Investigation of Reported Health Concerns near Waste Connections Oil and Gas Site in Erie

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Executive Summary

Since May 2017, the Oil and Gas Health Information and Response (OGHIR) Program at the Colorado Department of Public Health and Environment (CDPHE) has received odor and health concern reports from approximately 50 residents in Erie neighborhoods near the Waste Connections oil and gas site (40.018900°, -105.031917°). These residents have reported eye, nose and throat irritation, nosebleeds, respiratory effects such as increased asthma symptoms and difficulty breathing, headaches, and nausea. OGHIR has documented that many of these health and odor concerns occurred at the time when drilling operations were ongoing at the site, and when wind direction was coming from the direction of the well pad.

In response to these health and odor concerns, OGHIR collected multiple air samples during different days and times to measure the specific volatile organic compounds (VOCs) that have been associated with oil and gas emissions. These samples were collected in multiple locations in the neighborhoods surrounding the Waste Connections site. The measured VOC levels were compared to health guideline values set by federal and state agencies to assess the risk for harmful health effects.

The main findings from this investigation and air sampling suggest:

- The measured levels of all VOCs were well below health guideline levels which suggests a very low risk of harmful health effects.
- The levels of some VOCs were in the concentration range that would be detectable as an odor.
- The specific VOCs detected in air samples were consistent with the expected emissions from the diesel-based drilling fluid used on the Waste Connections site.
- Based on the health concerns reported by residents in the vicinity of the site during times of reported intense odors, measurements of multiple odorous chemicals in the air, and documented intermittent odors detected by the residents and CDPHE personnel, it is clear that some individuals have experienced physical symptoms related to odors from the site.

In conclusion, using currently available measurement technology and risk assessment methods, OGHIR is unable to document conditions that suggest an ongoing health hazard at this time. However, although the air measurements identified a large number of chemicals related to oil and gas emissions, there may be other chemicals that were not measured that may contribute to the respiratory irritation and odor concerns reported by residents. Furthermore, it is important to make the distinction that our risk assessment methods take into account short and long-term health effects, but do not necessarily reflect the risk for reversible health symptoms due to odors.

OGHIR is continuing to monitor health concerns in the vicinity of the Waste Connections site and will be conducting air monitoring around the nearby Pratt site which is currently in preparation for drilling. Individuals with ongoing health concerns are encouraged to contact OGHIR.

Background

Since May 2017, the Oil and Gas Health Information and Response program (OGHIR) at the Colorado Department of Public Health and Environment (CDPHE) has logged concerns from approximately 50 residents from multiple neighborhoods in Erie reporting odors and health symptoms possibly related to emissions from the Waste Connections oil and gas site.

In response to the large volume of ongoing health and odor concerns, OGHIR collected multiple outdoor air samples from May 31st – June 26 during different days and times to measure volatile organic compounds (VOCs) in the air at locations where residents reported health symptoms and odors.

Purpose

The purpose of this investigation was to evaluate health risks using the air data collected at multiple locations near the Wast Connections site in response to community concerns regarding health effects and odors.

Community Health Concerns

Approximately 50 residents from multiple neighborhoods in Erie reported odors and health symptoms possibly related to emissions from the Waste Connections oil and gas site. OGHIR has documented that many of these concerns occurred temporally with drilling operations on the Waste Connections site when wind direction was coming from the direction of the well pad. The main health symptoms reported include eye, nose and throat irritation, nosebleeds, respiratory effects such as exacerbation of asthma and difficulty breathing, headaches and nausea (Figure 1).

Methods

A total of four (4) individual air samples and seven (7) days of continuous air samples were collected from June 8 to June 26, 2017. Details of each air sampling measurement are described below and summarized in Table 1. Figure 2 shows the approximate sample locations.

Continuous Air Monitoring

The Colorado Air Monitoring Mobile Laboratory (CAMML) was deployed on June 8-14 into the neighborhoods where health symptoms and odors were reported. The CAMML was parked on a walking path ~1,500 feet south of the well pad, situated in between the well pad and a residential community (latitude: 40.018900° / longitude: -105.031917°). Outdoor air samples were collected at an inlet height of 16-18 feet from the ground. The air samples were collected using a Markes UNITY 2 Air Server tenax-based sorbent thermal desorption system and analyzed using a Thermo Scientific ISQ Series GC MS. Samples were collected every hour over a thirty minute period, which totaled 87 hours of continuous sample collection during the deployment (Attachment A). Based on analysis of site-collected meteorological data, wind direction indicated the CAMML was downwind of the Waste Connections site for a small portion of the sampling period (Attachment A).

Single Sample Collection

SUMMA Canister - Air samples were analyzed by an external accredited laboratory for VOCs in accordance with EPA method TO-14A.

Sorbent Tubes - Samples were collected using Tenax-based Markes International sorbent tubes, then sealed and frozen for analysis at a later date. Both hydrophyllic and hydrophobic sorbent tubes were used. Sorbent tubes were analyzed in the CAMML Thermal Desorption-Mass Spectrometry system.

Table 1. Air Sampling Summary

Sample	Location	Date(s) / Time of Collection	Odor Description	Wind Characteristics
CAMML	~1,500 feet south of the well pad, parked off the walking path	June 8-10, 12-14	Not collected	See Figure 3
Road (1)	~1,000 feet SW of the well pad, on the road	May 31, 10:45 am	Fleeting odor diesel, sweet	Winds light and variable from the N, NE, from the direction of the well pad
Road (2)	~1,000 feet SW of the well pad, on the road	May 31, 10:50 am	Fleeting odor diesel, sweet	Winds light and variable from the N, NE, from the direction of the well pad
Walking Path	~1,500 feet south of the well pad, on the walking path	June 20, 2-3:00 pm	Intermittent faint odors	light and variable winds alternating from north and south
Residential	~2,300 feet west of the well pad, in a residential community	June 26, 8:00 pm	Strong odor diesel fuel and WD-40	Winds 3-8 mph from E to ESE, from the direction of the well pad

Health Risk Evaluation

This risk evaluation was performed in accordance with the US Environmental Protection Agency guidance[1]. All measured VOCs were included in this screening level health risk evaluation.

1. Exposure Evaluation

The objective of an exposure evaluation is to select air monitoring data that most closely represents the amount of the chemical that would be inhaled by a person living in the area. In evaluating exposure, the duration of time a person might be inhaling that level is also considered. Two types of exposures are considered:

Short-term exposure represents intermittent, infrequent exposure that could occur repeatedly for a few hours to a few days. Often, short-term exposure concentrations are much higher than long-term exposure concentrations. For this evaluation, short-term exposure assumes a person lives, works, and otherwise stays near a given monitoring location for a time period of up to one day. It also assumes the measured concentrations of VOCs in the air remain constant over the entire day. The following data were selected to represent short-term exposure:

- The maximum air concentrations measured during continuous air monitoring were selected to represent short-term exposures.
- The single samples were also selected to represent short-term exposures as they were collected downwind of the site during a time when odors were noticed.

Long-term exposure assumes a person lives or stays near a given monitoring location for 24 hours per day, 365 days per year, for a lifetime (i.e., 70 years). It also assumes the measured concentrations of the VOCs

[1] US EPA (2004). Air Toxics Technical Resource Manual, EPA-453-K-04-001A.

in the air remain constant over the entire 70-year exposure period. The following data were selected to represent chronic exposure:

- The average air concentration of a VOC over the entire monitoring period from the continuous air monitoring data was selected to represent long-term exposure as these values are likely representative of longer-term exposures with varying site conditions and wind directions.
- The single samples were also evaluated as long-term exposures though they are likely more representative of short-term exposures.

2. Health Effect Evaluation

The objective of a health effect evaluation is to identify relevant guideline values for each of the measured VOCs to determine whether health or odor effects might occur due to exposure at the measured concentration. Health guideline levels are established by the US EPA and/or similar state agencies for both short and long-term exposure to VOCs. For chemicals that cause cancer, there will be a third set of values that describe cancer risk.

Non-cancer health effects: A non-cancer health guideline value is defined by the US EPA as the exposure level that is likely to be without appreciable risk of adverse non-cancer health effects in an exposed population, including sensitive individuals. Typically, there are separate health guideline values are for short and long-term exposures (Table 2). The health guideline value for each VOC is expressed as a concentration in units of parts per billion.

Cancer health effects: For VOCs that could cause cancer, VOC concentrations associated with $1x\ 10^{-6}$ (one in one million) to $1x10^{-4}$ (one in ten thousand) cancer risk levels were used as comparison values. For example, a risk level of one in a million ($1x10^{-6}$) implies that up to 1 out of one million equally exposed people could contract cancer if exposed continuously (i.e. 24 hours per day) to the specific concentration over a lifetime (i.e. 70 years). This would be in addition to those cancer cases that would normally occur in an unexposed population of one million people. The level of cancer risk that is of concern is a matter of individual, community, and regulatory judgment. However, the EPA typically considers risks below 1×10^{-6} to be so small as to be negligible. Therefore, the EPA uses a cancer risk of one in a million (1×10^{-6}) as a regulatory goal, which means that regulatory programs are generally designed to try to reduce risk to this level. However, the EPA considers all cancer risks lower than 1 in 10,000 ($1x10^{-4}$) to be "acceptable".

Odor concerns: Odor threshold values were selected from values established by the American Industrial Hygiene Association[2] or Texas Commission on Environmental Quality (TCEQ).

An odor threshold is the concentration at which the odor of a chemical can be detected by the average person. Some people have a more sensitive sense of smell and can detect odors at lower concentrations.

3. Risk Characterization

Risk characterization combines the information from the exposure evaluation and health effect evaluation steps to describe the potential health risks.

[2]American Industrial Hygiene Association (2013). Odor Thresholds for Chemicals With Established Occupational Health Standards, 2nd edition

Non-cancer health effects:

Individual VOCs: A hazard quotient (HQ) was determined for each individual VOC. This ratio is a risk estimate that compares the maximum or average air concentration for each VOC to short- and long-term health guideline values. HQs are an indication of whether there is potential cause for concern for adverse health effects.

Combined VOCs: When simultaneous exposures to multiple chemicals in the air can occur, it is important to evaluate the potential for risks to human health from combined exposures. To evaluate the combined risk, a Hazard Index or HI is used. An HI is calculated by adding together all of the individual HQs. This total HI is a conservative approximation of the total potential non-cancer risk for exposure to all of the VOCs.

HQs and His are calculated as follows:

$$\text{Short-term HQ} = \frac{\text{short-term exposure}}{\text{HGV (short-term)}}$$

$$\text{Long-term HQ} = \frac{\text{long-term exposure}}{\text{HGV (long-term)}}$$

HQ = Hazard Quotient
HGV = Health Guideline Value

$$HI = HQ_1 + HQ_2 + HQ_3 + \ldots.$$

HQs and HIs are evaluated as follows:

- If HQ or HI is less than 1, no further evaluation is necessary and it can generally be concluded that potential for adverse health effects from the exposures measured in this study is low.
- If HQ or HI is greater than or equal to 1, further evaluation is needed.

Cancer health effects:

To estimate the potential for increased cancer risks, the VOC concentration at each risk level within the generally "acceptable" risk range ($1x10^{-4}$ to $1x10^{-6}$) was compared to the exposure measurements. Combined cancer risks were also evaluated for all known cancer causing VOCs. This approach assumes the combined effect of each of the VOCs is additive.

Odor concerns:

Community odor concerns were evaluated qualitatively by comparing with available odor threshold values. The maximum short-term air concentration of a VOC in any of the samples was compared to the odor threshold values

Results

Long-Term Risk

- Cancer risks estimates for the two carcinogenic VOCs (benzene and ethylbenzene) individually (Table 3) or together (Table 4) were less than one in one hundred thousand, which is below the midpoint of the acceptable risk range of $1x10^{-6}$ to $1x10^{-4}$ (Table 3 - 4).
- All air concentrations of individual (Table 2) and combined (Table 4) VOCs were below long-term non-cancer health guideline values, with the highest hazard estimate (HQ) of approximately 0.1 for two chemicals (Figures 3 - 6).
    - Isoprene was the only VOC with a long-term hazard quotient above 0.1, which is about 10 times less than the health based guidance value (CAMML and road samples only) (Figures 3 and 5). Isoprene is primarily emitted from vegetation and humans and in lower quantities in tobacco smoke and automobile exhaust. Isoprene was not identified as a chemical likely emitted from the Waste Connections facility.
    - The highest average concentration of benzene approached a long-term hazard quotient of 0.1 in a single one-hour sample collected by the CAMML (Figure 3). All other benzene air concentrations were 10 – 100 times lower than the short and long-term health guideline values.

Short-Term Risk

- The maximum measured air concentrations of all detected VOCs across all the air samples, including during times when strong odors noted by CDPHE staff or citizens, were well below short-term non-cancer health guideline values (Table 2, Figures 3 – 6).
- Combined (cumulative) exposures to all VOCs was below a short-term non-cancer risk estimate of 1 (Table 4).

Odor Concerns

- The maximum short-term (1 hour sample) air concentrations of trimethylbenzenes, ethylbenzene, 1,4-diethylbenzene, and styrene were in the range of established odor detection levels (i.e., within 10-fold of the threshold values) (Table 5).

Limitations and Uncertainties

The following limitations must be considered when interpreting the results from this investigation:

- This air sampling represents a "snapshot" of VOC concentrations from all emission sources in the area. Samples collected under different conditions could have different results.
- Other substances that may be emitted from oil and gas were not sampled in this study and exposure to these substances may result in additional health risk.
- Whether the VOCs in the air will have a harmful effect on an individual's health depends upon many factors that are not all measured in this risk assessment. These include non-chemical factors such as age, family traits (i.e. genetics), and lifestyle behaviors.
- Meteorological data indicated that the wind was not coming from the direction of the Waste Connections site during the majority of the period of continuous air monitoring. Therefore, the data from the CAMML more likely represent average air concentrations of VOCs during normal conditions and not the highest potential concentrations of VOCs emitted from the oil and gas site during odor events.
- Odor concerns cannot be fully evaluated due to the lack of information regarding odor thresholds associated with physical symptoms and the combined effects of odors from multiple chemicals.

Conclusions

Evaluation of health concerns reported by residents in the vicinity of Waste Connections drilling site suggest upper respiratory irritation and physiological responses to odors. OGHIR has documented that many of these concerns occurred temporally with drilling operations on the site when wind direction was coming from the direction of the well pad.

While OGHIR has only been logging health concerns since October of 2015, the number and frequency of health concerns reported in association with the Waste Connections site is much higher than most other sites in the state. Based on the health concerns reported by residents in the vicinity of Waste Connections during times of reported intense odors, measurements of multiple odorous chemicals in the air, and documented intermittent odors detected by the residents and CDPHE personnel, it is clear that some individuals have experienced physical symptoms related to odors from the site. Typically, these symptoms have resolved as the odor decreased.

To evaluate the risk for short and long-term health effects, the Colorado Air Monitoring Mobile Laboratory (CAMML) was deployed, and multiple single air samples were collected between May 31st – June 26 during different days and times to measure volatile organic compounds (VOCs) in the air at locations where residents reported health symptoms and odors. The evaluation of the air samples during this time indicates a low risk of short or long-term harmful health effects due to VOC exposures in the vicinity of these oil and gas operations.

Using currently available measurement technology and risk assessment methods, OGHIR is unable to document conditions that suggest an ongoing health hazard at this time. However, although the air measurements identified a large number of chemicals related to oil and gas emissions, there may be other chemicals that were not measured that may contribute to the respiratory irritation and odor concerns reported by residents. Furthermore, it is important to make the distinction that our risk assessment methods take into account short and long-term health effects, but do not necessarily reflect the risk for reversible health symptoms due to odors.

Next Steps

OGHIR continues to monitor health concerns in the vicinity of the Waste Connections site and will be collecting air monitoring data in the neighborhoods by the upcoming Pratt site. Individuals with ongoing health concerns are encouraged to contact OGHIR by phone (303) 389-1687 or online www.colorado.gov/oghealth.

Figure 1. Summary of Health Symptoms Reported to OGHIR

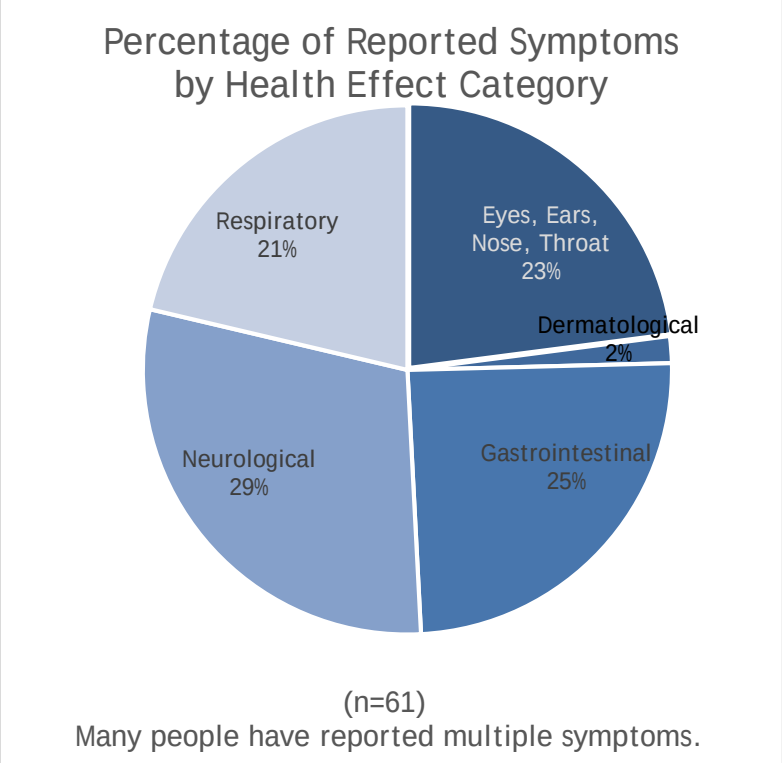


Figure 2. Map of Waste Connection Site (red arrow) and Sampling Locations (yellow stars).

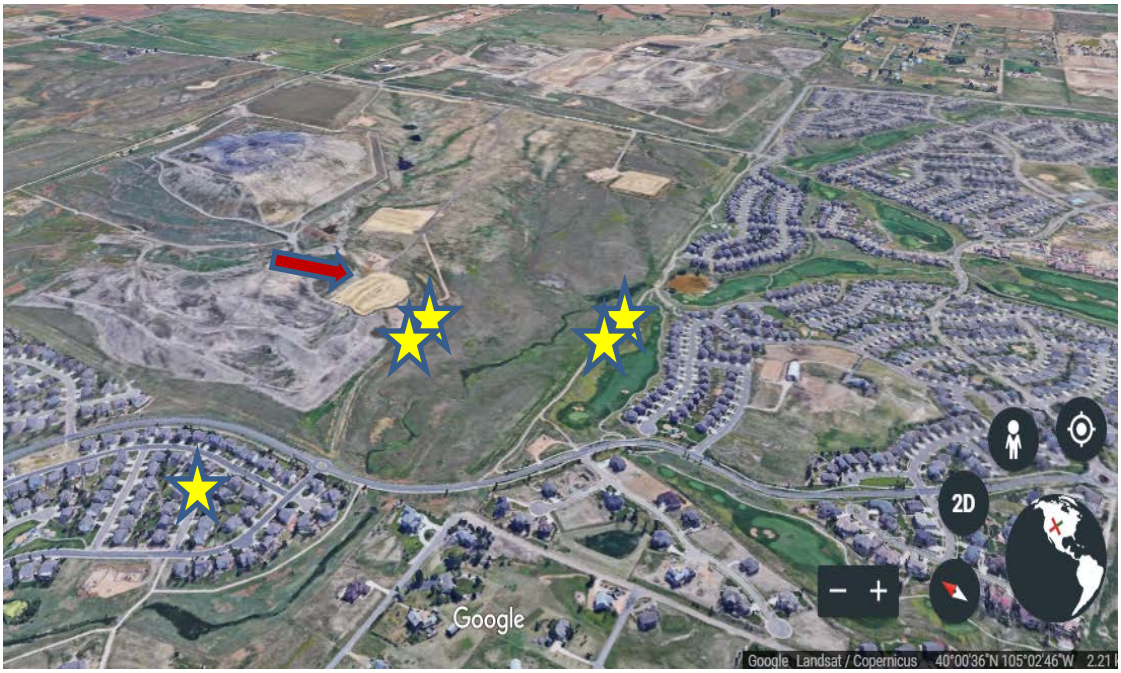


Table 2. Air measurements compared to non-cancer health guideline values. All values are in ppbV.

Chemical	CAMML		Walking Path	Road		Neighbor-hood	Health Guidelines	
	6-day Average	Maximum (1-hr)		1	2		Short-Term	Long-Term
1,2,3-Trimethylbenzene	0.078	0.822	ND	0.107	0.172	ND	**3000** T	**12** I
1,2,4-Trimethylbenzene	0.342	0.972	ND	0.211	0.119	0.051	**3000** T	**12** I
1,3,5-Trimethylbenzene	0.125	0.873	ND	0.131	0.111	0.032	**3000** T	**12** I
1,3-Diethylbenzene	ND	ND	ND	0.000	0.422	ND	**460** T	**46** T
1,4-Diethylbenzene	0.133	0.142	ND	0.000	ND	ND	**450** T	**46** T
1-Butene	0.210	0.990	ND	ND	ND	ND	**27000** T	**2300** T
1-Hexene	0.053	0.131	0.218	0.000	0.612	ND	**500**	**50** T
1-Pentene	0.203	0.917	0.362	0.000	0.132	ND	**12000** T	**560** T
2,2,4-Trimethylpentane	0.135	0.645	0.129	0.000	0.234	0.090	**4100** T	**390** T
2,2-Dimethylbutane	0.226	0.897	ND	0.058	0.264	ND	**1000** T	**100** T
2,3,4-Trimethylpentane	0.152	0.949	0.278	0.000	0.112	ND	**4100** R	**390** R
2,3-Dimethylbutane	0.407	0.994	0.149	0.255	0.485	ND	**990** T	**99** T
2,3-Dimethylpentane	0.232	0.982	0.173	0.164	0.175	ND	**8300** R	**2200** R
2,4-Dimethylpentane	0.026	0.139	0.882	0.124	0.121	ND	**8300** T	**2200** T
2-Butene (cis)	ND	ND	0.797	0.000	0.429	ND	**15000** T	**700** T
2-Butene (trans)	0.176	0.484	0.394	0.000	0.296	ND	**15000** T	**700** T
2-Methylheptane	0.178	0.924	0.839	0.406	0.749	0.055	**4100** T	**380** T
2-Methylhexane	0.357	0.991	0.119	0.464	0.220	ND	**8300** T	**2200** T
2-Methylpentane	0.344	1.186	0.112	1.452	0.157	0.218	**990** T	**90** T
3-Methylheptane	0.141	0.880	0.189	0.309	0.582	0.043	**4100** T	**380** T
3-Methylhexane	0.277	0.962	0.651	0.594	0.112	0.083	**8300** T	**2200** T
3-Methylpentane	0.267	0.984	0.259	0.825	0.468	0.117	**1000** T	**100** T
Acetylene	0.401	0.957	0.118	0.565	0.829	0.545	**25000** T	**2500** T
Benzene	0.256	0.926	0.366	0.420	0.369	0.133	**9** A	**9.3** I
Cyclohexane	0.225	0.916	0.129	0.992	0.163	0.105	**1000** T	**1743** I
Cyclopentane	0.216	0.983	0.320	0.352	0.132	0.058	**5900** T	**120** T
Ethane	4.607	46.581	ND	48.200	ND	5.050	**NA**	**NA**
Ethylbenzene	0.338	0.949	0.986	0.233	0.252	0.049	**5000** A	**230** I
Ethylene	0.589	1.642	ND	0.950	ND	0.580	**500000** T	**5300** T
Isobutane	0.616	6.200	0.166	5.275	0.147	0.680	**33000** T	**10000** T
Isopentane	0.704	5.998	0.153	4.640	0.828	0.680	**8100** T	**8000** T
Isoprene	0.317	0.957	0.172	0.000	0.524	0.098	**20** T	**2** T
Methylcyclohexane	0.257	0.936	0.388	1.914	0.263	0.214	**4000** T	**400** T
Methylcyclopentane	0.278	1.014	0.762	1.125	0.158	0.145	**750** T	**75** T
m-Ethyltoluene	0.109	0.859	ND	0.178	0.763	0.054	**250** T	**25** T
m-Xylene/P-Xylene	0.243	0.933	0.215	0.604	0.220	1.100	**1700** A	**23** I
n-Butane	1.151	14.794	0.329	12.550	0.463	1.668	**92000** T	**10000** T
n-Decane	0.241	0.884	ND	0.523	0.968	0.061	**1750** T	**175** T
n-Dodecane	ND	ND	ND	0.494	ND	0.103	**4500** D	**210** R
n-Heptane	0.266	0.932	0.239	1.416	0.288	0.180	**8300** T	**2200** T
n-Hexane	0.362	2.557	0.164	2.367	0.349	0.292	**1700** T	**198** I
n-Nonane	0.248	0.942	0.142	0.594	0.132	1.500	**3000** T	**38** P
n-Octane	0.216	0.847	0.236	0.910	0.135	0.119	**4100** T	**75** T
n-Pentane	0.593	6.275	0.236	4.640	1.752	0.732	**68000** T	**8000** T
n-Propylbenzene	0.166	0.830	ND	0.099	0.879	ND	**510** T	**203** P
n-Undecane	0.137	0.497	ND	0.618	0.116	0.105	**550** T	**55** T
o-Ethyltoluene	0.176	0.740	ND	0.000	0.572	ND	**250** T	**25** T
o-Xylene	0.190	0.859	0.142	0.171	0.680	0.051	**1700** A	**23** I
Pentene (cis-2-)	0.008	0.017	0.639	0.000	0.225	ND	**12000** T	**560** T
Pentene (trans-2-)	0.185	0.854	0.733	0.000	0.774	ND	**12000** T	**560** T
p-Ethyltoluene	0.071	0.349	ND	0.222	0.853	0.043	**250** T	**25** T
Propane	2.409	27.338	ND	28.200	0.257	2.783	**68000** T	**8000** T
Propylene	0.207	0.833	0.216	0.277	0.221	0.210	**NA**	**1743** C
Styrene	0.378	0.378	ND	0.000	0.713	ND	**5000** A	**235** I
Toluene	0.394	0.994	0.557	1.120	0.470	0.274	**2000** A	**1327** I

I = US EPA; A = ATSDR (US Agency for Toxic Chemicals and Disease Registry); P= PPRTV (US EPA Provisional Peer Reviewed Toxicity Values); C= CalEPA (California Office of Environmental Health Hazard Assessment); T= TCEQ (Texas Commission on Environmental Quality); D = DOE (Department of Energy Temporary Emergency Exposure Limit); R = Read Across; NA = no health value available; ND = not detected (i.e. concentration below instrument detection limit)

Table 3. Summary of average air measurements collected by the CAMML compared to lowest VOC concentration at each risk level within the generally "acceptable"[1] risk range ($1x10^{-4}$ to $1x10^{-6}$).

Substance	Average Air Measurement[2] (ppb)	Cancer Risk Estimate		
		Air Concentration at $1x10^{-6}$ (ppb)	Air Concentration at $1x10^{-5}$ (ppb)	Air Concentration at $1x10^{-4}$ (ppb)
Benzene[3]	0.26	0.041[2]	0.41[2]	4.1[2]
Ethylbenzene[4]	0.33	0.092[3]	0.92[3]	9.2[3]

[1]A one in a million cancer risk ($1x10^{-6}$) is considered a minimal cancer risk. A one in ten thousand cancer risk ($1x10^{4}$) is considered the upper limit of the US EPA "acceptable" range.
[2]The average value was calculated using the CAMML data across 6 days of continuous sampling.
[3]Determined using the US EPA inhalation unit risk of 7.8 $x10^{-6}$ per µg/m^3.
[4]Determined using the CalEPA inhalation unit risk of $2.5x10^{-6}$ per µg/m^3.

Table 4. Summary of cumulative risk estimates from each sampling site

Location	Combined Cancer Risk	Acute HI	Chronic HI
CAMML	1.0×10^{-5}	0.17	0.31
Walking Path	NA	0.05	0.19
Road		0.09	0.65
Neighborhood		0.02	0.17

NA = not applicable. The samples were short-term samples that do not represent air concentration for lifetime cancer risks

Table 5. Comparison of maximum air concentrations detected across all samples with odor threshold values

Chemical*	Maximum Concentration (ppbV)	Odor Threshold (ppbV)	Odor Characteristic
1,2,3-Trimethylbenzene	0.822	6	aromatic
1,2,4-Trimethylbenzene	0.972	6	aromatic
1,3,5-Trimethylbenzene	0.873	6	aromatic
1,3-Diethylbenzene	ND	0.38	NA
1,4-Diethylbenzene	0.142	0.38	NA
1-Butene	0.990	362	petroleum
1-Hexene	0.131	139	petroleum
1-Pentene	0.917	100	gasoline
2,2,4-Trimethylpentane	0.645	660	gasoline, oil
2,2-Dimethylbutane	0.897	426	gasoline
2,3,4-Trimethylpentane	0.949	660	gasoline, oil
2,3-Dimethylbutane	0.994	426	gasoline
2,3-Dimethylpentane	0.982	410	gasoline
2,4-Dimethylpentane	0.139	410	gasoline
2-Butene (cis)	ND	362	petroleum
2-Butene (trans)	0.484	362	petroleum
2-Methylheptane	0.924	660	gasoline
2-Methylhexane	0.991	410	gasoline
2-Methylpentane	1.186	426	gasoline
3-Methylheptane	0.880	660	gasoline
3-Methylhexane	0.962	410	gasoline
3-Methylpentane	0.984	426	gasoline
Acetylene	0.957	226000	gassy, garlic
Benzene	0.926	470	aromatic, sweet, solvent
Cyclohexane	0.916	520	pungent
Cyclopentane	0.983	NA	NA
Ethane	46.581	20328000	NA
Ethylbenzene	0.949	<2	oily, solvent
Ethylene	1.642	1700	grassy
Isobutane	6.200	421	natural gas
Isopentane	5.998	13000	sweet, gasoline
Isoprene	0.957	47	aromatic
Methylcyclohexane	0.936	149	petroleum
Methylcyclopentane	1.014	NA	NA
m-Ethyltoluene	0.859	NA	NA
m-Xylene/P-Xylene	0.933	12	sweet, creosote/burnt organic matter
n-Butane	14.794	421	natural gas
n-Decane	0.884	620	gasoline
n-Dodecane	ND	5310	gasoline
n-Heptane	0.932	410	gasoline
n-Hexane	2.557	1500	gasoline
n-Nonane	0.942	2300	gasoline
n-Octane	0.847	660	gasoline, oil
n-Pentane	6.275	1290	sweet
n-Propylbenzene	0.830	NA	NA
n-Undecane	0.497	110	hydrocarbon
o-Ethyltoluene	0.740	NA	NA
o-Xylene	0.859	12	sweet, creosote/burnt organic matter
Pentene (cis-2-)	0.017	190	gasoline
Pentene (trans-2-)	0.854	190	gasoline
p-Ethyltoluene	0.349	NA	NA
Propane	27.338	1497000	natural gas
Propylene	0.833	10100	gassy, aromatic
Styrene	0.378	2.8	sharp, sweet
Toluene	0.994	21	sour, burnt

*__Bolded__ chemicals represent air concentrations within an order of magnitude of the odor threshold
NA- Not Available, ND- Non Detect, Sources: AIHA & TCEQ

Figure 3. CAMML: (A) Short-term and (B) long-term risk estimates (hazard quotients - HQ) for individual and combined ("All") VOCs for non-cancer effects.

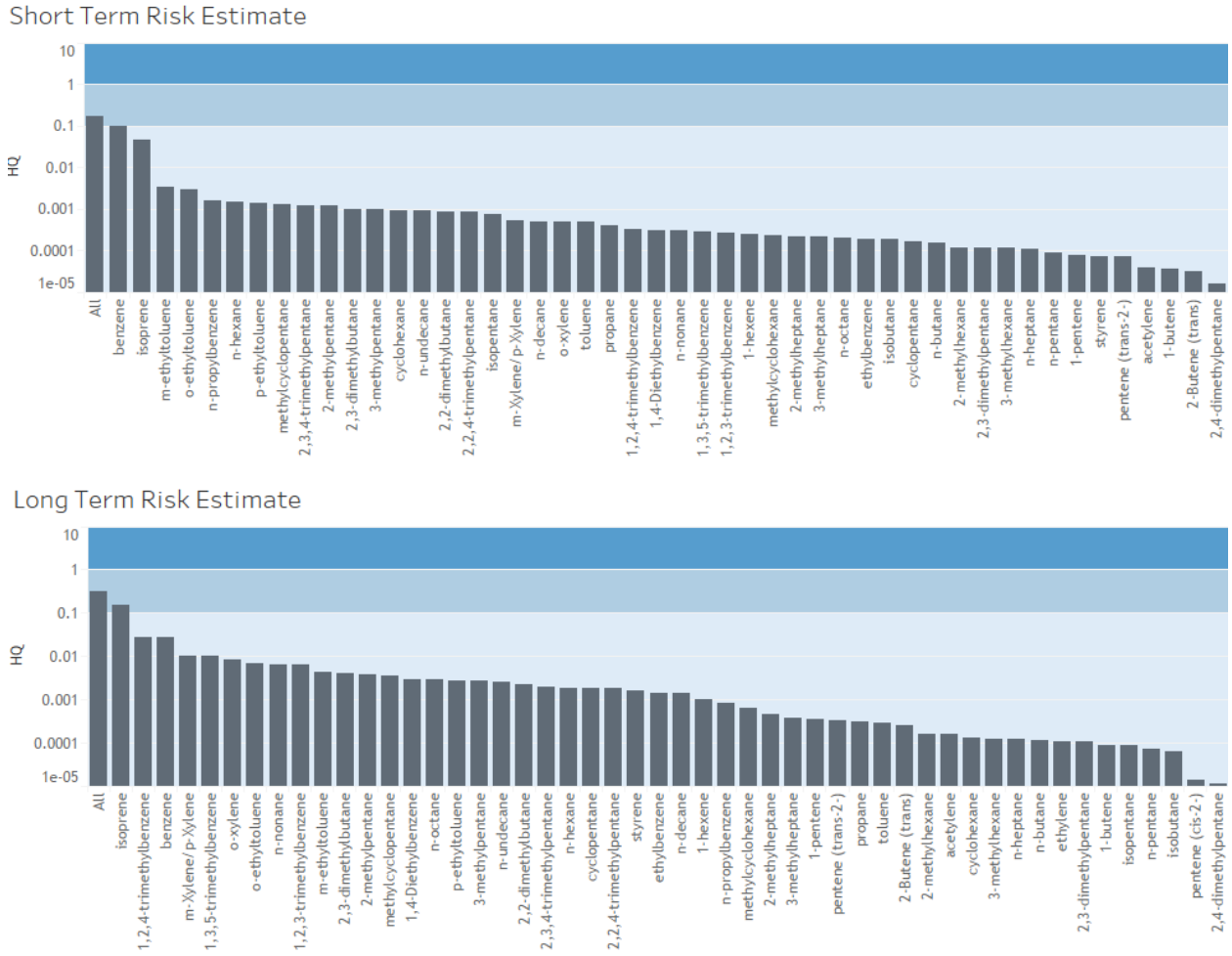
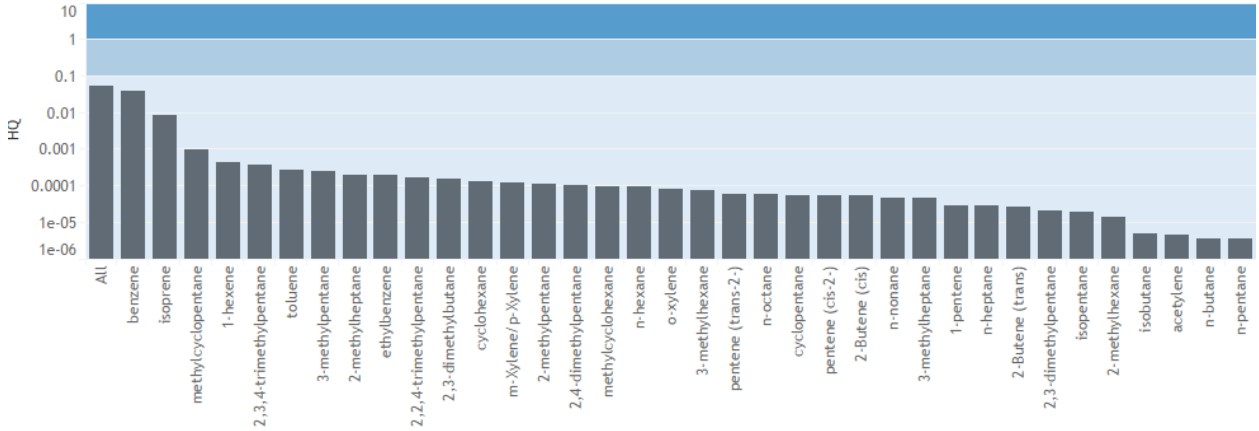


Figure 4. Walking Path

Short Term Risk Estimate



Long Term Risk Estimate

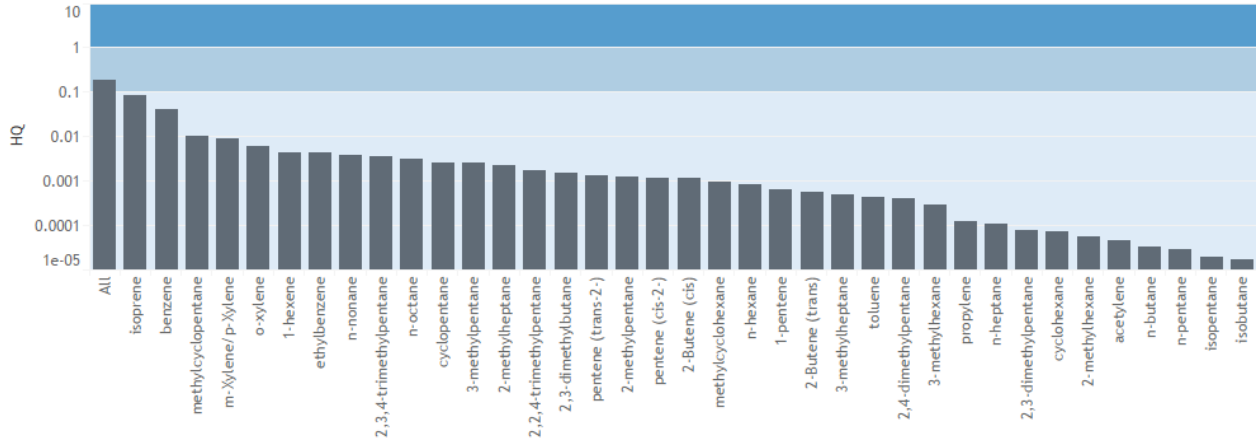
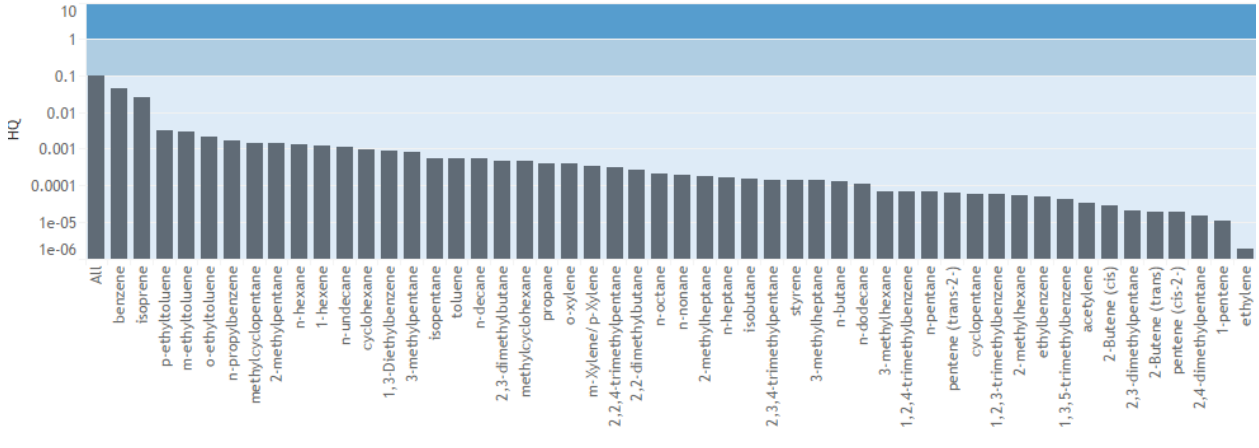


Figure 5. Road

Short Term Risk Estimate



Long Term Risk Estimate

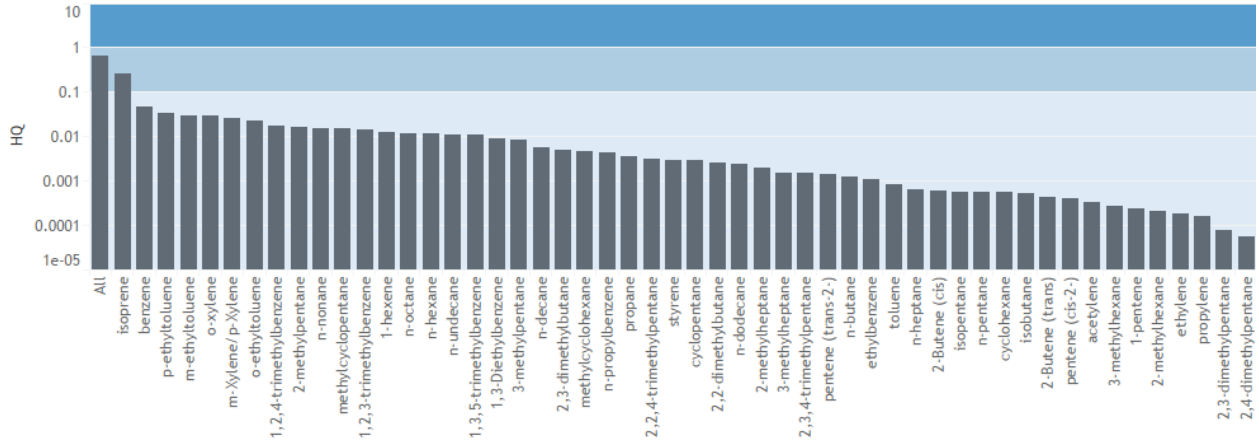
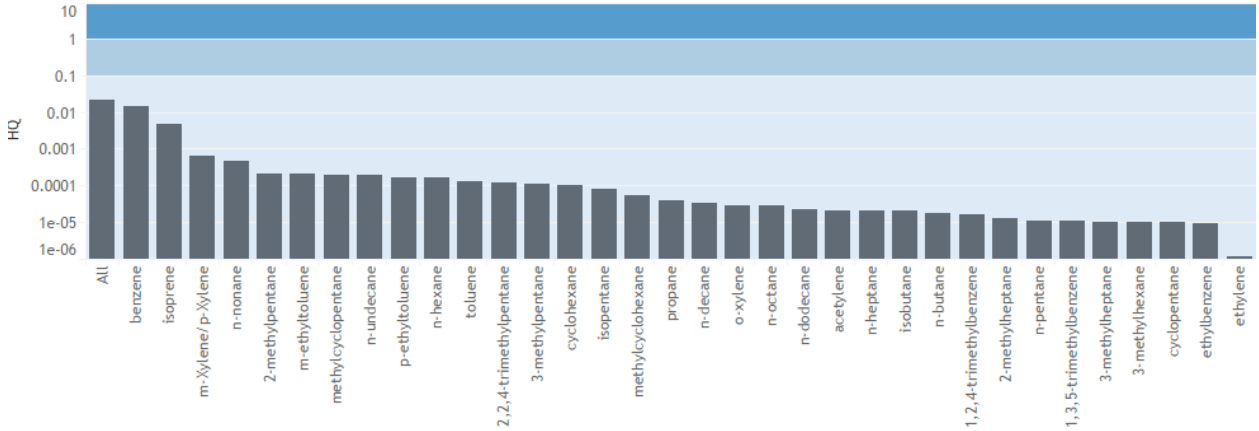
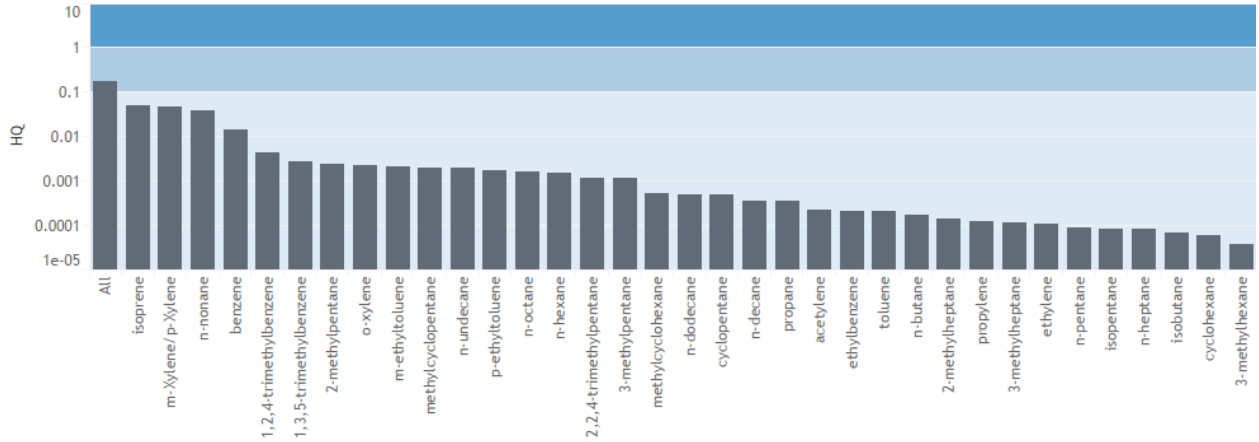


Figure 6. Residential Area

Short Term Risk Estimate

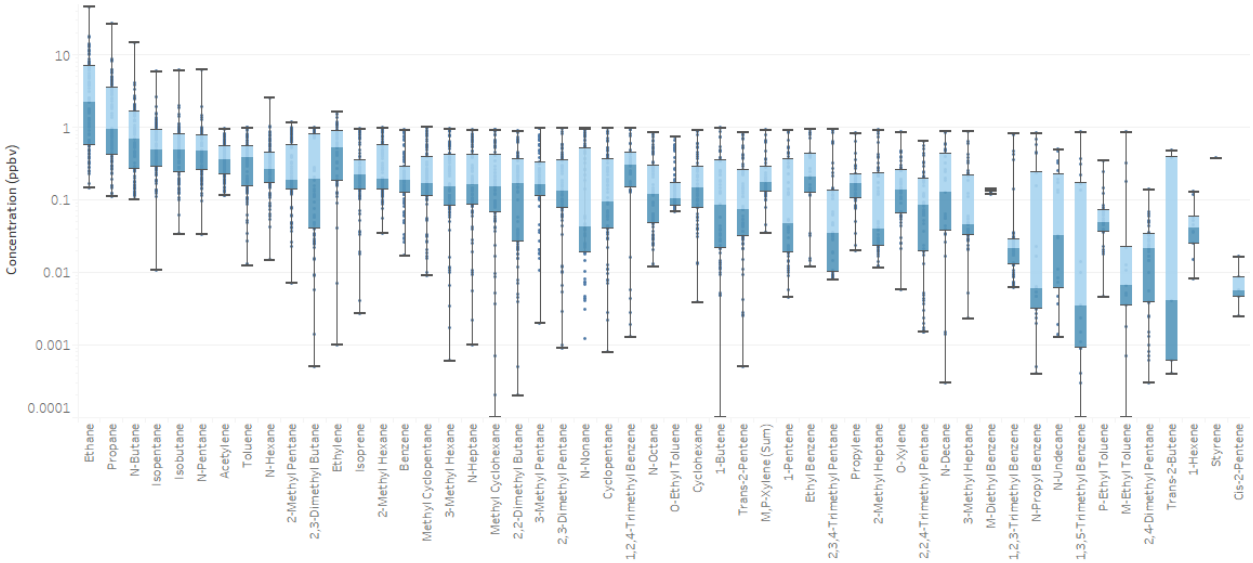


Long Term Risk Estimate



Attachment A

Air measurements of VOCs from the CAMML deployment. Box and whisker plot shows the minimum, 25th percentile, median, 75th percentile, and maximum concentrations on a log scale for each substance.



Wind Rose showing the frequency and speed of wind blowing from each direction during the continuous air monitoring with the Colorado Air Monitoring Mobile Laboratory (Deployment dates: June 8-14, 2017). The mobile lab is represented by the center of the dial, and the Waste Connections site is located approximately at 0 degrees (due north). The length of the spoke corresponds to the frequncy and speed of the wind blowing *from* the indicated direction. For example, the wind was blowing at low and high speeds *from* the southeast, for a large proportion of the time.