Health Consultation

PUBLIC COMMENT VERSION

KEYSTONE SANITARY LANDFILL

DUNMORE, LACKAWANNA COUNTY, PENNSYLVANIA

Prepared by:
Pennsylvania Department of Health

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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HEALTH CONSULTATION

PUBLIC COMMENT VERSION

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Prepared By:

Pennsylvania Department of Health
Division of Environmental Health Epidemiology
Under Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

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Summary

The Keystone Sanitary Landfill (KSL) is an active municipal solid waste collection site located at 249 Dunham Drive, Dunmore, Pennsylvania, in Lackawanna County. The landfill was built over mines known for ground subsidence and has been in operation over 40 years and has been generating electricity from the methane gas released from the landfill for the past 20 years or so. Environmental concerns have been an issue in this community. On February 17, 2015, the Pennsylvania Department of Health (PADOH) received a request from a Pennsylvania state representative and members of Friends of Lackawanna (a local non-profit organization committed to protecting the health and safety of the community) to conduct an environmental health study/evaluation of air quality surrounding the landfill. The community was concerned about harmful environmental exposures because of the landfill's operation and its future expansion. Based on these concerns, PADOH and the Agency for Toxic Substance and Disease Registry (ATSDR) began a collaboration with Pennsylvania Department of Environmental Protection (PADEP) to evaluate community concerns about potential community members' environmental exposures near the landfill, particularly focusing on evaluating air quality data near the landfill.

PADOH and ATSDR reviewed the data collected by PADEP, and provided the public health evaluation in this health consultation. The main objectives of this health consultation were to (1) determine if exposure to contaminants in ambient air surrounding the landfill poses a public health risk to the community near the landfill area under the landfill's current operating conditions, (2) evaluate available environmental information for other potential community exposure pathways of concern related to the landfill; and (3) address concerns about cancer rates in the community by summarizing the most recent cancer incidence data for the population living near the landfill.

Conclusions: PADOH and ATSDR reached the following five conclusions for the site assuming the data collection period is representative of typical conditions:

Conclusion 1

Long-term chemical exposures: PADOH and ATSDR conclude that chronic (long-term) exposure to the chemicals detected in ambient air near the landfill at the monitored locations is not expected to cause cancer or harmful non-cancer health effects under the landfill's current operating conditions.

Basis for Conclusion

- Long-term exposures to the detected contaminants concentration in ambient air near the landfill were below the levels known to cause non-cancer health effects.

- Benzene and formaldehyde were detected above ATSDR Cancer Risk Evaluation Guides (CREGs). Further analyses indicate the cancer risk estimates for these two contaminants were low and within the U.S. Environmental Protection Agency's (EPA) target cancer risk range of 1 in 1,000,000 to 1 in 10,000. These pollutants are commonly found in outdoor air and the cancer risk estimates based on community measurements were typical of exposure across similar communities in the United States.

Conclusion 2

Short-term chemical exposures: PADOH and ATSDR conclude that acute (short-term) exposure to some of the contaminants detected in ambient air near the landfill could have caused transitory health effects for sensitive populations, such as pregnant women, children, older adults and people with respiratory disease.

Basis for Conclusion

- Ammonia exceeded the acute ATSDR comparison value (CV) of 1,200 µg/m^3 once at the Mid Valley High School (MVH) location. Temporary acute health effects such as mild irritation of the eyes, nose, and throat could have occurred for some individuals, especially sensitive populations from exposure to ammonia on February 25, 2016 at the MVH location (8,000 µg/m^3). Note, issues with the sampling equipment occurred at the one-time high detection of ammonia, limiting our confidence in the maximum result for this chemical.

- Methylamine exceeded the National Oceanic and Atmospheric Administration (NOAA) odor threshold level of 26.7 µg/m^3 once at all three monitoring locations. Acute odor related health effects such as, mild irritation of the eyes, nose, throat and respiratory tract could have been experienced by some individuals, especially sensitive populations from exposure to methylamine on February 1, 2016 at the Sherwood Park (SHP) (1,100 µg/m^3) , as well as on February 4, 2016 at Keystone Sanitary Landfill (KSL) (1,200 µg/m^3) and MVH (1,200 µg/m^3) locations .

- Acetaldehyde was detected twice (on March 17, 2016 and March 29, 2016) above the odor threshold level (3 µg/m^3) at each of the three monitoring locations, with a maximum concentration of 14 µg/m^3 at KSL, 15 µg/m^3 at MVH, and 17 µg/m^3 at SHP. Acute odor-related health effects people could experience from exposure to this chemical include irritation of the eyes, skin, and respiratory tract.

- Hydrogen sulfide was detected above its odor threshold range of 0.5 – 300 ppb [ATSDR 2016]. The maximum concentrations were at 13,624 µg/m^3 (9,745 ppb) at the MVH athletic field location and at 134 µg/m^3 (96 ppb) at the working face of the landfill location during the mobile analytical unit (MAU) screening. Although, the detection limit for hydrogen sulfide in the community-based monitoring was much lower than that available with the MAU, no detections of hydrogen sulfide were observed in the community-based monitoring results.

  Additional information on effects of environmental odors on health as well as resources for residents who are concerned about odors in their community is available at https://www.atsdr.cdc.gov/odors/index.html.

Conclusion 3

Particulate matter exposures: Based on the particulate matter ($PM_{2.5}$) results from the Scranton air monitoring station, PADOH and ATSDR conclude that breathing the levels of $PM_{2.5}$ detected when the results are averaged over a long term (months or a year or more) is not expected to harm people's health. However, PADOH and ATSDR conclude that there were peak short-term (daily or 24-hour) $PM_{2.5}$ exposure concentrations that could harm people's health.

Basis for Conclusion

- The annual 2015 average (10.4 $\mu g/m^3$), the 8 months of 2016 average (8.5 $\mu g/m^3$), and the combined 2015-2016 20-month average (9.7 $\mu g/m^3$) $PM_{2.5}$ results were all either essentially at or below the World Health Organization (WHO) annual health based CV of 10 $\mu g/m^3$.

- There were daily average $PM_{2.5}$ levels of health concern in every month for sensitive populations (such as pregnant women, children, older adults and people with respiratory disease) at this location, and over half the months reviewed included daily average levels that would be of concern for sensitive groups . There were two daily average peak values (one in May 2015 and another in July 2016) that were particularly high and of health concern for all populations; note these appeared to be isolated events on a single day that were preceded and followed by days with much better air quality the rest of those months.

- All but two months over the 20-month period reviewed had at least one daily $PM_{2.5}$ average above the Environmental Protection Agency (EPA) Air Quality Index (AQI) lower range for the moderate air quality designation of 12.1 $\mu g/m^3$. The AQI level for moderate air quality reflects a level that may cause transient effects in sensitive individuals (such as pregnant women, children, older adults and people with respiratory disease). The percentage of days monitored above this short-term level per month ranged from 0 to 68%.

- Based on polar plot assessment of particulate concentration, wind direction and wind speed, $PM_{2.5}$ levels above 12 $\mu g/m^3$ were recorded for brief (less than 24-hour) durations when winds were from the southeast and in the direction of KSL.

- Overall, higher 24-hour average $PM_{2.5}$ levels were associated with very low wind speeds indicating a $PM_{2.5}$ source very close to the sensor . Annually, stronger winds from the southeast (the direction of KSL) correspond to the lowest levels of $PM_{2.5}$.

- The regulatory limits for ambient air quality in the U.S. are EPA's National Ambient Air Quality Standards (NAAQS), and these limits consider results averaged over longer time periods. The NAAQS include an annual average concentration for $PM_{2.5}$, not to exceed 12 $\mu g/m^3$, averaged over three consecutive calendar years, as well as a 24-hour average concentration not to exceed 35 $\mu g/m^3$, averaged over three consecutive calendar years. The Scranton station was in compliance for both the annual and 24-hour NAAQS $PM_{2.5}$ standards from 2014-2016.

Conclusion 4

Subsurface vapor exposures: PADOH and ATSDR conclude that a data gap exists for assessing current and future potential exposures from subsurface vapor migration from the landfill into residences (i.e., vapor intrusion). Planned changes in landfill operations (including excavation, liner construction and landfilling in an area closer to the Swinick community) could adversely impact future subsurface vapor migration pathways.

Basis for Conclusion

- The subsurface geology beneath the Swinick neighborhood is complex due to mining and other human activities that modified the subsurface in the area.
- Elevated concentrations of carbon monoxide (CO) and volatile organic compounds (VOCs) have been detected in subsurface vapors and indoor air of Swinick homes in the past, but the cause of these contaminants is not known.
- Various agency reports have given different interpretations of the significance and potential source(s) of the contaminants detected in the subsurface and indoor air in the Swinick community in the past.

Conclusion 5

Cancer incidence: PADOH and ATSDR conclude that the incidence rate for all cancers (combined) and the rates for breast cancer, melanoma, non-Hodgkin's lymphoma and prostate cancer for all six zip codes (combined) surrounding the landfill were significantly lower than the state rate. The laryngeal cancer rate in the combined zip code area was significantly higher compared to the state rate. Based on a review of peer-reviewed literature studies, there is inadequate (i.e. available studies are of insufficient quality, consistency or statistical power to decide the presence or absence of a causal association) evidence to suggest a causal link between laryngeal cancer and municipal solid waste disposal.

Basis for Conclusion

Cancer incidence rates in individual zip code areas and all the six zip codes combined were compared with the state rate by calculating standardized incidence ratios using U.S. Census and Pennsylvania cancer registry data from 2005-2014. However, cancer incidence rate analysis doesn't account for other non-environmental confounding risk factors such as heredity, occupation, diet, life style (smoking) etc., which are known to influence cancer incidence.

Recommendations

PADOH and ATSDR recommend that PADEP (1) continue to closely oversee landfill activities and enforce landfill permit regulations, including nuisance odor rules; (2) consider a fence line air monitoring program that includes publicly accessible real time results for selected limited analytes as part of the landfill's future permit requirements; (3) make publicly available the response and oversight activities that PADEP has conducted at the landfill; and (4) conduct timely responses to nuisance odor complaints and consider maintaining and posting an odor complaint log to document the frequency of odor complaints, intensity of odors, duration, odor characteristics, and weather conditions such as wind direction.

PADOH and ATSDR suggest PADEP and landfill authorities consider best practices for minimizing gull populations near KSL, including minimizing the open working face of the landfill to the extent feasible.

PADOH and ATSDR recommend that involved state and federal agencies should continue to emphasize to local authorities and community members that property owners should install and properly maintain carbon monoxide monitors in this area.

PADOH and ATSDR recommend that PADEP should consider working with the landfill to perform vapor intrusion investigations in the Swinick community to evaluate current indoor air levels of VOCs and to ensure that conditions do not change in the future after new operations commence in the historic Dunmore landfill area.

PADOH and ATSDR recommend that residents monitor air quality alerts for the area (for example, via EPA's AirNow website for the Scranton area at https://airnow.gov/index.cfm?action=airnow.local_city&mapcenter=0&cityid=608) and take protective actions as needed. This is particularly important for sensitive populations, older adults, and children.

Next Steps

PADOH and ATSDR will continue to assist PADEP, when requested with evaluation of additional environmental data from the landfill and surrounding communities.

PADOH and ATSDR will:

- Share this draft report with nearby residents and interested stakeholders, and summarize its findings and recommendations.
- Solicit public comments on this draft report as well as collect any additional health concerns and address both in the final report.
- Hold an open house to explain the findings to the residents.

Limitation of the findings

PADOH and ATSDR identified the following limitations and uncertainties in the sampling and the subsequent public health evaluation:

- The air sampling information represents ambient air quality in the community during the current operating scenario for the landfill. It does not represent air quality if the landfill expands its operations. Under the current expansion proposal, changes are anticipated that could impact the community's air quality including (1) landfill operations would move to a working face closer to residential areas; and (2) the additional weight and composition of landfilled materials might cause unknown changes in subsurface vapor conditions.

- While the agencies collaborated to be as comprehensive as feasible in the analytes included in the air monitoring, not every contaminant potentially associated with emissions from a landfill was included in the analyte list, and several contaminants had method detection limits above the ATSDR CVs and/or odor thresholds. In addition, a common odor causing landfill contaminant (hydrogen sulfide) was detected at high levels (13,624 $\mu g/m^3$ or 9,745 ppb) during one of the MAU monitoring periods, but was not detected during the community-based air monitoring. This observed difference in our monitoring data sets warrants further evaluation if strong sulfur odors are observed in the community in the future. Further, although acrolein was detected several times at all three monitoring locations, there are established data quality concerns with standard analyses for acrolein and the health agencies decided not to further evaluate acrolein.

- The community-based air monitoring occurred only for a three-month duration. The three months monitoring may not represent the full range of exposures that might occur throughout a full year. However, the selected three months do cover the time of the year when residents reported the most complaints about odors from the landfill.

- The objective of PADEP's air monitoring collaboration with the health agencies was to evaluate ambient air quality near the landfill where people are breathing the air. Hence, monitoring locations were prioritized on that basis. However, the available monitoring locations in the community were not in the direction of prevailing winds coming from the landfill. Therefore, the tradeoff in this situation was that contaminants related to landfill emissions were likely not detected at the community monitoring locations except in the less frequent times that winds were blowing opposite the prevailing direction. Lastly, sampling data were not collected at background locations for comparison to monitoring locations closest to the site.

Statement of Issues

On February 17, 2015, PADOH received a request from a Pennsylvania state representative as well as from community members to conduct an environmental health study and evaluate air quality surrounding the landfill. PADOH and ATSDR reviewed the available environmental data collected by PADEP near the landfill, and provided the public health evaluation in this health consultation.

Background

Keystone sanitary landfill is located at 249 Dunham Drive, Dunmore, Pennsylvania, in Lackawanna County. The landfill is within Dunmore and Throop boroughs adjacent to Interstate 81 and the Casey Highway 6 (Appendix A, Figures A1 and A2). The KSL spans approximately 1,000 acres, and it is one of the largest active landfills in Pennsylvania. This landfill operates under permits regulated by the PADEP, and receives approximately 7,000 tons of waste per day from Pennsylvania, New York, New Jersey and Connecticut (in person communication with KSL manager during site visit, March 10, 2015). At a site visit in 2015, landfill management characterized the composition of accepted waste as approximately 77% municipal solid wastes, 10% drill cuttings from unconventional natural gas drilling operations, 6% sludge and residual wastes, 4% flood wastes, and 3% construction and demolition wastes. KSL accepted 414,420.8, 507,180.5, 506,830.8, and 468,008.8 tons per quarter in 2015; 382,821.5, 453,615.8, 485,204.2, and 463,014.6 tons per quarter in 2016, and 371,075.8 and 461,523.5 tons per quarter in 2017 [Mcgurk 2017].

In April 2012, the landfill was approved to increase its maximum daily volume from 5,000 tons to 7,500 tons (KSL manager, personal communication during site visit, March 10, 2015). In 2014, the PADEP received an application for the Phase III expansion of the KSL. The expansion area is to be located on 435 acres within the current permit boundary and involves expanding over and between existing fill areas. The application originally proposed to increase the height of the landfill by 165 feet. Following KSL and PADEP evaluation of the application, KSL responded with new proposed landfill permit parameters, including a significant reduction in the proposed final height of the expansion and a reduction in volume and design life. Most waste as proposed in this new application will be placed in the valley between the existing disposal areas. The revised proposal would increase the facility's disposal capacity by 134 million cubic yards and expand Keystone's life-span by approximately 44 years ((PADEP Program Manager, email communication, May 1, 2017).

From February 2015 to the present, PADOH and ATSDR have been interacting with the community regarding their concerns over potential environmental contamination due to landfill operations and proposed expansion application. The community has environmental concerns related to noise, odors, dust and toxic contaminants in air due to landfill operations. Community members associate the following health concerns with the landfill: cancer, immune system disorders, nervous system disorders, birth defects, liver problems, skin problems, respiratory illnesses, muscular problems, nosebleeds, and headaches. Some community members who live near the landfill oppose the expansion of the landfill. They also have expressed concerns regarding the landfill's leachate water mixing into storm water, and odors due to activities surrounding the landfill. Additional information on community concerns is provided in Appendix B in a question and answer format.

This health consultation is principally focused on our public health evaluation of PADEP's 2016 ambient air sample results. In addition, this health consultation evaluates available data on particulate matter in ambient air in the area, subsurface investigation, as well as rates of cancer in the community. Information on PADEP's MAU air data, odor complaints in the community, surface water results, and community concerns are included in Appendices.
PADOH and ATSDR will invite the public to review this draft health consultation during the public comment review period.

Demographics

PADOH and ATSDR reviewed the population demographics within a 1-mile radius of the landfill (Appendix A, Figure A1) based on 2010 U.S. Census data. As of 2010, there were 6,794 people living within one mile of the landfill boundary. The population was 97% White, 1% Asian, and 2% other races, 6% were children (age 6 and younger), 22% were adults aged 65 and older, and 18% were females (ages 15 to 44 years). PADOH and ATSDR also reviewed the demographics nearby each monitoring station individually (Appendix A, Figures A3a-A3c). There were 3,707 people living within one mile of the KSL monitoring location, and 3,457 people living within one mile of the MVH monitoring location. Over 1,700 students attend the high school (7^{th}-12^{th} grade) and elementary school (kindergarten- 6^{th} grade) at this location. Also, there were 7,690 people living within one mile of the SHP monitoring location.

Environmental Data

Mobile Analytical Unit (MAU) Air Monitoring

As an initial screening procedure to identify contaminants in the air near the landfill, PADEP conducted air monitoring using an Open Path Fourier Transform Infrared (OPFTIR) spectrometer system on PADEP's MAU at the following six locations: SHP, MVH parking lot, MVH athletic field, Swinick neighborhood, the working face of the landfill where waste is actively deposited, and the leachate lagoon; see Appendix A, Figure A4. The first four of these locations were selected to represent where people live and work in the community, and the last two of these locations were selected as onsite potential contaminant source locations where emissions to the air would be expected to occur. MAU monitoring was conducted to identify contaminants near potential source locations on three dates: April 2015, June 2015, and March 2016. As mentioned earlier, air data from the OPFTIR method can only be helpful to instantly identify the pollutants emitted from the landfill/potential source location at the time of sampling only. This method has limited utility for public health exposure assessment because of its high detection limits and because the instantaneous readings cannot be converted into appropriate exposure values for the evaluation of potential health effects. In addition, this instrument's detection limits vary markedly from place to place due to factors such as instrument calibration, distance/angle that the electromagnetic beam traverses (beam path), deployment of beam transmission and reception, ambient air temperature, and relative humidity of air. Based on these data limitations, MAU results were not evaluated for further assessment.

A summary of the instantaneous contaminant concentrations reported from the PADEP MAU at both the offsite (community) and onsite (landfill) locations is provided in Appendix C, Table C5. Table C6 summarizes the maximum concentration of contaminants detected at the offsite (community) locations.

Community-Based Summa Canister Ambient Air Monitoring

Following the review of these MAU air monitoring data and literature on common landfill gas contaminants, PADOH, ATSDR, and PADEP selected certain contaminants for more rigorous community-based air monitoring using glass-lined summa canisters and sorbent tubes for analyzing the classes of pollutants identified as being present by the OPFTIR analysis and those known to be emitted from landfills. Both summa canisters and sorbent tubes have been extensively validated for monitoring air toxics in indoor and outdoor air. Contaminants selected for further monitoring were 75 VOCs – analyzed by method TO-15; 20 reduced sulfur compounds (e.g., mercaptan, hydrogen sulfide, carbon disulfide) analyzed by method ASTM D 5504-12; 3 carbonyls/aldehydes compounds (acetaldehyde, formaldehyde, and acrolein) analyzed by method TO-11; ammonia by modified National Institute for Occupational Safety and Health (NIOSH) 6015 method; methanol by modified NIOSH 2000 method, methylamine by Occupational Safety and Health Administration (OSHA) method 40, and triethylamine by modified OSHA method PV2060. Each sample was collected over a 24-hour period every 3 days from January – April 2016 at two community monitoring locations (MVH and SHP) and one near the landfill monitoring location (KSL) (Appendix A, Figure 3). The two community monitoring locations (MVH and SHP) were selected based on access issues and access agreements from nearby private residences. All three monitoring locations were within two miles from the active disposal area and within a mile from the permit boundary of the landfill property. A total of 90 samples were collected from all locations (30 samples from each location) and 87 valid measurements were evaluated (29 samples for each location). Photographs of the air monitoring locations and the interior of a sample box are provided in Appendix A Figures A5-A8.

These monitoring stations were deployed and operated by PADEP officials. The goal of the three-month sampling period, with locations in three directions from the landfill, and inclusive of a broad range of contaminants potentially related to the landfill, was to try to generate a representative picture of the local air quality for nearby residents.

From PADEP's odor complaints log document (Appendix C, Table C4), the maximum number of complaints occurred during the winter months. Hence, the chosen sampling period allowed us to capture air quality data during the months of greatest concerns about odors in the community.

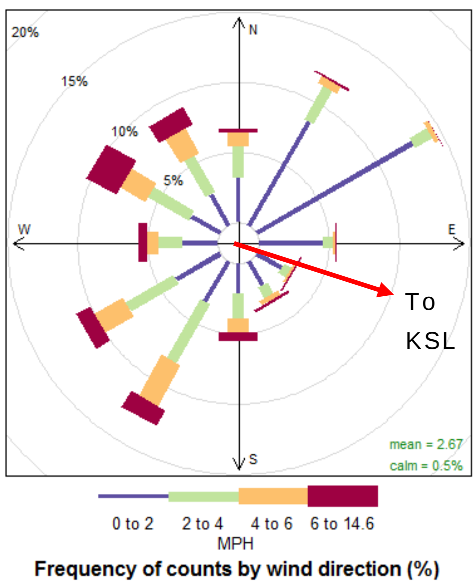
All samples were validated by checking monitoring parameters, including sampling flow rates. Duplicate samples were run randomly and were in tolerance with original samples. Sample analyses were completed by PADEP's contractor, Australian Laboratory Services, and analyzed in Cincinnati, Ohio and Simi Valley, California. PADOH and ATSDR evaluated only the validated sample results in this health consultation.

Wind Analysis

To assess the prevailing wind patterns near the landfill, PADOH and ATSDR obtained wind speed and wind direction data from the Scranton meteorological station located about 1.5 miles northwest of the landfill. ATSDR generated wind roses from the available data. A wind rose displays the statistical distribution of wind speeds and directions observed at a meteorological station. The wind rose in Figure 1 below indicates the prevailing wind direction in the area is from the northwest and southwest. Based on the prevailing wind information, the areas most likely to be affected from emissions from the current working face of the landfill are those areas located southeast and northeast of the current working face of the landfill.

As shown on Figures A3 in Appendix A, there are no residential areas and only Interstate 81 and Route 6 in the southeast and northeast direction adjacent to the landfill. The objective of PADEP's air monitoring collaboration with the health agencies was to evaluate ambient air quality near the landfill where people are breathing the air. Hence, monitoring locations were prioritized on that basis. The tradeoff in this situation was that contaminants related to landfill emissions were likely not detected at the community based monitoring locations except in the less frequent times that winds were blowing opposite the prevailing direction. Monthly and yearly wind direction patterns and additional supporting meteorological analyses are summarized in detail in Appendix D.

Figure 1: Annual Wind Rose Depicting Prevailing Wind Direction at Keystone Sanitary Landfill Based on Scranton Meteorological Station (April 2015 – April 2016)



Particulate Matter ($PM_{2.5}$) Ambient Air Monitoring

PADEP collected $PM_{2.5}$ data from the closest PADEP's Commonwealth of Pennsylvania Air Monitoring System (COPAMS) station in Scranton (Appendix D, Table D). There are several potential sources of $PM_{2.5}$ in the site area, including automobile and truck emissions on and off of the landfill, as well as industrial operations. PADOH and ATSDR evaluated regional $PM_{2.5}$ levels from PADEP's COPAMS station in Scranton from January 2015 to August 2016 in this public health evaluation to consider whether landfill operations were impacting this aspect of air quality.

Subsurface Air Quality Monitoring

PADOH and ATSDR reviewed available historical environmental data on potential subsurface impacts to indoor air quality near the KSL (Appendix E, Table E1to E3). Groundwater, residential indoor air, and sub-surface borehole sampling was conducted from 1997–2002 in the Swinick neighborhood of Dunmore by the PADEP and other agencies to evaluate subsurface levels of CO and other gases and the impact on residences. These investigations were not specifically related to the Keystone landfill site. After those investigations, a few residences were provided with permanent CO detectors and had their floor drain systems modified to prevent future gas migration into their homes; and venting of the affected subsurface areas was conducted to release CO to the atmosphere and decrease the potential for migration into the homes. The source of these subsurface gases in the community was not determined.

Cancer Registry Data

To address community's cancer health concern near the landfill, PADOH and ATSDR reviewed relevant cancer data near the landfill for the following six zip codes: 18434, 18447, 18509, 18510, 18512, and 18519 (Appendix F, Table F). Cancer incidence rates were compared for each six-individual zip code with the state rate and for all six zip codes combined with the state rate using U.S. Census and Pennsylvania cancer registry data from 2005-2014.

Health Effects Evaluation

Exposure Pathway Analysis

An exposure pathway is defined as the process by which people are exposed to or encounter chemical substances. An exposure pathway has five parts: (1) a source of contamination, (2) an environmental medium and transport mechanism, (3) a point of exposure, (4) a route of exposure, and (5) a receptor population. Generally, ATSDR considers three exposure categories: 1) completed exposure pathways, that is, all five parts of a pathway are present; 2) potential exposure pathways, that is, one or more of the parts may not be present, but information is insufficient to eliminate; and 3) eliminated exposure pathways, that is, a receptor population does not come into contact with contaminated media. Exposure pathways are used to evaluate specific ways in which people were, are, or will be exposed to environmental contamination in the past, present, and future.

Completed Exposure Pathway

Inhalation of ambient air near the landfill.

Landfills can impact air quality by emissions from the landfill migrating offsite. Emissions from a landfill can move through the landfill surface to the ambient air and be carried by wind to the community. A person's level of exposure to air contaminants from a landfill can vary depending on many factors that influence the direction, speed, and distance of migration of contaminants from the landfill. Some of these factors which may impact levels of exposure to some air contaminants include but are not limited to

- Landfill cover type,
- Natural and man-made pathways,
- Wind speed and direction,
- Moisture,
- Groundwater levels,

- Temperature, and
- Barometric and soil gas pressure

A completed exposure pathway exists through inhalation of ambient air near the landfill.

Potential Exposure Pathway
Incidental inhalation of landfill contaminants in indoor air through subsurface vapor migration (i.e. vapor intrusion)
Volatile and semi volatile landfill contaminants can migrate underground, percolate upward, and impact the indoor air of nearby buildings. Landfill operators, including at the KSL, collect gases created by the landfill to reduce the potential for migration offsite. To further evaluate this potential exposure pathway, PADOH and ATSDR reviewed available historical environmental data. A conclusive connection to any source or combination of sources (including blasting operations related to highway construction, abandoned surface and deep coal mines and related waste disposal areas underlying the community, or the landfill) was never determined. However, reviewing these historic assessments showed that future changes to operating conditions, including excavation of existing waste and landfilling activities closer to the Dunmore Swinick community, have the potential to alter preferential subsurface vapor pathways. This potential subsurface vapor exposure pathway is a data gap for public health exposure assessment. Further details on our public health review of historical information available on the subsurface pathway is provided in Appendix E.

Eliminated Exposure Pathway
Ingestion and absorption of landfill contaminants through groundwater and leachate water
Since residents in Dunmore and Throop Boroughs are connected to the public drinking water system, it can be concluded that there are no exposures associated with ingestion of groundwater contamination. Exposure from the landfill leachate water is also eliminated based on information from PADEP and from our site visits, because it appears that people do not have access to leachate on the landfill property. Contaminants detected in surface water or storm water runoff are provided in Appendix C, Table C8. More information on storm water runoff contaminants is provided in the Community Concerns Summary in Appendix B.

Data Screening and Comparison Values (CVs)

PADOH and ATSDR compared the maximum concentrations detected with available CVs to screen contaminants detected near the landfill (Table C1 in Appendix C) that are likely to cause adverse health effects. CVs are chemical and media-specific concentrations in air, soil, and drinking water that are used to identify environmental contaminants for further evaluation. CVs are conservative and non-site specific. CVs are based on health guidelines with uncertainty or safety factors applied to ensure that they are adequately protective of public health.

Concentrations above a CV will not necessarily be harmful. Contaminants that exceed a CV were further evaluated using other standards and/or scientific studies, where appropriate, to determine whether adverse health effects are likely. When an ATSDR CV is not available, screening values are acquired from other environmental and health agencies. However, the basis for values obtained from other environmental and health agencies (CARB, TCEQ and NOAA) were not reviewed/approved by ATSDR. CVs are not intended to be used as environmental clean-up levels. After screening the contaminants of potential concern, PADOH calculated an exposure point concentration (EPC) that is believed to represent typical upper bound exposure averages. A conservative EPC is the 95% upper confidence limit of the arithmetic mean (95UCL). See Appendix G for detailed information on CVs and calculations on 95UCL.

Evaluation of Community-Based Ambient Air Monitoring Data

As noted above, PADOH and ATSDR screened ambient air data to select contaminants of potential concern (COPC). These COPC were then subjected to further analyses. Appendix C, Table C1 summarizes the contaminants detected during the January through April 2016 monitoring event. The maximum concentration of the following contaminants exceeded either chronic or acute CVs: 1,4-dioxane, benzene, naphthalene, ammonia, formaldehyde, acetaldehyde, acrolein and methylamine.

Of these contaminants, 1,4-dioxane, naphthalene, ammonia, methylamine, and acetaldehyde were rarely detected and were above their respective CVs for one or two days over the entire sampling period. These infrequent and intermittent maximum concentration exposures are not considered chronic exposures. Therefore, they were not selected for further chronic health evaluation. Maximum concentrations of acrolein, benzene, and formaldehyde frequently exceeded the ATSDR CREG values. However, acrolein is a highly reactive chemical and this complicates analysis and detection. In 2010, EPA reported a study that raised significant concerns about the reliability of acrolein monitoring results using summa canisters and the currently available methods [EPA 2010]. Therefore, due to established data quality concerns with standard analyses for acrolein, the acrolein data were not further evaluated in this health consultation.

The levels detected for all the COPC were either low or below the available acute CVs, except for methylamine and ammonia. These two contaminants were selected for acute-health effects evaluation.

General health effects information on contaminants selected (benzene, formaldehyde, ammonia, methylamine and $PM_{2.5}$) for further health effects evaluation are summarized in Appendix H.

Contaminants Selected for Chronic Public Health Analysis from Community-Based Ambient Air Monitoring Data

Using the conservative EPC of 95UCL, PADOH selected two contaminants (benzene and formaldehyde) for potential chronic health effects evaluation (Table 1, see below).

Benzene

Benzene was detected at quantifiable levels in 7 out of 29 air samples at the KSL and SHP locations and 6 out of 29 air samples at the MVH location. The 95UCL was 0.57 $\mu g/m^3$ at KSL, 0.75 $\mu g/m^3$ at MVH, and 0.71 $\mu g/m^3$ at SHP. These levels exceeded the ATSDR CREG value of 0.13 $\mu g/m^3$ for cancer health effects. However, the 95UCLs at all three locations were less than 29 $\mu g/m^3$ and 9.6 $\mu g/m^3$ – the ATSDR CV for acute and chronic exposure to benzene for non-cancer health effects.

Non-cancer Exposure Evaluation
Since the 95UCLs of benzene levels measured at all three locations were less than the ATSDR acute and chronic CV, non-cancer health effects (both acute and chronic) are not expected from exposure to benzene at any of the three locations.

Cancer Exposure Evaluation
The ATSDR CREG for benzene is 0.13 µg/m^3 and is equivalent to the risk of one additional cancer per lifetime among a population of 1,000,000 exposed individuals (or the risk is equal to 0.000001). The CREG is very low given the typical cancer risk in the United States is one in two men (0.5) or one in three women (0.33)[1].

To estimate excess lifetime cancer risk from exposure to benzene from these monitoring data, the exposure concentration was multiplied by the EPA inhalation unit risk (IUR). The EPA IUR for benzene is 0.0000078 µg/m^3. Based on national average ambient air levels in rural areas (1.5 µg/m^3), PADOH estimated that an individual continuously breathing ambient air (in remote/rural areas in USA) containing benzene with a concentration of 1.5 µg/m^3 over his or her lifetime (78 years)[2] would theoretically have about a 1.2x10^{-5} or 1 in 100,000 increased chance of developing cancer. PADOH calculated the cancer risks at the benzene levels detected at KSL (0.57 µg/m^3), MVH (0.75 µg/m^3) and SHP (0.71 µg/m^3) monitoring locations. The estimated excess lifetime cancer risk for KSL was 4.4x10^{-6} or about 4 in 1,000,000 and for MVH was 5.8x10^{-6} or about 6 in 1,000,000 and for SHP was 5.5x10^{-6} or about 6 in 1,000,000 (Table 2 below). The estimated cancer risks at all three locations were less than the estimated cancer risk associated with national average ambient remote/rural outdoor air (Note: monitoring of benzene was not conducted at background locations). Therefore, residents living near KSL, MVH and SHP do not have elevated cancer risk from exposure to ambient benzene. In summary, the cancer risk estimates from exposure to benzene at all three locations were low under current operating conditions at the landfill.

[1] https://www.cancer.org/cancer/cancer-basics/lifetime-probability-of-developing-or-dying-from-cancer.html
[2] https://www.epa.gov/expobox/about-exposure-factors-handbook

Table 1. Summary of Contaminants Detected (January – April 2016) Above Comparison Values near the Keystone Sanitary Landfill, Dunmore PA ($\mu g/m^3$)

Contaminants	CV	CV Source	MDL	Monitoring Locations								
				KSL location			Community Locations					
				Landfill (KSL)			Mid Valley High School (MVH)			Sherwood Park (SHP)		
				Range	Detects/ Total samples	95 UCL	Range	Detects/ Total samples	95 UCL	Range	Detects/ Total samples	95 UCL
Benzene	9.6 0.13	cMRL CREG	0.79	<0.79 - 1.6	7/29	0.57	<0.79 - 2.6	6/29	0.75	<0.79 - 2.1	7/29	0.71
Formaldehyde	9.8 0.077	cMRL CREG	0.15	<0.15 - 6.9	26/29	2.1	<0.15 - 2.5	23/29	1.5	<0.15 - 2.3	25/29	1.5

Table 2. Cancer and Non-Cancer Risk Estimates of Contaminants Detected (January – April 2016) Above Comparison Values Near the Keystone Sanitary Landfill, Dunmore, PA ($\mu g/m^3$)

Contaminants	CV	CV Source	IUR	Monitoring Locations								
				KSL location			Community Locations					
				Landfill (KSL)			Mid Valley High (MVH)			Sherwood Park (SHP)		
				95UCL	ELCR	HQ	95UCL	ELCR	HQ	95UCL	ELCR	HQ
Benzene	9.6 0.13	cMRL CREG	7.8E-06	0.57	4.4E-06	0.1	0.75	5.8E-06	0.1	0.71	5.5E-06	0.1
Formaldehyde	9.8 0.077	cMRL CREG	1.3E-05	2.1	2.7E-05	0.2	1.5	1.9E-05	0.1	1.5	1.9E-05	0.1
Total Cancer Risk and Hazard Index					3.1E-06	0.3		2.5E-06	0.2		2.4E-06	0.2

$\mu g/m^3$ = micro gram per cubic meter; RfC = Reference Concentration; CREG = Cancer Risk Evaluation Guide; a/cMRL = acute/chronic minimum risk level; ND = Not Detected; 95UCL = 95% mean Upper Confidence Limit; MDL = Method Detection Limit; For most NDs recommended censored value of MDL/2, and for a few NDs recommended censored values of MDL/square root of 2 is used for calculating 95UCL.; For formaldehyde, there were only few non-detects, hence MDL/ square root of 2 was used, and for benzene there were only few detects, hence MDL/2 was used to calculate 95UCL CV = Comparison Value; IUR = Inhalation Unit Risk; ELCR = Excess Lifetime Cancer Risk = IUR x 95% mean UCL value; HQ = Hazard Quotient = 95UCL Air/cMRL or RfC; NA = Not Available/Applicable; An example of ELCR calculation for continuous benzene exposure for a lifetime of over 78 years at MVH location: 7.8E-06 x 0.75 = 5.8E-06

Formaldehyde

Formaldehyde was detected at quantifiable levels in 26 out of 29 air samples at KSL, 23 out of 29 air samples at MVH and 25 out of 29 air samples at SHP. The 95UCL at KSL was 2.1 µg/m^3, at MVH was 1.5 µg/m^3, and at SHP was 1.5 µg/m^3. All these levels exceeded the ATSDR CREG value of 0.077 µg/m^3 for cancer health effects. However, the 95UCLs at all three locations were less than 49 µg/m^3 and 9.8 µg/m^3 — ATSDR's CV for acute and chronic exposure respectively to airborne formaldehyde for non-cancer effects.

Non-Cancer Exposure Evaluation

The formaldehyde 95UCLs calculated for each of the three locations were less than ATSDR's acute and chronic CV of 49 µg/m^3 and 9.8 µg/m^3 respectively. Therefore, non-cancer health effects (both acute as well as chronic) are not expected from ambient air formaldehyde exposures at any of the three locations.

Cancer Exposure Evaluation

The ATSDR CREG for formaldehyde is 0.077 µg/m^3 and is equivalent to the risk of one additional cancer per lifetime among a population of 1,000,000 exposed individuals (or the risk is equal to 0.000001). The CREG is very low given the typical cancer risk in the United States is one in two men (0.5) or one in three women (0.33)[3].

To estimate excess lifetime cancer risk from exposure to formaldehyde at the detected levels during this monitoring, the 95UCL was multiplied by the EPA IUR. The EPA IUR for formaldehyde is 0.000013 per µg/m^3. Based on the average concentration of formaldehyde in U.S. suburban outdoor ambient air of 7.4 µg/m^3 (Appendix H), PADOH estimated that an individual living in a suburban environment continuously breathing ambient air containing formaldehyde (7.4 µg/m^3) over his or her lifetime would theoretically have about 9.6x10^{-5} or 10 in 100,000 increased risk of developing cancer. For indoor air containing formaldehyde at 20.91 µg/m^3 (Appendix H), the estimated cancer risk was 2.7x10^{-4} or about 3 in 10,000 increased chance of developing cancer.

PADOH calculated the excess lifetime cancer risks for formaldehyde at KSL (2.7x10^{-5} or 3 in 100,000), MVH (1.9x10^{-5} or about 2 in 100,000) and SHP (1.9x10^{-5} or about 2 in 100,000) (Table 2 above). These estimated excess lifetime cancer risks are slightly below cancer risk for typical ambient air formaldehyde exposures in the U.S. Therefore, based on the excess lifetime cancer risks, the residents living near the KSL, MVH, and SHP monitoring locations have no greater cancer risk from exposure to formaldehyde when compared to the general population of U.S. residents living in a similar environment. In summary, the cancer risk estimates from exposure to formaldehyde at all three locations were low and not expected to cause harmful cancer health effects under current operating conditions at the landfill.

[3] https://www.cancer.org/cancer/cancer-basics/lifetime-probability-of-developing-or-dying-from-cancer.html

Contaminants Selected for Acute Public Health Analysis from Community-Based Ambient Air Monitoring Data

Ammonia exceeded acute the ATSDR CV on one day at one location. Methylamine exceeded NOAA odor threshold level of 26.7 µg/m^3, on one day at all locations. However, the maximum level of methylamine detected at one location (SHP) wasn't found to coincide with the other two locations (KSL and MVH) on the same day.

Ammonia

Ammonia was detected five days out of 29 days at all three locations. The levels detected at the KSL and SHP monitoring stations were below the ATSDR acute MRL; but, at the MVH monitoring station, ammonia was detected once (8,000 µg/m^3 on February 25, 2016) exceeding the ATSDR acute CV of 1,200 µg/m^3. Note, issues with sampling equipment on a foul weather day (rain, snow, thunderstorm, 40+ mile per hour winds) were observed on the day of the high ammonia detection at MVH, which may have affected the sample reading. However, to be conservative, PADOH and ATSDR assumed the data were acceptable and evaluated this result further. The highest level detected (8,000 µg/m^3) at MVH location is about four times lower than the lowest observed adverse effect level (34,760 µg/m^3) noted in a study of human volunteers [Verberk et al. (1977)], and approximately seven times higher than the acute MRL ATSDR derived from this study. Hence, it is possible that people who are sensitive to ammonia might have experienced acute health effects such as mild irritation of the eyes, nose, and throat. These effects could have possibly lasted for a short period since exposures occurred just once over a three-month monitoring period.

Methylamine

Methylamine detected once at all three monitoring locations exceeded NOAA odor threshold level of 26.7 µg/m3. However, the levels detected at SHP (1,100 µg/m^3 on February 1, 2016) and at KSL and MVH (1,200 µg/m^3 on February 4, 2016), were about 21 - 23 times lower than the lowest level (25,407 µg/m^3) at which acute health effects were observed in an available study (Bingham et al. 2001) of people exposed to this chemical in air (see Appendix H). Uncertainty remains regarding the lowest level (25,407 µg/m^3) at which acute health effects could occur in the general population. Therefore, it is possible that exposure to methylamine at the highest levels detected on those days at all three locations could have resulted in odor induced acute health effects such as mild irritation of the nose, eyes, and throat, particularly for sensitive populations (such as pregnant women, children, older adults and people with respiratory disease).

Contaminants with Comparison Values Below the Method Detection Limit

A few contaminants that were not detected during the community-based monitoring have cancer CVs (CREG values) below the method detection limits. This included the following contaminants: vinyl chloride, 1,3-butadiene, acrylonitrile, chloroform, carbon tetrachloride, 1,2-dibromoethane, hexachlorobutadiene, and cis-dichloropropene (see Table 3 below). Therefore, we cannot make a quantitative cancer risk determination about potential exposure to these contaminants. However, non-cancer health effects from exposure to these chemicals is not expected, since the detection limits were below their respective non-cancer CV values.

Table 3: Contaminants with Comparison Values Below Method Detection Limits (µg /m^3)

Contaminants	MDL	Concentration	Health CV	Source
Acrylonitrile	0.781	ND	0.015	CREG
1,3-Butadiene	0.774	ND	0.033	CREG
Carbon tetrachloride	0.754	ND	0.17	CREG
Chloroform	0.781	ND	0.043	CREG
Cis-Dichloropropene	0.680	ND	0.25	CREG
1,2-Dibromoethane	0.768	ND	0.0017	CREG
Hexachlorobutadiene	0.778	ND	0.045	CREG
Vinyl chloride	0.792	ND	0.11	CREG

µg/m^3 = micro grams per cubic meter; CREG = Cancer Risk Evaluation Guide; ND = Not Detected; MDL = Method Detection Limit; CV = Comparison Value

Evaluation of Air Monitoring Data for Odor Symptoms

Per the information recorded in PADEP's odor complaint logs (Appendix C, Table C4), there were only six odor complaints which occurred during the air sampling period (January – April 2016). Appendix C, Table C2 shows the frequencies of three contaminants (acetaldehyde, ammonia and methylamine) that were detected above their odor threshold levels in the community-based air monitoring near the KSL using summa canisters and sorbent tubes. Note, odors in the environment can come from many sources. Also, not all odors are toxic. Toxicity depends on the substances, its exposure concentration, and the frequency and duration of exposure. If the right conditions exist, odorous contaminants can be toxic and cause health effects. Odors can also cause odor-related symptoms even if they are not causing toxicity. Odor-related symptoms people can experience from these chemicals include shortness of breath, headaches, nausea, and irritation of the eyes, nose and respiratory tract. These symptoms would have usually resolved when the odor goes away. A few sulfur compounds were detected in the MAU monitoring (particularly hydrogen sulfide) but were not detected in the community-based air monitoring. Appendix C, Table C3 shows the number of contaminants that may cause odor-related symptom but were not able detected in the community-based air monitoring due to the high detection limit. Hence, odor related symptoms cannot be discussed for these non-detects. Additional information on effects of environmental odors on health as well as resources for residents who are concerned about odors in their community is available at https://www.atsdr.cdc.gov/odors/index.html.

Acetaldehyde was detected twice at each location with a maximum concentration of 14 µg/m^3 at KSL, 15 µg/m^3 at MVH, and 19 µg/m^3 at SHP exceeding the odor threshold level of 3 µg/m^3 [Nagata 2003]. Acetaldehyde is common in landfill gases. Acetaldehyde has a pungent suffocating odor, but at dilute concentrations the odor is fruity and pleasant. Acute exposure to acetaldehyde results in irritation of the eyes, skin, and respiratory tract. Transient irritation of the eyes, nose, and throat could have resulted from brief exposures to these contaminants. The presence of acetaldehyde above the odor threshold on those days could have potentially affected nearby community's quality of life.

Ammonia was detected only once at MVH (8,000 µg/m^3) on February 25, 2016 exceeding the odor threshold range of 3,487 – 36,962 µg/m^3 [NRC 2008]. Ammonia is a corrosive irritant gas. It causes irritation of the eyes, nose, and throat at the levels detected in air. Since the detected ammonia concentration falls within the odor threshold range, exposure to ammonia on that day could have potentially affected the nearby community's quality of life, particularly sensitive populations (such as pregnant women, children, older adults and people with respiratory disease).

Methylamine was detected once at each location (1,200 µg/m^3 at KSL and MVH on February 4, 2016, and 1,100 µg/m^3 at SHP on February 1, 2016) above the odor threshold level of 26.7 µg/m^3 [NOAA 1999]. Methylamine is a colorless gas with a fish or ammonia like odor. Therefore, it is possible that exposure to methylamine at the highest levels detected on those days at all three locations could have potentially affected the nearby community's quality of life, particularly sensitive populations.

Hydrogen sulfide (H_2S) was detected only in the MAU monitoring but was not detected in the community-based air monitoring. H_2S is a colorless, flammable gas with a distinctive rotten egg odor and was detected above its odor threshold range of 5 – 300 ppb [ATSDR 2016]. The maximum concentrations were at 13,624 µg/m3 (9,745 ppb) at the MVH athletic field location and at 134 µg/m3 (96 ppb) at the working face of the landfill location during the mobile analytical unit (MAU) screening. Although, the detection limit for H_2S in the community-based monitoring was much lower than that available with the MAU, no detections of H_2S were observed in the community-based monitoring results. The short-term presence of high levels of H_2S on that one day could have adversely affected some individuals at the MVH athletic field location, especially sensitive populations.

Evaluation of $PM_{2.5}$ Ambient Air Monitoring Data

A summary of the $PM_{2.5}$ 24-hour daily maximum and monthly average monitoring results from PADEP's COPAMS station in Scranton from January 2015-August 2016 is given in Appendix D, Table D. This time period corresponds to the overall duration of all of the field activities evaluating air quality in the community near the KSL.

PADOH and ATSDR used the EPA AQI lower range for the moderate air quality designation of 12.1 µg/m^3 to screen the Scranton COPAMS data for short-term (daily 24-hour) exposures. The AQI level for moderate air quality reflects a level that may cause transient effects in sensitive populations. PADOH and ATSDR used the WHO Air Quality Guideline (AQG) of 10 µg/m^3 to screen for long-term (annual average 24-hour) exposures.

As shown in Table D, the annual average $PM_{2.5}$ concentrations in 2015 (10.4 µg/m^3) and the average of the 8 months of 2016 when our monitoring took place (8.5 µg/m^3), as well as the combined 2015-2016 average (9.7 µg/m^3) were all either at or below the WHO AQG annual value of 10 µg/m^3. This means that long term health impacts from $PM_{2.5}$ levels in this area are not expected. However, all but two months over the 20-month period reviewed had at least one 24-hour average above the short-term CV. The percentage of days monitored per month with PM2.5 values above the short-term CV ranged from 0 to 68%.There were two 24-hour average peak values (one in May 2015 and another in July 2016) that were particularly high; note these appeared to be isolated events that were preceded and superseded by days with much better air quality.

Nine out of the 20 months evaluated had the 24-hour average $PM_{2.5}$ levels in the good to moderate AQI category range. The moderate category corresponds to $PM_{2.5}$ concentrations of 12.1-35.4 μg/m^3. In the moderate AQI range, respiratory symptoms are possible in sensitive individuals, and there is possible aggravation of heart or lung disease in people with cardiopulmonary disease and older adults. EPA recommends that sensitive people should consider reducing prolonged or heavy exertion when air quality is in the moderate AQI range.

Six out of the 20 months evaluated had the 24-hour average $PM_{2.5}$ levels in the good to unhealthy for sensitive groups AQI category range, which corresponds to $PM_{2.5}$ concentrations of 35.5-55.4 μg/m^3. In the unhealthy for sensitive groups AQI range, there is an increasing likelihood of respiratory symptoms in sensitive groups including older adults, and children; aggravation of heart or lung disease and premature mortality in people with heart or lung disease. EPA recommends that people with pre-existing heart or lung disease, older adults, and children[4] should reduce prolonged or heavy exertion when air quality is unhealthy for sensitive groups in the AQI range.

Four out of the 20 months evaluated had the 24-hour average $PM_{2.5}$ levels in the good to unhealthy AQI category range. The unhealthy category corresponds to $PM_{2.5}$ concentrations of 55.5-150.4 μg/m^3. One month in the evaluation period had a single maximum result reaching the very unhealthy AQI category range. The very unhealthy category corresponds to $PM_{2.5}$ concentrations of 150.5-250.4 μg/m^3. In the unhealthy and very unhealthy AQI ranges, there is increased aggravation of respiratory symptoms in sensitive groups including older adults, and children; increased aggravation of heart or lung disease and premature mortality in people with heart or lung disease; and increased respiratory effects in general population. At these levels, EPA recommends that people with heart or lung disease, older adults, children, etc., should avoid prolonged or heavy exertion [EPA 2016].

Note, the particulate matter CVs (WHO and EPA AQI) that PADOH and ATSDR used for screening purposes in this report are lower than the regulatory requirements the Commonwealth follows for ambient air quality. The regulatory limits for ambient air quality in the U.S. are EPA's NAAQS, and these limits consider results averaged over longer time periods. The NAAQS include an annual average concentration for $PM_{2.5}$, not to exceed 12 μg/m^3, averaged over three consecutive calendar years, as well as a 24-hour average concentration not to exceed 35 μg/m^3, averaged over three consecutive calendar years [EPA 2012]. The Scranton COPAMS station was in compliance for both the annual and 24-hour NAAQS $PM_{2.5}$ standards from 2014-2016.

Evaluation of Subsurface Air Monitoring Data

A detailed summary of the available subsurface air monitoring information is provided in Appendix E. Various reports have given different levels of interpretation of the historical subsurface air monitoring results in the Swinick community neighboring KSL. A conclusive connection to any source or combinations of sources (including blasting operations related to highway construction, abandoned surface and deep coal mines and related waste disposal areas underlying the community, or the KSL) was never determined. Regardless, historical data show

[4] https://www.airnow.gov/index.cfm?action=aqibasics.aqi

several VOCs detected in boreholes installed in the site area that could be of potential concern if similar levels were detected inside the air of homes.

Residential data from the past suggested that VOC concentrations in residential areas were not as high as in boreholes. However, the past residential sampling for VOCs only included one sampling event in four homes, and the source of the VOCs (especially toluene, which was detected widely and at high levels) was never conclusively determined. Given the incompleteness of the records available on this past VOC sampling information and the fact that these data do not represent current conditions, we did not evaluate this information formally in this document.

Since the residential community was (1) constructed above a former coal mine, (2) is adjacent to a former sedimentation pond for coal washing, and (3) the residential fill, at certain depths, is of coal fines, and could produce VOCs including toluene, this issue should be further investigated because historical contamination could be an ongoing source of exposure if contaminated subsurface vapors are entering homes in the area. Although groundwater is not present in significant quantities in the upper aquifer system containing the former mine workings, it is conceivable that a previous spill could remain in pockets/fractures and that resulting volatiles could travel relatively long distances through the mine workings/fractures in the area.

Cancer Registry Data Review

PADOH and ATDSR have reviewed cancer statistics for Lackawanna County and local communities near KSL since the 1990s. Specific colorectal cancer types have been observed to be elevated in Lackawanna County and Northeast Pennsylvania overall in the past [ATSDR 1992, PADOH/ATSDR 1993, PADOH/ATSDR 1999].

Based on current community resident requests, PADOH reviewed cancer data from the Pennsylvania Cancer Registry from 2005-2014 for residents living near the landfill. Residents who were diagnosed with cancer over the period 2005-2014 while living at an address located in zip codes 18434, 18447, 18509, 18510, 18512, and 18519 were included. The following types of cancer were reviewed: bladder, brain, breast, cervix, colon, esophagus, Hodgkin's lymphoma, kidney, larynx, leukemia, liver, lung, melanoma, non-Hodgkin's lymphoma, oral cavity, ovary, pancreas, prostate, stomach, testis, thyroid, uterus and other cancer types. Cancer incidence rates were compared for each of the six individual zip codes with the state rate, and all six zip codes combined with the state rate. In summary, the majority of cancer subtypes were not significantly different from the state rate, all the zip codes combined incidence rates were significantly lower for breast cancer, melanoma, non-Hodgkin's lymphoma and prostate cancer and significantly higher for cancer of the larynx (Appendix F, Table F). Based on the American Cancer Society the common environmental risk factors for laryngeal cancer are, long and intense exposures to wood dust, paint fumes, and certain chemicals used in the metalworking, petroleum, plastics, and textile industries [ACS 2014]. Based on a review of peer-reviewed literature published between 1983-2008, Porta *et al* (2009) a study concluded that there is inadequate (i.e. available studies are of insufficient quality, consistency or statistical power to decide the presence or absence of a causal association) evidence to suggest a causal link between laryngeal cancer and municipal solid waste disposal. A detailed summary of the health outcome review of cancer in the community is provided in Appendix F.

Child Health Considerations

PADOH and ATSDR recognize that developing fetuses, infants, and children have unique vulnerabilities. PADOH and ATSDR considered potential health effects for children as part of this public health evaluation. A child's exposure can differ from an adult's in many ways. A child drinks more liquid, eats more food, and breathes more air per unit of body weight than an adult and has a larger skin surface area in proportion to body volume. A child's behavior and lifestyle also influence exposure levels. Children crawl on the floor, put things in their mouths, play closer to the ground, and spend more time outdoors. These behaviors can result in longer exposure durations and higher intake rates. Children are shorter than are adults; this means they breathe dust, soil, and vapors close to the ground. A child’s lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, access to medical care, and risk identification. Thus, adults need as much information as possible to make informed decisions regarding their children’s health.

Conclusions

PADOH and ATSDR reached the following five conclusions for the site assuming the data collection period is representative of typical conditions:

Conclusion 1

<u>Long-term chemical exposures:</u> PADOH and ATSDR conclude that chronic (long-term) exposure to the chemicals detected in ambient air near the landfill at the monitored locations is not expected to cause cancer or harmful non-cancer health effects under landfill’s current operating conditions.

Basis for Conclusion

- Long-term exposures to the detected contaminants concentration in ambient air near the landfill were below the levels known to cause non-cancer health effects.

- Benzene and formaldehyde were detected above ATSDR CREGs. Further analyses indicate the cancer risk estimates for these two contaminants were low and within the EPA’s target cancer risk range of 1 in 1,000,000 to 1 in 10,000. These pollutants are commonly found in outdoor air and the cancer risk estimates based on community measurements were typical of exposure across similar communities in the United States.

Conclusion 2

Short-term chemical exposures: PADOH and ATSDR conclude that acute (short-term) exposure to some of the contaminants detected in ambient air near the landfill could have caused transitory health effects for sensitive populations, such as pregnant women, children, older adults and people with respiratory disease.

Basis for Conclusion

- Ammonia exceeded the acute ATSDR CV (1,200 $\mu g/m^3$) once at the MVH location. Temporary acute health effects such as mild irritation of the eyes, nose, and throat could have occurred for some individuals, especially sensitive populations from exposure to ammonia on February 25, 2016 at the MVH location (8,000 $\mu g/m^3$). Note, issues with the sampling equipment occurred at the one-time high detection of ammonia, limiting our confidence in the maximum result for this chemical.

- Methylamine exceeded the NOAA odor threshold level of 26.7 $\mu g/m^3$ once at all three monitoring locations. Acute odor related health effects such as, mild irritation of the eyes, nose, throat and respiratory tract could have been experienced by some individuals, especially sensitive populations from exposure to methylamine on February 1, 2016 at SHP (1,100 $\mu g/m^3$), as well as on February 4, 2016 at KSL and MVH locations (1,200 $\mu g/m^3$).

- Acetaldehyde was detected twice (on March 17 and 29, 2016) above odor threshold level (3 $\mu g/m^3$) at each of the three monitoring locations, with a maximum concentration of 14 $\mu g/m^3$ at KSL, 15 $\mu g/m^3$ at MVH, and 17 $\mu g/m^3$ at SHP. Acute odor-related health effects people could experience from exposure to this chemical include irritation of the eyes, skin, and respiratory tract.

- Hydrogen sulfide was detected above its odor threshold range of 0.5 – 300 ppb [ATSDR 2016]. The maximum concentrations were at134 $\mu g/m^3$ (96 ppb) at the working face of the landfill location during the MAU screening. Although, the detection limit for hydrogen sulfide in the community-based monitoring was much lower than that available with the MAU, no detections of hydrogen sulfide were observed in the community-based monitoring results.

  Additional information on effects of environmental odors on health as well as resources for residents who are concerned about odors in their community is available at https://www.atsdr.cdc.gov/odors/index.html.

Conclusion 3

Particulate matter exposures: Based on the particulate matter ($PM_{2.5}$) results from the Scranton air monitoring station, PADOH and ATSDR conclude that breathing the levels of $PM_{2.5}$ detected when the results are averaged over a long term (months or a year or more) is not expected to harm people's health. However, PADOH and ATSDR conclude that there were peak short-term (daily or 24-hour) $PM_{2.5}$ exposure concentrations that could harm people's health.

Basis for Conclusion

- The annual 2015 average (10.4 μg/m^3), the 8 months of 2016 average (8.5 μg/m^3), and the combined 2015-2016 20-month average (9.7 μg/m^3) $PM_{2.5}$ results were all either essentially at or below the WHO annual health based CV of 10 μg/m^3.

- There were daily average $PM_{2.5}$ levels of health concern in every month for sensitive populations at this location, and over half the months reviewed included daily average levels that would be of concern for sensitive groups including older adults and children. There were two daily average peak values (one in May 2015 and another in July 2016) that were particularly high and of health concern for all populations; note these appeared to be isolated events on a single day that were preceded and followed by days with much better air quality the rest of those months.

- All but two months over the 20-month period reviewed had at least one daily $PM_{2.5}$ average above the EPA AQI lower range for the moderate air quality designation of 12.1 μg/m^3. The AQI level for moderate air quality reflects a level that may cause transient effects in sensitive populations. The percentage of days monitored above this short-term level per month ranged from 0 to 68%.

- Based on polar plot assessment of particulate concentration, wind direction and wind speed, $PM_{2.5}$ levels above 12 μg/m^3 were recorded for brief (less than 24-hour) durations when winds were from the southeast and in the direction of KSL.

- Overall, higher 24-hour average $PM_{2.5}$ levels were associated with very low wind speeds indicating a $PM_{2.5}$ source very close to the sensor (e.g., a source not likely KSL but potentially the nearby Interstate 81 highway, agricultural or construction activity, or other nearby sources of particulate matter). Annually, stronger winds from the southeast (the direction of KSL) correspond to the lowest levels of $PM_{2.5}$.

- The regulatory limits for ambient air quality in the U.S. are EPA's NAAQS, and these limits consider results averaged over longer time periods. The NAAQS include an annual average concentration for $PM_{2.5}$, not to exceed 12 μg/m^3, averaged over three consecutive calendar years, as well as a 24-hour average concentration not to exceed 35 μg/m^3, averaged over three consecutive calendar years. The Scranton station was in compliance for both the annual and 24-hour NAAQS $PM_{2.5}$ standards from 2014-2016.

Conclusion 4

Subsurface vapor exposures: PADOH and ATSDR conclude that a data gap exists for assessing current and future potential exposures from subsurface vapor migration from the landfill to residences (i.e., vapor intrusion). Planned changes in landfill operations (including excavation, liner construction and landfilling in an area closer to the Swinick community) could adversely impact future subsurface vapor migration pathways.

Basis for Conclusion

- The subsurface geology beneath the Swinick neighborhood is complex due to mining and other human activities that modified the subsurface in the area.
- Elevated concentrations of CO and VOCs have been detected in subsurface vapors and indoor air of Swinick homes in the past, but the cause of these contaminants is not known.
- Various agency reports have given different interpretations of the significance and potential source(s) of the contaminants detected in the subsurface and indoor air in the Swinick community in the past.

Conclusion 5

Cancer incidence: PADOH and ATSDR conclude that the incidence rate for all cancers (combined) and the rates for breast cancer, melanoma, non-Hodgkin's lymphoma and prostate cancer for all six zip codes (combined) surrounding the landfill were significantly lower than the state rate. The laryngeal cancer rate in the combined zip code area was significantly higher compared to the state rate. Based on a review of peer-reviewed literature study, there is inadequate (i.e. available studies are of insufficient quality, consistency or statistical power to decide the presence or absence of a causal association) evidence to suggest a causal link between laryngeal cancer and municipal solid waste disposal.

Basis for Conclusion

Cancer incidence rates in individual zip code areas and all the six zip codes combined were compared with the state rate by calculating standardized incidence ratios using U.S. Census and Pennsylvania cancer registry data from 2005-2014. However, cancer incidence rate analysis doesn't account for other non-environmental confounding risk factors such as heredity, occupation, diet, life style (smoking) etc., which are known to influence cancer incidence.

Limitations

PADOH and ATSDR identified the following limitations and uncertainties in the sampling and the subsequent public health evaluation:

- The air sampling information represents ambient air quality in the community during the current operating scenario for the landfill. It does not represent air quality if the landfill expands its operations. Under the current expansion proposal, changes are anticipated that could impact the community's air quality including (1) landfill operations would move to a working face closer to residential areas; and (2) the additional weight and composition of landfilled materials might cause unknown changes in subsurface vapor conditions.

- While the agencies collaborated to be as comprehensive as feasible in the analytes included in the air monitoring, not every contaminant potentially associated with emissions from a landfill was included in the analyte list, and several contaminants had method detection limits above the ATSDR CVs and/or odor thresholds. In addition, a common odor causing landfill contaminant (hydrogen sulfide) was detected at high levels (13,624 µg/m^3 or 9,745 ppb) during one of the MAU monitoring periods, but was not detected during the community-based air monitoring. This observed difference in our monitoring data sets warrants further evaluation if strong sulfur odors are observed in the community in the future. Further, although acrolein was detected several times at all three monitoring locations, there are established data quality concerns with standard analyses for acrolein and the health agencies decided not to further evaluate acrolein.

- The community-based air monitoring occurred only for a three-month duration. The three months monitoring may not represent the full range of exposures that might occur throughout a full year. However, the selected three months do cover the time of the year when residents reported the most complaints about odors from the landfill.

- The objective of PADEP's air monitoring collaboration with the health agencies was to evaluate ambient air quality near the landfill where people are breathing the air. Hence, monitoring locations were prioritized on that basis. However, the available monitoring locations in the community were not in the direction of prevailing winds coming from the landfill. Therefore, the tradeoff in this situation was that contaminants related to landfill emissions were likely not detected at the community monitoring locations except in the less frequent times that winds were blowing opposite the prevailing direction. Lastly, sampling data were not collected at background locations for comparison to monitoring locations closest to the site.

Recommendations

PADOH and ATSDR recommend that PADEP (1) continue to closely oversee landfill activities and enforce landfill permit regulations, including nuisance odor rules; (2) consider a fence line air monitoring program that includes publicly accessible near real time results for selected limited analytes as part of the landfill's future permit requirements; (3) make publicly available the response and oversight activities that PADEP has conducted at the landfill; and (4) conduct timely responses to nuisance odor complaints and consider maintaining and posting an odor complaint log to document the frequency of odor complaints, intensity of odors, duration, odor characteristics, and weather conditions such as wind direction.

PADOH and ATSDR suggest PADEP and landfill authorities consider best practices for minimizing gull populations near KSL, including minimizing the open working face of the landfill to the extent feasible.

PADOH and ATSDR recommend that involved state and federal agencies should continue to emphasize to local authorities and community members that property owners should install and properly maintain carbon monoxide monitors in this area.

PADOH and ATSDR recommend that PADEP should consider working with the landfill to perform vapor intrusion investigations in the Swinick community to evaluate current indoor air levels of VOCs and to ensure that conditions do not change in the future after new operations commence in the historic Dunmore landfill area.

PADOH and ATSDR recommend that residents monitor air quality alerts for the area (for example, via EPA's AirNow website for the Scranton area at https://airnow.gov/index.cfm?action=airnow.local_city&mapcenter=0&cityid=608) and take protective actions as needed. This is particularly important for sensitive populations, such as pregnant women, children, older adults and people with respiratory disease.

Next Steps

PADOH and ATSDR will continue to assist PADEP, when requested with evaluation of additional environmental data from the landfill and surrounding communities.

PADOH and ATSDR will:

- Share this draft report with nearby residents and interested stakeholders, and summarize its findings and recommendations.
- Solicit public comments on this draft report as well as collect any additional health concerns and address both in the final report.
- Hold an open house to explain the findings to the residents.

Report Preparers

Author
Sasidevi Arunachalam, MS PHS,
Health Assessment Program
Bureau of Epidemiology,
Division of Environmental Health Epidemiology
Pennsylvania Department of Health

Principle Investigator
Farhad Ahmed, MBBS, MPH,
Health Assessment Program
Bureau of Epidemiology,
Division of Environmental Health Epidemiology
Pennsylvania Department of Health

ATSDR Regional Representative
Robert H. Helverson, MS
Region Representative
Division of Community Health Investigations
Agency for Toxic Substances and Disease Registry

Centers for Disease Control and Prevention

ATSDR Region 3 Director
Lora Siegmann Werner, MPH
Regional Director
Division of Community Health Investigations
Agency for Toxic Substances and Disease Registry
Centers for Disease Control and Prevention

Technical Project Officer
Robert E. Robinson, MBA
Environmental Health Scientist
Division of Community Health Investigations
Agency for Toxic Substances and Disease Registry
Centers for Disease Control and Prevention

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Mcgurk, T. E-mail to L. Werner of the Agency for Toxic Substances and Disease Registry et al. RE: We are finally going to Scranton medical school today at 12:15. Thursday, August 17, 2017 2:40 pm.

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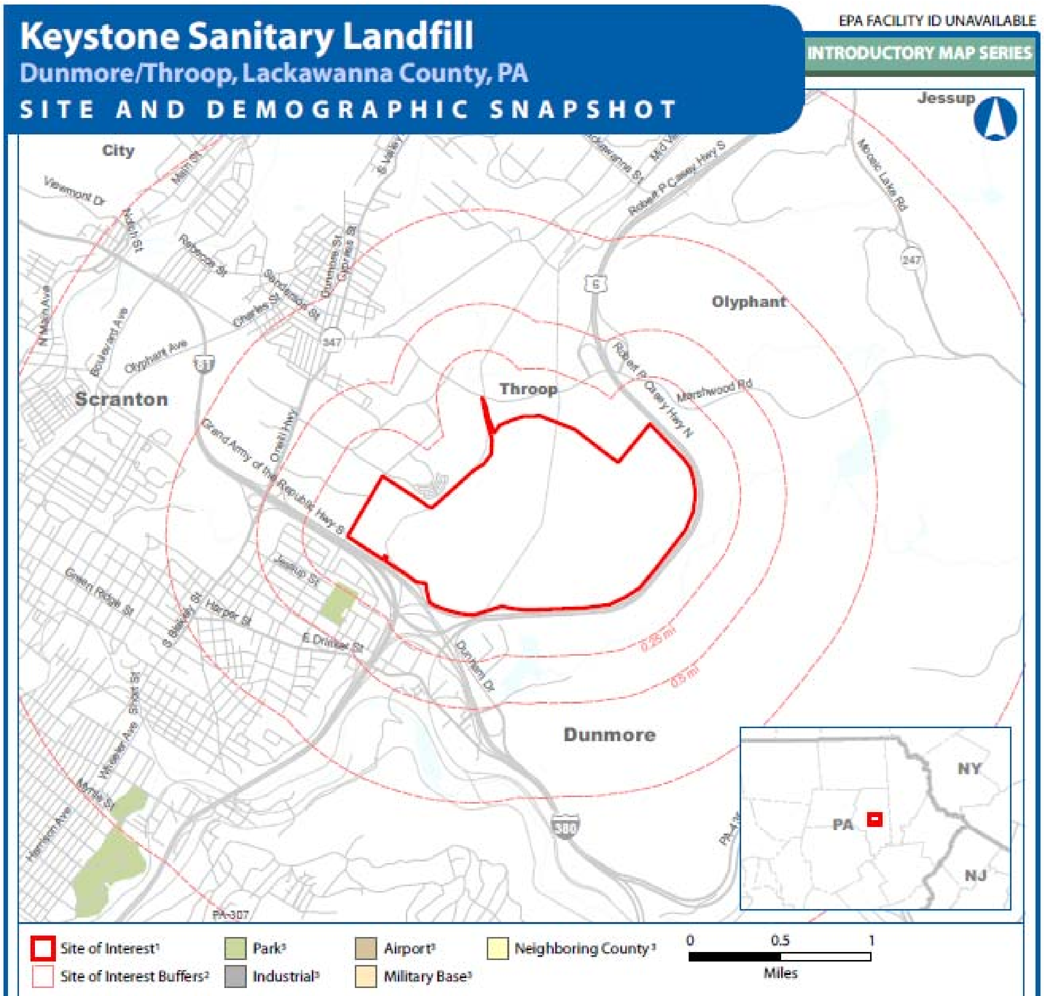
Appendix A

Maps and Photographs

Figure A1: Site Location and Demographics



Demographic Statistics[4,5]

Within 1 Miles buffer of site boundary

Measure	2000	2010	Change	Measure	2000	2010	Change
Total Population	7,259	6,794	-6%	Two or More Races	30	59	+96%
White Alone	7,177	6,583	-8%	Hispanic or Latino[6]	52	107	+105%
Black Alone	26	38	+46%	Children Aged 6 and Younger	510	409	-19%
Am. Indian & AK Native Alone	2	3	+50%	Adults Aged 65 and Older	1,719	1,502	-12%
Asian Alone	17	71	+317%	Females Aged 15 to 44	1,367	1,237	-9%
Native Hawaiian & Other Pacific Islander Alone	2	0	-100%	Housing Units	3,361	3,317	-1%
Some Other Race Alone	7	41	+485%	Housing Units Pre 1950	5,500	2,346	-57%

Data Sources: [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]TomTom International BV (2012). [4]US Census 2010.
Notes: [5]Calculated using area-proportion spatial analysis method. [6]Individuals identifying origin as Hispanic or Latino may be of any race.
Projection: NAD 1983 StatePlane Pennsylvania North FIPS 3701 Feet.

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Figure A2: KSL and Municipal Boundaries (Dunmore and Throop Boroughs)

Figure A3: Summa Canister and Sorbent Tube Monitoring Locations (KSL, MVH, and SHP) and Scranton Meteorological Station

Figure A3a: KSL Monitoring Location Demographics

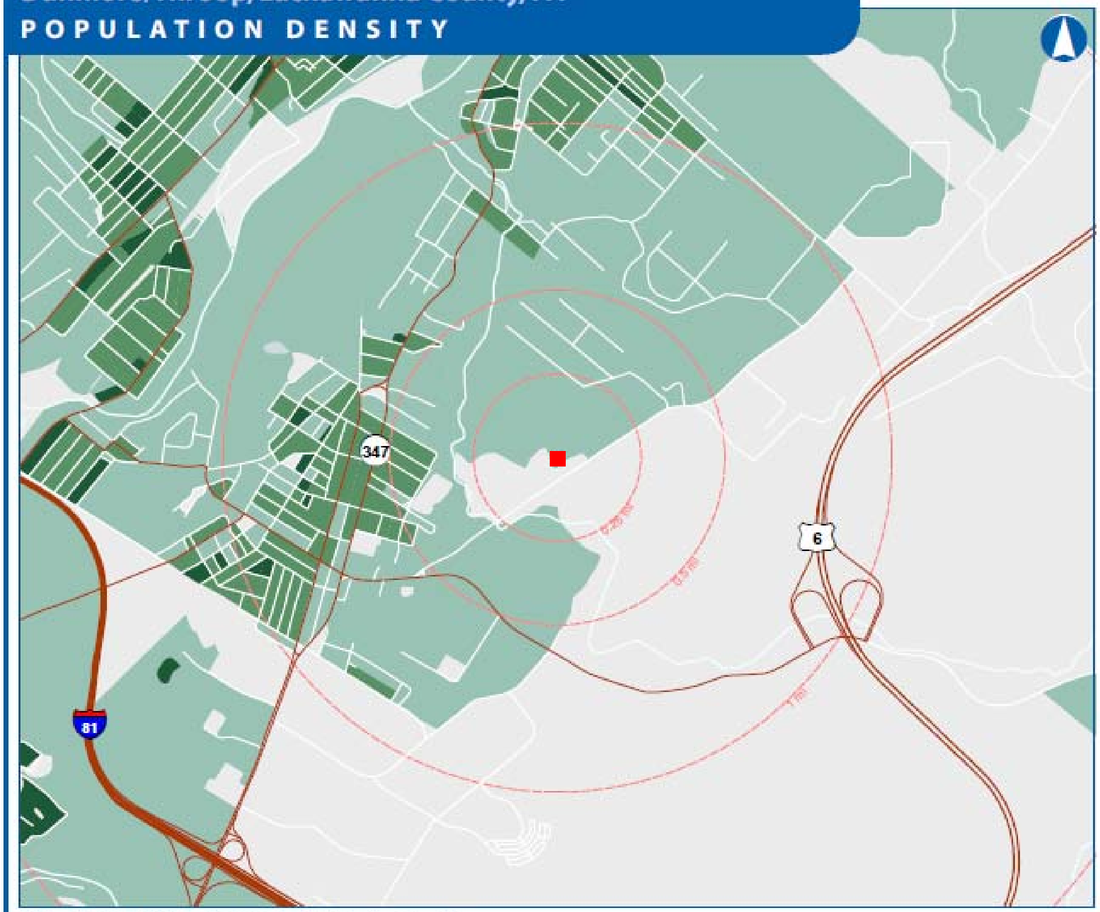
Keystone Sanitary Landfill

Dunmore/Throop, Lackawanna County, PA

POPULATION DENSITY

EPA FACILITY ID UNAVAILABLE

INTRODUCTORY MAP SERIES



The **Population Density Map** depicts the site of interest and the distribution and number of people residing in the surrounding community. The distribution of population in and around a site is critical to understanding a community's potential for exposure to hazardous substances.

Based on US Census 2010 statistics, **106,770** individuals reside within a **5-mile buffer** of the site of interest.

Site of Interest

- Site of Interest[1]
- Site of Interest Buffers[2]

Population Density by Census Block[3] (No. per sq. mi.)

- Zero
- 0 to 5,000
- 5,000 to 10,000
- > 10,000

Healthcare Facilities

- Hospitals[4]
- Urgent Care[5]

Total Population[3,6]
Within specified distance of site boundary

Distance	2000	2010	Change
0.25 mile	2	53	+2550%
0.50 mile	398	543	+36%
1 mile	3,448	3,707	+7%
3 miles[7]	49,589	48,088	-3%
5 miles[7]	106,917	106,770	+0%

Data Sources: [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]US Census 2010. [4]Oak Ridge National Laboratory (2013).[5] TomTom International BV (2012).
Notes: [6]Calculated using area-proportion spatial analysis method. [7]Buffer not shown.
Projection: NAD 1983 StatePlane Pennsylvania North FIPS 3701 Feet.

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Figure A3b: MVH Monitoring Location Demographics

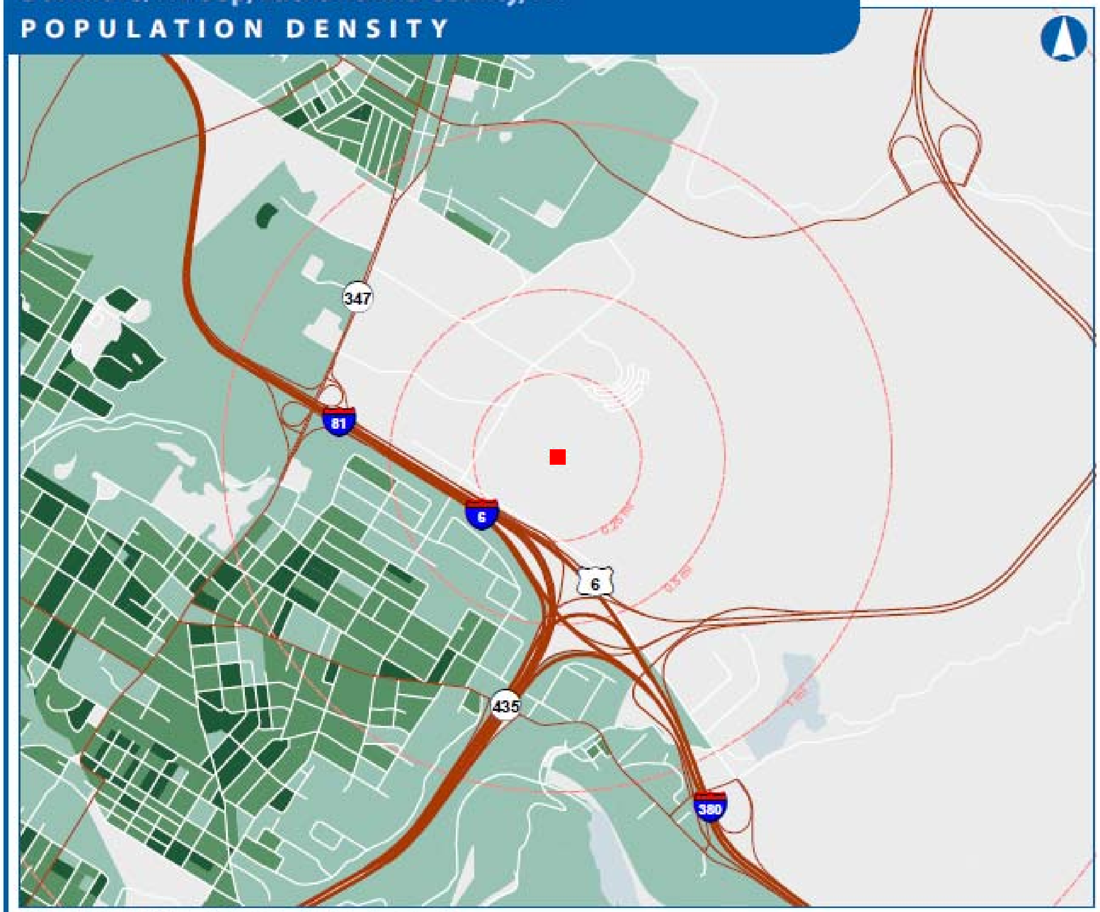
Midvalley School

Dunmore/Throop, Lackawanna County, PA

POPULATION DENSITY

EPA FACILITY ID: UNAVAILABLE

INTRODUCTORY MAP SERIES



The **Population Density Map** depicts the site of interest and the distribution and number of people residing in the surrounding community. The distribution of population in and around a site is critical to understanding a community's potential for exposure to hazardous substances.

Based on US Census 2010 statistics, **119,354** individuals reside within a **5-mile buffer** of the site of interest.

Site of Interest

- Site of Interest[1]
- Site of Interest Buffers[2]

Population Density by Census Block[3] (No. per sq. mi.)

- Zero
- 0 to 5,000
- 5,000 to 10,000
- > 10,000

Healthcare Facilities

- Hospitals[4]
- Urgent Care[5]

Total Population[3,6]
Within specified distance of site boundary

Distance	2000	2010	Change
0.25 mile	0	0	+0%
0.50 mile	263	264	+0%
1 mile	3,685	3,457	-6%
3 miles[7]	59,073	58,212	-1%
5 miles[7]	119,630	119,354	+0%

Data Sources: [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]US Census 2010. [4]Oak Ridge National Laboratory (2013).[5] TomTom International BV (2012).
Notes: [6]Calculated using area-proportion spatial analysis method. [7]Buffer not shown.
Projection: NAD 1983 StatePlane Pennsylvania North FIPS 3701 Feet.

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Figure A3c: SHP Monitoring Location Demographics

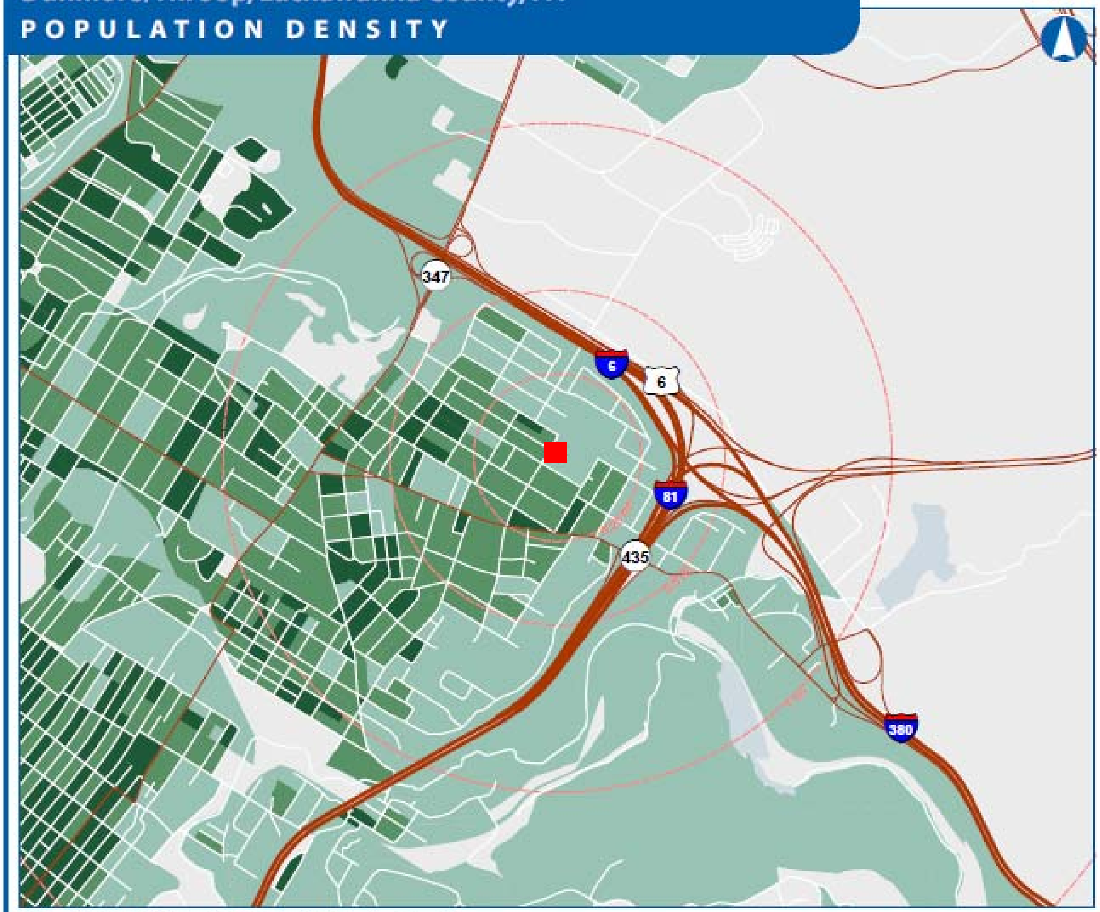
EPA FACILITY ID: UNAVAILABLE

INTRODUCTORY MAP SERIES

Sherwood Park

Dunmore/Throop, Lackawanna County, PA

POPULATION DENSITY



The **Population Density Map** depicts the site of interest and the distribution and number of people residing in the surrounding community. The distribution of population in and around a site is critical to understanding a community's potential for exposure to hazardous substances.

Based on US Census 2010 statistics, **118,944** individuals reside within a **5-mile buffer** of the site of interest.

Site of Interest

- Site of Interest[1]
- Site of Interest Buffers[2]

Population Density by Census Block[3] (No. per sq. mi.)

- Zero
- 0 to 5,000
- 5,000 to 10,000
- > 10,000

Healthcare Facilities

- Hospitals[4]
- Urgent Care[5]

Total Population[3,6]

Within specified distance of site boundary

Distance	2000	2010	Change
0.25 mile	1,185	1,099	-7%
0.50 mile	3,298	3,093	-6%
1 mile	8,181	7,690	-6%
3 miles[7]	64,032	63,657	+0%
5 miles[7]	119,249	118,944	+0%

Data Sources: [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]US Census 2010. [4]Oak Ridge National Laboratory (2013).[5] TomTom International BV (2012).
Notes: [6]Calculated using area-proportion spatial analysis method. [7]Buffer not shown.
Projection: NAD 1983 StatePlane Pennsylvania North FIPS 3701 Feet.

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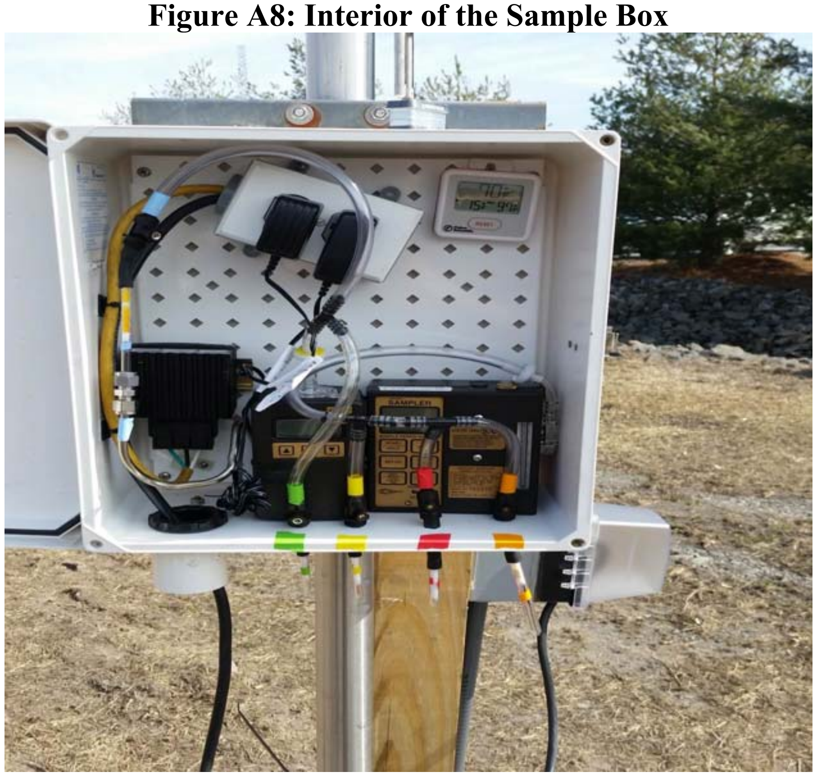
Figure A4: Mobile Analytical Unit (MAU) Sampling Locations

Figure A5: Keystone Sanitary Landfill Sampler

Figure A6: Mid Valley High School Sampler

Figure A7: Sherwood Park Sampler

Figure A8: Interior of the Sample Box



Appendix B

Community Concerns Summary

PADOH and ATSDR Region 3 (ATSDR R3) addressed the following community concerns questions we gathered during our site visits and phone calls.

Have public health agency staff visited the landfill and met with community members?

PADOH, ATSDR and PADEP made several site visits to the landfill to observe current site conditions, identify monitoring and sampling locations, meet with community members, participate in public availability sessions, and attend public meetings. On March 10, 2015, staff from each agency conducted a visit to the landfill to observe the current site conditions and activities. The landfill management provided a bus tour of the 1,000-acre landfill, including the active "open face" where waste is being dumped.

On April 27, 2015, the agency staff (PADOH, ATSDR, and PADEP) in conjunction with an odor science specialist from the Monell Chemical Senses Centre attended an open house public availability meeting to speak with residents about their concerns. On May 5, 2015, PADOH and ATSDR provided an update and answered questions via conference call with the Lackawanna County Medical Society. On June 17, 2015, the three agencies made a second site visit, near the landfill, to the Dunmore reservoir and Scranton Sewer facility. The agencies also conducted a site visit on February 25, 2016, to observe the three monitoring locations near the landfill and meet with concerned community members. On March 8, 2016 ATSDR met with concerned community members at a Green Ridge Neighbors Association meeting.

How have the health agencies and PADEP been coordinating on this evaluation?

From February 2015 through May 2016, PADOH had weekly conference calls with ATSDR and PADEP discussing various issues that include proposed time lines, past data, reports, and plans on air monitoring data collection, locations, funds, and procedures. PADEP designed and sponsored the community-based air monitoring effort after detailed discussions with the health agencies on the approach. PADEP shared additional information about the landfill and the potential for community exposures with the health agencies upon request. PADOH and ATSDR shared periodic updates on this written document with PADEP.

How did the health agencies incorporate information about odor complaints into this evaluation?

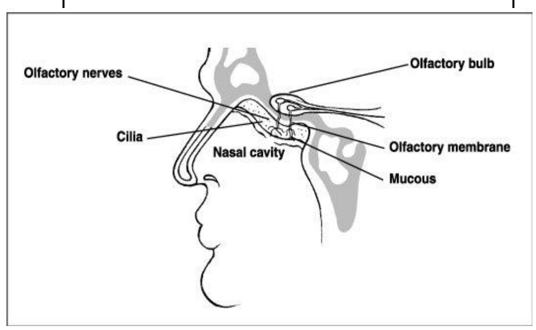
PADOH and ATSDR used information from community odor complaints reported to PADEP to help make decisions about the strategy for the community-based air monitoring effort at this site, and used this information to qualitatively assess the potential for symptoms related to odors in the community. Per the information recorded in PADEP's odor complaint logs (Appendix C, Table C4), only six odor complaints occurred during the air sampling period (January – April 2016).

During discussions with community members and PADEP, PADOH and ATSDR learned that most of the odor complaints were from drivers who use public roadways adjacent to the landfill (Highway 6 and Interstate 81). This information supported siting the KSL and Sherwood Park monitoring locations. Per the information recorded in PADEP's odor complaint logs (Appendix C, Table C4), the maximum number of community odor complaints occurred during the winter months. Therefore, we believe the community-based air monitoring included the time of year with the highest concerns about odors.

Is it possible to have health symptoms from environmental odors even if the concentrations measured in air do not appear high enough to cause health effects?

Yes, a substantial body of literature shows that offensive or objectionable odors themselves can cause health symptoms [ATSDR 2015; Schiffman and Williams 2005]. These symptoms may result from protective inborn or learned aversions to offensive odors, which may signal danger or threats to health [Schiffman *et al.* 2000, Schiffman and Williams 2005, Bulsing *et al.* 2009]. The presence of odors in a community can also lead to a diminished sense of well-being or quality of life for community members [Shusterman 2002]. Health complaints reported from exposure to offensive odors (such as those emanating from animal processing facilities, wastewater treatment plants, or landfills) include eye, nose, and throat irritation; headache; nausea; diarrhea; hoarseness; sore throat; cough; chest tightness; nasal congestion; palpitations; shortness of breath; stress; drowsiness; and alterations in mood [Schiffman *et al.* 2000]. Usually the symptoms occur at the same time as the odor and resolve when the odor goes away. But in sensitive people, such as those with asthma, the very young, or the very old, odors can result in symptoms that last longer and may aggravate existing medical conditions [Bulsing *et al.* 2009]. In addition, previous exposure to high levels of an irritating substance has been shown to make some people acutely sensitive to the substance in the future. If these people smell even very low levels of the substance, they might experience symptoms ranging from headaches and nausea to effects associated with panic attacks, such as lightheadedness or shortness of breath [Schiffman *et al.* 2000]. ATSDR has developed an odors web page https://www.atsdr.cdc.gov/odors/index.html that contains additional reference information on effects of environmental odors on health as well as resources for residents who are concerned about odors in their community [ATSDR 2015].

Figure C1. Human Nasal Anatomy



People can detect contaminants by smell at very low concentrations. When humans breathe in air, it travels through nasal passages which are lined with mucus membranes as shown in the Figure C1 to the right. These mucus membranes assist in filtering out unwanted particles from the inhaled air and secrete a mucus layer that lines the nasal passages [Krough 2005]. The olfactory epithelium in the specific area of mucus membrane that houses the olfactory nerve cells is located at the top of the nasal cavity [Axel 2006]. Olfactory nerve cells, also referred to as receptor cells, transmit olfactory information to the brain upon being triggered by an odorant molecule (environmental substances) in the inhaled air. The odorant may be perceived in many ways depending on the concentration.

A change in concentration will change the receptor codes and therefore a change in the perceived smell will occur [Malnic *et al.* 1999]. Furthermore, some odorants can be detected at lower concentrations than other odorants. Axel and Buck (1991) have provided understanding on how the nose can distinguish more than 10,000 distinct smells. The researchers discovered a gene pool of more than 1,000 different genes that encode olfactory receptors in the nose.

Mixtures of different contaminants that have odors have received limited investigation. It is possible a mixture of contaminants present in the air may produce additive, antagonistic, or synergistic odor effects.

The estimation of odor production and dispersion from landfill sites is a very complicated task because of the different chemical species that exist in the landfill gas emissions. The monitoring of the odor annoyance generated by a landfill area is difficult, since it is a multi-area, multi-source problem, with irregular (discontinuous) emissions of odors.

Is it possible that the following health conditions could be associated with the landfill - cancer, immune system disorders, nervous system disorders, birth defects, liver problems, skin problems, respiratory illnesses, muscular problems, nosebleeds, and headaches?

Based on the community-based ambient air monitoring data for this site reviewed in this document, the public health agencies did not see contaminants detected at levels in the air that could cause health conditions such as cancer, immune system disorders, nervous system disorders, birth defects, liver problems, and/or muscular problems. However, as discussed earlier in the document, based on a few contaminants that were detected at high levels (methylamine and ammonia) on one or two days, temporary acute health effects such as mild irritation of eyes, nose, and throat and/or headaches could be possible in limited circumstances. Epidemiological studies on possible health impacts for communities who live near landfills in U.S are limited [Martine V 2000]. There are some studies for possible respiratory effects, although further study is needed to confirm this and to make determinations about the other health conditions mentioned above.

Are landfill-fed seagulls impacting the community's health near the Keystone Sanitary Landfill?

Community members have expressed concerns about possible adverse effects from the seagull population. Community members are concerned about the nuisance effect of landfill-fed seagulls polluting the nearby public water reservoir. Although this is not an exposure to a chemical exposure from the landfill, PADOH and ATSDR recognize that there is an environmental public health concern related to gull populations, landfills, and surface drinking water supplies.

As summarized in USDA 2010, gulls are attracted to landfills as a food source, and landfills may contribute to an increase in gull populations. Federal regulations mandate that landfills prevent or control potential vectors, such as gulls (40 CFR 258.22). Birds can play an important role in the transmission of diseases to people, when people come into contact with fecal droppings of those birds. Research has shown that gulls carry various species of bacteria such as Bacillus sp., Clostridium sp., Campylobacter spp., Escherichia coli, Listeria spp., and Salmonella spp. Transmission of bacteria from gulls to humans is difficult to document. Contamination of public water supplies by gull feces has been stated as the most plausible source for disease transmission.

Gull feces also contribute to accelerated nutrient loading of aquatic systems, which has serious implications for municipal surface water drinking water sources, such as the one near KSL.

PADOH and ATSDR suggest PADEP and landfill authorities consider best practices for minimizing gull populations near KSL, including minimizing the open working face of the landfill to the extent feasible.

Why isn't leachate from the landfill analyzed as a pathway of concern in this health consultation document?

Community members have raised health concerns about exposure to the landfill's leachate water. PADOH and ATSDR explored this pathway using information from our visits to the site and from PADEP. Using the available information, it does not appear that people are directly exposed to leachate from the landfill. Community members do not have access to the areas onsite at the landfill where the runoff accumulates.

Concerns about this pathway were raised again after an incident on September 24, 2015. A foul-smelling discharge of black fluid was discharged into Scranton's combined sewer system which caused partial evacuation of a residential care facility for people with disabilities. PADEP investigated this incident, but could not determine the source of the discharge. At the request of PADOH to further evaluate community health concerns about this incident, PADEP tested for potential odor-causing VOCs from landfill's storm water runoff. The analytical results of the sampling conducted on October 29, 2015 are presented in Appendix C, Table C7.

Although this storm water runoff is not a drinking water source, PADOH screened the detected levels of VOCs in the water samples against drinking water CVs as a point of reference. The contaminants in the sample were below those likely to cause odor or health effects after incidental contact with this water. Among the metals, arsenic was detected at a concentration of 4.4 µg/L which is above the ATSDR CREG of 0.016 µg/L, and below EPA's MCL of 10 µg/L for drinking water. Incidental dermal contact or ingestion of water containing small amounts of arsenic is not expected to cause any non-cancer or cancer health effects. Lead was detected in the water at a concentration of 20.9 µg/L which is above the EPA's action level of 15 µg/L for drinking water. Incidental dermal contact or ingestion of lead contaminated water is not likely to increase the blood lead level to a level that could cause any health effects.

References for Appendix B

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Appendix C

Sampling Data Summary Information

Table C1: Summary of Contaminants Detected (January – April 2016) Using Summa Canisters and Sorbent Tubes Near the Keystone Sanitary Landfill, Dunmore, PA

Contaminants	**CV** (in **ppb** for **TO15** and in ***μg/m³*** for ***TO11***)	**CV Source**	**MDL**	**Monitoring locations**					
				KSL location		**Community Locations**			
				Landfill		**Mid Valley High**		**Sherwood Park**	
				Detects/ Total samples	**Concen. range**	**Detects/ Total samples**	**Concen. range**	**Detects/ Total samples**	**Concen. range**
TO15 COMPOUNDS (ppb)									
1,2,4-Trimethyl benzene	900 12	TCEQsESL(H) EPA RfC	0.16	**2/29**	**ND - 10**	1/29	ND - 0.47	1/29	ND -0.56
1,3,5-Trimethyl benzene	900 12	TCEQsESL(H) EPA RfC	0.16	1/29	ND - 2.4	ND	ND	ND	ND
1,3-Butadiene	2	EPA RfC	0.35	ND	ND	1/29	ND -0.75	ND	ND
1,4-Dioxane	30 2,000 **0.055**	cMRL aMRL **CREG**	0.14	ND	ND	ND	ND	**1/29**	**ND -0.41**
4-Ethyltoluene	25 250	TCEQlESL TCEQsESL(H)	0.10	1/29	ND - 1.3	ND	ND	ND	ND
4-Methyl-2-pentanone	20 200	TCEQlESL TCEQsESL(H)	0.19	ND	ND	1/29	ND - 1.7	1/29	ND -0.98
Acetone	13,000 26,000	cMRL aMRL	2.1	3/29	ND - 10	3/29	ND - 26	4/29	ND - 8.3
Acetonitrile	20 200 37.5	TCEQlESL TCEQsESL(H) RSL	0.30	1/29	ND	ND	ND -0.69	ND	ND
alpha-Pinene	63	TCEQlESL	0.090	ND	ND	1/29	ND -0.17	1/29	ND -0.13

Contaminants	**CV** (in **ppb** for **TO15** and in ***µg/m³*** for ***TO11***)	**CV Source**	**MDL**	**Monitoring locations**					
				KSL location		**Community Locations**			
				Landfill		**Mid Valley High**		**Sherwood Park**	
				Detects/ Total samples	**Concen. range**	**Detects/ Total samples**	**Concen. range**	**Detects/ Total samples**	**Concen. range**
	630	TCEQsESL(H)							
Benzene	3 9 **0.04**	cMRL aMRL **CREG**	**0.24**	**7/29**	**ND -0.49**	**6/29**	**ND -0.82**	**7/29**	**ND -0.65**
Chloro methane	50 500	cMRL aMRL	0.24	1/29	ND -0.31	1/29	ND -0.47	1/29	ND - 0.3
cis-1,2-Dichloro ethene	200 2,000	TCEQlESL TCEQsESL(H)	0.13	ND	ND	ND	ND	1/29	ND - 1.7
Cyclohexane	1,700	EPA RfC	0.29	1/29	ND - 1.7	1/29	ND - 5	ND	ND
Dichloro difluoro methane (CFC)	1,000 10,000 19.9	TCEQlESL TCEQsESL(H) RSL	0.16	29/29	0.39 - 1.9	28/29	ND -0.58	29/29	0.32 - 2.6
d-Limonene	20 200	TCEQlESL TCEQsESL(H)	0.14	1/29	ND -0.19	1/29	ND -0.35	2/29	ND -0.29
Ethanol	1,000 10,000	TCEQlESL TCEQsESL(H)	2.7	2/29	ND - 17	3/29	ND - 19	2/29	ND - 19
Ethyl Acetate	400 870 19.9	TCEQlESL TCEQsESL(O) RSL	0.28	11/29	ND - 5.8	7/29	ND - 17	8/29	ND - 7.5
Ethyl benzene	60 5,000	cMRL aMRL	0.12	1/29	ND -0.59	1/29	ND -0.22	ND	ND
m, p- Xylenes	50 2,000	cMRL aMRL	0.23	1/29	ND - 2.4	2/29	ND -0.79	2/29	ND -0.48
Methyl Methacrylate	2 17 175	TCEQlESL TCEQsESL(O) RSL	0.24	ND	ND	ND	ND	1/29	ND -0.56

Contaminants	CV (in **ppb** for **TO15** and in ***µg/m³*** for ***TO11***)	CV Source	MDL	Monitoring locations					
				KSL location		Community Locations			
				Landfill		Mid Valley High		Sherwood Park	
				Detects/ Total samples	Concen. range	Detects/ Total samples	Concen. range	Detects/ Total samples	Concen. range
Naphthalene	**0.7** **85**	**cMRL** TCEQsESL(O)	**0.095**	**2/29**	**ND - 2.2**	ND	ND	ND	ND
Methylene Chloride	300 600 29	cMRL aMRL CREG	0.22	2/29	ND -0.35	3/29	ND - 2.1	1/29	ND - 1.2
n-Heptane	85 850	TCEQlESL TCEQsESL(H)	0.19	2/29	ND - 1.4	2/29	ND -0.70	3/29	ND -0.79
n-Hexane	600 1,800	MRL TCEQsESL(H)	0.22	2/29	ND-0.76	2/29	ND - 1.7	2/29	ND -0.89
n-Nonane	200 2,000 3.9	TCEQlESL TCEQsESL(H) RSL	0.15	2/29	ND - 1.5	1/29	ND -0.21	1/29	ND -0.18
n-Octane	75 750	TCEQlESL TCEQsESL(H)	0.17	2/29	ND -0.92	1/29	ND -0.29	2/29	ND -0.18
n-Propyl benzene	50 500	TCEQlESL TCEQsESL(H)	0.16	1/29	ND -0.64	ND	ND	ND	ND
o-Xylene	50 2,000	cMRL aMRL	0.18	1/29	ND -0.94	2/29	ND -0.28	1/29	ND -0.18
Propene	2,000	cCARB REL	0.29	16/29	ND - 4.2	15/29	ND - 2.1	13/29	ND - 2
Styrene	200 5,000	cMRL aMRL	0.12	ND	ND	4/29	ND - 1.4	ND	ND
Tetrahydro Furan (THF)	50 500	TCEQlESL TCEQsESL(H)	0.26	ND	ND	1/29	ND -0.61	ND	ND
Toluene	1,000 2,000	cMRL aMRL	0.21	15/29	ND - 3.1	12/29	ND - 6.5	7/29	ND - 4.5

Contaminants	CV (in **ppb** for **TO15** and in ***µg/m³*** for ***TO11***)	CV Source	MDL	Monitoring locations					
				KSL location		Community Locations			
				Landfill		Mid Valley High		Sherwood Park	
				Detects/ Total samples	Concen. range	Detects/ Total samples	Concen. range	Detects/ Total samples	Concen. range
Trichloro fluoro methane	1,000 10,000 130	TCEQlESL TCEQsESL(H) RSL	0.089	27/29	ND -0.27	28/29	ND -0.25	29/29	0.2 - 1.4
Trichloro trifluoro ethane	500 5,000	TCEQlESL TCEQsESL(H)	0.065	ND	ND	1/29	ND - 2.5	1/29	ND - 1.4
TO11 COMPOUNDS (µg/m³)									
Ammonia	70 1,200	cMRL **aMRL**	1.2	5/29	ND - 59	4/29	<12 **-8000**	4/29	<12 -600
Formaldehyde	9.8 49 0.077	cMRL aMRL **CREG**	0.15	26/29	<0.93 **-6.9**	23/29	<0.93 **-2.5**	25/29	<0.93 - **2.3**
Acetaldehyde	9 470 0.45 9.4	**RfC** aCARBREL **CREG** **RSL**	0.15	2/29	<0.93 **-14**	2/29	<0.93 **-15**	2/29	<0.93 - **19**
Acrolein	0.02 6.9	**RfC** **aMRL**	0.15	5/29	<0.46 **-13**	5/29	<0.46 **-15**	6/29	<0.46 - **17**
Methylamine	6.4 26.1	TCEQlESL NOAA	10	1/29	<470 - **1200**	1/29	<470 - **1200**	1/29	<470 - **1100**

Contaminants in bold exceeded Comparison Values (CVs); ppb = parts per billion; Concen. = Concentration; µg/m³ = micro gram per cubic meter; MDL = Minimum Detection Limit; RfC = Reference Concentration; CREG= Cancer Risk Evaluation Guide; a/cMRL= acute/chronic minimum risk level; NIOSH- REL = National Institute for Occupational Safety and Health- Reference Exposure Levels; NAAQS = 8-hour National Ambient Air Quality Standards; a/c CARB-REL = acute/chronic California Air Resources Board Reference Exposure Levels; ACGIH = American Conference of Governmental Industrial Hygienists; TCEQlESL = Texas Commission on Environmental Quality long-term Effects Screening Level; TCEQsESL(O) = TCEQ short-term ESL based on odor effects; TCEQsESL (H) = TCEQ short-term ESL based on health effects; NOAA = National Oceanic and Atmospheric Administration; The basis for CVs obtained from CARB, NOAA, and TCEQ were not reviewed/approved by ATSDR

Table C2: Air Contaminants Detected Above Odor Threshold Values (µg/m³) Using Summa Canisters and Sorbent Tubes Near the Keystone Sanitary Landfill, Dunmore, PA

Contaminants	Maximum Concentration µg/m³	Location/frequency	Odor threshold values µg/m³
Acetaldehyde	14 15 17	KSL/2 MVH/2 SHP/2	3 (1.5 ppb) Nagata Y. 2003
Ammonia	8,000	MVH/1	3,487 - 36,962 (5,000 ppb – 53,000 ppb) NRC 2008
Methylamine	1,200 1,200 1,100	KSL/1 MVH/1 SHP/1	26.7 (21 ppb) NOAA 1999

KSL = Keystone Sanitary Landfill; MVH = Mid Valley High School; SHP = Sherwood Park; ppb = parts per billion; µg/m³ = micro gram per cubic meter; NRC = National Research Council (US) Committee on Acute Exposure Guideline Levels.

Table C3: Air Contaminants with Odor Threshold Levels Below Method Detection Limits Using Summa Canister and Sorbent Tubes near Keystone Sanitary Landfill, Dunmore, PA

Contaminants	MDL	Odor threshold levels
Reduced sulfur compounds (µg/m³)		
Hydrogen Sulfide	11	0.7 (0.5 ppb)
Methyl mercaptan	16	4
Ethyl mercaptan	20	0.02
Dimethyl sulfide	20	8
Isopropyl mercaptan	25	0.02
Tert-butyl mercaptan	30	0.11
n-propyl mercaptan	25	0.04
Thiophene	28	1.9
Isobutyl mercaptan	30	0.03
Diethyl sulfide	30	0.12
n-butyl mercaptan	30	0.01
Dimethyl disulfide	15	8
Tetra hydro thiophene	24	1.8
Diethyl disulfide	15	8
TO11 compounds (µg/m³)		
Triethylamine	<450	22

µg/m³ = micro gram per cubic meter; MDL = Method Detection Limit

Table C4: Community Odor Complaints Summary (2011 - 2016)

Months	**Years**							
	2011	2012	2013	2014	2015	2016	Total	Percentage
January	6	20	13	0	0	2	41	12%
February	6	14	7	5	1	0	33	9%
March	0	2	9	0	2	4	17	5%
April	2	0	2	1	6	0	11	3%
May	0	12	0	0	1	0	13	4%
June	1	11	2	0	0	0	14	4%
July	0	9	2	0	2	4	17	5%
August	1	20	0	0	3	16	40	11%
September	7	9	1	0	5	1	23	6%
October	17	23	0	0	10	5	55	15%
November	9	19	0	0	12	4	44	12%
December	26	18	1	0	5	2	52	14%
Total	75	157	37	6	47	38	360	100%
Winter (December-February)								35%
Spring (March-May)								12%
Summer (June-August)								20%
Fall (September-November)								33%

Source: PADEP Northeast office odor complaint log.

Table C5: Maximum Instantaneous Concentrations Reported from PADEP MAU for April 2015, June 2015 and March 2016 Near the Keystone Sanitary Landfill, Dunmore, PA (ppb) (All Locations)

	Monitoring Locations														
	Community Locations									**Non-Community Locations**					
	Sherwood Park			**Mid Valley High School Athletic Field/Parking Lot**			**Swinick Neighborhood**			**Keystone Landfill Leachate Lagoon**			**Keystone Landfill Working Face**		
Contaminants	**April, 2015**	**June, 2015**	**Mar. 2016**	**April, 2015**	**June, 2015**	**Mar. 2016**	**April, 2015**	**June, 2015**	**Mar. 2016**	**April, 2015**	**June, 2015**	**Mar. 2016**	**April, 2015**	**June, 2015**	**Mar. 2016**
1,2,4-Trimethyl benzene	<172	<56	<199	<175/ <171	226/ <309	<233/ <307	<217	<315	<162	<275	<1027	515	<440	99	357
2-Methyl butane	<17	<12	45	<30/ <18	<19/ <50	<23/ <37	<30	<68	<19	<37	<53	<92	<150	267	90
2-Methyl pentane	<31	<12	<43	<30/ <32	<37/ <64	<47/ <60	<40	<68	<32	<49	<63	<105	<135	605	149
3-Methyl pentane	<21	<12	<43	23/ <23	<26/ <65	<30/ <46	<34	<68	<22	<48	<64	<110	<141	114	<61
Acetaldehyde	*167*	<45	<207	*74/ 86*	<121/ <142	<97/ *178*	<102	<393	<107	<113	<200	<666	<337	<56	<246
Ammonia	<5	<2	<7	<4/<4	<6/<8	<6/<8	<5	<13	6	341	**2783**	596	43	52	11
Benzene	**212**	**48**	<146	<148/ 144	<143/ <138	<191/ <249	<154	<141	<141	<845	<5163	<1762	<315	<87	<198
Carbon disulfide	*211*	<45	<156	*250*/ 112	<81/ <183	<89/ <160	<129	<234	<85	194	<168	<475	<540	50	<205
Carbon monoxide	54	26	205	50/ 232	86/ 80	28/ <29	150	210	99	66	94	733	336	51	127
Chloroform	6	<5	<28	<4/5	<11/ <11	6/14	7	<44	<8	<5	<20	<104	<37	<4	<24
Dimethyl sulfide	<64	<32	<87	<58/ <67	<63/ <144	*115*/ <136	<95	<146	<64	<131	<168	<241	<320	<71	<157
Ethane	<64	<31	<97	<60/ <68	80/ <165	<94/ <131	<93	<179	<64	<125	206	<261	<358	80	442
Ethanol	<18	<13	<34	<17/ <17	<27/ <40	<23/ 41	<19	<56	<23	<97	<550	<300	215	368	169
Ethyl benzene	<67	<36	179	<62/ <69	73/ <174	125/ <138	<109	<166	<71	<135	<827	<319	<498	339	429
Ethylene	<10	<7	<24	10/ <10	<16/ <19	<14/ <17	<11	<47	<12	<99	<579	<225	<32	<9	<26
Formaldehyde	11	<4	<15	<13/ 13	<15/ <18	<18/ <24	<15	<20	<14	19	<20	<29	<36	<6	<24
Hydrogen	<4974	<2156	<6863	<5049/	<6432/	***9745/***	<7205	<11992	<4708	<9117	<10703	<17333	<17015	<2177	96

	Monitoring Locations														
	Community Locations									Non-Community Locations					
	Sherwood Park			Mid Valley High School Athletic Field/Parking Lot			Swinick Neighborhood			Keystone Landfill Leachate Lagoon			Keystone Landfill Working Face		
Contaminants	**April, 2015**	**June, 2015**	**Mar. 2016**	**April, 2015**	**June, 2015**	**Mar. 2016**	**April, 2015**	**June, 2015**	**Mar. 2016**	**April, 2015**	**June, 2015**	**Mar. 2016**	**April, 2015**	**June, 2015**	**Mar. 2016**
sulfide				<4974	<10777	<10157									
Iso-butane	<17	<9	<26	<16/<18	<19/<39	29/<37	<27	<39	<18	<36	53	<73	<133	<37	96
Methane	60	138	<89	58/<49	155/448	111/<99	<65	374	153	<81	651	592	1669	1024	1592
Methanol	13	<3	<11	<11/13	12/<12	<14/23	<12	<11	14	1590	842	219	87	46	33
Methyl mercaptan	<128	*68*	*281*	<119/<130	<139/<311	<172/<265	<198	<304	<134	*118*	*455*	<565	***1881***	<157	***934***
Methyl tert-butyl ether	<10	<3	<12	11/15	13/<15	<14/<18	<12	<14	13	141	<46	<68	<25	<5	<15
Naphthalene	27	10	<26	<16/20	<20/<27	<21/63	<19	<32	30	<22	<53	<75	<48	<5	<27
n-butane	<22	<11	39	<20/<23	<26/<52	<34/<45	<33	<55	<22	<43	61	<86	498	565	441
n-hexane	<43	<24	148	<39/<45	55/<121	<57/<92	<75	<118	<46	<91	<131	<227	<343	683	309
Nitric acid	27	<4	<18	14/19	<14/<20	29/<25	18	<20	14	<50	<271	<106	33	22	23
Nitrogen dioxide	<78	<41	<117	**100/**<79	<86/<202	385/<159	<117	<195	<81	<143	<196	<356	<552	<89	***609***
Nitrous oxide	<6	15	<23	<6/<7	<12/54	<8/<13	<9	<40	<10	<13	57	<70	<36	<5	<24
Nitrous acid	6	<5	<5	<4/<4	<4/<6	<6/12	8	7	<4	<10	<29	<23	13	1	<6
n-octane	338	<67	<198	<129/322	363/<280	<188/668	610	<279	776	459	<306	817	1901	638	934
n-pentane	<26	<16	82	<24/<28	<32/<87	<39/<57	<48	<87	<29	<61	<95	<170	1552	343	574
Ozone	<23	<5	<23	<23/*28*	<27/<21	<29/<39	<24	<22	<21	<121	<735	<257	<48	<14	<30
Propane	<24	<14	107	<22/<25	37/<69	35/<52	<42	<66	<26	<52	103	<129	<217	126	203
Styrene	<24	<6	<27	<24/25	<25/<32	<32/64	<25	<31	<23	<97	<333	<224	63	18	<33
Sulfur	<93	<44	<125	<92/	<121	<128/	<118	<209	<92	<267	<257	<353	<297	<35	**264**

	Monitoring Locations														
	Community Locations									Non-Community Locations					
	Sherwood Park			Mid Valley High School Athletic Field/Parking Lot			Swinick Neighborhood			Keystone Landfill Leachate Lagoon			Keystone Landfill Working Face		
Contaminants	**April, 2015**	**June, 2015**	**Mar. 2016**	**April, 2015**	**June, 2015**	**Mar. 2016**	**April, 2015**	**June, 2015**	**Mar. 2016**	**April, 2015**	**June, 2015**	**Mar. 2016**	**April, 2015**	**June, 2015**	**Mar. 2016**
dioxide				<92	<203	<176									
Toluene	<84	<51	<139	<80/ <79	<80/ <199	<103/ <166	<138	<201	<84	<201	<281	<511	973	36	402
Triethylamine	15	<5	<25	<11/ 12	<16/ <17	<16/ <21	<13	<45	<15	14	<585	<75	<39	<9	<30
m-xylene	51	<17	<70	<47/ <12	<55/ <75	<63/ 118	<55	<82	53	<66	<128	<189	<141	<13	<77
o-xylene	<30	45	<58	32/30	<33/ <73	<39/ <59	<48	107	<32	<81	<116	<218	<283	<11	<80
p-xylene	<76	<36	<149	<80/ <80	<108/ <160	<106/ 243	<108	<178	92	<111	<326	<419	<308	<25	<141

ppb = parts per billion; Contaminants in bold exceeded acute comparison values (CVs)/ National Ambient Air Quality Standard values; Contaminants in bold italics exceeded acute CVs and odor threshold levels; Contaminants in italics exceeded odor threshold levels

Table C6: Maximum Instantaneous Concentrations Reported from PADEP MAU for April 2015, June 2015 and March 2016 at near the Keystone Sanitary Landfill, Dunmore, PA (Community Locations Only) (ppb)

Contaminants	**Acute CV/Source Odor Threshold /Source**	**Community Locations**								
		Sherwood Park			**Mid Valley High School Athletic Field/Parking Lot**			**Swinick Neighborhood**		
		April 2015	**June 2015**	**March 2016**	**April 2015**	**June 2015**	**March 2016**	**April 2015**	**June 2015**	**March 2016**
1,2,4-Trimethyl benzene	900/TCEQsESL	<172	<56	<199	<175/ <171	226/ <309	<233/<307	<217	<315	<162
2-Methyl butane	NA	<17	<12	45	<30/<18	<19/<50	<23/<37	<30	<68	<19
3-Methyl pentane	NA	<21	<12	<43	23/<23	<26/<65	<30/<46	<34	<68	<22
Acetaldehyde	256/aCARB *1.5/Nag.2003*	*167*	<45	<207	*74/ 86*	<121/<142	<97/*178*	<102	<393	<107
Ammonia	1,700/aMRL	<5	<2	<7	<4/<4	<6/<8	<6/<8	<5	<13	6
Benzene	**9/aMRL**	**212**	**48**	<146	<148/**144**	<143/<138	<191/<249	<154	<141	<141
Carbon disulfide	2,400/TCEQsESL *210/Nag.3003*	*211*	<45	<156	*250*/112	<81/<183	<89/<160	<129	<234	<85
Carbon monoxide	35,000/NAAQS	54	26	205	50/232	86/ 80	28/<29	150	210	99
Chloroform	100/aMRL	6	<5	<28	<4/5	<11/<11	6/14	7	<44	<8
Dimethyl sulfide	500/ACGIH *3/Nag.2003*	<64	<32	<87	<58/<67	<63/<144	*115*/<136	<95	<146	<64
Ethane	NA	<64	<31	<97	<60/<68	80/<165	<94/<131	<93	<179	<64
Ethanol	10,000/TCEQsESL	<18	<13	<34	<17/<17	<27/<40	<23/ 41	<19	<56	<23
Ethyl benzene	5,000/aMRL	<67	<36	179	<62/<69	73/<174	125/<138	<109	<166	<71
Ethylene	NA	<10	<7	<24	10/<10	<16/<19	<14/<17	<11	<47	<12
Formaldehyde	40/aMRL	11	<4	<15	<13/13	<15/<18	<18/<24	<15	<20	<14
Hydrogen sulfide	***70/aMRL 0.5/ATSDR 2001***	<4,974	<2,156	<6,863	<5,049/ <4,974	<6,432/ <10,777	***9,745/*** <10,157	<7,205	<11,992	<4,708

Contaminants	**Acute CV/Source Odor Threshold /Source**	**Community Locations**								
		Sherwood Park			**Mid Valley High School Athletic Field/Parking Lot**			**Swinick Neighborhood**		
		April 2015	**June 2015**	**March 2016**	**April 2015**	**June 2015**	**March 2016**	**April 2015**	**June 2015**	**March 2016**
Iso- butane	NA	<17	<9	<26	<16/<18	<19/<39	29/<37	<27	<39	<18
Methane	NA	60	138	<89	58/<49	155/448	111/<99	<65	374	153
Methanol	3,000/TCEQsESL	13	<3	<11	<11/13	12/<12	<14/23	<12	<11	14
Methyl mercaptan	500/NIOSH- REL 15 min *0.07/Nag.2003*	<128	*68*	*281*	<119/ <130	<139/<311	<172/<265	<198	<304	<134
Methyl tert-butyl ether	2000/aMRL	<10	<3	<12	11/15	13/<15	<14/<18	<12	<14	13
Naphthalene	85/TCEQsESL (O)	27	10	<26	<16/20	<20/<27	<21/63	<19	<32	30
n-hexane	1,800/TCEQsESL	<43	<24	148	<39/<45	55/<121	<57/<92	<75	<118	<46
n-butane	NA	<22	<11	39	<20/<23	<26/<52	<34/<45	<33	<55	<22
Nitric acid	86/CARB REL	27	<4	<18	14/19	<14/<20	29/<25	18	<20	14
Nitrogen dioxide	**100/NAAQS** ***120/Nag.2003***	<78	<41	<117	**100**/<79	<86/<202	***385***/<159	<117	<195	<81
Nitrous oxide	2,500/TCEQsESL	<6	15	<23	<6/<7	<12/54	<8/<13	<9	<40	<10
Nitrous acid	NA	6	<5	<5	<4/<4	<4/<6	<6/12	8	7	<4
n-octane	NA	338	<67	<198	<129/322	363/<280	<188/668	610	<279	776
n-pentane	NA	<26	<16	82	<24/<28	<32/<87	<39/<57	<48	<87	<29
Ozone	70/NAAQS	<23	<5	<23	<23/28	<27/<21	<29/<39	<24	<22	<21
Propane	NA	<24	<14	107	<22/<25	37/<69	35/<52	<42	<66	<26
Styrene	5,000/aMRL	<24	<6	<27	<24/25	<25/<32	<32/64	<25	<31	<23
Triethylamine	NA	15	<5	<25	<11/12	<16/<17	<16/<21	<13	<45	<15
m-xylene	2,000/aMRL	51	<17	<70	<47/<12	<55/<75	<63/118	<55	<82	53
o-xylene	2,000/aMRL	<30	45	<58	32/30	<33/<73	<39/<59	<48	107	<32

Contaminants	Acute CV/Source Odor Threshold /Source	Community Locations								
		Sherwood Park			Mid Valley High School Athletic Field/Parking Lot			Swinick Neighborhood		
		April 2015	June 2015	March 2016	April 2015	June 2015	March 2016	April 2015	June 2015	March 2016
p-xylene	2,000/aMRL	<76	<36	<149	<80/<80	<108/<160	<106/243	<108	<178	92

Contaminants in bold exceeded acute comparison values (CVs); Contaminants in italics exceeded odor thresholdNag. = Nagata; ppb = parts per billion, RfC = Reference Concentration; CREG = Cancer Risk Evaluation Guide; a/cMRL = acute/chronic minimum risk level; NIOSH – REL = National Institute for Occupational Safety and Health- Reference Exposure Levels; NAAQS = 8-hour National Ambient Air Quality Standards; aCARB REL = acute California Air Resources Board Reference Exposure Levels; ACGIH = American Conference of Governmental Industrial Hygienists; TCEQsESL = Texas Commission on Environmental Quality short-term Effects Screening Levels; TCEQsESL(O) = TCEQ short-term ESLs based on Odor effects.

Table C7: Contaminants Detected in Surface Water Storm Water Runoff (Sample from Onsite Storm Water Drain, October 29, 2015), Keystone Sanitary Landfill, Dunmore, PA

Contaminants detected (Metals and Volatile Organic Compounds)	Maximum Concentration (µg/L)	Drinking water health CVs (µg/L)	
Arsenic	**4.4**	**2.1** **0.016** 10	**Child cEMEG** **CREG** EPA MCL
Barium	305.0	1,400	Child cEMEG
Cadmium	<2.0	0.7 5	Child cEMEG EPA MCL
Calcium	9,100	NA	
Chromium	6.94	100	EPA MCL
Copper	18.0	1,300	EPA MCLG
Iron	7,994.0	300	EPA SDWR
Lead	**20.9**	**15**	**EPA action level**
Manganese	275.0	300 350	EPA LTHA Child cRMEG
Magnesium	6,028	NA	
Mercury	<1.0	2	EPA MCL
Selenium	<7.0	35 50	Child cEMEG EPA MCL/LTHA
Silver	<10	35 100	Child cRMEG EPA LTHA
Zinc	120.0	2,100	Child cEMEG
Sodium	7,082	20,000	EPA Drinking Water Advisory
Potassium	7,373	NA	
Fluoride	<200	4,000	EPA MCL
Phenols	61.1	2,100	Child cRMEG
Methyl Ethyl Ketone (MEK)@	16.6	4,200	Child cEMEG
Tertiary Butyl alcohol (TBA)*	31.1	NA	
Tetrahydrofuran (THF)#	4.1	6,300	Child cRMEG

Contaminants in bold exceeded comparison values; µg/L = micro gram per liter; CV = Comparison Value; cEMEG = child Environmental Media Evaluation Guideline; CREG = Cancer Risk Evaluation Guide; EPA = Environmental Protection Agency; MCL = EPA Maximum Contaminant Level; EPA MCLG = EPA Maximum Contaminant Level Goal; EPA SDWR = EPA Secondary Drinking Water Regulations; EPA LTHA = EPA Life Time Health Advisory; cRMEG = Chronic Reference dose Media Evaluation Guideline; @ MEK identified in blank 2.5 µg/L; * TBA identified in blank 25.8 µg/L; # THF identified in blank 2 µg/L

Appendix D

Meteorological Analyses Supporting Information

Climate and Prevailing Winds

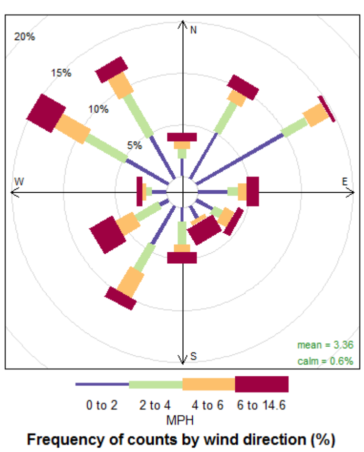
PADOH and ATSDR reviewed meteorological conditions near the KSL, because the climate and prevailing wind patterns of a given location affect how contaminants move through the air. Wind speed information was available from the Scranton air monitoring station approximately 1.5 miles NW from KSL, and temperature information was available from the Wilkes-Barre airport weather monitoring station (about 10 miles from KSL).

The average monthly temperatures recorded at the nearby Wilkes-Barre airport during the 2016 sampling had a range between 28.2^{0}F and 47.7^0 F from January 2016 to April 2016 (http://w2.weather.gov/climate/xmacis.php?wfo=bgm).

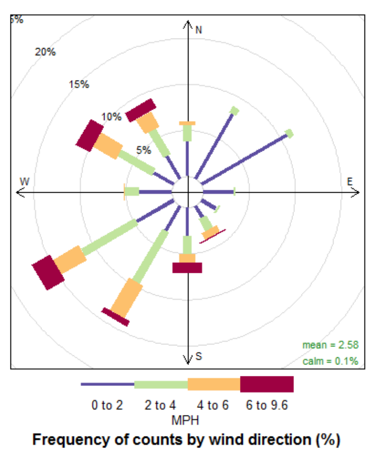
Figure 1 in the main body of the document depicts wind speed and direction in the community on an annual basis in a format know as a wind rose, using data from the Scranton air monitoring station over the time period April 2015-April 2016. Figure B1 below breaks out this wind speed and direction information monthly and seasonally, to support analysis of any seasonal changes in this information. Based on the one year of data summarized in Figure B1, there is some slight variability in wind direction and wind speed seasonally in this area.

Figure D1: Monthly and Seasonal Wind Roses Depicting Prevailing Wind Direction at Keystone Landfill Based on Scranton Meteorological Information (April 2015-April 2016)

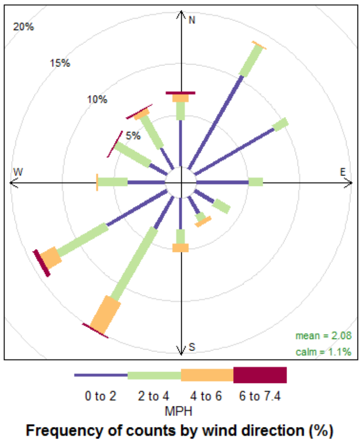
April 2015



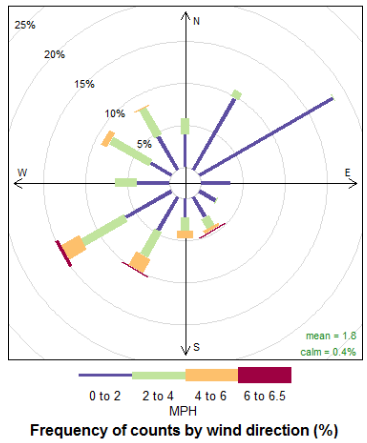
May 2015



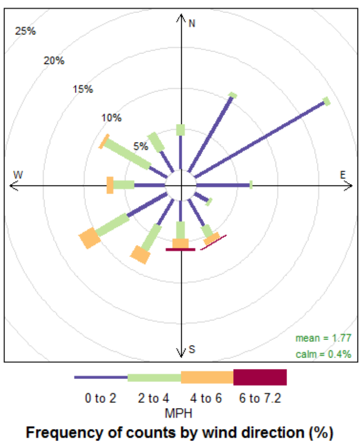
June 2015



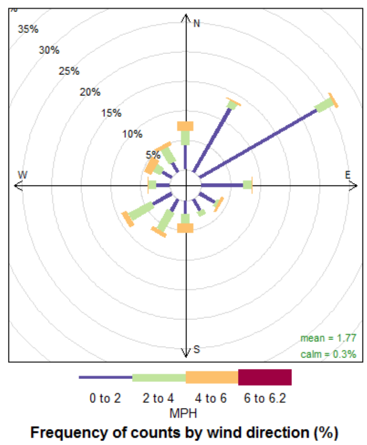
July 2015



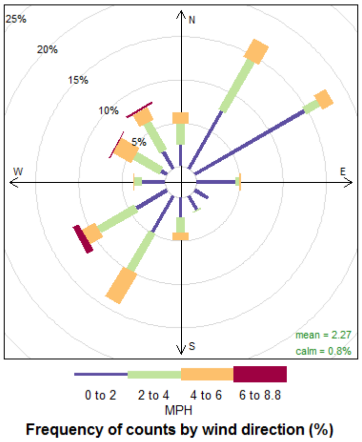
August 2015



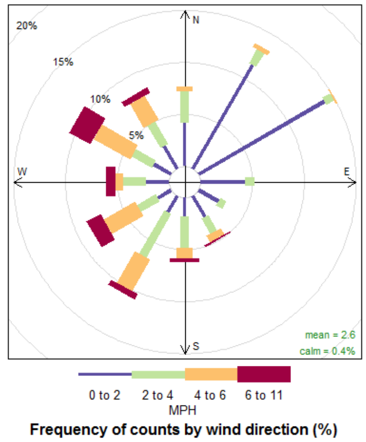
September 2015



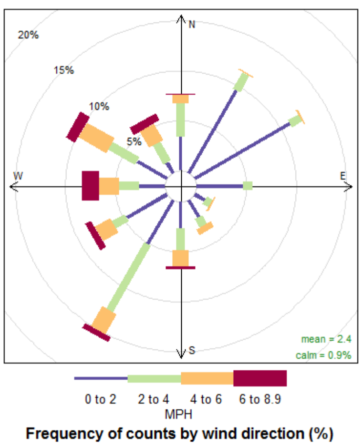
October 2015



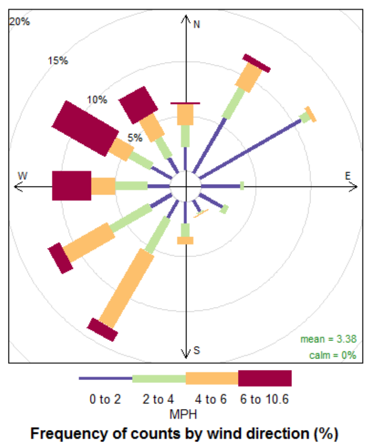
November 2015



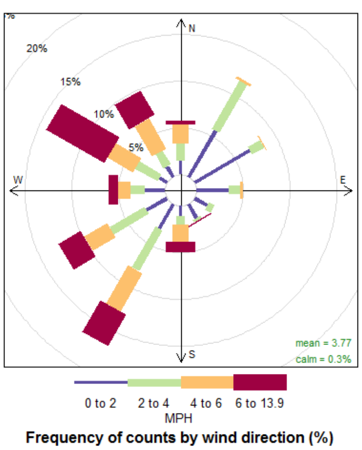
December 2015



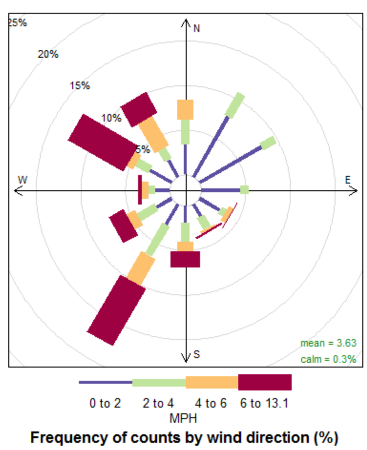
January 2016



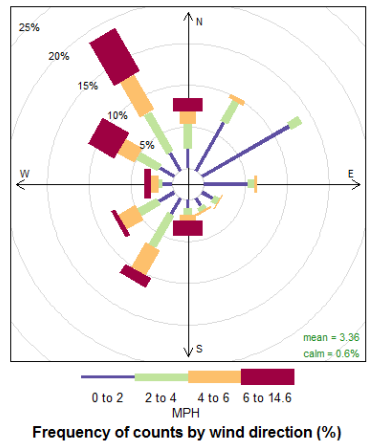
February 2016



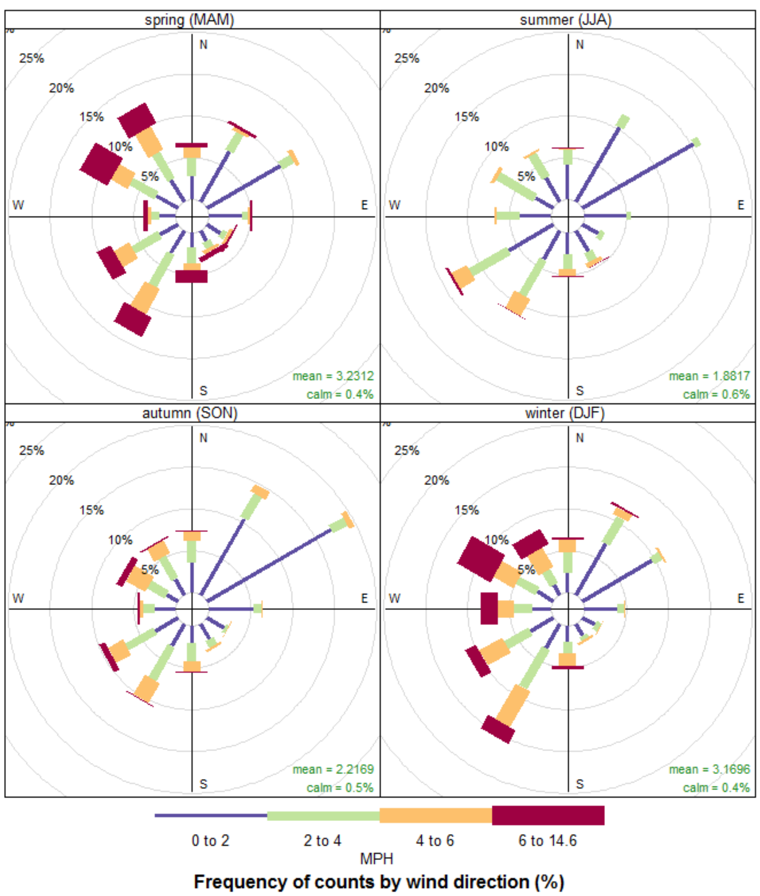
March 2016



April 2016



Seasonal Wind Roses



Hourly wind data were abstracted for each month from April 2015 to April 2016 from the Scranton air monitoring station. Hourly wind data were cleaned and analyzed in R, a statistical computing program, to determine wind patterns during the period of interest.

Note, however, that more years of weather data are needed to determine monthly/seasonal trends in wind speed and wind directions with more accuracy. Average monthly wind roses with several years of data would be less prone to variability from short term weather conditions. Comparing monthly wind roses, created using several years of data, to the long-term average would give a better picture of typical and/or unusual winds. This review focused only on the period of time monitored.

The yearly wind pattern (see Figure 1 in the main document) indicates the area usually experiences slower winds (0-4 mph) from the northeast, as well as stronger winds (2-14.6 mph) from the northwest and southwest. Very little wind comes from the southeast, which is the direction of the KSL towards residential areas. Seasonally, wind direction appears similar between spring and winter (more frequent winds from the northwest), and summer and autumn (more winds form the northeast and southeast). Wind speed seems to vary seasonally as well. The seasonal wind roses indicate wind speed increases during the spring and winter (mean wind speed of 3.23 mph and 3.17 mph respectively), and decreases in the summer and autumn (mean wind speed of 1.88 mph and 2.22 mph respectively). The highest mean monthly wind speeds were recorded during the three- month sampling period (January 29th 2016 to April 29th 2016), and the prevailing winds during this time were from the southwest and northwest. The months with the highest maximum wind speed were April 2015 and Aril 2016 (maximum wind speed of 14.6 mph). The month with lowest maximum wind speed was September (maximum wind speed of 6.2 mph). The month with the greatest percentage of calm wind speeds (wind speed of 0) was June 2015 (1.1%). This summary wind pattern information is specific to the year of data reviewed. Analysis of more years of weather data would be needed to determine long term monthly/seasonal trends in wind speed and wind directions.

Polar Plot Analysis of Particulate Matter 2.5 ($PM_{2.5}$) Data

Polar plots are a tool that provide a graphical method for showing the influence of wind speed and wind direction on air pollutant concentrations. By using polar coordinates, the plots provide a useful graphical technique which can provide directional information on sources of air pollution in an area [Carslaw and Beevers 2012]. Polar plots are calculated using statistical smoothing techniques to show a continuous surface. The monitoring station is represented at the center of the plot. The angles show the wind direction (e.g. the upper quadrants show concentrations with winds coming from the north), and the distance from the origin indicates the wind speed (e.g. the further out the high concentrations appear the higher the wind speeds when they were monitored, calm conditions appearing closer to the origin). To conduct polar plotting, a sufficient time series data set of pollutant concentrations is needed. Usually continuous monitoring for a pollutant is optimal, although limited polar plotting can be conducted using 24-hour data. Of the pollutant concentration data available for this KSL air quality evaluation, only the $PM_{2.5}$ data set contained enough data points for polar plot analysis.

Table D: Summary of January 2015-August 2016 $PM_{2.5}$ Results from Scranton COPAMS Station ($\mu g/m^3$)

Month	Year	24-hour Average Daily Ranges	24-hour Average Per Month	24-hour Average # of Days > CV* (%)	AQI Category Range**	# Days Monitored
January	2015	0-**40.2**	13.4	15 (48%)	Good-Unhealthy for Sensitive Groups	31
February	2015	0-**41.8**	15.6	19 (68%)	Good-Unhealthy for Sensitive Groups	28
March	2015	1.2-**36.5**	12.4	15 (48%)	Good-Unhealthy for Sensitive Groups	31
April	2015	0-19.7	6.6	0 (0%)	Good-Moderate	30
May	2015	0.5-**147.3**	10.5	11 (35%)	Good-Unhealthy	31
June	2015	0-**46.7**	8.6	3 (10%)	Good-Unhealthy for Sensitive Groups	30
July	2015	0-**97.2**	10.6	9 (29%)	Good-Unhealthy	31
August	2015	0-27.4	9.1	6 (19%)	Good-Moderate	31
September	2015	0-**36**	9.1	7 (26%)	Good-Unhealthy for Sensitive Groups	27
October	2015	0-23.1	7.6	3 (12%)	Good-Moderate	25
November	2015	0-24.7	9.3	6 (20%)	Good-Moderate	30
December	2015	0-33.9	12.1	12 (39%)	Good-Moderate	31
2015 Annual Average: 10.4 µg /m³						
January	2016	0-**37.3**	11.5	12 (39%)	Good-Unhealthy for Sensitive Groups	31
February	2016	0-30.2	7.9	3 (10%)	Good-Moderate	29
March	2016	0-29.9	9.2	6 (19%)	Good-Moderate	31
April	2016	0-31.1	7.8	1 (4%)	Good-Moderate	26
May	2016	0-**85.2**	8.1	5 (16%)	Good-Unhealthy	31
June	2016	0-22.9	7.1	1 (3%)	Good-Moderate	30
July	2016	0-**159.7**	8.9	1 (3%)	Good-Very Unhealthy	20
August	2016	0-**64.7**	7.1	0 (0%)	Good-Unhealthy	22
2016 January-August Average: 8.5 µg /m³ January 2015-August 2016 Average: 9.7 µg /m³						

* Short Term CV: EPA Air Quality Index (AQI) lower range for the moderate air quality designation of 12.1 µg /m³
Bold results indicate a month with at least one daily average result exceeding the maximum limit of the moderate AQI range of 35.4 µg /m³, representing a health concern for sensitive individuals and/or the general population.
**EPA Particulate Matter AQI Health Effect Statements, adapted from: https://www3.epa.gov/airnow/aqi-technical-assistance-document-may2016.pdf.

The data abstraction and cleaning methods used for the wind data described above were also applied to the $PM_{2.5}$ data. Polar plots were created with the cleaned $PM_{2.5}$ data to determine if wind patterns may have influenced the dispersion of $PM_{2.5}$ during the period of interest. Figures D2 (annual) and D3 (monthly) are polar plots analyzing the influence of wind speed and direction on $PM_{2.5}$ levels monitored at PADEP's Scranton air monitoring station (Appendix A, Figure A3).

Figure D2: Annual polar plot of $PM_{2.5}$ air monitoring and meteorological data from the Scranton station (April 2015-April 2016)

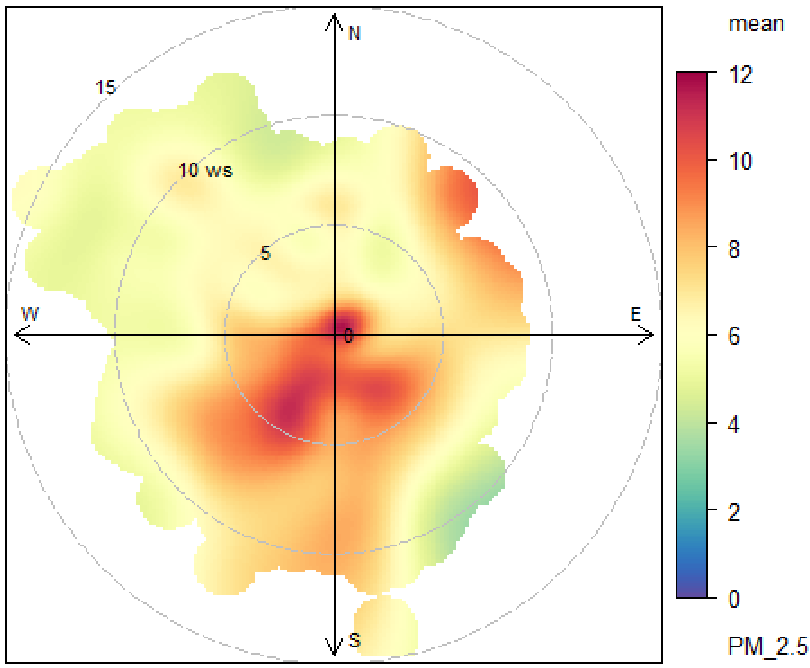
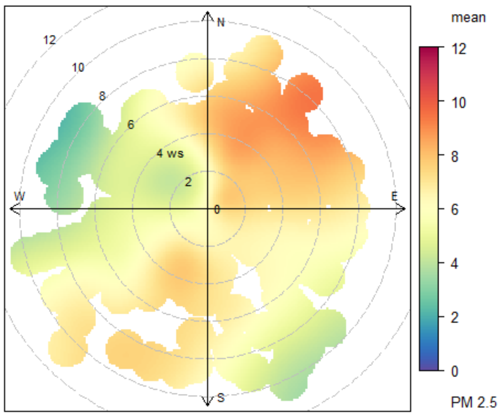
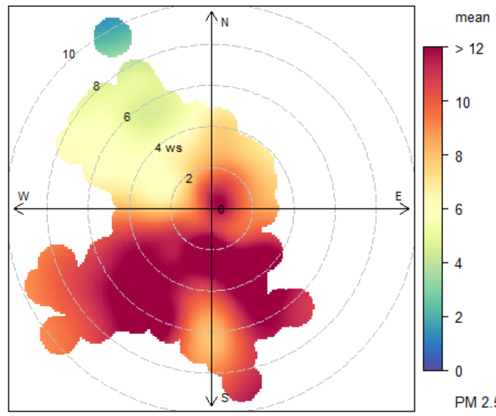


Figure D3: Monthly polar plots of $PM_{2.5}$ air monitoring and meteorological data from the Scranton station (April 2015-April 2016)

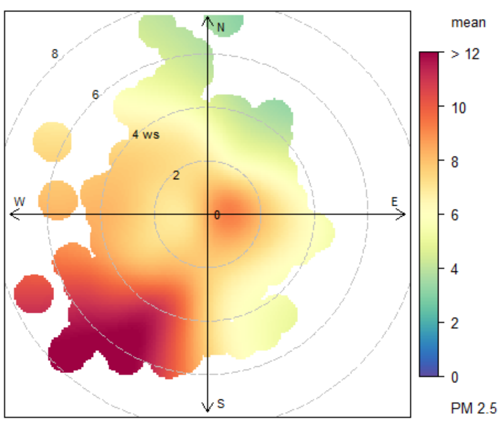
April 2015



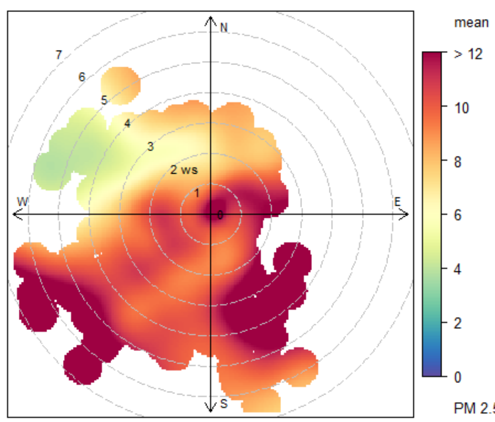
May 2015



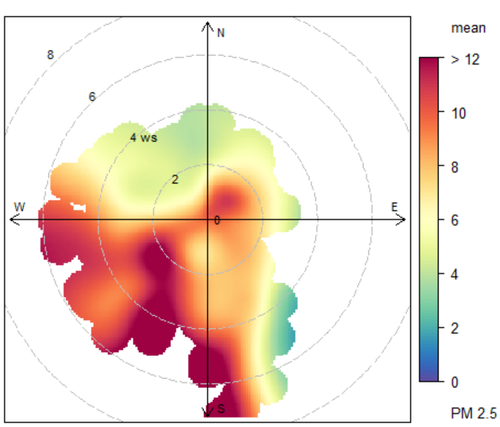
June 2015



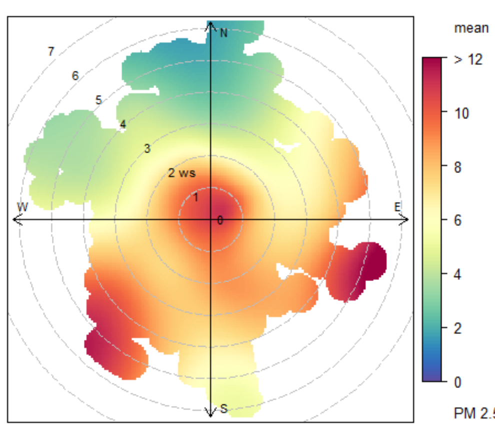
July 2015



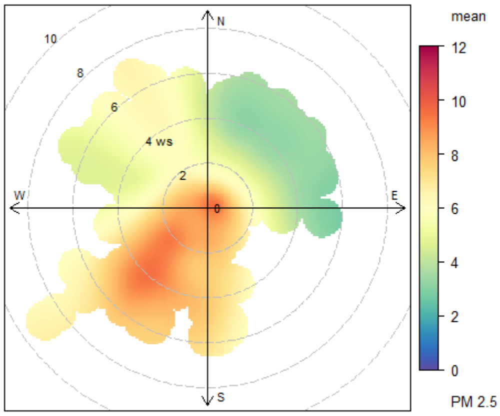
August 2015



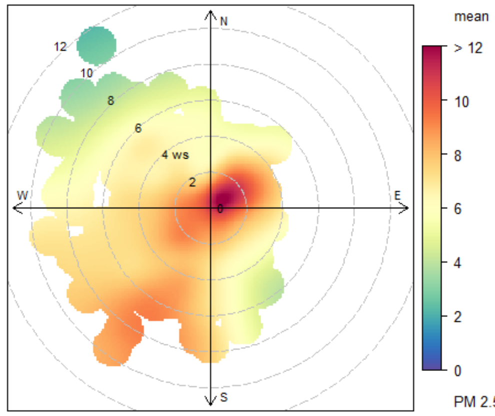
September 2015



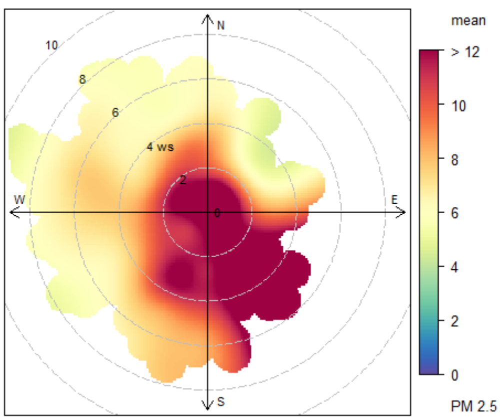
October 2015



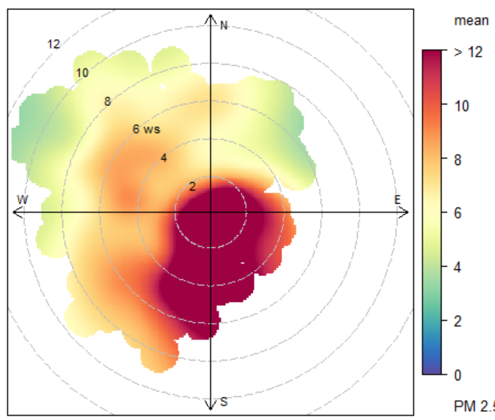
November 2015



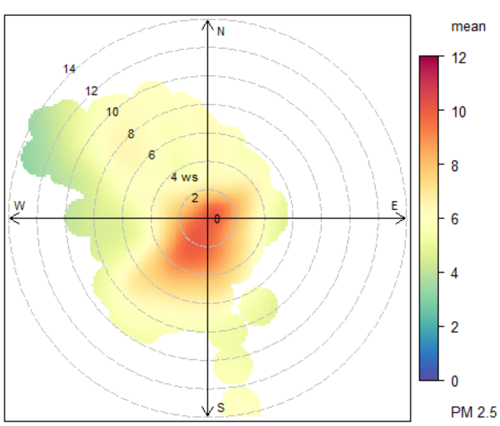
December 2015



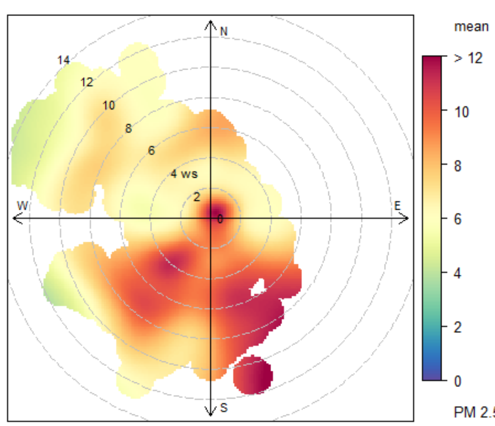
January 2016



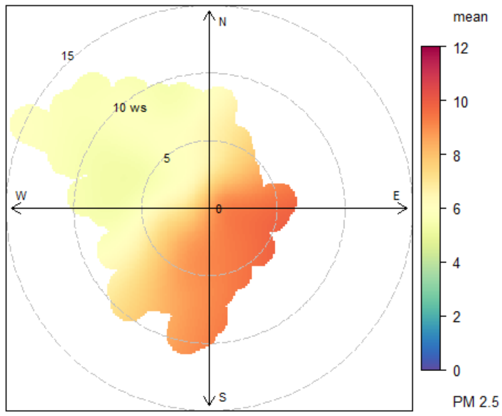
February 2016



March 2016



April 2016



The yearly polar plot indicates higher $PM_{2.5}$ levels are associated for the most part with very low wind speeds. Maximum $PM_{2.5}$ concentrations are present with little to no wind from the northeast. Higher concentrations are also present when winds less than 5 mph blow from the southwest and southeast. Light winds from the southeast correspond to elevated levels of $PM_{2.5}$. These higher $PM_{2.5}$ concentrations associated with little to no wind indicates a source very close to the sensor (e.g., not likely KSL but potentially the nearby Interstate 81 highway, agricultural or construction activity, or other nearby sources of particulate matter). Annually, stronger winds (7-10 mph) from the southeast correspond to the lowest levels of $PM_{2.5}$. However, based on the polar plot assessment of particulate concentration, wind direction, and speed, $PM_{2.5}$ levels above 12 $\mu g/m^3$ were recorded for brief (less than 24-hour) durations from the southeast and in the direction of KSL during 6 months of the monitoring period (e.g., May 2015, July 2015, September 2015, December 2015, January 2016, and March 2016). Higher levels of $PM_{2.5}$ recorded in these instances may indicate a source to the southeast (potentially the landfill).

Reference for Appendix D

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Appendix E

Subsurface Exposure Pathway Analysis

A detailed summary of the available subsurface air monitoring information for this community is provided in this Appendix. The goal of this effort was to summarize historical environmental investigations including groundwater, residential indoor air, and sub-surface borehole sampling conducted from 1997 – 2002 in the Swinick neighborhood of Dunmore by the PADEP and other agencies. This information may be used to determine the potential for adverse health effects, identify data gaps, and make recommendations to protect the public health as part of the PADOH/ATSDR public health review of environmental exposures near the KSL site in Dunmore, PA.

Note on Site Data and Organization

Several reports exist describing actions at the Dunmore Gas Site; however, many of the reports are older and the file is not complete. ATSDR Region 3 performed a file review of the available EPA records and documents for the site. The file review was complicated by the fact that several investigations/sampling events were performed by different agencies, including the EPA, PADEP, Pennsylvania Department of Transportation (Penn DOT), and the U.S. Office of Surface Mining (OSM) Reclamation, and the local fire department. While many of the reports and sampling details were found during the file review, some information is incomplete and or missing. The statements and timeline in this summary are reconstructed from interpreting multiple reports, not all of which were released publicly.

Figure E1 shows locations of the boreholes for CO sampling (installed to measure gases present in abandoned mine workings underground) in the neighborhood and nearby areas, and homes monitored. In the rest of this appendix, these variables will be collectively referred to as “mine related gases” because they can be associated with old mine workings.

Background and Timeline of Activities

Initial Event and Response Activities

On February 6, 1997, construction activities occurred included the blasting of bedrock during the I-81 interchange construction. On February 7, 1997, an 18-year old resident living 130 feet from the blast trench was diagnosed with CO poisoning, and very high CO levels (between 300-500 ppm throughout the residence and up to 2,400 ppm at a basement drain) were measured in the home [PADEP 1997]. The fire department responded to the incident in 1997 and field monitoring showed CO levels in the basement of the home at 840 ppm and PG Energy confirmed elevated levels at 2,400 ppm in a basement drain. The following table summarizes (Table E1 – see below) CO monitoring by the PADEP on February 7, 1997, in the affected home.

No faulty appliance or other source of CO was found in the home. Other agencies were called in to identify the source of CO. During February 7-8, 1997, five homes nearest the blast site were voluntarily evacuated as a precautionary measure.

Following the initial incident, on February 8, 1997, PADEP conducted emergency response for CO, carbon dioxide (CO_2), low oxygen (O_2), and detections of percent lower explosive limit (%LEL). This monitoring after the incident established that CO levels in the home were not an immediate threat to public health. The levels of CO were measured up to 14 ppm in the homes. These readings were not thought to be associated with the highway blasting, and further investigation was undertaken. The following table summarizes the residential CO monitoring (Table E1- see below).

The residential area is part of the Swinick development in Dunmore, which consists of approximately 200 homes located across I-81 from the KSL site. Most the development is constructed on abandoned strip or deep mine areas. Historical aerial photographs showed that the area adjacent to the development was once a sedimentation pond for coal washing operations and that the fill, at certain depths, is of coal fines. Topsoil was used as cover in the residential homes. The area along the current I-81 interchange near the KSL and Swinick development, has undergone major construction activities beginning in 1995 [EPA 1998].

Table E1: Residential Carbon Monoxide Monitoring

Address	Location in the Home	CO (ppm)
Shirley Ln*	1st floor	320
	Basement	840
	Furnace Room	230
	Floor Drain, near furnace	260
	Outside cleanout of sewer	500
Swinick Dr.*	1st floor	2
	Basement	7
	Foundation	72
	Floor Drain Joint	14
	Floor Drain	7
Swinick Dr.*	Garage	14
	Kitchen	2.0
Shirley Ln*	Garage	0
	1st floor	2
	Basement	5
Shirley Ln	1st floor	0
	Basement	0
Shirley Ln	1st floor	0
	Basement	0
Shirley Ln	1st floor	0
	Basement	0
Shirley Ln	1st floor	0
	Basement	0
Shirley Ln	1st floor	0
	Basement	0
Shirley Ln	1st floor	0
	Basement	0
Shirley Ln*	1st floor	0

* In addition to most impacted residence on Shirley Ln, these homes were voluntarily evacuated after the incident.

In winter-spring 1997, a multi-agency task force including OSM, PADEP, EPA, and Penn DOT performed initial response activities. Activities included installing boreholes to measure underground gas levels and temperature and conducting residential monitoring to determine gas levels in homes throughout the neighborhood. One of the original test boreholes, located at Throop and Ward Streets, was drilled to determine the outer boundaries of the site. This borehole had CO levels over 1,000 ppm, 100% LEL, O_2 at 12.7% and hydrogen sulfide levels at 645 ppm. Subsequent monitoring of this borehole showed consistent levels of CO from 300 ppm to 1,000 ppm. According to residents, this area was previously used as a trash disposal in the 1950's prior to the construction of the homes [EPA 1997a]. OSM drilled 36 boreholes, and EPA and Penn DOT sampled gases in over 100 Geoprobe soil borings in the area.

According to a 1998 EPA report, these initial studies ruled out an underground mine fire and pointed to February 1997 underground blasting conducted for highway construction as the likely source of harmful CO levels in the home. Gases were postulated to have entered the home through an abandoned water pipe and French drain system. EPA stated that the drain system would be modified so that gases could not enter again. The residents of the five evacuated homes returned, except for the home with resident diagnosed with CO poisoning [PADEP 1997].

Further Investigation of O_2/CO/CO_2 Issues

Further investigations into the cause and extent of the CO levels were performed by OSM, EPA, PADEP, and Penn DOT. Soil gas and mine gas samples were collected at the 92 boreholes (CO levels: 2- 90 ppm) throughout the site [EPA 1997c]. In March 1997, EPA Region 3 investigated, at the request of Congressman McDade, of the CO in the subsurface to identify the source including potential mine fires. In June 1997, EPA installed 7 boreholes throughout the area for monitoring of underground gases (labeled "Site Assessment Technical Assistance-SATA boreholes"), and in October 1997, weekly monitoring began at more than 40 homes in the neighborhood. Homes were monitored weekly and the SATA boreholes were monitored continuously for mine related gases until spring 1998.

The borehole data shows about half of the homes had detections of CO, elevated CO_2 and low O_2. In some of these homes the levels appeared to be associated with human activities, such as the use of unvented open flame heaters or automobile use in attached garage [Tetratech, undated]. In other homes, no explanation for the levels was identified. EPA, in coordination with Penn DOT and PADEP, also placed CO monitors in homes, based on proximity to the blasting and levels of CO during blasting. Some homes were identified for ongoing, continuous monitoring based on the level and frequency of detected gases [Tetratech, undated]. The continuous CO monitoring was conducted by PADEP at Station 19 and by Penn DOT at stations 2, 30 and an unknown home (by Penn DOT). Up to 16 homes had CO detections and about 13 had CO_2 detections; the CO/CO_2/O_2 levels did not always correlate with each other. The results showed levels were not a public health threat, with the continuous residential data for CO between 1 and 5 ppm. Subsequent residential monitoring showed low levels of CO and it was determined that CO was no longer in the homes at levels that would be a public health concern.

EPA and PADEP took steps to address the potential for future CO elevations including venting the boreholes and the installation of CO monitors in the affected homes [EPA 1997c]. Household sources were not identified or described in the information available; it does not appear that vapor intrusion systems were installed in any homes by any agencies as part of the response activities described.

In April 1997, confirmation sampling was performed at four residential basements using summa canisters. ATSDR was not able to locate address data for these four homes in the reports available to us. Field monitoring for CO before summa canister collected showed CO levels were 0 to 3.9 ppm. The summa canister sampling data showed CO was non-detect for three samples and 71 ppm in another. Methane levels ranged from 200 ppm to 960 ppm and CO2 levels in the homes ranged from 1,000 to 30,000 ppm [EPA 1997a].

In February 1999, PADEP installed 8 boreholes labeled Exposure Concentration Point ECP-1 through 8. The ECP and SATA boreholes were monitored for gases continuously, and samples were collected for 4 quarters of the year from various depths using summa canisters for VOC analysis. The four residences selected for ongoing sampling also had continuous gas monitoring. In February 2000, one sample for VOC analysis was collected from each home [Tetra Tech EMI 2000].

In 1997, NIOSH performed an investigation, due to the blasting operations in the area and concern for occupational exposures. The NIOSH investigation identified the most probably causes for CO generation in the area, including:

1. CO generation in the blast trenches which took one to two days to migrate to the homes (which corresponds with the time line of events);
2. A sealed underground pocket of CO from coal operations that was released by blasting or other operations;
3. Oxidation of carbonaceous materials is occurring to produce CO; and,
4. Historical fire underground generating CO that was released during blasting [EPA 1997a].

During the CO investigation, EPA evaluated other potential sources of CO in the area. The potential for sewage leakage was investigated, based on a sulfur dioxide (SO_2) level of 40 ppm in borehole at Throop and Ward Street. The area was wet and the sewer line was nearby but fecal coliform tests were negative. EPA also visited the KSL and evaluated five gas monitoring wells surrounding the facility. The CO levels near the KSL ranged from 0.26 to 13 ppm, CO_2 from 450 to 56,000 ppm and methane was 1 to 3.1 ppm. Based on this, the landfill was not considered the source of CO entering the affected home [EPA 1997a].

In April 2001, gas samples were collected from selected ECP and SATA boreholes and analyzed for VOCs [Weston 2002].

Major Findings and Various Interpretations of Findings
Gas samples from boreholes indicated that low O_2, high CO, and high CO_2 conditions are prevalent in the subsurface. Methane was not frequently detected and was not present at high levels. Several VOCs were also detected in boreholes, including toluene at high levels (often greater than 1,000 ppb) and widespread throughout the sampled area.

At the end of the investigation, EPA concluded that the residents of Dunmore are no longer being exposed to harmful levels of CO in their homes, based on six months of monitoring efforts by PADEP and EPA [EPA 1997a]. EPA also concluded that CO levels were not a result of mine fire but was likely due to a French drain or a roof drain (which are used to remove water from properties) at the home that allowed CO to enter the home where the young man was exposed to high levels of CO. Based on the investigations, EPA believed blasting operations by Penn DOT as well as CO present in abandoned mines in the area could have caused elevated CO and migration to the homes via preferential pathways and basements. The data shows that EPA and PADEP found high level of CO in the subsurface, especially at the deeper locations [PADEP 1997].

The four homes sampled for VOCs had lower levels of toluene than the boreholes (up to 40 ppb in homes versus up to 13,600 ppb in boreholes). However, some contaminants were detected at higher levels. See screening evaluation for additional analytical information.

Various reports have given different levels of interpretation of the results, summarized below:

- Tetra Tech EMI [2000] reported results from continuous gas, temperature, and VOC monitoring in boreholes and 4 homes. Toluene and other VOCs were detected in most of the boreholes and at trace levels in the homes. No spatial pattern could be determined. CO and CO_2 were detected at elevated levels, and O_2 was low; specific homes had significant elevations of CO, CO_2, or both CO and CO_2. The results varied over time, and no spatial pattern could be determined.
- PADEP [2000] analyzed continuous gas data, temperature, and VOC data from boreholes as well as geological information. The 2000 DEP Final Project Report [4] concluded that KSL could be a source of CO, CO_2, and VOCs in the subsurface. The conclusion was based on temperature analysis and presence of a thrust fault which could allow gas flow.
- Weston [2002] compared Dunmore data with 2 other sites (a mine fire site and a landfill in a former coal mine) and concluded that the subsurface gases at Dunmore do not appear to be emanating from the KSL. The conclusion was based on correlation analysis and on composition of the Dunmore gases, which did not match expected typical landfill gas composition with high percent of methane.

The file indicated that the following actions were taken by PADEP and EPA:

1. A few residents were provided with permanent CO detectors for their homes (addresses and current operation unknown);

2. Modification of the floor drain systems of affected residences (addresses unknown) to ensure future highway blasting does not cause CO to enter the homes; and,

3. Venting the affected subsurface areas to release CO to the atmosphere and decrease the potential for migration into the homes [EPA 1997b].

Other Information

- Groundwater in the Dunmore area is primarily in a lower aquifer below the formerly mined coal seams [Gadinski et al 2000, PADEP undated]. The groundwater is found primarily at approximately 500 feet below ground and corresponds to the elevation of the local mine pool that drains the mines within the area. The upper aquifer system is reported to be mainly dry, with surface water infiltrating through and running along low permeability zones towards surface water discharge further away [PADEP undated]. Limited trapped groundwater may remain in some areas of the upper aquifer/former mine workings [Gadinski et al 2000].

- Additional information obtained from PADEP officials includes the following:
  - The Keystone landfill has not had many VOC problems in groundwater monitoring [Hannigan 2015].
  - The landfill has a gas extraction system which has operated for years, so the landfill is under negative pressure (personal communication, PADEP conference call with ATSDR, May 21, 2015). PADEP has stated that odor complaints near the landfill were significantly reduced after the collection system at the landfill was improved in 2013. We do not have information on the effectiveness of the collection system prior to 2013.
  - Numerous underground storage tank releases have apparently occurred in this area (personal communication, PADEP NE conference call with ATSDR, May 21, 2015). No online listing of releases is available and ATSDR is not able to review the potential significance of this information related to possible subsurface exposure pathways at this time.
  - The landfill operator sampled and analyzed raw landfill gas; preliminary results were shared with ATSDR and other agencies on July 15, 2015 [Bellas 2015].

Screening Level Evaluation of VOC Detections

ATSDR screened the maximum VOC detections in the borehole and residence air samples from 1999 and 2000. In the four homes that were only sampled once each in February 2000, 3 substances (benzene, chloroform, and 1,2,4-trimethylbenzene) exceeded cancer or non-cancer CVs; toluene was detected in each of these homes as well but below CVs (Table E2 – see below). Given the incompleteness of the records available on this past VOC sampling information and the fact that these data do not represent current conditions, we did not formally evaluate this information in this document.

2015 PADEP Memorandum

As a result of PADOH and ATSDR's current Keystone evaluation and interagency discussions with PADEP, PADEP asked a hydrogeologist staff to conduct a peer review of the Weston [2002] and Tetra Tech TMI [2000] reports [Hartnett 2015]. In this memorandum, Hartnett states that "although the data generated within these two reports is extensive, a definitive source(s) of the CO cannot be determined" and that "it may be possible that more in-depth study on the air/gas movements within these measures and other known geologic features may identify the source(s). This would entail the installation of multiple nested pairs of wells and years' worth of subsurface and atmospheric data; however, due to the complexities of the mine workings in this area, additional studies may still yield inconclusive results." Given this situation, and because "no one has made an IAQ [Indoor Air Quality] complaint in the study area since this was first reported," Harnet concludes that "additional investigations are not warranted at this time."

Table E2: Screening Level Evaluation – Residential VOC Results (ppb)

Contaminants	Maximum Conc. in Homes A-D	Non-Cancer CV and Source	Cancer CV	# of Homes with Substance Detected > CV / Cancer CV
Benzene	7	3 cMRL 9 aMRL	0.04	2/4
Chloroform	1	20 cMRL 100 aMRL	0.0089	0/4
Toluene	39.5	1000 cMRL 2000 aMRL	none	0/N/A
1,2,4-Trimethylbenzene	18	12 RfC	none	2/N/A

ppb = parts per billion; CV = comparison value
cMRL = chronic ATSDR Minimal Risk Level; RfC = EPA Reference Concentration
aMRL = acute ATSDR Minimal Risk Level

In the boreholes, which were sampled from various depths of 14 boreholes during 4 quarterly sampling events, 10 substances exceeded cancer or non-cancer CVs (Table E3 – see below).

Table E3: Screening Level Evaluation – Borehole VOC Results (ppb)

Contaminants	Maximum Conc. in Any Borehole Sample	Non-Cancer CV and Source	Cancer CV	% of Samples with Detections / Detections > Lowest CV
Benzene	5	3 cMRL 9 aMRL	0.04	19% / 19%
Chloroform	24	20 cMRL 100 aMRL	0.0089	28% / 28%
Dichlorodifluoromethane	154	20 - RSL	none	35% / 9%
1,2-Dichloroethane	1	600 cMRL	0.009	0.4% / 0.4%
Methylene Chloride	57	300 cMRL 600 aMRL	18	30% / 1%
Tetrachloroethylene	15	6 cMRL 6 aMRL	0.57	17% / 14%
Toluene	13,600	1000 cMRL 2000 aMRL	none	98% / 18%
Trichloroethylene	7	0.4 cMRL	0.041	6% / 6%
1,2,4-Trimethylbenzene	25	12 RfC	none	23% / 1%
Xylene	125	23 RfC 2000 aMRL	none	48% / 4%

ppb = parts per billion
CV = comparison value
cMRL = chronic ATSDR Minimal Risk Level
RfC = EPA Reference Concentration
aMRL = acute ATSDR Minimal Risk Level
Note: Results included 250 samples total for all boreholes, depths, and sampling events. Data from 4 sampling events in 1999-2000; additional sampling in selected boreholes in 2001 showed similar VOC/toluene concentrations in boreholes.

References for Appendix E

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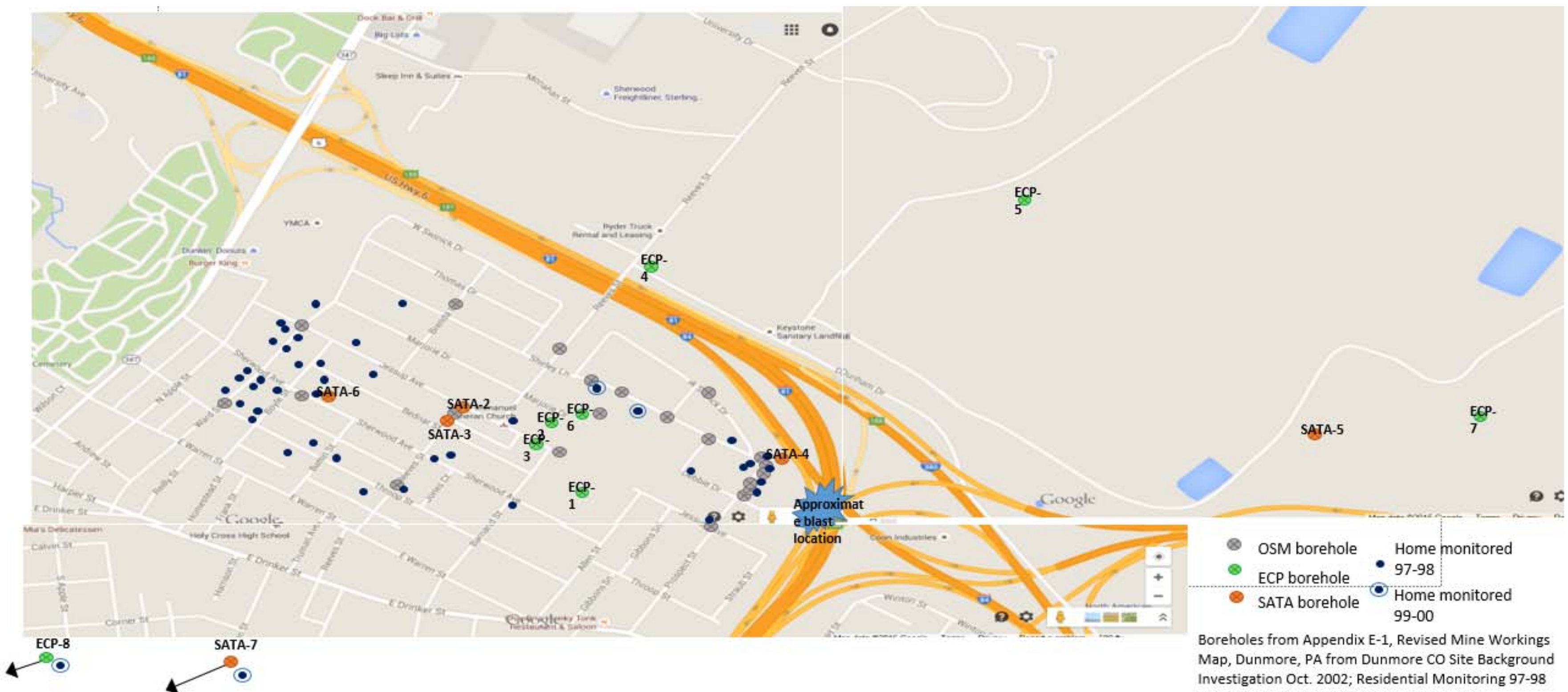
Figure E1. Approximate Locations of the Boreholes for Carbon Monoxide Sampling, Dunmore PA



Boreholes from Appendix E-1, Revised Mine Workings Map, Dunmore, PA from Dunmore CO Site Background Investigation Oct. 2002; Residential Monitoring 97-98 Excel file, and inferred from site documents. (approximate locations)

Appendix F

Health Outcome Data (Cancer Registry Data Review)

To address community resident requests, PADOH reviewed relevant cancer data near the landfill. PADOH reviewed cancer data (2005 - 2014) for the six zip codes (18434, 18447, 18509, 18510, 18512, and 18519) surrounding the KSL for the following types of cancer: bladder, brain, breast, cervix, colon, esophagus, Hodgkin lymphoma, kidney, larynx, leukemia, liver, lung, melanoma, non-Hodgkin's lymphoma, oral cavity, ovary, pancreas, prostate, stomach, testis, thyroid, uterus and other cancer types. Cancer incidence rate comparisons were made with the rest of the state.

Cancer incidence rates were compared for each of the six individual zip codes with the state rate, and all six zip codes combined with the state (whole state excluding the six zip codes area) using Pennsylvania cancer registry data from 2005 - 2014. The expected number of cancer cases were calculated for each of the six individual zip codes, and all six zip codes combined using the state rate (minus the comparison area) and then compared with the observed number of cancer cases for the 23 different types of cancers (see Table F below). Age-adjusted standardized incidence ratio (SIR) were calculated by dividing the observed number of cases by the expected number of cancer cases.

Age-adjusted SIR calculation involves comparing the observed number of cancer cases to a number that would be expected if the community were experiencing the same rate of cancer as a larger comparison area (in this case the state of Pennsylvania). Specifically, this is done by calculating rates for the comparison area and multiplying by the population in the zip code. The final number is the expected number of cases in the zip code. The observed number of cases is then divided by the expected number of cases in the zip code. This ratio of observed over expected is called an SIR. A ratio greater than 1.0 indicates that more cases occurred than expected; and a ratio less than 1.0 indicates that fewer cases occurred than expected. As an example, a ratio of 1.5 is interpreted as one-and-a-half times as many cases as the expected number, and a ratio of 0.9 indicates nine-tenths as many cases as the expected number. The SIR is considered statistically significant if the 95% confidence interval (CI) between the lower and higher confidence limits does not include 1.0. The CI helps to determine the precision of the SIR estimate. The more narrow the CI, the more confidence one has in the precision of the SIR estimate.

In the interest of brevity, we are discussing only those results which are statistically significant. For all cancers combined, the combined area zip codes and the zip code 18510 had lower cancer incidence rates than the rest of the state. The incidence rate for zip code 18510 was 15% lower than the rest of the state (SIR: 0.85, 95% CI: 0.79 – 0.92). The combined zip codes incidence rate was 7% lower than the rest of the state (SIR: 0.93, 95% CI: 0.90 – 0.96).

The incidence rate for breast cancer was lower for the six zip codes combined area when compared to the rest of the state, and was 12% lower than the rest of the state (SIR: 0.88, 95% CI: 0.81 – 0.96). The incidence rate for liver cancer in zip code 18512 was 60% lower than the rest of the state (SIR: 0.40, 95% CI: 0.13 – 0.93). The incidence rates for melanoma were 62% to 30% lower than the rest of the state in each of the six zip codes. For the combined zip codes, the melanoma incidence rate was 43% lower when compared with the rest of the state at SIR 0.57, 95% CI: 0.48 – 0.68. For all six zip codes combined, the non-Hodgkin's lymphoma incidence rate was 19% lower than the rest of the state with an SIR of 0.81 (95% CI: 0.69 – 0.95). The incidence rate for prostate cancer was 28% lower than the rest of the state in zip code 18447 with an SIR of 0.72 (95% CI: 0.56 – 0.91). The incidence rate for prostate cancer was also 28% lower than the rest of the state in zip code 18510 with an SIR of 0.72 (95% CI: 0.56 – 0.92). The incidence rate for prostate cancer for combined zip codes was 17% lower with an SIR of 0.83 (95% CI: 0.74 – 0.91). The incidence rate for stomach cancer was 71% higher than the rest of the state in zip code 18512 with an SIR of 1.71 (95% CI: 1.07 – 2.59). The incidence rate for laryngeal cancer in zip code 18509 and for all the zip code combined area was 122% and 39% higher respectively, than the rest of the state {SIR for zip code 18509 was 2.22 (95% CI: 1.24 – 3.66) and SIR for all zips combined was 1.39 95% CI: 1.02 – 1.86)}. The incidence rate for leukemia in zip code 18512 was 59% higher than the rest of the state with an SIR of 1.59, (95% CI: 1.02 – 2.37).

In summary, when examining the six zip codes combined area, the incidence rate for all cancers (combined) and the rates for breast cancer, melanoma, non-Hodgkin's lymphoma and prostate cancer were significantly lower than the state rate. The laryngeal cancer rate in the combined zip code area was significantly higher than the state rate (Table F). Based on the American Cancer Society the common environmental risk factors for laryngeal cancer are, long and intense exposures to wood dust, paint fumes, and certain chemicals used in the metalworking, petroleum, plastics, and textile industries [ACS 2014]. Based on a review of peer-reviewed literature published between 1983-2008, Porta *et al* (2009) the study concluded that there is inadequate (i.e. available studies are of insufficient quality, consistency or statistical power to decide the presence or absence of a causal association) evidence to suggest a causal link between laryngeal cancer and municipal solid waste disposal.

One limitation of an SIR analysis is that the population under study in a small community (such as in a few zip codes) usually results in fewer cancer cases. A small number of cancer cases typically yield wide CI, meaning that the SIR is not as precise as desired.

Cancer is a common disease with a multitude of risk factors (genetic, environmental, and behavioral). The Pennsylvania cancer registry does not collect information on these risk factors. Therefore, the current analysis was not able to consider the prevalence of these risk factors in the population studied. In most cancer cases, it is difficult to find a direct cause-and-effect relationship between one exposure or risk factor and the cancer type. One of the reasons for this is the long latency period (time gap between initial exposure time and diagnosis or appearance of signs and symptoms). For many cancer types, it may take decades for a cancer to develop and be diagnosed. People also migrate from one location to another, and therefore it becomes difficult to find the source of exposure that may have caused a particular cancer. Cancers diagnosed in PA residents are only reported to the PA cancer registry. Diagnoses made after the individual moved out of state may not be included in the PA cancer registry. Likewise, diagnoses made in people who have recently moved into the Commonwealth (with exposures happening elsewhere) will be included in the PA cancer registry, regardless of where exposure occurred.

Even when a statistically significant increase in cancer incidence is detected, determining the validity of an association between an environmental agent and the development of cancer is difficult as behavioral (e.g. nutrition, physical activity, and substance use), genetic (e.g. inherited mutations, hormones, and immune conditions), and environmental (e.g. chemicals, radiation, pathogens and other contaminants) factors interact and affect cancer growth. These factors may act together or in sequence to initiate or promote cancer. Ten or more years often pass between exposures or mutations and detectable cancer, and the latency of some cancers may be closer to 20 to 30 years. Furthermore, difficulties in identifying the mode of transmission or a biological pathway, the level of exposure, and amount of exposure time all contribute to the complexities of cancer inquiry investigations.

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Table F: Age-Adjusted Standardized Incidence Ratios (2005-2014) for Cancers by Type for Residents near the Keystone Landfill *(6-zi*o codes and all zip codes combined) Compared to All Pennsvlvania Residents

Cancer type	Statistics	Zip codes						
		18434	18447	18509	18510	18512	18519	All zip codes (combined)
All cancers (combined)	Observed	292	790	845	716	946	358	3947
	Expected	316.8	849.6	886.8	837.7	973.5	365.1	4229.5
	SIR	0.92	0.93	0.95	**0.85**	0.97	0.98	**0.93**
	95% CI	0.82 - 1.03	0.87 - 1	0.89 - 1.02	0.79 - 0.92	0.91 - 1.04	0.88 - 1.09	0.9 - 0.96
Bladder	Observed	23	49	43	29	61	26	231
	Expected	15.7	42.0	42.6	41.0	48.4	17.6	207.3
	SIR	1.47	1.17	1.01	0.71	1.26	1.48	1.11
	95% CI	0.93 - 2.2	0.86 - 1.54	0.73 - 1.36	0.47 - 1.02	0.96 - 1.62	0.97 - 2.17	0.98 - 1.27
Brain	Observed	8	29	22	26	27	17	129
	Expected	10.4	27.5	29.9	28.7	31.5	12.1	140.0
	SIR	0.77	1.05	0.74	0.91	0.86	1.41	0.92
	95% CI	0.33 - 1.52	0.71 - 1.51	0.46 - 1.11	0.59 - 1.33	0.57 - 1.25	0.82 - 2.26	0.77 - 1.09
Breast	Observed	36	111	130	115	125	46	563
	Expected	48.1	128.0	135.8	123.5	147.7	55.8	638.9
	SIR	0.75	0.87	0.96	0.93	0.85	0.82	**0.88**
	95% CI	0.52 - 1.04	0.71 - 1.04	0.8 - 1.14	0.77 - 1.12	0.7 - 1.01	0.6 - 1.1	0.81 - 0.96
Cervix	Observed	2	6	2	4	6	0	20
	Expected	1.9	4.8	5.3	4.8	5.5	2.2	24.6
	SIR	1.06	1.25	0.38	0.83	1.08	0.00	0.81
	95% CI	0.13 - 3.85	0.46 - 2.72	0.05 - 1.36	0.23 - 2.13	0.4 - 2.36	-	0.5 - 1.26
Colon	Observed	36	84	86	88	109	41	444
	Expected	31.6	84.8	86.7	83.1	97.3	35.6	419.2
	SIR	1.14	0.99	0.99	1.06	1.12	1.15	1.06
	95% CI	0.8 - 1.57	0.79 - 1.23	0.79 - 1.22	0.85 - 1.3	0.92 - 1.35	0.83 - 1.56	0.96 - 1.16
Esophagus	Observed	2	11	10	10	10	2	45
	Expected	3.2	8.8	9.0	8.5	10.1	3.7	43.3

Cancer type	Statistics	Zip codes						
		18434	18447	18509	18510	18512	18519	All zip codes (combined)
Esophagus	SIR	0.62	1.25	1.11	1.17	0.99	0.54	1.04
	95% CI	0.07 - 2.23	0.63 - 2.24	0.53 - 2.05	0.56 - 2.16	0.48 - 1.83	0.07 - 1.94	0.76 - 1.39
Hodgkin	Observed	0	7	3	3	5	2	20
	Expected	1.4	3.6	4.8	5.2	4.2	1.8	21.1
	SIR	0.00	1.94	0.62	0.58	1.18	1.14	0.95
	95% CI	-	0.78 - 3.99	0.13 - 1.81	0.12 - 1.69	0.38 - 2.75	0.14 - 4.1	0.58 - 1.47
Kidney	Observed	7	22	21	21	27	7	105
	Expected	9.5	25.5	26.6	24.7	29.2	11.1	126.6
	SIR	0.74	0.86	0.79	0.85	0.92	0.63	0.83
	95% CI	0.3 - 1.52	0.54 - 1.31	0.49 - 1.21	0.53 - 1.3	0.61 - 1.34	0.25 - 1.3	0.68 - 1
Larynx	Observed	4	8	15	4	9	5	45
	Expected	2.4	6.6	6.8	6.3	7.5	2.8	32.3
	SIR	1.66	1.22	**2.22**	0.63	1.20	1.78	**1.39**
	95% CI	0.45 - 4.25	0.53 - 2.41	1.24 - 3.66	0.17 - 1.62	0.55 - 2.29	0.58 - 4.15	1.02 - 1.86
Leukemia	Observed	9	16	14	13	24	7	83
	Expected	5.0	13.1	14.3	13.9	15.1	5.7	67.1
	SIR	1.81	1.22	0.98	0.93	**1.59**	1.22	1.24
	95% CI	0.83 - 3.43	0.7 - 1.98	0.54 - 1.65	0.5 - 1.6	1.02 - 2.37	0.49 - 2.51	0.98 - 1.53
Liver	Observed	7	6	16	8	5	4	46
	Expected	4.1	11.1	11.4	10.7	12.5	4.7	54.6
	SIR	1.72	0.54	1.40	0.74	**0.40**	0.85	0.84
	95% CI	0.69 - 3.54	0.2 - 1.17	0.8 - 2.27	0.32 - 1.47	0.13 - 0.93	0.23 - 2.18	0.62 - 1.12
Lung	Observed	33	102	126	93	138	50	542
	Expected	40.6	109.1	111.4	105.0	126.3	46.5	538.9
	SIR	0.81	0.93	1.13	0.89	1.09	1.08	1.01
	95% CI	0.56 - 1.14	0.76 - 1.14	0.94 - 1.35	0.72 - 1.09	0.92 - 1.29	0.8 - 1.42	0.92 - 1.09
Melanoma	Observed	9	30	32	22	39	8	140

Cancer type	Statistics	Zip codes						
		18434	18447	18509	18510	18512	18519	All zip codes (combined)
Melanoma	Expected	18.3	48.7	51.8	48.6	55.8	21.3	244.4
	SIR	**0.49**	**0.62**	**0.62**	**0.45**	**0.70**	**0.38**	**0.57**
	95% CI	0.23 - 0.94	0.42 - 0.88	0.42 - 0.87	0.28 - 0.69	0.5 - 0.96	0.16 - 0.74	0.48 - 0.68
Myeloma	Observed	3	10	8	7	8	2	38
	Expected	3.7	10.0	10.2	9.7	11.5	4.2	49.4
	SIR	0.80	1.00	0.78	0.72	0.69	0.47	0.77
	95% CI	0.17 - 2.35	0.48 - 1.84	0.34 - 1.54	0.29 - 1.49	0.3 - 1.37	0.06 - 1.7	0.54 - 1.06
NHL	Observed	11	38	33	28	41	12	163
	Expected	15.1	40.3	41.9	40.0	46.4	17.2	200.8
	SIR	0.73	0.94	0.79	0.70	0.88	0.70	**0.81**
	95% CI	0.36 - 1.3	0.67 - 1.29	0.54 - 1.11	0.46 - 1.01	0.63 - 1.2	0.36 - 1.22	0.69 - 0.95
Oral	Observed	4	22	24	22	23	6	101
	Expected	6.5	17.5	18.3	17.1	19.8	7.5	86.6
	SIR	0.62	1.26	1.31	1.29	1.16	0.80	1.17
	95% CI	0.17 - 1.59	0.79 - 1.9	0.84 - 1.96	0.81 - 1.95	0.74 - 1.74	0.29 - 1.74	0.95 - 1.42
Ovary	Observed	5	14	11	8	13	3	54
	Expected	4.1	10.9	11.6	10.9	12.5	4.6	54.5
	SIR	1.23	1.29	0.95	0.73	1.04	0.65	0.99
	95% CI	0.4 - 2.87	0.7 - 2.16	0.47 - 1.7	0.32 - 1.45	0.56 - 1.79	0.13 - 1.89	0.74 - 1.29
Pancreas	Observed	11	19	21	14	22	6	93
	Expected	8.1	21.8	22.2	21.4	25.1	9.1	107.8
	SIR	1.36	0.87	0.94	0.65	0.88	0.66	0.86
	95% CI	0.68 - 2.43	0.52 - 1.36	0.58 - 1.44	0.36 - 1.1	0.55 - 1.33	0.24 - 1.43	0.7 - 1.06
Prostate	Observed	33	67	73	64	97	38	372
	Expected	34.0	93.2	91.1	88.8	104.4	39.3	450.7
	SIR	0.97	**0.72**	0.80	**0.72**	0.93	0.97	**0.83**
	95% CI	0.67 - 1.36	0.56 - 0.91	0.63 - 1.01	0.56 - 0.92	0.75 - 1.13	0.69 - 1.33	0.74 - 0.91

Cancer type	Statistics	Zip codes						
		18434	18447	18509	18510	18512	18519	All zip codes (combined)
Stomach	Observed	4	13	11	11	22	7	68
	Expected	4.2	11.2	11.5	11.1	12.9	4.7	55.5
	SIR	0.96	1.16	0.96	1.00	**1.71**	1.49	1.22
	95% CI	0.26 - 2.45	0.62 - 1.98	0.48 - 1.71	0.5 - 1.78	1.07 - 2.59	0.6 - 3.07	0.95 - 1.55
Testis	Observed	2	3	6	4	5	0	20
	Expected	1.2	3.0	4.5	4.3	3.5	1.6	18.2
	SIR	1.65	0.99	1.34	0.93	1.41	0.00	1.10
	95% CI	0.2 - 5.97	0.21 - 2.91	0.49 - 2.91	0.25 - 2.39	0.46 - 3.29	-	0.67 - 1.7
Thyroid	Observed	6	28	26	24	26	11	121
	Expected	8.7	22.6	26.1	24.0	25.8	10.5	117.7
	SIR	0.69	1.24	1.00	1.00	1.01	1.04	1.03
	95% CI	0.25 - 1.51	0.82 - 1.79	0.65 - 1.46	0.64 - 1.49	0.66 - 1.48	0.52 - 1.87	0.85 - 1.23
Uterus	Observed	9	24	24	18	29	10	114
	Expected	9.6	26.1	27.7	25.1	30.0	11.4	129.8
	SIR	0.93	0.92	0.87	0.72	0.97	0.88	0.88
	95% CI	0.43 - 1.77	0.59 - 1.37	0.56 - 1.29	0.43 - 1.14	0.65 - 1.39	0.42 - 1.62	0.72 - 1.06
Other Cancers	Observed	28	71	88	80	75	48	390
	Expected	30.0	79.9	83.8	81.3	91.5	33.9	400.3
	SIR	0.93	0.89	1.05	0.98	0.82	1.41	0.97
	95% CI	0.62 - 1.35	0.69 - 1.12	0.84 - 1.29	0.78 - 1.23	0.64 - 1.03	1.04 - 1.87	0.88 - 1.08

SIR = Standardized Incidence Ratio for significant difference is bolded; 95% CI = 95% Confidence Interval; Numbers highlighted in green are significantly lower than the state and numbers highlighted in red are significantly higher than the state

Appendix G

Detailed information on Comparison Values (CVs) and 95UCL calculations

CVs can be based on either carcinogenic or non-carcinogenic effects. There are several CVs available for screening environmental contaminants to identify contaminants of potential concern. These include ATSDR Environmental Media Evaluation Guides (EMEGs) and Reference Media Evaluation Guides (RMEGs). EMEGs are estimated contaminant concentrations that are not expected to result in adverse noncarcinogenic health effects. RMEGs represent the concentration in water or soil at which daily human exposure is unlikely to result in adverse noncarcinogenic effects. If the substance is a known or a probable carcinogen, ATSDR's Cancer Risk Evaluation Guides (CREGs) values were used for further evaluation of the substances. Concentrations greater than CREGs do not necessarily mean that people will develop cancer from exposures, but further evaluation is necessary to assess the risk of cancer.

Cancer-based CVs are calculated from the EPA oral Cancer Slope Factor (CSF) or Inhalation Unit Risk (IUR). CVs based on cancerous effects account for a lifetime exposure (78 years) with a theoretical excess lifetime cancer risk of one extra case per one million exposed people. Non-cancer values are calculated from ATSDR's Minimal Risk Levels (MRLs), EPA's Reference Doses (RfDs), or EPA's Reference Concentrations (RfCs) [ATSDR 2005].

Cancer Risk Evaluation Guides (CREGs) are media-specific CVs that are used to identify concentrations of cancer-causing substances that are likely to result in an increase of cancer rates in an exposed population. ATSDR develops CREGs using EPA's CSF or IUR, a target risk level (10^{-6}), and default exposure assumptions. The EPA target risk level of 10^{-6} represents an estimated risk of one excess cancer cases in a population of one million.

MRLs are developed by ATSDR and are an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure. MRLs are based only on non-carcinogenic effects. If sufficient data are available, MRLs are derived for acute (1-14 days), intermediate (15-365 days), and chronic (365 days and longer) durations for the oral and inhalation routes of exposure [ATSDR 2005].

Screening levels developed by the EPA were also used in this public health assessment. The EPA has developed chronic RfCs for inhalation. RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious non-cancer health effects during a lifetime. RfCs are derived assuming exposure to a single substance in a single media. In this document, if there was no MRL for a given contaminant, the EPA RfC was used.

PADOH also used EPA's screening level/preliminary remediation goal website, entitled "Regional Screening Levels for Chemical Contaminants at Superfund Sites. The Regional Screening Levels (RSLs) table provides CVs for residential and commercial-industrial exposures to soil, air and tap water [EPA 2016].

Finally, if a contaminant did not have an ATSDR MRL or CREG, or EPA RfC or RSL air value, PADOH used screening levels developed by other environmental and health agencies such as the

Texas Commission on Environmental Quality (TCEQ) ; National Ambient Air Quality Standards (NAAQS); California Air Resources Board Reference Exposure Levels (CARB-REL); American Conference of Governmental Industrial Hygienists (ACGIH); National Institute for Occupational Safety and Health Reference Exposure Levels (NIOSH-REL); and National Oceanic and Atmospheric Administration (NOAA). However, the basis for values obtained from other environmental and health agencies haven't been reviewed/approved by ATSDR.

PADOH calculated an exposure point concentration (EPC) of the contaminants detected for further evaluation. EPC is believed to represent typical upper bound exposure averages. A conservative EPC is the 95% upper confidence limit (95UCL) of the arithmetic mean concentration. For a given number of discrete environmental samples in an exposure unit, the calculated arithmetic mean may be lower or higher than the actual arithmetic mean. However, it is highly unlikely (i.e., no more than 5 percent probability) that the 95UCL will be lower than the exposure unit's actual arithmetic mean. Usually the number of environmental samples in an exposure unit increases, the difference between the 95UCL and the sample arithmetic mean decreases. To calculate the 95UCL for contaminants that had mostly non-detects (i.e., benzene), we used the recommended censored value of the method detection limit (MDL)/2 and for contaminants with a few non-detects (formaldehyde), we used the recommended censored value of the MDL/square root of 2 [Finkelstein et al. 2001].

Reference for Appendix G

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Appendix H

General Health Effects Information on Selected Contaminants

Ammonia

Ammonia is a corrosive irritant gas. It causes irritation of the eyes, nose, and throat. ATSDR used the study of Verberk et al. (1977) to drive an acute MRL of 1,700 ppb (1,200 µg/m^3) [ATSDR 2004]. The study examined the effects of ammonia in a group of 16 volunteers. Exposure to ammonia at 50,000 ppb (34,760 µg/m^3) for 2 hours resulted in mild irritation to the eyes, nose, and throat. This level was considered as the Lowest Observed Adverse Effect Level (LOAEL). ATSDR used an uncertainty factor of 30 (3 for use of a LOAEL and 10 for human variability) which resulted in an acute MRL of 1,200 µg/m^3. Uncertainty remains regarding the lowest level at which no health effects would occur particularly for sensitive populations (such as pregnant women, children, older adults and people with respiratory disease).

Benzene

Benzene is a highly flammable, colorless liquid with a sweet odor. Benzene evaporates into air very quickly and dissolves only slightly in water. Benzene is used primarily to make other contaminants that are in turn used to make products such as Styrofoam, plastics, resins, synthetic fibers, rubbers, lubricants, dyes, detergents, drugs, and pesticides [ATSDR 2007]. Benzene is present in crude oil, gasoline, and smoke from forest fires and cigarettes [Rinsky et al. 1987]. It has been identified in outdoor air samples of both rural and urban environments and in indoor air. The following daily median benzene air concentrations were reported in the Volatile Organic Compound National Ambient Database (1975-1985): remote (0.47 ppb or 1.5 µg/m^3), rural (0.47 ppb or 1.5 µg/m^3), suburban (1.8 ppb or 5.7 µg/m^3), urban (1.8 ppb or 5.7 µg/m^3), indoor air (1.8 ppb or 5.7 µg/m^3), and work place air (2.1 ppb or 6.7 µg/m^3) [Roberts et al. 1985].

Benzene also has been shown to pass from the mother's blood to the fetus [Rinsky et al. 1987]. Long-term exposure to benzene can affect the immune system and cause cancer of the blood-forming organs. Exposure to benzene has been associated with a leukemia called acute myeloid leukemia [Yin SN *et al*. 1987; EPA 2003; HSDB 1994]. The Department of Health and Human Services has determined that benzene is a human carcinogen [DHHS 2014]. The IARC and the EPA have also determined that benzene is carcinogenic to humans.

Formaldehyde

Formaldehyde is an organic compound that is emitted from many sources, and small amounts of formaldehyde are naturally produced by plants, animals, and humans. Formaldehyde is used in the production of fertilizer, paper, plywood, and it is also used as a preservative in some foods and many household products. Releases of formaldehyde into the air occur from industries using or manufacturing formaldehyde, wood products (such as particle-board, plywood, and furniture), automobile exhaust, cigarette smoke, paints and varnishes, and carpets and permanent press fabrics. Indoor air typically contains higher levels of formaldehyde than outdoor air [ATSDR 2015]. A study of 184 single family homes in different cities [RIOPA 2005] found a mean concentration of formaldehyde in outdoor ambient air of 3.69 µg/m^3 (3 ppb) and in housing of 20.91 µg/m^3 (17 ppb). In addition, the U.S. Consumer Product Safety Commission report stated that formaldehyde is normally present at low levels, usually less than 36.9 µg/m^3 (30 ppb), in both outdoor and indoor air. The outdoor air in rural areas has lower formaldehyde concentrations than urban areas (due to sources such as automobile exhaust). Residences or offices that contain products that release formaldehyde into air can have levels greater than 36.9 µg/m^3. In general, formaldehyde levels in outdoor air range from 0.25 to 7.4 µg/m^3 in rural and suburban areas and 1.2 to 25 µg/m^3 in urban areas [ATSDR 2015].

Acute and chronic inhalation exposure to formaldehyde in humans can result in respiratory symptoms, and eye, nose, and throat irritation. Exposure to high levels of formaldehyde in occupational settings can result in the development of leukemia, a cancer of the blood or blood forming tissue in the body. Formaldehyde is widely recognized as carcinogenic to humans [U.S. EPA 1989; NTP 2011].

Hydrogen Sulfide

Hydrogen sulfide (H_2S) is a colorless, flammable gas with a distinctive rotten egg odor with typical odor threshold range of 0.5 – 30 ppb [ATSDR 2016]. H_2S is formed by anaerobic (oxygen-free) degradation of sulfur-containing compounds and is a major concern for odors and exposures from landfills, wastewater treatment facilities, and animal production operations. It is used in the production of sulfur and sulfuric acid. Studies in humans suggest that the respiratory tract and nervous system are the most sensitive targets of H_2S toxicity. Exposure to low concentrations of H_2S may cause irritation to the eyes, nose, or throat. It may also cause difficulty in breathing for some asthmatics. Respiratory distress or arrest has been observed in people exposed to very high concentrations of H_2S [ATSDR 2016]. MAU monitoring detected H_2S at MVH athletic field location at 13,624 µg/m^3 (9,745 ppb) and at the working face of the landfill location at 134 µg/m^3 (96 ppb). The short-term presence of high levels of H_2S on that one day could have adversely some individuals at MVH athletic field location, especially sensitive populations such as children, older adults, and those with preexisting health conditions.

Methylamine

Methylamine is colorless gas with a pungent fish like odor. The contaminant is alkaline and causes severe irritation or necrosis of mucous membranes and skin. Methylamine was detected once at each location (1,200 µg/m^3 at KSL and MVH on February 4, 2016, and 1,100 µg/m^3 at SHP on February 1, 2016). Information regarding acute toxicity of methylamine in humans is very limited. It has been reported in one study [Bingham *et al*, 2001] that irritation of eyes, nose and throat has resulted from exposure to methylamine concentrations of 20,000 ppb (25,407 µg/m^3) to 100,000 ppb (127,035 µg/m^3).

Particulate Matter

Particulate matter, or PM, is the term for particles found in the air, including dust, dirt, soot, smoke, and liquid droplets. These solid and liquid particles come in a wide range of sizes. $PM_{2.5}$ is a fraction of total PM, and refers to particulate matter with an aerodynamic diameter of 2.5 microns or less. Some of these small particles can be suspended in the air for long periods of time. $PM_{2.5}$ particles are referred to as "fine" particles and are believed to pose the greatest health risks. There are natural and manmade sources of particulate matter. Particulate matter is a mixture with physical and chemical qualities that vary by source and location. “Primary” emissions sources, or sources that release $PM_{2.5}$ directly into the air, are responsible for some airborne $PM_{2.5}$. In addition to primary emission sources, “secondary” particles form in the air from chemical reactions involving precursor gaseous emissions, such as sulfur dioxide, nitrogen oxides, and VOCs. Note that these secondary particles can form at locations far from those emissions sources that released the precursors.

References for Appendix H

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