or 6 Liter Silonite® Canister
Volatile Organic Compounds + TICs	EPA TO-15 http://www.epa.gov/ttnamti1/files/ambient/airtoxic/to-15r.pdf	1 Liter or 6 Liter Silonite® Canister
Aldehydes (Carbonyl Compounds)	EPA TO-11A http://www.epa.gov/ttnamti1/files/ambient/airtoxic/to-15r.pdfhttp://www.epa.gov/ttnamti1/files/ambient/airtoxic/to-11ar.pdf	Sorbent Tube; low flow sampling pump
Amines	ALS Lab Method AQL 101 http://www.caslab.com/Forms-Downloads/Flyers/CARBOXYLIC Sampling FLYER.pdf	Sorbent Tube; low flow sampling pump
Carboxylic Acids	ALS Lab Method AQL 102 http://www.caslab.com/Forms-Downloads/Flyers/AMINES Method 101 FLYER.pdf	Sorbent Tube; low flow sampling pump
Polycyclic Aromatic Hydrocarbons	EPA TO-13A http://www.epa.gov/ttnamti1/files/ambient/airtoxic/to-15r.pdfhttp://www.epa.gov/ttnamti1/files/ambient/airtoxic/to-13arr.pdf	Polyurethane Foam (PUF) media; high-volume sampling apparatus
Dioxins/Dibenzofurans	EPA TO-9 http://www.epa.gov/ttnamti1/files/ambient/airtoxic/to-15r.pdfhttp://www.epa.gov/ttnamti1/files/ambient/airtoxic/to-9arr.pdf	Polyurethane Foam (PUF) media; high-volume sampling apparatus

3.1 SOURCE GAS

The major objective of collecting source gas samples from beneath the Ethylene Vinyl Alcohol (EVOH) cap is to characterize the chemical constituents in the landfill source gas from the specified locations without interference from ambient sources of the same constituents (e.g. gasoline or diesel powered equipment operating on and near the landfill). Note that the EVOH now covers the entire landfill (except for a portion of the North Quarry). In 2012 and 2013, source gas samples were collected from beneath the flexible membrane liner (FML) that covered portions of the landfill at that time.

As described below, air-tight sampling ports were designed and utilized to ensure only gas from below the EVOH was collected.

The following equipment was used to collect source gas samples from under the EVOH:

- High volume samplers and PUF cartridges – 4 hour samples for PAHs and Dioxins/Dibenzofurans
- Personal Sampling Pumps and Sorbent tubes – 1 – 8 minute samples for aldehydes, hydrogen cyanide, amines, mercury, ammonia, carboxylic acids
- Silonite® canisters – Grab (1 minute) samples for VOCs, reduced sulfur compounds and fixed gases
- Gasoline generators

The following list describes specific source gas sample locations, and the analyte/analyte groups sampled at each location.

- **Onsite landfill locations**
  - ***Flare*** – Full Suite of Analytes less PAHs and Dioxins/Dibenzofurans
  - ***North Quarry*** – Full Suite of Analytes
  - ***Neck*** – Full Suite of Analytes
  - **South Quarry** – Full Suite of Analytes

PAH and Dioxins/Dibenzofuran samples were not collected from the gas stream entering the flare due to the practical difficulties in configuring a sample port into existing infrastructure as well as difficulties with collecting a representative sample from a high pressure gas line using the high-volume samplers and PUF media required for these analytical methods.

In order to ensure that adequate volumes of gas would be present for sample collection, source gas sampling flux boxes were built into the EVOH at the North Quarry, Neck and South Quarry locations. Photograph #1 depicts the flux-box located at the South Quarry. With the exception of samples for quantification of PAHs and Dioxins/Dibenzofurans, small volumes of gas were required and could be acquired through small air-tight sampling ports inserted into the top of the flux-box. For these "source gas" samples, the sample apparatus (sorbent tubes, personal sampling pumps (PSP) and Teflon tubing or Silonite® canisters) was connected directly to these small, barbed, air-tight ports. Sample collection times ranged from 1 minute to approximately 8 minutes and were dependent on specific laboratory analytic methodology for each individual analyte or analyte group. Photograph #2 depicts source gas sampling sorbent tubes and low flow PSPs connected via Teflon tubing to the airtight barbed fittings in the flux box. Additional source gas samples were collected from the piping components leading to the onsite flare. Photograph #3 depicts a sorbent tube and low flow PSP connected to the piping components leading to the flare. Photograph #4 represents the collection of a grab canister sample from the sampling port on the flux-box.

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 pumps. In order to collect ample sample mass and achieve meaningful laboratory detection limits, samples are generally collected over an extended time period, often as long as 24-hours. However, in past sampling events the source gas contained a large amount of moisture. Therefore in order to avoid oversaturation of the PUF media filters and to collect representative samples, source gas samples were collected over a 4 hour time period from the flux-boxes located at the North Quarry, Neck and South Quarry landfill locations.

The flux-boxes were fitted with a dual port manifold allowing two samplers to operate simultaneously. One sample was utilized to collect a source gas samples for analysis of PAHs, while the other sample was analyzed for Dioxins/Dibenzofurans. The Manifolds were fabricated in the landfill shop to facilitate the movement of gas from under the EVOH directly to the intake ports of the high-volume samplers. These manifold structures provided a means to draw gas directly from under the EVOH into the sampler with minimum interference or influence from ambient air. Photograph #5 shows high volume sampling of source gas from under the EVOH on the North Quarry.

High-volume samplers require an uninterrupted AC power supply to run the pumps. Gasoline powered generators were used for AC Power for source gas sampling and were positioned approximately 50 feet away and downwind of the sample location.

3.2 COLLECTION OF AMBIENT AIR SAMPLES

The following equipment was used to collect ambient air samples at on-site (landfill locations), perimeter upwind and perimeter downwind locations:

- High volume samplers and PUF cartridges – 24 hour samples for PAHs and Dioxins/Dibenzofurans

- Personal Sampling Pumps and Sorbent tubes – 4 hour samples for aldehydes, hydrogen cyanide, amines, mercury, ammonia, carboxylic acids
- Silonite® canisters – 8 hour samples for VOCs, reduced sulfur compounds and fixed gases

All ambient air samples were collected between 3 to 6 feet above ground surface to represent "breathing zone" height. The intake port on the high volume samplers have been designed to sample air at breathing zone height. In order to achieve breathing zone height for PSPs and Silonite® canisters they were attached to an aluminum frame mounted on a tripod so that the sample collection intake ports were approximately 3 to 6 feet above the ground surface. Photographs #6 and #7 are representative of the sample collection structures and pump assemblies.

The following list describes specific ambient air sample locations, relative wind direction associated with sample location and the analyte/analyte groups sampled at each location. Detailed summary tables of sampling procedures are provided as Appendix A. The full suite of analytes was collected at one onsite landfill location and one upwind and downwind location. It was not feasible to collect samples for PAHs and Dioxins/Dibenzofurans at all locations since samples were collected over a 24 hour period. Hydrogen cyanide and mercury samples were eliminated from several locations as these compounds have not been detected in ambient air in previous comprehensive sampling events.

- **Onsite landfill locations**
    - ***Flare –*** Full Suite of Analytes
    - ***North Quarry*** – Full Suite of Analytes less PAHs and Dioxins/Dibenzofurans
    - ***Neck*** – Full Suite of Analytes less PAHs and Dioxins/Dibenzofurans
    - ***South Quarry*** – Full Suite of Analytes less PAHs and Dioxins/Dibenzofurans
- **Upwind Locations**
    - ***Grassy Knoll Lower Level -*** Full Suite of Analytes
    - ***Grassy Knoll upper Level*** - (VOCs, reduced sulfur compounds, fixed gases, aldehydes amines, ammonia and carboxylic acids)
    - **Grab at Grassy Knoll Lower Level** - Limited Suite of Analytes (VOCs, reduced sulfur compounds, fixed gases)
- **Downwind Locations**
    - ***Southeast Corner*** – Full Suite of Analytes
    - ***East Fence*** – Limited Suite of Analytes (VOCs, reduced sulfur compounds, aldehydes amines, ammonia and carboxylic acids)
    - ***Retention Pond*** - Limited Suite of Analytes (VOCs, reduced sulfur compounds, fixed gases, aldehydes amines, ammonia and carboxylic acids)
    - ***Republic Fueling*** - Limited Suite of Analytes (VOCs, reduced sulfur compounds, fixed gases)

   - ***Grab at Southwest Side of Landfill (Downwind of South Quarry)*** - Limited Suite of Analytes (VOCs, reduced sulfur compounds, fixed gases)

In all instances, sample flow rates and sample durations were selected to collect sufficient sample volume needed to optimize analytical detection and reporting limits. Long sampling durations were used to optimize collection of transient compounds.

The gasoline generators powering the high volume samplers were tended throughout the 24-hour sample period to make certain that air collection was not interrupted. Photograph #8 depicts the sampling apparatus used to collect the upwind ambient air samples for the full suite of analytes.

3.3 QUALITY ASSURANCE PROCEDURES

Stantec's Quality Assurance/Quality Control procedures address all facets of this project, specifically: field sampling procedures; documentation of sampling conditions, instrument calibration, sample identification and sample custody; independent validation of the analytical results received from ALS Laboratories; technical review and checking of all data summary tables; and both quality review and independent peer review of this report.

3.3.1 Quality Assurance for Field Sampling

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; and procedures to minimize potential cross contamination and interferences. Appendix A, Tables A-1 through A-4 provide specific details on sample collection times and instrument calibration.

Table 1 lists all samples collected by analytical group, date, sample identifiers and laboratory report identifiers. As specified on Table 1, representative media blanks were submitted for each analytical method.

Instrument Calibration

All personal 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 analyte-specific sorbent tubes. 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).

All of the Tisch ® high volume PUF air samplers were pre-calibrated, utilizing manufacturer's guidelines (*Tisch Environmental, Inc. Operations Manual TE-PUF Poly-Urethane Foam High Volume Air Sampler*) prior to sample collection. A copy of the operation manual is included as Appendix D. Calibration of the PUF samplers was performed without a foam plug or filter paper. The glass cartridge was in the module to prevent leaks and ensure a good seal. A TE-5040A Calibrator (orifice) was placed on top of the 4" filter holder and the manometer was connected to the pressure top on the calibrator. The unit was then turned on and 5 manometer readings were recorded with the magnehelic gauge set at 70, 60, 50, 40 and 30 inches of water, respectively. The resulting values were used to generate a calibration curve and resulting linear equations were used to calculate flow rates for the sampling event. Where discrepancies between pre- and post-sample magnehelic readings were noted, the change was assumed to be linear over time, and the sample volume provided to the analytical lab for converting detected mass to concentration was the arithmetic average of the pre- and post-calibrated magnehelic gauge readings (consistent with industry standard methods).

Handling of Sample Media

PUF media for Method TO-9 dioxin/dibenzofuran analysis were received from the ALS Laboratory in Houston, TX and the PUF media for the Method TO-13 PAH analysis were received from the ALS Laboratory in Simi Valley, CA. The sample media arrived wrapped in aluminum foil and inside securely sealed laboratory cleaned jars in ice-filled coolers. Sample media were stored on ice until deployment into the high volume samplers. After the samples were collected the sample media was again wrapped in aluminum foil, placed in laboratory supplied jars and placed in coolers with ice packs and returned via FedEx to the ALS Laboratory location where the media originated.

A unique identifier was assigned to each sample (see Table 1) and recorded on the Chain of Custody forms supplied by ALS Laboratories. Labels were pre-printed prior to mobilization to the field. All samples and blanks 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.

3.3.2 Independent Data Validation

Stantec's analytical chemist, Elizabeth Crowley, reviewed all of the data packages and Electronic Data Deliverables (EDDs) received from ALS Laboratories. Ms. Crowley prepared validation reports corresponding to the laboratory data packages. The data validation reports are provided in Appendix C of this report.

3.3.3 Technical Quality Assurance for Report Preparation

Stantec's internal QA/QC protocol requires technical review of all data, calculations, etc. presented in our reports; quality review of the document for accuracy of content and presentation; and independent peer review.

- All data tables were checked against the original laboratory analytical reports by a team member who did not compile the original tables. Other quantitative information presented in this report, such as exposure screening levels were independently verified.

- The Quality Review and Independent Peer Review is conducted by senior-level individuals with the appropriate expertise and credentials, and who have minimal or no involvement in preparing the report. Patrick H. Vaughan provided the Quality Review and Gerald R. Myers provided the Independent Peer Review for this report.

3.4 DEVIATIONS FROM SAMPLING SCHEDULE

The following list details all deviations from the sampling schedule as presented in Table 1:

- On July 29, 2014, the upwind location 1 (Grassy Knoll Lower Level) ambient air sample for ammonia was not collected due to a pump failure. An upwind ammonia sample was collected on July 30, 2014 at the Grassy Knoll Upper Level location.
- July 29, 2014: An 8-hour ambient Summa canister was not deployed at the South Quarry Landfill location. An 8-hour ambient Summa canister was deployed on July 30, 2014 at the South Quarry Landfill location.
- On July 30, 2014 the North Quarry landfill ambient air sample for hydrogen cyanide was not collected due to pump failure.

4.0 SAMPLING LOCATIONS

Table 1 summarizes the ambient air and landfill source gas samples collected on July 29, 30 and 31, 2014. Figure 1 shows an aerial view of the Bridgeton Landfill and immediately adjacent properties. Locations where ambient air and source gas samples were collected are indicated – and were located using the GPS coordinates provided by MDNR at the time the samples were collected. The sampling strategy was designed to characterize the constituents of concern in the landfill source gas; the local/regional ambient air mass moving onto the landfill before passing over the landfill (upwind or background); ambient air on the landfill at the same locations where source gas was collected; and ambient air moving off of the landfill towards the surrounding community (downwind).

4.1 SOURCE GAS SAMPLE LOCATIONS

As indicated in Section 1.0, source gas samples were collected in those locations specified by MDNR and agreed to by Bridgeton. In 2012 and 2013, source gas samples were collected from locations described as the Amphitheater, the Second Tier, and the East Face (Figure 2 and 3). No samples were collected from the inlet to the flare in 2012 or 2013. In April/May 2013 (Figure 2) and August 2012 (Figure 3), the locations from which source gas samples were collected corresponded to areas of the landfill that were covered by flexible membrane liner (FML) at that time. Samples of source gas could be collected from beneath the FML without significant dilution by ambient air. By July 2014, except for a grassy portion of the North Quarry, most of the landfill surface was covered by the EVOH.

Source gas samples from the North Quarry, Neck and South Quarry were collected from specially-constructed “flux-boxes” that minimized ambient air dilution of the gas. Similar custom flux-boxes and sampling ports were used in 2012 and 2013.

The sample port at the Inlet to the Flare represents the mixed stream of gas from all locations in the collection system. The gas collection system draws from deep within the waste mass from all areas of the landfill.

In the June 19, 2014 Order MDNR specified that source gas be collected from the following locations:

- ***North Quarry***
- ***Neck***
- ***South Quarry***
- ***Inlet to the Flare***

The North Quarry represents source gas from the area of the landfill where the subsurface reaction has not occurred. The Neck is a location between the North Quarry and the South Quarry. The South Quarry represents source gas from the area where the reaction is presently occurring.

There were no source gas samples taken from locations in 2012 and 2013 that would be comparable to the North Quarry.

The source gas location described as the Second Tier in 2012 and 2013 is in the same general area as the 2014 location described as the Neck.

The source gas locations described as the Amphitheater and East Face in 2012 and 2013 represented two areas of the South Quarry.

The July 2014 sampling event differs from the previous events in that samples were collected from the inlet to the flare in addition to locations under the ethylene vinyl alcohol (EVOH) cap. The gas collection system is located deep within the waste mass. Samples of source gas from the North Quarry, Neck and South Quarry represent source gas that has migrated upwards from deeper in the waste mass and accumulated under the EVOH.

No samples were taken from the gas entering the flare in 2012 and 2013. The gas collection system and flare station have been significantly enhanced since 2013, and the samples taken from the Flare Inlet in July 2014 represent contributions from all areas of the landfill serviced by the gas collection system.

4.2 AMBIENT AIR SAMPLING LOCATIONS

Sampling locations were selected based on relative wind direction and to correlate with sample locations from historical comprehensive sampling events at the landfill. Ambient air samples were collected to characterize the local/regional ambient air mass moving onto the landfill before passing over the landfill (upwind or background); ambient air on the landfill; and ambient air moving off of the landfill towards the surrounding community (downwind).

4.2.1 On Landfill Locations

In July 2014, ambient (on-landfill) air samples were collected at the same four locations as the source gas samples (Figure 1). On-landfill ambient samples were located within 10 feet of the flux-boxes on top of the EVOH at the North Quarry, Neck and South Quarry. The sample at the Flare Station was collected approximately 50 feet from the Flare Inlet. On July 29, on-landfill ambient air samples were collected from the Flare Station and South Quarry. On-landfill ambient air samples were collected from the North Quarry and Neck on July 30. No on-landfill ambient samples were collected on July 31 when the source gas samples for dioxin/dibenzofurans and PAH analyses were being collected to avoid potential influence from the source gas being exhausted through the high volume sampling units.

4.2.2 Downwind Sample Locations

Downwind ambient air samples representing air moving from the landfill into the surrounding community were collected at locations inside the facility fence-line where there was a noticeable odor at the time the sampling was initiated (Figure 1). Odors on the landfill were not consistently present in the same locations and at the same intensity. Intermittent “plumes” of intense odor were present immediately downwind of an open excavation on the east slope of the landfill on July 29, when downwind samples were collected from the Southeast Corner and along the East Fence bordering Boenker's field.

In addition to the 8-hour Summa canister sample collected in the Southeast Corner, an instantaneous grab 1-liter Summa canister sample was collected along the East Fence approximately 300 feet downwind of the excavation at a moment when the odor at that location was intense. The results from the grab sample are discussed separately.

On July 30, downwind samples were collected from the fence line adjacent to the Retention Pond (D1), from the East Fence bordering Boenker's field in approximately the same location as the sample collected the previous day. An 8-hour Summa canister sample was also collected inside the fence-line northeast of the Republic Vehicle Fueling Station to the north of the Flare.

In 2012 ambient downwind samples were collected from the same general areas inside the facility fence-line (Figure 3) as in 2014. In 2013, the downwind sample locations selected by SWAPE were off of the landfill property adjacent to the Metropolitan Sewer District (MSD) lift station to the west of the landfill, the east end of the Materialogic parking lot, and on the property occupied by Northwest Auto (an auto-body repair shop) located between the landfill boundary and St. Charles Rock Road (Figure 2).

4.2.3 Upwind Sample Locations

Ambient air samples representing local/regional background were collected in the open grassy field, or Grassy Knoll to the north of the landfill office (Figure 1). The Grassy Knoll is at a slightly higher elevation than the entrance road and landfill office. No landfill odor was present on the Grassy Knoll on the days that the samples were collected. The Grassy Knoll was also the most frequent upwind sample location in 2012 and 2013.

Upwind and downwind samples were always collected contemporaneously in 2012 and 2014.

5.0 ANALYTICAL RESULTS

Review of the laboratory analytical reports, data validation forms, field notes and instrument calibration records indicate that all data are acceptable for the intended purpose. Appendix A, Tables A-1 through A-4 summarize the sampling procedures, sample identifiers and relevant calibration information for each date and location for the July 2014 sampling event. Analytical reports from ALS Laboratories are presented in Appendix B. Stantec's analytical chemist (Elizabeth Crowley) reviewed the laboratory data packages from ALS Laboratories for samples collected in July 2014. All data were considered usable. Data validation reports are provided in Appendix C.

5.1 AMBIENT AIR

As described in Sections 3 and 4, ambient air samples were collected to characterize the upwind/background air mass arriving at the landfill, ambient air at the source gas sample locations and ambient air at downwind locations along the facility fence-line where the odor was noted.

The analytical results for ambient air are organized and discussed for each of the three days when sample were collected. Table 2 presents the analytical results for all ambient samples collected on July 29, Table 3 presents results for July 30, and Table 4 presents results for July 31, 2014.

5.1.1 Constituents of Concern in Ambient Air on July 29

Climate summary for Tuesday July 29: Low temperature 59 deg. F, high temperature 82 deg. F; no precipitation; partly cloudy; morning winds from the west and west-northwest; afternoon winds from the northwest and north. There was an open excavation on the east slope of the landfill related to remedial activities that was the source of odors on the east and south portions of the landfill on July 29.

Ambient air samples were collected from the following locations on July 29 (Figure 1).

Upwind: The Grassy Knoll to the north of the landfill office and entrance road (Grassy Knoll Lower Level – Figure 1);

On-Landfill: The Flare Station near the control building; and the South Quarry within ten feet of the source gas flux-box (Flare Station – Figure1);

Downwind: Southeast corner of the fence in the low-lying area adjacent to Boenker Lane and Boenker Farm Field (Southeast Corner – Figure 1); and on the fence immediately across the road from the open excavation on the east side of the landfill (East Fence – Figure 1). Odors were present at both of these locations when sampling was initiated on the morning of July 29.

Analytical results for all ambient samples collected on July 29 are presented in Table 2.

5.1.1.1 Analytical Results for Upwind Ambient Air on July 29

Constituents analyzed for but not detected: Hydrogen, carbon monoxide, methane, carbon dioxide, hydrogen cyanide, mercury, amines, carboxylic acids, and reduced sulfur compounds.

VOCs: Low concentrations of the following VOCs were detected: 2-butanone (MEK), isopropyl alcohol, acetone, acetonitrile, acrolein, benzene, carbon tetrachloride, chloromethane, dichlorodifluoromethane (Freon 12), ethanol, ethyl acetate, m, p-xylenes, methylene chloride, n-hexane, styrene, toluene, trichloroflurometháne, and trichlorotrifluoroethane. The following **TICs** were detected: acetic acid, 2-ethylhexylacetate, hexamethylcyclotrisiloxane, three unidentified siloxanes, and one unidentified compound.

Aldehydes: Acetaldehyde and formaldehyde were detected.

PAHs: A twenty-four (24) hour high-volume sample was collected starting on July 29 and ending on July 30 and submitted for analysis of PAHs. Low concentrations of the following PAHs were detected: acenaphthene, fluoranthene, fluorene, naphthalene, and phenanthrene.

Dioxins/Dibenzofurans: A twenty-four (24) hour high-volume sample was collected starting on July 29 and ending on July 30 and submitted for analysis of dioxins/dibenzofurans. Table 6 presents the detailed analytical results for the ambient air samples that were analyzed for dioxins/dibenzofurans. The two isomers detected in the upwind/background sample, 1,2,3,4,6,7,8-HpCDD and OCDD were converted to 2,3,7,8-TCDD equivalents and added together to yield a total TCDD equivalent (TEQ) concentration of 2.74E-10 µg/m^3.

5.1.1.2 Analytical Results for Ambient Air on the Landfill on July 29

Ambient Air at the Flare Station

Constituents analyzed for but not detected: hydrogen, carbon monoxide, methane, carbon dioxide, hydrogen cyanide, amines, mercury, carboxylic acids, and reduced sulfur compounds.

VOCs: The following VOCs were detected: 2-butanone (MEK), 2-hexanone, isopropyl alcohol, acetone, acetonitrile, benzene, carbon tetrachloride, chloromethane, dichlorodifluoromethane (Freon 12), d-limonene, ethanol, ethyl acetate, methylene chloride, n-hexane, n-heptane, n-nonane, propene, toluene, trichlorofluoromethane, and trichlorotrifluoroethane. **TICs**: propane, trimethylsilanol, hexamethylcyclotrisiloxane, n-nonanal, 2-ethylhexylacetate, n-decanal, and one unidentified siloxane.

Aldehydes: Acetaldehyde, formaldehyde and n-hexaldehyde were detected.

PAHs: A twenty-four (24) hour high-volume sample was collected from the Flare Station starting on July 29 and ending on July 30 and submitted for analysis of PAHs. Low concentrations of the following PAHs were detected (see Table 2): acenaphthene, fluoranthene, fluorene, naphthalene, and phenanthrene.

Dioxins/Dibenzofurans: A twenty-four (24) hour high-volume sample was collected from the flare Station starting on July 29 and ending on July 30 and submitted for analysis of dioxins/dibenzofurans. Table 6 presents the detailed analytical results for the ambient air samples that were analyzed for dioxins/dibenzofurans. The three isomers detected in the upwind/background sample, 1,2,3,4,6,7,8-HpCDD, OCDD and 1,2,3,4,6,7,8-HpCDF were converted to 2,3,7,8-TCDD equivalents and added together to yield a total TCDD TEQ concentration of 3.12E-10 µg/m^3.

Ammonia: Ammonia was detected at a concentration of 130 µg/m^3 in ambient air at the Flare Station.

Ambient Air at the South Quarry

Constituents analyzed for but not detected: hydrogen, carbon monoxide, methane, carbon dioxide, hydrogen cyanide, amines, mercury, ammonia, carboxylic acids, and reduced sulfur compounds.

VOCs: The following VOCs were detected: 1,2,4-trimethylbenzene, 2-butanone (MEK), 2-hexanone, isopropyl alcohol, acetone, acetonitrile, acrolein, alpha-pinene, benzene, carbon disulfide, carbon tetrachloride, chloromethane, cyclohexane, dichlorodifluoromethane (Freon 12), d-limonene, ethanol, ethyl acetate, ethylbenzene, m, p-xylenes, methylene chloride, n-butyl acetate, n-hexane, n-heptane, n-nonane, o-xylene, propene, styrene, tetrahydrofuran, toluene, trichlorofluoromethane, and trichlorotrifluoroethane. **TICs**: isobutane, n-pentane, 1-propanol, trimethylsilanol, 1-butanol, hexamethylcyclotrisiloxane, n-nonanal, n-octanal, n-decanal, C13H28 branched alkane, one unidentified siloxane, and one additional unidentified compound.

Aldehydes: Acetaldehyde, formaldehyde and n-hexaldehyde were detected.

5.1.1.3 Analytical Results for Ambient Air at Downwind Fence-Line Locations on July 29

On July 29, downwind samples for the full list of constituents of concern were collected at the fence in the southeast corner of the landfill property near Boenker Lane (Southeast Corner - Figure 1). This location is in a low-lying area down-slope from the South Quarry where work had been ongoing since 2012 and was occurring in late July 2014 Also on July 29, sorbent tube samples for analysis of aldehydes, amines, ammonia, and carboxylic acids were collected from a location on the East Fence immediately downwind of an open excavation on the east slope of the landfill (East Fence - Figure 1). A strong odor was intermittently present at this location. A grab sample was collected in a 1-Liter Silonite® canister in an attempt to characterize the VOC and reduced sulfur compound constituents in the odor.

Southeast Corner

Constituents analyzed for but not detected: Hydrogen, carbon monoxide, methane, carbon dioxide, hydrogen cyanide, ammonia, mercury, amines, carboxylic acids, and reduced sulfur compounds were not detected.

VOCs: The following VOCs were detected: 2-butanone (MEK), isopropyl alcohol, acetone, acetonitrile, benzene, carbon tetrachloride, chloromethane, dichlorodifluoromethane (Freon

12), ethanol, ethyl acetate, methylene chloride, n-butyl acetate, n-hexane, propene, tetrahydrofuran, toluene, trichlorofluoroethane, and trichlorotifluoroethane. **TICs**: trimethylsilanol, acetic acid, hexamethylcyclotrisiloxane, 2-butoxyethanol, two unidentified siloxanes and one additional unidentified compound.

Aldehydes: Acetaldehyde, formaldehyde and n-hexaldehyde were detected.

PAHs: A twenty-four (24) hour high-volume sample was collected starting on July 29 and ending on July 30 and submitted for analysis of PAHs. Low concentrations of the following PAHs were detected: acenaphthene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene.

Dioxins/Dibenzofurans: A twenty-four (24) hour high-volume sample was collected starting on July 29 and ending on July 30 and submitted for analysis of dioxins/dibenzofurans. Table 6 presents the detailed analytical results for the ambient air samples that were analyzed for dioxins/dibenzofurans. The three isomers detected in the upwind/background sample, 1,2,3,4,6,7,8-HpCDD, OCDD and 1,2,3,4,6,7,8-HpCDF were converted to 2,3,7,8-TCDD equivalents and added together to yield a total TCDD TEQ concentration of 3.29E-10 µg/m^3.

East Fence

Constituents analyzed for but not detected: Amines, ammonia, and reduced sulfur compounds were not detected.

VOCs: A grab sample was collected in a 1 liter Silonite® canister during a period when the odor at this location was intense. With one other exception on July 31, all ambient samples for VOCs, reduced sulfur compounds and fixed gases were collected for 8 hours in 6 liter Silonite® canisters. The VOCs detected during the intense odor were: 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, 1,3-butadiene, 2-butanone (MEK), isopropyl alcohol, 4-ethyltoluene, 4-methyl-2-pentanone, acetone, acetonitrile, benzene, carbon disulfide, chloromethane, cumene, cyclohexane, dichlorodifluoromethane (Freon 12), d-limonene, ethanol, ethylbenzene, m,p-xylenes, naphthalene, n-heptane, n-hexane, n-nonane, n-octane, n-propylbenzene, o-xylene, propene, styrene, tetrahydrofuran, toluene, and trichlorofluoromethane. **TICs** detected were: isobutene, isoprene, cyclopentene, three C5H10 compounds, C5H8 compound, four C6H12 compounds, C7H14 compound, C8H16 and C7H12 compounds.

Aldehydes: Acetaldehyde, formaldehyde, n-hexaldehyde, and valeraldehyde were detected.

Carboxylic acids: Butanoic (butyric) acid and hexanoic (caproic) acid were detected.

5.1.2 Constituents of Concern in Ambient Air on July 30

Climate summary for Wednesday July 30: Low temperature 64 deg. F, high temperature 86 deg. F; no precipitation; mostly cloudy; morning winds calm shifting to the north northwest; afternoon winds from the northeast and north. The open excavation on the east slope was in the process of being closed.

Ambient air samples were collected from the following locations on July 30 (Figure 1).

Upwind: The Grassy Knoll to the north of the landfill office and entrance road.

On-Landfill: The Neck and the North Quarry within ten feet of the source gas flux-box at each location.

Downwind: Three downwind samples were collected on July 30, 2014: 1) Samples were collected from the east fence of the landfill property immediately downwind of where the excavation was occurring (East Fence – Figure 1); 2) samples were collected from a location proximate to the retention pond south of the Republic Services vehicle parking area (Retention Pond – Figure 1); and 3) samples were collected from a location north of the Flare Station and on the fence adjacent to the fueling station for the Republic Services vehicles (Republic Fueling – Figure 1).

Odors were present at all of three of the downwind locations when sampling was initiated in the morning of July 30.

Analytical results for all ambient samples collected on July 30 are presented in Table 3.

5.1.2.1 Analytical Results for Upwind Ambient Air on July 30

Constituents analyzed for but not detected: Amines, ammonia, carboxylic acids, and reduced sulfur compounds were not detected.

VOCs: Low concentrations of the following VOCs were detected: 2-butanone (MEK), acetone, acetonitrile, acrolein, carbon tetrachloride, chloromethane, dichlorodifluoromethane (Freon 12), ethanol, ethyl acetate, toluene, trichlorofluromethane, and trichlorotrifluoroethane. The following **TICs** were detected: trimethylsilanol, hexamethylcyclotrisiloxane, n-octanal, n-nonanal, three unidentified siloxanes, and one other unidentified compound.

Aldehydes: Acetaldehyde, formaldehyde and n-hexaldehyde were detected.

5.1.2.2 Analytical Results for Ambient Air on the Landfill on July 30

Ambient Air at the Neck

Constituents analyzed for but not detected: hydrogen, carbon monoxide, methane, carbon dioxide, hydrogen cyanide, amines, mercury, ammonia, carboxylic acids, and reduced sulfur compounds.

VOCs: The following VOCs were detected: 2-butanone (MEK), isopropyl alcohol, acetone, acetonitrile, acrolein, benzene, carbon tetrachloride, chloromethane, dichlorodifluoromethane (Freon 12), d-limonene, ethanol, ethyl acetate, methylene chloride, n-butyl acetate, n-hexane, propene, toluene, trichlorofluoromethane, and trichlorotrifluoroethane. **TICs**: hexamethylcyclotrisiloxane, n-nonanal, n-decanal, and one unidentified compound.

Ambient Air at the North Quarry

Constituents analyzed for but not detected: hydrogen, carbon monoxide, methane, carbon dioxide, amines, mercury, ammonia, carboxylic acids, and reduced sulfur compounds.

VOCs: The following VOCs were detected: 2-butanone (MEK), isopropyl alcohol, acetone, acetonitrile, acrolein, benzene, carbon tetrachloride, chloromethane, dichlorodifluoromethane (Freon 12), d-limonene, ethanol, ethyl acetate, methylene chloride, n-hexane, propene, toluene, trichlorofluoromethane, and trichlorotrifluoroethane. **TICs**: trimethylsilanol, hexamethylcyclotrisiloxane, n-nonanal, n-decanal, and two unidentified siloxanes.

5.1.2.3 Analytical Results for Ambient Air at Downwind Fence-Line Locations on July 30

East Fence

Constituents analyzed for but not detected: Amines, ammonia, carboxylic acids, and reduced sulfur compounds.

VOCs: The following VOCs were detected: 2-butanone (MEK), isopropyl alcohol, acetone, acetonitrile, acrolein, benzene, carbon tetrachloride, chloromethane, dichlorodifluoromethane (Freon 12), ethanol, ethyl acetate, m,p-xylenes, methylene chloride, n-butyl acetate, n-nonane, propene, tetrahydrofuran, toluene, trichlorofluromethane, and trichlorotrifluoroethane. The following TICs were detected: trimethylsilanol, hexamethylcyclotrisiloxane, one unidentified siloxane, and one other unidentified compound.

Aldehydes: Acetaldehyde, formaldehyde and n-hexaldehyde were detected.

Retention Pond

Constituents analyzed for but not detected: Amines, ammonia, carboxylic acids, and reduced sulfur compounds.

VOCs: The following VOCs were detected: 2-butanone (MEK), isopropyl alcohol, acetone, acetonitrile, benzene, carbon tetrachloride, chloromethane, dichlorodifluoromethane (Freon 12), d-limonene, ethanol, ethyl acetate, methylene chloride, propene, toluene, trichlorofluromethane, and trichlorotrifluoroethane. The following **TICs** were detected: hexamethylcyclotrisiloxane, n-nonanal, n-decanal, and one unidentified siloxane.

Aldehydes: Acetaldehyde, formaldehyde and n-hexaldehyde were detected.

Republic Fueling

Constituents analyzed for but not detected: Reduced sulfur compounds were not detected.

VOCs: The following VOCs were detected: 2-butanone (MEK), acetone, carbon tetrachloride, chloromethane, dichlorodifluoromethane (Freon 12), d-limonene, ethanol, ethyl acetate, methylene chloride, n-butyl acetate, propene, toluene, trichlorofluromethane, and trichlorotrifluoroethane. The following **TICs** were detected: hexamethylcyclotrisiloxane, n-nonanal, and one unidentified siloxane.

5.1.3 Constituents of Concern in Ambient Air on July 31

Climate summary for Thursday July 31: Low temperature 64 deg. F, high temperature 86 deg. F; no precipitation; scattered clouds; morning winds calm shifting to the east and variable.

No ambient sampling had been scheduled for Thursday July 31, however, the landfill source gas being exhausted from the high volume sampling units drawing source gas from the South Quarry (for dioxin/dibenzofurans and PAH analyses) caused a strong odor. Bridgeton personnel deployed misting/deodorizing spray to control the exhaust from the high volume samplers. Stantec collected grab 1 liter Silonite® canister samples from the west fence-line across the street from the MSD Lift Station (Southwest Side of Landfill – Figure 1) which was downwind of the South Quarry and a companion upwind sample from the Grassy Knoll (Grassy Knoll Lower Level – Figure 1) for TO-15 analysis. The results from the two July 31 grab samples are presented in Table 4.

Upwind: Very low concentrations of dichlorodifluoromethane (Freon 12), propene and toluene were detected at the Grassy Knoll Lower Level location.

Downwind: Almost identical low concentrations of the same three compounds were detected Southwest side of the landfill.

The results from both samples are consistent with local/regional background.

5.2 LANDFILL SOURCE GAS

Table 5 presents a summary of the analytical results for all samples of landfill source gas collected in July 2014. Figure 1 shows the locations of the four source gas sample locations: The Flare Inlet, Neck, North Quarry and South Quarry as specified by MDNR in the June 19, 2014 Orders.

The subsurface reaction (which is suspected as being the cause of the odors) is thought to be well-controlled south of the Neck; and no subsurface reaction was or is occurring in the North Quarry. The South Quarry is still active and the gases entering the Flare Inlet represent contributions from all areas of the landfill gas collection system. Samples from the Neck, North Quarry and South Quarry locations represent gas that has migrated upward through the waste mass and accumulated between the surface of the landfill and the EVOH cover. Samples from the Flare Inlet represent contributions from all locations within the waste mass that are serviced by the gas collection system. Although the composition is related, gas from the Flare Inlet is not directly comparable to the gas collected from immediately beneath the EVOH.

5.2.1 Analytical Results for Source Gas from the Neck

Constituents analyzed for but not detected: Hydrogen, carbon monoxide, hydrogen cyanide, amines, mercury, ammonia, and carboxylic acids. No dioxins or dibenzofurans were detected in source gas from the Neck (Table 7).

VOCs: The following VOCs were detected: 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, 1,3-butadiene, 1,4-dichlorobenzene, 4-ethyltoluene, acetone, acetonitrile, alpha-pinene, benzene, chlorobenzene, cumene, cyclohexane, dichlorodifluoromethane (Freon 12), d-limonene, ethylbenzene, m, p-xylenes, methyl tertiary butyl ether (MTBE), n-heptane, n-hexane, n-nonane, n-octane, n-propylbenzene, o-xylene, propene, tetrahydrofuran, toluene, and trichlorotrifluoroethane. **TICs**: propane, isobutene, n-butane, two C4H8 alkenes, two C5H10 compounds, cyclopentene, one C7H12 compound, two C8H16 compounds, one C8H14 compound, one C8H16 compound, camphene, and one C12H26 branched alkane.

Aldehydes: Acetaldehyde was the only aldehyde detected.

Reduced sulfur compounds: The following reduced sulfur compounds were detected: 3-methylthiophene, carbon disulfide, dimethyl disulfide, dimethyl sulfide, ethyl methyl sulfide, and thiophene.

PAHs: A four (4) hour high-volume sample was collected on the morning of July 31 and submitted for analysis of PAHs. Low concentrations of acenaphthene and naphthalene were detected.

Dioxins/Dibenzofurans: A four (4) hour high-volume sample was collected on the morning of July 31 and submitted for analysis of dioxins/dibenzofurans. No dioxin or dibenzofurans isomers were detected in source gas from the Neck (Table 7).

5.2.2 Analytical Results for Source Gas from the North Quarry

Constituents analyzed for but not detected: Hydrogen, carbon monoxide, hydrogen cyanide, amines, mercury, ammonia, and carboxylic acids. No PAHs were detected in source gas from the North Quarry.

VOCs: The following VOCs were detected: 1,2,4-trimethylbenzene, 1,2-dichloro-1,1,2,2-tetrafluoroethane, 1,3,5-trimethylbenzene, 1,3-butadiene, 1,4-dichlorobenzene, 4-ethyltoluene, acetonitrile, alpha-pinene, benzene, chlorobenzene, cis-1,2-dichloroethene, cumene, cyclohexane, dichlorodifluoromethane (Freon 12), ethylbenzene, m, p-xylenes, methyl tertiary butyl ether (MTBE), n-heptane, n-hexane, n-nonane, n-octane, n-propylbenzene, o-xylene, propene, tetrahydrofuran, toluene, trichlorotrifluoroethane and vinyl chloride. **TICs**: propane, isobutane, isobutene, n-butane, two C4H8 alkenes, one C5H10 compound, cyclopentene, methyl cyclopentene isomer, two C7H12 compounds, 3-ethyltoluene, one C11H24 compound, and one C12H26 branched alkane.

Aldehydes: Acetaldehyde was the only aldehyde detected.

Reduced sulfur compounds: The following reduced sulfur compounds were detected: 3-methylthiophene, carbon disulfide, dimethyl disulfide, dimethyl sulfide, ethyl methyl sulfide, tetrahydrothiophene, and thiophene.

PAHs: A four (4) hour high-volume sample was collected on the morning of July 31 and submitted for analysis of PAHs. No PAHs were detected in source gas from the North Quarry.

Dioxins/Dibenzofurans: A four (4) hour high-volume sample was collected on the morning of July 31 and submitted for analysis of dioxins/dibenzofurans. Table 7 presents the detailed analytical results for the ambient air samples that were analyzed for dioxins/dibenzofurans. OCDD, the only isomer detected was converted to 2, 3, 7, 8-TCDD equivalents to yield a total TCDD equivalent concentration (TEQ) of 5.13E-11 µg/m^3.

5.2.3 Analytical Results for Source Gas from the South Quarry

Constituents analyzed for but not detected: Hydrogen cyanide, amines, mercury, and ammonia.

Fixed gases: Carbon monoxide, methane, carbon dioxide and hydrogen were detected in source gas from the South Quarry.

VOCs: The following VOCs were detected: 1,2,4-trimethylbenzene, 1,2-dichloroethane, 1,3,5-trimethylbenzene, 1,3-butadiene, 1,4-dichlorobenzene, 2-butanone (MEK), 2-hexanone, 2-propanol (isopropyl alcohol), 4-ethyltoluene, acetone, alpha-pinene, benzene, chlorobenzene, chloroethane, chloromethane, cumene, d-limonene, ethanol, ethyl acetate, ethylbenzene, m, p-xylenes, n-butyl acetate, n-hexane, n-nonane, n-octane, n-propylbenzene, o-xylene, propene, styrene, tetrachloroethene, tetrahydrofuran, and toluene. **TICs**: dimethyl sulfide, methyl acetate, 2-butanol, 2-methylfuran, methyl propionate, 2-methyltetrahydrofuran, 2-pentanone, methyl isobutyrate, 2-ethylfuran, methyl butyrate, dimethyl disulfide, 3-methyl-methylbutyrate, ethyl butyrate, n-decane, and p-isopropyltoluene

Aldehydes: Acetaldehyde, 2,5-dimethylbenzaldehyde, benzaldehyde, butyraldehyde, n-hexaldehyde, and propionaldehyde were detected.

Reduced sulfur compounds: The following reduced sulfur compounds were detected: 3-methylthiophene, carbon disulfide, carbonyl sulfide, dimethyl disulfide, dimethyl sulfide, ethyl methyl sulfide, methyl mercaptan, n-butyl mercaptan, tetrahydrothiophene, and thiophene.

Carboxylic acids: The following carboxylic acids were detected: 2-ethylhexanoic acid, 2-methyl butanoic acid, 2-methyl pentanoic acid, 2-methyl propionic acid (isobutyric), 3-methyl butanoic acid (isovaleric), 3-methyl pentanoic acid, 4-methyl pentanoic acid (isocaproic), acetic acid, benzoic acid, butanoic acid (butyric), hexanoic acid (caproic), pentanoic acid (valeric), and propionic acid (propanoic).

PAHs: A four (4) hour high-volume sample was collected on the morning of July 31 and submitted for analysis of PAHs. Acenaphthene, naphthalene, and fluorene were detected in source gas from the South Quarry.

Dioxins/Dibenzofurans: A four (4) hour high-volume sample was collected on the morning of July 31 and submitted for analysis of dioxins/dibenzofurans. Table 7 presents the detailed analytical results for the ambient air samples that were analyzed for dioxins/dibenzofurans. OCDD, the only isomer detected was converted to 2, 3, 7, 8-TCDD equivalents to yield a total TCDD TEQ concentration of 3.36E-11 µg/m^3.

5.2.4 Analytical Results for Source Gas from the Flare Inlet

Constituents analyzed for but not detected: Hydrogen cyanide, amines, and ammonia.

Fixed gases: Carbon monoxide, methane, carbon dioxide and hydrogen were detected in source gas from the Flare Inlet.

Mercury: Mercury was detected at a concentration of 70 µg/m^3 in the gas from the Flare Inlet. This was the only sample (of source gas or ambient air) where mercury was reported.

VOCs: The following VOCs were detected: 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, 1,3-butadiene, 1,4-dichlorobenzene, 1,4-dioxane, 2-butanone (MEK), 2-hexanone, 2-propanol (isopropyl alcohol), 4-ethyltoluene, 2-methyl-2-pentanone, acetone, alpha-pinene, benzene, carbon disulfide, chlorobenzene, chloroethane, chloromethane, cumene, d-limonene, ethanol, ethyl acetate, ethylbenzene, m, p-xylenes, methyl tertiary butyl ether (MTBE), naphthalene, n-butyl acetate, n-hexane, n-nonane, n-octane, n-propylbenzene, o-xylene, propene, styrene, tetrahydrofuran, toluene, and vinyl acetate. **TICs**: dimethyl sulfide, methyl acetate, 1-propanol, 2-butanol, 2-methylfuran, methyl propionate, methyl butanoate, dimethyl disulfide, methyl 3-methylbutanoate, ethyl butanoate, methyl pentanoate, 2-methyl cyclopentanone, methyl hexanoate, butyl butanoate, and p-isopropyltoluene

Aldehydes: Acetaldehyde, benzaldehyde, butyraldehyde, formaldehyde, m,p-tolualdehyde, and propionaldehyde were detected.

Reduced sulfur compounds: The following reduced sulfur compounds were detected: 2,5-dimethylthiophene, 2-ethylthiophene, 3-methylthiophene, carbon disulfide, carbonyl sulfide, dimethyl disulfide, dimethyl sulfide, ethyl mercaptan, ethyl methyl sulfide, hydrogen sulfide, methyl mercaptan, n-butyl mercaptan, tetrahydrothiophene, and thiophene.

Carboxylic acids: The following carboxylic acids were detected: 2-ethylhexanoic acid, 2-methyl butanoic acid, 2-methyl pentanoic acid, 2-methyl propionic acid (isobutyric), 3-methyl butanoic acid (isovaleric), 3-methyl pentanoic acid, 4-methyl pentanoic acid (isocaproic), acetic acid, benzoic acid, butanoic acid (butyric), heptanoic acid (enanthoic), hexanoic acid (caproic), nonanoic acid (pelargonic), octanoic acid (caprylic), pentanoic acid (valeric), and propionic acid (propanoic).

No high volume samples for PAH or dioxin/furan analysis were collected from the gas stream entering the Flare Inlet.

5.3 DISCUSSION OF SAMPLING RESULTS FOR JULY 2014

5.3.1 Public Health and Occupational Screening Levels for Ambient Air

Along with the analytical results and laboratory minimum reporting limits (MRLs), health based screening levels are provided in four columns on the left-hand side of the tables to help “benchmark” the concentrations. Two general categories of screening levels are presented and discussed: risk-based screening levels and occupational exposure limits.

US EPA risk-based Regional Screening Levels (RSL) are concentrations of constituents in air in residential (Residential RSL) and industrial settings (Industrial RSL) that are considered to be protective of individuals who are exposed to those concentrations over many years. 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 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). US EPA updates the RSL tables two times a year. The most recent RSL concentrations (November 2014) were used in this report.

Although the EPA RSLs for carcinogenic chemicals were derived to correspond to a cancer risk of 1 in 1 million, many States and other jurisdictions consider a cancer risk of 1 in 100,000 to be a point of departure for regulating chemicals in the environment and mitigating potential risks. For carcinogenic chemicals such as benzene, the RSL concentrations for ambient air would be ten times higher for a target cancer risk of 1 in 100,000. We have conservatively chosen to present the lower concentrations.

RSLs for chemicals that produce adverse non-cancer effects (and are also not considered to be carcinogens) are concentrations that are very unlikely to produce health effects in people who are exposed to those concentrations over many years. Non-cancer RSL concentrations were derived to correspond to a non-cancer hazard index (HI) of 1.0. For most States and jurisdictions an estimated hazard index greater than 1.0 for non-cancer health effects from potential exposures to chemicals in the ambient environment is the point of departure for further evaluation and consideration of actions to mitigate the exposure.

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. RSLs are extremely conservative and do not account for other (non-environmental) sources of exposure to the same chemicals or personal risk factors for developing disease.

Occupational Exposure Limits (OELs) published as OSHA PELs (Permissible Exposure Limits) and ACGIH TLVs (Threshold Limit Values) are presented for all constituents for which occupational exposure standards or guidelines were available. 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.

5.3.2 Ambient Air

Analytical results for all ambient air samples collected during the July 2014 event can be found in Tables 2, 3 and 4.

Fixed Gases, Hydrogen Cyanide and Mercury

Only oxygen + argon and nitrogen, the normal constituents of ambient air were detected. Hydrogen, carbon monoxide, methane, and carbon dioxide were not detected in any of the ambient air samples. Hydrogen cyanide and mercury were not detected in any ambient air sample.

Volatile Organic Compounds

The analytical results from 8-hour samples collected in 6-liter Silonite® canisters can be compared for upwind, on-landfill, and downwind fence-line locations on July 29 and 30 (Tables 2 and 3). The grab samples collected from the Road across from the excavation on July 29 and during the odor event on the morning of July 31 will be discussed separately.

Low concentrations of 2-butanone, isopropyl alcohol, acetone, acetonitrile, acrolein, benzene, carbon tetrachloride, chloromethane, dichlorodifluoromethane (Freon 12), ethanol, ethyl acetate, methylene chloride, xylenes, n-hexane, propene, toluene, trichlorfluoromethane and trichlorotrifluoroethane were found in the upwind samples from the Grassy Knoll on July 29 and or July 30.

With a few exceptions, the same compounds were detected in ambient air from the source gas locations on the Neck, North Quarry, South Quarry and Flare Station, and from the downwind fence-line locations.

The concentrations of VOCs detected in 8-hour ambient air samples from the four source gas locations were similar (within one order of magnitude) to the concentrations detected at the downwind fence-line locations and to the concentrations detected in the upwind samples collected on the same day. There were no clear patterns by compound or by location.

With the exceptions discussed below, the concentrations of all VOCs detected in 8-hour samples of ambient air (regardless of location) were less than the conservative risk-based industrial and residential RSLs. The laboratory sample MRLs were sufficiently low for all VOCs to allow meaningful comparisons of the detected concentrations to the risk-based RSL concentrations. The concentrations of all VOCs (including benzene) detected in 8-hour samples of ambient air were thousands of times less than the corresponding OSHA PEL and ACGIH TLV concentrations for workplace exposures.

- Three VOCs were detected in one or more 8-hour ambient air samples at concentrations higher than the corresponding risk-based EPA RSLs; acrolein, carbon tetrachloride, and benzene.
    - All detected concentrations of acrolein, including the concentrations in the upwind samples were higher than both the residential and industrial RSLs of 0.021 and 0.088 µg/m^3, respectively, but well below the OSHA PEL and ACGIH TLV of 250 µg/m^3.
    - The concentrations were similar in all sample locations and represent local/regional background conditions at the time the samples were collected.

  - The presence of acrolein in ambient air cannot be attributed to the landfill and is not a concern for the surrounding community.

- All detected concentrations of carbon tetrachloride, including the concentrations in the upwind samples were approximately the same as the Residential RSL (0.47 µg/m³), but less than the industrial RSL (2 µg/m³), and ten thousand times lower than the OSHA PEL (30,000 µg/m³), and ACGIH TLV (15,000 µg/m³).

  - Carbon tetrachloride is stable in the atmosphere and is almost always detected in ambient air at concentrations just below 1.0 µg/m³ (ATSDR 2005).

  - The concentrations were similar in all sample locations and represent local/regional background conditions at the time the samples were collected.

  - The presence of carbon tetrachloride in ambient air cannot be attributed to the landfill and is not a concern for the surrounding community.

- The highest concentrations of benzene detected in 8-hour samples of ambient air were 1.7 µg/m³ at the Southeast Corner (July 29) and 1.6 µg/m³ on the East Fence (July 30). Both of these locations were within 300 to 1,000 feet of the open excavation on the east slope of the landfill where the odor was noted. These concentrations are essentially identical and are equal to the industrial RSL (1.6 µg/m³), but higher than the residential RSL (0.36 µg/m³).

  - Both the industrial and residential RSL concentrations correspond to a target cancer risk of 1 in 1 million for individuals who are exposed on a daily basis over many years.

  - As mentioned in Section 5.3.2, the risk-based RSLs corresponding to a 1 in 100,000 cancer risk would be 16 µg/m³ for industrial exposure and 3.6 µg/m³ for residential exposure.

    - All concentrations of benzene detected in ambient air on the landfill and at downwind fence-line locations in July 2014 were lower than the RSL concentrations corresponding to a 1 in 100,000 cancer risk.

  - By comparison, the occupational standards for benzene are thousands of times higher than the industrial RSL, e.g. OSHA PEL = 32,000 µg/m³, and the ACGIH TLV = 1,600 µg/m³.

  - All detections of benzene exceeding the residential RSL were inside the fence-line, on-site and are not representative of off-site concentrations since they do not account for anticipated dilution in the air mass moving off of the landfill boundaries, or for contributions from other non-landfill sources in the surrounding community.

- To put the concentrations of benzene detected in ambient air into context, the annual average benzene concentration reported by the St. Louis Community Air Project (US EPA 2005) was 1.5 µg/m^3. According to US EPA (2010), for the US as a whole, the mean and 90th percentile concentrations of benzene in ambient air in 2009 were 0.85 µg/m^3 and 1.39 µg/m^3, respectively.

On July 29, a grab sample was collected in a 1-liter Silonite® canister during a period of strong odor from the open excavation (location identified as the East Fence in table 2). The objective of this sample was to determine the concentrations of VOCs and reduced sulfur compounds during a short period when the odor as very strong.

Because this was a 1-liter sample volume, the laboratory MRLs were slightly higher for the target analyte VOCs than the MRLs for the 6-liter samples. The concentrations of VOCs potentially associated with source gas in the grab sample were higher than the concentrations of the same VOCs in the 8-hour sample from the Southeast Corner on the same day (July 29) and from the East Fence on the following day (July 30) when intrusive work was still occurring.

- The concentration of benzene detected in the grab sample while the odor was intense was 370 µg/m^3.
    - However, as stated previously the concentrations of benzene in the 8-hour samples from the Southeast Corner (July 29) and the East Fence (July 30) were 1.7 and 1.6 µg/m^3, respectively.
- The grab sample does not represent long-term exposure to individuals working on the Landfill or to members of the surrounding community.
    - Risk-based screening levels and occupational exposure limits for long-term chronic exposure are not relevant comparisons for the brief exposures represented by the grab sample collected downwind of the open excavation on July 29.
- Even given the fleeting nature of the exposure, the concentration of benzene detected in the grab sample when the odor was intense was lower than either the OSHA PEL (32,000 µg/m^3) or the ACGIH TLV (1,600 µg/m^3) for an 8-hour work day over many years.
- The much lower concentrations of benzene detected in the 8-hour samples from the Southeast Corner and the East Fence reflect the transient nature of the odor and the temporal and spatial variability of the concentrations of VOCs in ambient air.

As described in Section 5.1.3 1-liter grab 1 liter Silonite® canister samples were collected upwind and downwind of the South Quarry during an odor event on July 31 associated with the exhaust from the high volume sampling units drawing source gas from the South Quarry (for dioxin/dibenzofurans and PAH analyses). As can be seen from Table 4, very few VOCs were detected and there was no difference between upwind and downwind. This could be because the misting/deodorizing spray that Bridgeton personnel quickly deployed was effective in controlling the exhaust from the high volume samplers prior to the time that the grab samples could be collected.

Aldehydes

Acetaldehyde, formaldehyde and n-hexaldehyde were detected at similar low concentrations in upwind, on-landfill, and downwind fence-line locations on both July 29 and 30 (Tables 2 and 3).

- The concentrations of acetaldehyde and formaldehyde detected in ambient air upwind, on the landfill, and downwind on July 29 and 30 were well below their respective OSHA PELs (acetaldehyde = 360,000 µg/m^3; and formaldehyde = 1,000 µg/m^3) and ACGIH TLVs (acetaldehyde = 45,000 µg/m^3; and formaldehyde = 400 µg/m^3).

- All detected concentrations of formaldehyde, including the concentrations in the upwind samples were higher than both the residential (0.22 µg/m^3) and industrial RSLs (0.94 µg/m^3).

- Detected concentrations of acetaldehyde, including the concentrations in the upwind samples were close to, or higher than the residential RSL (1.3 µg/m^3) but less than the industrial RSL (5.6 µg/m^3).

    - The concentrations of acetaldehyde and formaldehyde were similar in all sample locations and represent local/regional background conditions at the time the samples were collected.

- To put the concentrations of aldehydes detected in ambient air into context, the annual average acetaldehyde and formaldehyde concentrations reported by the St. Louis Community Air Project (US EPA 2005) were 4.8 µg/m^3 and 4.6 µg/m^3, respectively.

The presence of acetaldehyde and formaldehyde in ambient air cannot be attributed to the landfill and is not a concern for the surrounding community.

Reduced Sulfur Compounds

No reduced sulfur compounds were detected in any ambient air sample. A number of reduced sulfur compounds were detected in source gas, particularly from the South Quarry and the Flare

Inlet. However, as will be discussed in section 6.3, the laboratory MRLs are higher than the odor threshold for many of these compounds.

- Carbon disulfide and hydrogen sulfide are the only two reduced sulfur compounds for which risk-based RSLs have been derived. The laboratory MRLs for carbon disulfide were 10-100 times lower than the residential RSL (730 µg/m^3) and the industrial RSL (3,100 µg/m^3); and over 1,000 times lower than the OSHA PEL (60,000 µg/m^3) or the ACGIH TLV (3,000 µg/m^3).

- It should be noted that the laboratory sample MRLs for hydrogen sulfide were higher than the residential (2.1 µg/m^3) and industrial (8.8 µg/m^3) RSLs; but much lower than the OSHA PEL (28,000 µg/m^3) and the ACGIH TLV (1,400 µg/m^3).

- There are occupational exposure limits for carbon disulfide, ethyl mercaptan, hydrogen sulfide, methyl mercaptan and n-butyl mercaptan. The laboratory sample MRLs were well below the occupational limits for these compounds.

- The laboratory sample MRLs were sufficiently sensitive to detect any reduced sulfur compounds present in ambient air at concentrations approaching occupational exposure levels.
  - As will be further discussed in Section 6.3 of this report, the odor thresholds for the reduced sulfur target analyte compounds are lower than levels that are potentially of concern to public health.

Amines

No amines were detected in any ambient sample and were also not detected in any of the four source gas samples (Table 5).

- Triethylamine is the only amine for which risk-based screening levels have been derived. The laboratory sample MRLs were higher than the residential (7.3 µg/m^3) and the industrial (31 µg/m^3) RSLs

- The laboratory sample MRLs were lower than the OSHA PEL and ACGIH TLV for those amines with occupational exposure limits, including triethylamine.
  - As with the reduced sulfur compounds, the odor threshold for many of the amines is lower than the laboratory MRLs.

Carboxylic Acids

Carboxylic acids were not detected in any of the 8-hour upwind, on-landfill, or downwind fence-line ambient air samples, with the notable exception of the July 29 sample from the East Fence (Table 2). As explained previously, this location was approximately 300 feet immediately across from the open excavation on the east slope of the landfill.

- Butanoic acid (butyric) was detected at 6.5 µg/m^3 and hexanoic acid (caproic) was detected at 2.8 µg/m^3.

- No risk-based screening levels have been derived for the carboxylic acids.

- The laboratory sample MRLs for acetic acid were lower than the OSHA PEL (25,000 µg/m^3) and ACGIH TLV (27,000 µg/m^3). Acetic acid is the only carboxylic acid with occupational exposure levels.

- Carboxylic acids were detected in source gas from both the South Quarry and the Flare Inlet. Many of these compounds have odor thresholds below the laboratory MRLs.

PAHs

Acenaphthene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene were detected at similar low concentrations in upwind, on-landfill, and downwind fence-line ambient air. Benzo[a]pyrene and related carcinogenic PAHs associated with incomplete combustion of organic matter were not detected in ambient air or in any of the source gas samples (Table 5).

- The concentrations of all PAHs detected in ambient air from the upwind, on-landfill, and downwind fence-line were lower than the OSHA PEL and ACGIH TLV for naphthalene (50,000 µg/m^3). This occupational exposure limit is applicable to naphthalene and the associated "coal tar-pitch volatile" PAHs.

- All detected concentrations of naphthalene were lower than the residential (0.072 µg/m^3) and industrial (0.36 µg/m^3) RSLs.

- The concentrations of naphthalene and associated PAHs detected in ambient air represent local/regional background conditions at the time the samples were collected.

- The presence of naphthalene and associated PAHs in ambient air cannot be attributed to the landfill and is not a concern for the surrounding community.

Dioxins/Dibenzofurans

The same dioxin/dibenzofuran isomers were detected at similar low concentrations in upwind, on-landfill and downwind fence-line ambient air (Table 6); and in the source gas samples (Table 7).

- There are no OSHA PELs or ACGIH TLVs for dioxin/dibenzofurans isomers.
- All detected concentrations of 2,3,7,8-TCDD TEQs in ambient air were more than 100 times lower than the residential (6.4E-08 µg/m^3) and industrial (3.2E-07 µg/m^3) RSLs.
- The low concentrations of 2, 3, 7, 8-TCDD TEQs detected in ambient air represent local/regional background conditions at the time the samples were collected.
    - The average TCDD TEQ concentration in ambient air in the US is 1.11E-08 µg/m^3, and the average in urban areas is 1.5911E-08 µg/m^3 (US EPA 2013).
- The presence of low concentrations of 2, 3, 7, 8-TCDD TEQs in ambient air cannot be attributed to the landfill and are not a concern for the surrounding community.

5.3.3 Source Gas

Analytical results for the source gas samples are provided in Table 5.

There are striking differences in the numbers of constituents and the concentrations detected in the four source gas locations. The relatively lower number of constituents detected and lower concentrations of those constituents in source gas from the Neck and North Quarry supports the conclusion that these areas are not impacted by the subsurface reaction.

The sample results confirm that the subsurface reaction in the South Quarry is still active; and the results from the Flare Inlet reflect all contributions from the gas collection system. Although not directly comparable for reasons explained previously, the composition of the gas collected from the Flare Inlet is similar to the gas collected from under the EVOH at the South Quarry location. This indicates that the South Quarry is the largest contributor to the gases entering the Flare. The facility managers estimate that the South Quarry represents approximately 80% of the gas flow in the collection system entering the Flare.

Hydrogen cyanide, ammonia and amines were not detected in any of the source gas samples. The landfill is not likely to be the source of the ammonia detected in the ambient air sample from the Flare Station on July 29.

VOCs, reduced sulfur compounds and carboxylic acids are the constituents of concern detected at the highest concentrations in the South Quarry and the Flare Inlet.

Low concentrations of naphthalene, acenaphthene, and fluorene were detected in source gas from the South Quarry and Neck. Benzo[a]pyrene and related cPAHs associated with incomplete combustion of organic matter were not detected in any of the source gas samples (Table 5). The reaction in the landfill is not producing cPAHs.

No dioxin or dibenzofurans isomers were detected in the source gas from the Neck. Only OCDD was detected in the source gas from the North Quarry and the South Quarry (Table 7). The concentrations were virtually identical and approximately 10 times lower than the concentrations detected in the ambient samples. The reaction in the landfill is not contributing dioxins/dibenzofurans to the ambient air on the landfill or in the surrounding community.

6.0 COMPARISON OF 2014 SAMPLING RESULTS TO 2013 AND 2012 RESULTS

6.1 AMBIENT AIR

6.1.1 Upwind Ambient Air

Table 8 presents a summary of all constituents of concern detected in one or more samples of upwind ambient air in 2012, 2013 and 2014. These sample sets represent local/regional air quality in Bridgeton, MO during the warmer months of the year. The majority of the upwind samples were collected from locations on the Grassy Knoll to the north of the entrance road and landfill office.

VOCs

Due to the observed temporal variability of the numerous individual compounds detected in ambient air samples even on successive days (see Tables 2 and 3), for illustrative purposes year to year comparison of VOCs is made on the basis of total Target Analyte VOCs (tVOCs). The tVOC concentration in ambient air (µg/m^3) is the sum of the TO-15 target analytes actually detected in the sample. Total Tentatively Identified Compounds (tTICs) are also presented as an indicator of non-target analytes detected.

It should be noted that the most frequent use of tVOC is for evaluation of indoor air quality where the tVOC concentration can be an indicator of potential sensory irritation (European Collaborative Action, 1997). TVOCs have also been used as a crude measure of exposure by some researchers (Kim et al., 2012). The MDNR AreaRAE monitors also report total VOC concentrations although not based on concentrations of the Method TO-15 target analytes. It is not appropriate to compare tVOC concentrations based on addition of individual TO-15 analyte concentrations to the tVOC concentrations reported by the MDNR AreaRAE monitors.

The tVOC concentrations detected in upwind ambient air in 2012, 2013 and 2014 are shown in the table below. Benzene concentrations are listed in parentheses. Benzene is the VOC present in landfill source gas that is of greatest potential concern for public health; and will be discussed specifically in all sections that follow.

Total VOCs in Upwind Ambient Air (µg/m³)			
Location	**Total Target Analytes (Benzene)**	**Total TICs**	**Total VOCs**
2012			
Grassy Knoll 1	20.2 (ND)	19.2	39.4
Grassy Knoll 2	20.8 (ND)	14.9	35.7
Grassy Knoll 3	28.1 (ND)	33.1	61.2
Grassy Knoll 4	3.98 (ND)	5.4	9.4
Grassy Knoll 5	5.1 (ND)	6	11.1
Grassy Knoll 6	4.2 (ND)	5.6	9.8
2013			
Grassy Knoll 1	18.5 (ND)	205.9	224.4
Grassy Knoll 2	13.5 (ND)	123	136.5
Pond	14.4 (ND)	12.6	27
2014			
Grassy Knoll 1	39.5 (0.23)	40.3	79.8
Grassy Knoll 2	25.67 (ND)	294.5	320.17

- Benzene was detected in the upwind (Grassy Knoll 1) sample collected on July 29, 2014 at a concentration less than the residential and industrial RSLs, but not in any other upwind background sample.
    - Low concentrations of benzene (~1.0 µg/m³) are frequently detected in ambient air in urban areas.

Aldehydes

Like the VOCs, there can be considerable temporal variability in the concentrations of aldehydes detected in ambient air. Acetaldehyde and formaldehyde were the individual compounds most frequently detected in upwind samples for 2012, 2013 and 2014.

- Acetaldehyde displayed the most temporal variability.

  - Concentrations of acetaldehyde detected on August 16, 2012 were the highest reported for upwind ambient air in 2012, 2013 and 2014; and were higher than the industrial (5.6 µg/m^3) and residential (1.3 µg/m^3) RSLs.
  - Concentrations of acetaldehyde detected on the next day, August 17, 2012 were much lower (less than the industrial RSL and approximately equal to the residential RSL), and consistent with the concentrations of acetaldehyde detected in upwind ambient air in 2013 and 2014.

- Similar low concentrations of formaldehyde were detected in upwind ambient air in 2012, 2013 and 2014.
  - All detected concentrations of formaldehyde were higher than the industrial (0.94 µg/m^3) and residential (0.22 µg/m^3) RSLs.
- The conservative RSLs for acetaldehyde and especially for formaldehyde are close to the laboratory method detection limits for these compounds. Consequently, almost any detected concentration of formaldehyde will be higher than the RSL concentrations.
- Acetaldehyde and formaldehyde are ubiquitous in ambient air, particularly in urban areas.

PAHs

Acenaphthene, fluoranthene, fluorene, naphthalene, phenanthrene and pyrene were detected at similar concentrations in upwind samples from 2013 and 2014 (no sample was collected for PAHs in 2012).

- Naphthalene is the only PAH detected in upwind ambient air for which risk-based RSLs have been derived. All detected concentrations of naphthalene were less than both the industrial and residential RSLs.

Dioxins/Dibenzofurans

- 2, 3, 7, 8-TCDD TEQ concentrations were very low and similar in 2012, 2013 and 2014. All 2, 3, 7, 8-TCDD TEQ concentrations in upwind ambient air were less than both the industrial and residential RSLs.

6.1.2 Ambient Air on the Landfill

Ambient air samples were collected from locations adjacent to the source gas sampling locations in 2012, 2013, and 2014 (Figures 1, 2 and 3). Table 9 presents a summary of all constituents of concern detected in one or more on-landfill ambient air samples. The on-landfill ambient air samples characterize potential exposures to people working near the source gas areas. Trends over the three years of sampling are summarized below.

VOCs

Numerous VOCs were detected in ambient air on the landfill during all three sampling events. As explained in Section 6.1.1 tVOCs were used for year to year comparisons as presented in the following table.

Total VOCs in Ambient Air on the Landfill (µg/m³)			
Location	**Total Target Analytes (Benzene)**	**Total TICs**	**Total VOCs**
2012			
Amphitheater	39.8 (1.1)	14.9	54.7
Second Tier	26.2 (ND)	22.4	48.6
East Face	58.6 (6.2)	75.6	134.2
2013			
Amphitheater	295.3 (27)	181.8	477.1
Second Tier	86.8 (9.7)	125.2	212
2014			
Flare Station	49.9 (0.42)	65.2	115.1
North Quarry	47.8 (0.28)	31.6	79.4
Neck	33.2 (0.47)	18.8	52
South Quarry	79.9 (0.71)	67.9	147.8

- The total concentrations of target analyte VOCs, including benzene in ambient air on the landfill increased from 2012 to 2013 and then decreased in 2014.
    - The highest concentrations of tVOC target analytes and benzene were detected in ambient air at the Amphitheater location in 2013.
    - In 2014, tVOC target analyte concentrations in ambient air were similar in all four locations, although total target analytes, TICs and benzene concentrations were slightly higher at the South Quarry than the other three on-landfill locations.
- Concentrations of all individual target analyte VOCs detected in ambient air on the landfill in 2012, 2013 and 2014 were hundreds to thousands of times lower than the corresponding OSHA PEL and ACGIH TLV.

- The highest concentration of benzene detected in ambient air on the landfill was 27µg/m^3 on April 16, 2013 from the Amphitheater.
  - This concentration is lower than both the OSHA PEL (32,000 µg/m^3) and the ACGIH TLV (1,600 µg/m^3).
  - All concentrations of benzene detected in ambient air on the landfill in 2012 and 2013 were higher than the conservative industrial RSL.
  - ***In 2014, all concentrations of benzene detected in ambient air on the landfill were less than the industrial RSL and significantly lower than detected in 2012 and 2013***

Aldehydes

Acetaldehyde and formaldehyde in ambient air on the landfill were consistently detected at concentrations similar to ambient background for the same year for 2012, 2013, and 2014.

- All concentrations of acetaldehyde detected in ambient air on the landfill were thousands of times lower than both the OSHA PEL (360,000 µg/m^3) and the ACGIH TLV (45,000 µg/m^3).
  - All concentrations of formaldehyde detected in ambient air on the landfill were approximately 100 to 1,000 times lower than the OSHA PEL (1,000 µg/m^3) and the ACGIH TLV (400 µg/m^3).
- All concentrations of formaldehyde detected in ambient air on the landfill were less than ten times higher than the industrial RSL (0.94 µg/m^3).
- The concentrations of acetaldehyde and formaldehyde detected in ambient air on the landfill were similar to the contemporaneous upwind background concentrations in 2012, 2013 and 2014.
- The presence of acetaldehyde and formaldehyde in ambient air on the landfill was consistent with background and cannot be attributed to the landfill.
- The detected concentrations of acetaldehyde and formaldehyde were not a health concern for people working on the landfill in 2012, 2013 or 2014.

PAHs

Acenaphthene, fluoranthene, fluorene, naphthalene, phenanthrene and pyrene in ambient air on the landfill were detected at similar concentrations in 2012, 2013 and 2014.

- The concentrations of the PAHs in ambient air on the landfill were similar to the concentrations detected in upwind ambient air.

- ***Benzo[a]pyrene and related carcinogenic PAHs associated with incomplete combustion of organic matter were not detected in any sample of ambient air from locations on the landfill in 2012, 2013 or 2014.***

- Naphthalene was detected as a Method TO-15 target analyte at a concentration of 1.5 μg/m^3 in ambient air from the Second Tier location on May 8, 2013.

- The concentrations of naphthalene detected in high-volume samples analyzed by Method TO-13 were less than 1.0 μg/m^3 in 2012, 2013 and 2014.

- All detected concentrations of naphthalene in ambient air on the landfill were more than ten thousand times lower than the OSHA PEL and ACGIH TLV (50,000 μg/m^3); and with the exception noted previously, all concentrations of naphthalene detected in ambient air on the landfill were lower than the industrial RSL (0.36 μg/m^3).

- The presence of low concentrations of naphthalene and associated PAHs in ambient air on the landfill was consistent with background cannot be attributed to the landfill.

- The detected concentrations of naphthalene were not a health concern for people working on the landfill in 2012, 2013 or 2014.

Dioxins/Dibenzofurans

2, 3, 7, 8-TCDD TEQ concentrations in ambient air on the landfill were very low and similar in 2012, 2103 and 2014.

- There is no OSHA PEL or ACGIH TLV for 2, 3, 7, 8-TCDD TEQs.

- All TCDD TEQs detected in ambient air on the landfill in 2012, 2013 and 2014 were ten to one hundred times lower than the industrial RSL (3.2E-07 μg/m^3).

- The presence of low concentrations of TCDD TEQs in ambient air on the landfill was consistent with background (US EPA 2013) and cannot be attributed to the landfill.

- The detected low concentrations of TCDD TEQs were not a health concern for people working on the landfill in 2012, 2013 or 2014.

6.1.3 Ambient Air Downwind

Ambient air samples were collected from locations on the facility fence-line where the odor was present when sample collection was initiated. Table10 summarizes all constituents of concern detected in ambient air at downwind locations in 2012, 2013 and 2014. In 2012 and 2014, all downwind samples were collected on the facility boundary at the fence-line. In 2013, downwind samples were collected from locations off of the landfill property selected by SWAPE.

From the locations indicated on Figure 1 and Figure 2, it can be seen that the odor was most frequently present on the east, southeast and northeast boundaries of the landfill. The downwind fence-line samples collected in 2012 and 2014 were intended to represent constituents of interest in the air mass moving off of the landfill and into the surrounding community prior to mixing or dilution. It has been assumed that any contributions from landfill source gas migrating or released to the ambient air would be reflected in the concentration of constituents of concern at the fence-line.

VOCs

As explained in Section 6.1.1 tVOCs were used for year to year comparisons as presented in the following table.

Total VOCs in Ambient Air at Downwind Locations (µg/m³)			
Location	**Total Target Analytes (Benzene)**	**Total TICs**	**Total VOCs**
2012			
Pond Center	58.5 (10)	58.9	117.4
Pond East	47.3 (10)	42.2	89.5
Pond West	53.8 (16)	34.4	88.2
East Fence #1	34.5 (11)	34.6	69.1
East Fence #2	34.5 (ND)	__	34.5
South Fence	41.3 (6.1)	12.4	53.7
2013			
MSD Lift Station	110.2 (25)	147.8	258
Materialogic East	58 (12)	136.9	194.9
Northwest Auto	21.2 (0.79)	26.4	47.6
2014			
Southeast Corner (7/29)	39.1 (1.7)	40.9	80
East Fence (7/30)	50 (1.6)	34	84
Retention Pond (7/30)	34.8 (0.35)	21.7	56.5
Republic Fueling (7/30)	36.7 (ND)	22.4	59.1

The ambient downwind samples collected in 2012 and 2014 were collected on the landfill property along the fence-line and are directly comparable. The downwind samples collected in 2013 were taken from two locations on the commercial property to the southwest of the landfill in close proximity to the Metropolitan Sewer District (MSD) Lift Station and the East end of the Materialogic parking lot; and from the Northwest Auto Body (repair shop) property. Since the 2013 sample locations were not inside the facility fence-line, the results are not directly comparable to the samples collected in 2012 and 2014, but are included in the discussion.

- The VOCs most frequently detected in downwind ambient air samples from 2012, 2013 and 2014 were: acetone, acetonitrile, benzene, dichlorodifluoromethane, ethyl acetate, ethylbenzene, m, p-xylenes, propene, tetrahydrofuran, toluene, and trichlorotrifluoromethane.

- Concentrations of all detected VOCs in ambient air upwind, from locations on the landfill and downwind where an odor was noted were lower than their respective OSHA PELs or ACGIH TLVs for all compounds including benzene.

- Except for benzene, ethylbenzene, naphthalene, and trichloroethylene, the concentrations of all VOCs detected in 4-hour (2012 and 2013) and 8-hour (2014) downwind fence-line ambient air samples were lower than the corresponding industrial and residential RSLs.

- In 2012 and 2013, all concentrations of benzene detected in ambient air at downwind fence-line locations (2012) and nearby off-site locations (2013) were higher than the conservative residential RSL (0.36 µg/m^3) and all except one were also higher than the conservative industrial RSL (1.6 µg/m^3).

- In 2014, the concentrations of benzene in 8-hour ambient air samples at downwind fence-line locations were equal to the industrial RSL in the Southeast Corner (July 29, 2014) and the East Fence (July 30, 2014).
    - The concentration of benzene in downwind ambient air on the fence-line adjacent to the Retention Pond (July 30, 2014) was equal to the residential RSL and below detection limits on the fence-line adjacent to the Republic Services Fueling Facility (July 30, 2014).

- ***Although the total target analyte, total TIC and total VOC concentrations were similar for all downwind fence-line and off-site samples collected in 2012, 2013, and 2014. The detected concentrations of benzene were significantly lower in 2014 than in 2012 or 2013.***

- Ethylbenzene was detected at a concentration of 1.8 µg/m^3 at the MSD Lift Station location on May 7, 2013. This concentrations was higher than the residential RSL (1.1 µg/m^3) but lower than the industrial RSL (4.9 µg/m^3).

  - Ethylbenzene is a component of automotive fuels and low concentrations are occasionally detected in ambient air. As with other individual VOCs, ethylbenzene can exhibit temporal and spatial variability and detection depends on the presence of the compound relative to the laboratory sample quantitation limits (which are also variable).

- To put the concentrations of ethylbenzene detected in ambient air into context, the annual average concentrations reported by the St. Louis Community Air Project (US EPA 2005) ranged from 0.63 µg/m^3 to 2.33 µg/m^3.

- The low concentration of ethylbenzene detected in this sample was not a health concern for the surrounding community.

- As mentioned in Section 5.3 naphthalene was detected at an estimated concentration of 0.74J µg/m^3 as a TO-15 target analyte at the East Fence location (July 29, 2014) but was not reported above detection limits (for method TO-15) in any other downwind sample from 2012, 2013, or 2014.

- Trichloroethylene was detected at 1.0 µg/m^3 in the off-site sample from the Northwest Auto Body shop on May 8, 2013.

  - This concentration was higher than the industrial RSL (0.88 µg/m^3) and residential RSL (0.21 µg/m^3).

  - However, trichloroethylene was detected at similar concentrations in upwind, on-landfill and downwind locations on the same day.

  - The presence of similar low concentrations of trichloroethylene in all ambient air samples from the same sampling timeframe cannot be attributed to the landfill.

  - The low concentrations of trichloroethylene detected in ambient air were not a health concern for the surrounding community.

Aldehydes

Concentrations of aldehydes detected in ambient air at downwind locations were similar to upwind concentrations during the same sampling event for 2012, 2013 and 2014.

- The presence of acetaldehyde and formaldehyde in ambient air at downwind locations was consistent with background as demonstrated by upwind sampling and cannot be attributed to the landfill.

- The detected concentrations of acetaldehyde and formaldehyde were not a health concern for the surrounding community in 2012, 2013 or 2014.

PAHs

Acenaphthene, fluoranthene, fluorene, naphthalene, phenanthrene and pyrene were detected at similar concentrations by EPA Method TO-13 in ambient air at all downwind locations from 2012, 2013 and 2014.

- ***Benzo[a]pyrene and related carcinogenic PAHs associated with incomplete combustion of organic matter were not detected in any sample of ambient air from downwind locations in 2012, 2013 or 2014.***
- The presence of low concentrations of naphthalene and associated PAHs in ambient air at downwind locations was consistent with background cannot be attributed to the landfill.
- The detected concentrations of naphthalene were not a health concern for the surrounding community in 2012, 2013 or 2014.
- To put the concentrations of naphthalene detected in ambient air into context, the annual average concentration reported by the St. Louis Community Air Project (US EPA 2005) was 0.28 µg/m^3.

Dioxins/Dibenzofurans

2, 3, 7,8-TCDD equivalent concentrations in ambient air at downwind locations were very low and similar in 2012, 2103 and 2014.

- The presence of low concentrations of TCDD TEQs in ambient air at downwind locations was consistent with background (US EPA 2013) and cannot be attributed to the landfill.
- The detected low concentrations of TCDD TEQs were not a health concern for the surrounding community in 2012, 2013 or 2014.

6.2 SOURCE GAS

In 2012 and 2013, samples of landfill source gas under the FML were collected from the same three locations referred to as the Amphitheater, the Second Tier and the East Fence or Backside (Figures 2 and 3). In 2014, samples of source gas from under the EVOH were collected from the North Quarry, Neck and South Quarry; and from the source gas entering the Flare (Figure 1). Table 11 summarizes all constituents of concern that were detected in the landfill source gas in 2012, 2013 or 2014.

VOCs

From Table 11 it can be seen that the occurrence of specific VOC target analytes and TICs were highly variable between years and between sampling locations during the same year. Total VOCs and benzene are used to illustrate year to year comparisons in the following table.

Total VOCs in Source Gas ($\mu g/m^3$)			
Location	**Total Target Analytes (Benzene)**	**Total TICs**	**Total VOCs**
2012			
Amphitheater	1,646,500 (120,000)	1,064,000	2,710,500
Second Tier	1,062,800 (620,000)	1,361,000	2,423,800
East Face	876,500 (390,000)	1,422,000	2,298,500
2013			
Amphitheater	2,412,100 (370,000)	3,024,000	5,436,100
Second Tier	7,996,000 (2,000,000)	7,180,000	15,176,000
East Face	940,900 (360,000)	3,67,000	4,597,900
2014			
North Quarry	41,801(9,200)	81,200	123,001
Neck	88,632 (40,000)	138,500	227,132
South Quarry	14,262,400 (1,500,000)	71,500,000	85,762,400
Flare Inlet	9,760,300 (880,000)	93,800,000	103,560,300

- In 2012, the three reaction areas were producing similar amounts of total VOCs; the highest concentration of benzene was detected in the Second Tier (Neck).
- By 2013, the total amount of VOCs detected in source gas from all three locations had increased relative to 2012. The largest increase in total target analytes, benzene specifically, TICs and total VOCs occurred in the Second Tier (Neck).
- In 2014, the total VOC concentrations and benzene concentrations in source gas from the Neck had decreased significantly compared to the previous two years (Second Tier).
- Total target analyte and TIC concentrations in the source gas from the South Quarry were higher than the total VOC concentrations detected in the Amphitheater and East Face in 2013. As indicated previously, source gas from the Amphitheater, Second Tier and East Face represented specific locations within the larger reaction area of the South Quarry.

  - It should be specifically noted that the concentration of benzene detected in the source gas from the South Quarry in 2014 was comparable to the concentrations detected in source gas from the Second Tier in 2013.

- The source gas from the Flare Inlet represents VOCs from all areas of the gas collection system, which draws from deep within the waste mass.

  - Of the three source gas areas sampled in 2014, the South Quarry contributes the largest amount of total VOCs entering the Flare.

  - The sample results for the Flare Inlet cannot be directly compared to any of the source gas samples collected from beneath the FML in 2012 or 2013 or to the samples collected from beneath the EVOH in 2014.

Aldehydes

Although the target analyte list of aldehyde compounds is much shorter than the target analyte list for VOCs, the occurrence and concentrations of individual aldehydes in the source gas is also variable between years and sampling locations. As with the VOCs, a total of the detected concentrations of the individual aldehydes detected in samples of source gas are used to illustrate year to year comparisons. Total aldehyde concentrations detected in source gas sample from 2012, 2013 and 2014 are summarized below in μg/m^3, with (acetaldehyde; formaldehyde) concentrations in parentheses.

- The only detection of formaldehyde in source gas was from the Flare Inlet.
- Acetaldehyde was the only aldehyde detected in source gas from the North Quarry and Neck in 2014.

Total Aldehydes Detected in Source Gas (μg/m^3)

Location	Total Aldehydes - (Acetaldehyde; Formaldehyde)
	2012
Amphitheater	7,880 (1,200; ND)
Second Tier	1,800 (ND; ND)
East Face	4.032 (350; ND)
	2013
Amphitheater	20,740 (3,400; ND)
Second Tier	22,400 (120; ND)
East Face	1,680 (ND; ND)
	2014
North Quarry	49 (49; ND)
Neck	64 (64; ND)
South Quarry	13,730 (1,600; ND)
Flare Inlet	18,778 (3,000; 78)

Reduced sulfur compounds

The occurrence and concentrations of individual reduced sulfur compounds is also variable between years and sampling locations. Total reduced sulfur compound concentrations detected in source gas samples from 2012, 2013 and 2014 are summarized below in µg/m^3. Detected concentrations of hydrogen sulfide are shown in parentheses.

Total Reduced Sulfur Compounds Detected in Source Gas (µg/m^3)	
Location	**Total Reduced Sulfur Compounds – (Hydrogen Sulfide)**
	2012
Amphitheater	271,700 (ND)
Second Tier	650,187 (27)
East Face	655,147 (ND)
	2013
Amphitheater	886,220 (4,500)
Second Tier	1,656,440 (38,000)
East Face	1,162,148 (1,600)
	2014
North Quarry	7,577 (ND)
Neck	4,542 (ND)
South Quarry	1,251,300 (ND)
Flare Inlet	2,898,320 (320)

- Total reduced sulfur compounds increased in all three source gas areas from 2012 to 2013.
- In 2014, total reduced sulfur compounds in source gas from the North Quarry and Neck were similar.
    - The sample from the North Quarry represents the total concentration of reduced sulfur compounds in gas from an area that has not been involved in the subsurface reaction.
    - The Neck corresponds to the Second Tier location in 2012 and 2013. The significant decrease in reduced sulfur compounds is an indicator that the subsurface reaction has been controlled in the area proximate to the Neck, resulting in less of an impact in the area of the Neck.

- The sample from the South Quarry location represents reduced sulfur compounds in the gas between the surface of the landfill and the EVOH in the portion of the landfill where the subsurface reaction was most active in 2014. The total reduced sulfur concentration of the reaction gas in 2014 is similar to 2013, and has neither increased nor decreased significantly.
    - The average total reduced sulfur compound concentration from all three source gas areas sampled in 2013 was 1,234,936 µg/m^3 compared to 1,251,300 µg/m^3 in the gas from the South Quarry in 2014.
- The sample from the Flare Inlet represents the reduced sulfur compounds entering the flare from all parts of the gas collection system. As stated previously, approximately 80% of the gas flow to the Flare comes from the reaction in the South Quarry.
- MDNR's ambient air monitoring program includes hydrogen sulfide as a specific constituent of concern; however this compound has never been a major contributor to the total reduced sulfur concentrations in source gas.
    - In 2012, hydrogen sulfide was less than 0.5% of the total reduced sulfur concentration in source gas from the Second Tier/Neck. In 2013, hydrogen sulfide was 0.5% of the reduced sulfur total from the Amphitheater; 2.3% of the total from the Second Tier/Neck and 0.13% of the total from the East Slope.
    - Hydrogen sulfide concentrations in source gas decreased in 2014 compared to both 2012 and 2013. [2014?]
    - Hydrogen sulfide was not detected in source gas from the North Quarry, Neck or South Quarry; and contributed approximately 0.01% of the total reduced sulfur compounds in the gas from the Flare Inlet.

Carboxylic acids

Like the VOCs, aldehydes and reduced sulfur compounds, the occurrence and concentrations of individual carboxylic acid compounds is variable between years and sampling locations.

Total Carboxylic Acids Detected in Source Gas (µg/m³)	
Location	**Total Carboxylic Acids**
	2012
Amphitheater	184,780
Second Tier	ND
East Face	79,000
	2013
Amphitheater	778,470
Second Tier	1,212,770
East Face	442,900
	2014
North Quarry	ND
Neck	ND
South Quarry	389,250
Flare Inlet	1,888,600

- Total concentrations of carboxylic acids increased in all three source gas areas from 2012 to 2013. In 2014, no carboxylic acid compounds were detected in source gas from the Neck or North Quarry.

- The concentrations in source gas from the South Quarry in 2014 were similar to the total concentrations detected in source gas from the East Face in 2013.

- The sample from the Flare Inlet represents the carboxylic acid compounds entering the flare from all parts of the gas collection system.

PAHs

Total PAH concentrations detected in source gas and naphthalene concentrations in parentheses are shown in the table below.

Total PAHs Detected in Source Gas (µg/m³)	
Location	**Total PAHs (naphthalene)**
	2012
Amphitheater	43.3 (35)
Second Tier	8.8 (7.9)
East Face	13.7 (13)
	2013
Amphitheater	268 (220)
Second Tier	30.3 (30)
East Face	126.7 (120)
	2014
North Quarry	ND
Neck	5.2 (5.1)
South Quarry	301(300)
Flare Inlet	Not Sampled

- Similar low concentrations of total PAHs were detected in all three source gas locations in 2012.
- Total PAH concentrations in source gas from the Amphitheater increased from 2012 to 2013.
- Concentrations of total PAHs in source gas from the Second Tier/Neck increased slightly from 2012 to 2013 and then decreased in 2014.
- Concentrations of total PAHs in source gas from the South Quarry were similar to the concentrations detected in the source gas from the Amphitheater in 2013.
- For all source gas samples, naphthalene was the major contributor to the total concentration of PAHs detected.
- ***Benzo[a]pyrene and related carcinogenic PAHs associated with incomplete combustion of organic matter were not detected in any sample of source gas in 2012, 2013 or 2014.***

Dioxins/Dibenzofurans

- From Table 11, it can be seen that the 2,3,7,8-TCDD TEQ concentrations in source gas were within approximately the same order of magnitude for all three source gas areas for the same sampling event.
- Concentrations did not increase over time.

6.3 ODOR THRESHOLDS

Table 12 presents the lowest published odor threshold for constituents found in source gas and ambient air along with the range of laboratory Minimum Reporting Limits (MRL) for samples collected in 2014. 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.

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. Dimethyl sulfide and dimethyl disulfide were the two sulfur compounds consistently detected at the highest concentrations in the source gas samples from 2012, 2013 and 2014. Because the odor thresholds for many of the reduced sulfur compounds are below laboratory MRLs, it is reasonable to assume that some of these compounds may be present in ambient air and contribute to odors.

The carboxylic acids as a group have odors that are commonly described as “sour”, “perspiration”, “body odor”, and “cheesy”. Butanoic (butyric) and pentanoic (valeric) acid have odor thresholds that are at or below the laboratory MRLs. Concentrations of butanoic acid and hexanoic acid were detected above laboratory MRLs in the ambient air sample taken from the East Fence immediately downwind of the open excavation on the South Quarry on July 29, 2014. Butanoic acid has a very low odor threshold and is the primary compound responsible for the characteristic odor of human vomit. Because the odor thresholds for many of the carboxylic acid compounds are below laboratory MRLs, it is reasonable to assume that some of these compounds may be present in ambient air and contribute to odors.

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.

It should also be noted that a number of the TICs reported by Method TO-15 were present at high concentrations in the source gas from the South Quarry (and the gas from the Flare Inlet) in July 2014. Of particular interest from an odor perspective are compounds related to butanoic acid (e.g. 2-butanol, 3-methyl methylbutyrate, ethyl butyrate, methyl butyrate, methyl isobutyrate, and ethyl butanoate).

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.

6.4 RELATIONSHIP BETWEEN ODOR AND EXPOSURE TO CONSTITUENTS OF CONCERN

Odors from the landfill are not continuously present and are not present at the same intensity at any given location in the surrounding community. Although odors have been most frequently observed along the east, southeast corner and south border of the landfill, the odors are not continuous. A review of the MDNR daily odor monitoring reports supports this conclusion.

The presence of an odor is not synonymous with exposure to constituents associated with the reaction gas at concentrations of toxicological concern for public health. As discussed in the immediately preceding section, the groups of compounds that are the major contributors to the odor are the carboxylic acid and reduced sulfur compounds. These compounds have very low odor thresholds, but are also of a very low order of toxicity.

The relationship between odor and exposure is illustrated by comparing the ambient air sampling results collected on July 29 and July 30, 2014 immediately downwind of an open excavation on the east slope of the landfill. On those days, intermittent periods of intense odor were observed along the East Fence and in the Southeast Corner (see Figure 1). For an observer standing at a fixed location downwind of the excavation, the presence and intensity of the odor was highly variable over a matter of minutes, although some odor was noticeable most of the time. The 8-hour 6-Liter Silonite® canister samples collected from the Southeast Corner (July 29) and the East Fence (July 30) and sorbent tube samples for carboxylic acids and aldehydes from those same locations represent the potential exposure to an observer who remained in each of those locations for an eight-hour period. During that 8-hour period, the concentrations of constituents in ambient air associated with the open excavation would have fluctuated. Thus the analytical results represent the weighted average of concentrations over the sampling period.

In order to characterize potential instantaneous exposures, a 1-Liter Silonite® canister was used to collect a grab sample at a moment when the odor at the East Fence was intense. The presence of intense odors at the East Fence location during the time the samples were collected was further substantiated by detectable concentrations of butanoic and hexanoic acid.

A comparison of the concentrations of benzene detected in the two 8-hour samples to the concentration of benzene detected in the instantaneous grab sample illustrates the relationship between odor and exposure.

- The concentrations of benzene detected in the two 8-hour samples downwind of the excavation were higher than the conservative residential RSL, but equal to the industrial RSL (1.6 μg/m^3).
- A benzene concentration of 350 μg/m^3 was detected in the instantaneous grab sample collected during a moment of intense odor.
    - This finding suggests that concentrations of VOCs, particularly benzene, may occur at higher than time-weighted ambient concentrations for brief periods during strong odors and in close proximity to source gas releases.
        - It should be noted that this concentration of benzene is still well below the OSHA PEL and ACGIH TLV for an 8-hour workplace exposure.
- The 8-hour time weighted concentrations of benzene detected downwind of the open excavation are below levels of concern.
    - An individual could be exposed to this concentration of benzene 8 hours per day, 250 days per year for 25 years and not experience a cancer risk greater than 1 in 1,000,000 as a result.
    - Furthermore, additional dilution as the air mass moves off of the landfill and into the surrounding neighborhoods is not accounted for in this evaluation.
- Even the instantaneous concentration of benzene associated with the intense odor is below the US EPA Acute Exposure Guideline Levels (AEGL) for short term exposures to members of the general population during a release event: 10 minute AEGL = 130 PPM (415,300 μg/m^3); 30 minute AEGL = 73 PPM (233,200 μg/m^3); 60 minute AEGL = 52 PPM (166,120 μg/m^3); 4 hour AEGL = 18 PPM (57,500 μg/m^3); and 8 hour AEGL = 9 PPM (28,752 μg/m^3).

7.0 SUMMARY AND CONCLUSIONS

The comprehensive sampling is intended to characterize chemical constituents of concern present in the landfill source gas and ambient air that may contribute to the odors and/or are of potential concern for public health. Members of the surrounding community are not directly exposed to landfill source gas, but could be exposed to constituents in the source gas that are released to the ambient air and move off of the landfill boundaries.

The following conclusions are based on the findings of the three comprehensive sampling events conducted in August 2012, April/May 2013 and July 2014.

- Low concentrations of aldehydes, PAHs and dioxins/dibenzofurans were detected in ambient air. The following evidence indicates that the landfill is not the source of these compounds.
    - Concentrations of aldehydes, PAHs and dioxins/dibenzofurans in ambient air on the landfill and at downwind fence-line locations were similar to the concentrations in upwind ambient air for all samples collected in 2012, 2013 and 2014.
    - The concentrations of aldehydes detected in ambient air are within the background range for urban areas, including St. Louis and are not a concern for public health.
    - Benzo[a]pyrene and related carcinogenic PAHs (cPAHs) associated with incomplete combustion of organic matter have not been detected in any sample of source gas or ambient air collected in 2012, 2013, or 2014.
    - The concentrations of dioxins/dibenzofurans in landfill source gas were similar to ambient background in 2012, 2013 and 2014.
    - The concentrations of dioxins/dibenzofurans detected in ambient air are within the background range for urban areas and are not a concern for public health.
- The landfill is not a source of ammonia or hydrogen cyanide.
    - Ammonia was detected in ambient air at the Flare Station in 2014, but not in any other sample of ambient air. Ammonia has not been detected in any landfill source gas sample from 2012, 2013 or 2014.
    - Hydrogen cyanide has not been detected in any sample of ambient air or in any landfill source gas sample from 2012, 2013, or 2014.

- Mercury has not been detected in any sample of ambient air. Mercury was detected in source gas from the Flare Inlet in 2014, but has not been detected in any other landfill source gas sample from 2012, 2013 or 2014.

- Concentrations of benzene detected in ambient air from locations on the landfill and downwind locations had decreased significantly in 2014 as compared to 2012 and 2013.

    - In 2014, the concentrations of benzene detected in ambient air were consistent with average annual background in the St. Louis area and US as a whole.

- Benzene concentrations were below occupational exposure standards in all samples of ambient air from locations on the landfill and downwind in 2012, 2013 and 2014.

    - The highest benzene concentration detected in any 4-hour (2012 and 2013) or 8-hour (2014) ambient air sample from locations on the landfill or downwind locations was 27 µg/m^3 at the Amphitheater on April 16, 2013. All other detected concentrations were lower. This concentration was orders of magnitude lower than the OSHA PEL (32,000 µg/m^3) and the ACGIH TLV (32,000 µg/m^3).

- Benzene concentrations were at or below the conservative US EPA risk-based Regional Screening Level (RSL) of 1.6 µg/m^3 (or 0.0005 Parts Per Million) in all 8-hour samples of ambient air from locations on the landfill and downwind fence-line locations in 2014. The RSL was derived to correspond to a cancer risk of 1 in 1 million (1E-06) for long-term exposure to an industrial worker (8 hours per day for 250 days per year for 25 years).

    - In 2012 and 2013, concentrations of benzene exceeding the risk-based industrial RSL, but 100 to 1,000 times lower than the OSHA PEL and ACGIH TLV were detected in ambient air from locations on the landfill and downwind locations.

- Higher concentrations of benzene and other VOCs may be present for brief periods (minutes) in locations where intrusive activities into the landfill cause the release of source gas and strong odors.

    - Benzene was detected at 370 µg/m^3 in an "instantaneous grab sample" collected on July 29, 2014 during a period of intense odor. The sample was collected within 500 feet downwind of an open excavation on the east face of the landfill.

    - The concentration of benzene detected in the grab sample was lower than the OSHA PEL and the ACGIH TLV for 8-hour workplace exposures.

  - The concentrations of benzene detected in 8-hour samples in the same general location downwind of the open excavation on July 29 and July 30, 2014 were 1.7 µg/m^3 in the Southeast Corner and 1.6 µg/m^3 on the East Fence, respectively.
  - The results of these particular samples support the conclusion that even in a location close to the source where intermittent intense odors were present, the time weighted exposure to benzene over 8-hours was comparable to the conservative risk-based RSL for long-term exposures.
- The concentrations of constituents of concern detected in source gas from the Neck in July 2014 were significantly less than what was detected in samples from this general area, previously referred to as the Second Tier in 2012 and 2013.
  - The concentrations and specific groups of constituents of concern in source gas from the Neck resemble source gas from the North Quarry where the subsurface reaction is not occurring.
- The concentrations of VOCs, reduced sulfur compounds and carboxylic acids detected in source gas from the South Quarry in July 2014 were similar to the concentrations of these same groups of constituents detected in source gas from reaction areas in the Amphitheater and East Face locations in 2013. Concentrations of reduced sulfur compounds and carboxylic acids in the source gas were lower in all locations in 2012 than in 2013.
- Based on the constituents of concern detected in source gas from the South Quarry and the gas entering the Flare, the major groups of compounds contributing to the occasional odors are VOCs, reduced sulfur compounds (e.g. dimethyl sulfide and mercaptans), and carboxylic acids (e.g. butanoic and hexanoic acids).
- The constituents of concern contributing to occasional odors in the community are of low order of toxicity and do not pose a health threat to members of the community.

Recommendations

The findings from the three comprehensive sampling events conducted in August 2012, April/May 2013 and July 2014 support the following recommendations.

The two additional sampling events mandated by the Second Amended Order (June 19, 2014) should focus on the following constituents of concern present in the landfill source gas that are likely to be associated with the odor and are of greatest potential concern for public health:

- VOCs and TICs (particularly benzene)

- Reduced sulfur compounds, and
- Carboxylic acids

Continued sampling for those constituents of concern that have never been detected in landfill source gas and/or those constituents that are frequently detected in ambient air as a result of local and regional sources will not provide useful information about potential exposures to the surrounding community that can be attributed (at least in part) to releases of reaction gas from the landfill. Sampling for the following constituents should be discontinued:

- Fixed Gases
- Ammonia
- Mercury and Compounds
- Hydrogen Cyanide
- Aldehydes
- Amines
- Polycyclic Aromatic Hydrocarbons (PAHs)
- Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans (Dioxins/Dibenzofurans)

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