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

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Executive Summary

Since July 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 55 residents in Erie neighborhoods near the Pratt oil and gas site operated by Crestone Peak Resources (40.016648°, -105.0224488°). These reports are in addition to the many residents reporting odor and health concerns from the nearby Waste Connections drilling site (40.018900°, -105.031917°). Residents have reported eye, nose and throat irritation, nosebleeds, respiratory effects such as lung irritation 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 from July 27 – August 7, 2017 to measure volatile organic compounds (VOCs) associated with oil and gas emissions. These samples were collected in multiple locations in the neighborhoods near the Pratt 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.

This air sampling investigation found:

- The measured levels of all VOCs were well below federal or state health guideline values, which suggest a low risk of harmful health effects.
- Many of the VOCs detected in air samples were consistent with the expected emissions from the diesel-based drilling fluid used on the Pratt site.
- The levels of some VOCs were in the range that would be detectable as an odor.
- Based on the measurements of multiple substances that can produce odors and documented sporadic odors detected by the residents during times when health symptoms occur, it is clear that some people have experienced physical symptoms related to odors from the site. Typically, these symptoms have resolved as the odor decreased.

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. Although the air measurements identified a large number of VOCs related to oil and gas emissions, there may be other substances 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 evaluate if the VOCs are at levels that could cause short and long-term harmful health effects, but do not necessarily reflect the risk for reversible health symptoms due to odors.

OGHIR continues to monitor health concerns in the vicinity of the Pratt and Waste Connections sites and will be conducting additional air monitoring during the next phases of operations. Individuals with ongoing health concerns are encouraged to contact OGHIR.

Background

Since July 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 55 residents from multiple neighborhoods in Erie reporting odors and health symptoms possibly related to emissions from the Pratt oil and gas site. These reports are in addition to the many residents reporting odor and health concerns from the nearby Waste Connections drilling site.

As an initial response to the large volume of health and odor concerns from the Waste Connections site, OGHIR collected multiple outdoor air samples from May 31st – June 26 to measure volatile organic compounds (VOCs) in the air at locations where residents reported health symptoms and odors. The completed report: *Investigation of Reported Health Concerns near Waste Connections Oil and Gas Site in Erie* (July 31, 2017) is availble online at www.colorado.gov/oghealth.

In response to continuing health and odor concerns related to the nearby Pratt site, OGHIR deployed the Colorado Air Monitoring Mobile Laboratory to collect air samples from July 27 – August 7, 2017 in different locations near where residents reported health symptoms and odors.

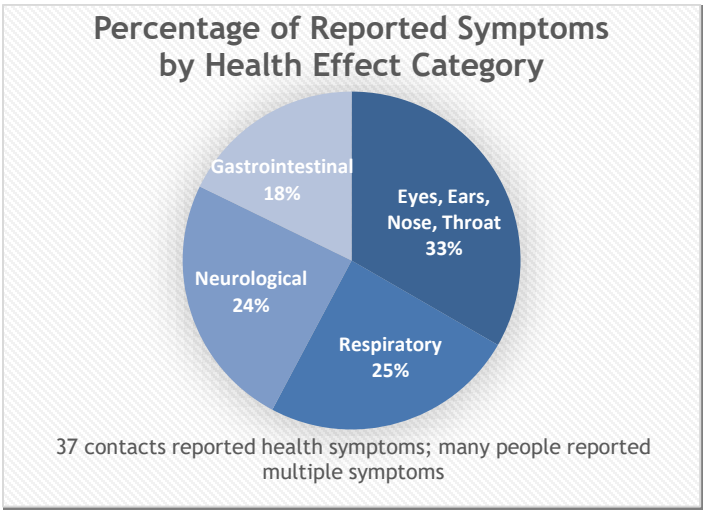
Purpose

The purpose of this investigation was to evaluate whether people living near the Pratt oil and gas site were at risk of harmful health effects from exposures to substances in the air.

Community Health Concerns

Fifty-five (55) residents from multiple neighborhoods in Erie reported concerns related to emissions from the Pratt oil and gas site. Some residents reported that symptoms and odors occurred during the same times when wind direction was coming from the direction of the Pratt site well pad. The main reported health symptoms include eye, nose and throat irritation, nosebleeds, respiratory effects such as lung irritation and difficulty breathing, headaches and nausea (Figure 1).

Figure 1. Summary of health symptoms reported to OGHIR



Methods

OGHIR collected five (5) individual air samples and 18 days of continuous air samples (approximately 300 hours) in various locations south of the Pratt site from June 8 to June 26, 2017 (Figure 2). Details of each air sampling measurement are described below and summarized in Table 1.

Continuous Air Monitoring

OGHIR deployed the Colorado Air Monitoring Mobile Laboratory (CAMML) on July 27 - August 14 on a walking path ~950 feet south-west of the well pad, situated in between the well pad and a residential community where health symptoms and odors were reported (40.014593°, -105.024727°). Air samples were collected at an inlet height of 16-18 feet from the ground 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 298 hours of continuous sample collection during the deployment (Attachment A). Based on analysis of site-collected meteorological data, wind direction indicated the CAMML was directly downwind of the Pratt site approximately 15% of the time (Attachment A).

Single Sample Collection

Sorbent Tubes – OGHIR collected single air samples using Tenax-based Markes International sorbent tubes that were sealed and frozen for analysis at a later date (Samples 1-5 in Table 1). Both hydrophyllic and hydrophobic sorbent tubes were used. Sorbent tubes were analyzed in the CAMML Thermal Desorption-Mass Spectrometry system.

Figure 2. Map of Pratt site (red arrow), grab sampling locations (yellow stars), and CAMML location (orange star).

Table 1. Air sampling summary

Sample	Location	Date(s) / Time of Collection	Odor Description	Wind Characteristics
CAMML	~950 feet south-west of the well pad, parked off the walking path	July 27- August 14	Not collected	Wind rose located in Appendix
1	~900 feet SE of the well pad, on the walking path	Aug 22, 4:30 pm	Moderate fleeting diesel odor	Winds light and variable from the N, NW, from the direction of the well pad
2	~900 feet SE of the well pad, on the walking path	Aug 22, 4:35 pm	Moderate fleeting diesel odor	Winds light and variable from the N, NW, from the direction of the well pad
3	~2,500 feet SE of the well pad, near the playground	Aug 7, 9:49 am	Moderate fleeting diesel odor	Winds light and variable from the N, NW, from the direction of the well pad
4	~950 feet SW of the well pad, near the CAMML location on the walking path	Aug 7, 9:44 am	Moderate fleeting diesel odor	Winds light and variable from the N, NE, from the direction of the well pad
5	~950 feet SW of the well pad, near the CAMML location on the walking path	Aug 7, 10:05 am	Moderate fleeting diesel odor	Winds light and variable from the N, NE, from the direction of the well pad

Health risk evaluation

The risk evaluation approach was consistent with 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 represent the amount of the substance that would be inhaled by a person living in the area. The exposure evaluation also considers the length of time that a person would inhale the substance. Two types of exposures are considered:

   Short-term exposure represents intermittent exposures that could occur repeatedly for a few hours to a few days. Often, short-term exposures are much higher than long-term exposures. For this evaluation, short-term exposure assumes the worst case scenario that a person breaths the outdoor air continuously for a few hours to a few days and the measured concentrations of VOCs in the air remain constant over that entire time. The following data were selected to represent short-term exposure:

   - The maximum air concentrations measured during continuous air monitoring.
   - The single samples collected downwind of the site during a time when there were noticeable odors.

   Long-term exposure assumes a person is breathing the outdoor air continuously (24 hours per day, 365 days per year) for a lifetime (i.e. 70 years) and the measured concentrations of the VOCs in the air remain constant over the entire 70-year exposure period. The following data were used to represent long-term exposure:

   - The average air concentration of a VOC over the entire monitoring period from the continuous air monitoring data are most representative of longer-term exposures with varying site conditions and wind directions.

[1] US EPA (2004). Air Toxics Technical Resource Manual, EPA-453-K-04-001A, Volume 1, Chapters 12-13.

- Although more likely to represent short-term exposures, the single samples were also evaluated as long-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 non-cancer health effects might occur due to exposure at the measured concentration. Health guideline values are established by the US EPA and/or similar state agencies for both short and long-term exposure to VOCs. For substances that cause cancer, there is 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 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) theoretical cancer risk levels were used as comparison values. For example, a risk level of one in a million 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 and uses a cancer risk of one in a million (1×10^{-6}) as a regulatory goal. In general, risk levels below one in ten thousand (1 in 10,000; $1x10^{-4}$) are considered low risk and within the EPA "acceptable" excess cancer risk range.

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 substance 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.

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 substances in the air can occur, it is important to evaluate the potential for risks to human health from combined exposures. To evaluate

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

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:

$$\textbf{Short-term hazard quotient (HQ)} = \frac{\text{short-term exposure}}{\text{short-term health guideline value}}$$

$$\textbf{Long-term hazard quotient (HQ)} = \frac{\text{long-term exposure}}{\text{long-term health guideline value}}$$

$$\textbf{Hazard Index (HI)} = HQ_1 + HQ_2 + HQ_3 + \ldots$$

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

Short-Term Risk

- The maximum measured air concentrations of all detected VOCs across all air samples, including during times when noticeable odors were present, were below short-term non-cancer health guideline values (Table 2, Figure 3).
- Benzene was the only VOC with a short-term hazard quotient slightly above 0.1, which is 10 times less than the health guideline value (Figure 3). Benzene exceeded a short-term hazard quotient of 0.1 in less than 3% of all samples (8 samples).
- Combined exposures to all VOCs were below a short-term non-cancer risk estimate of 1 (Table 4).

Long-Term Risk

- All air concentrations of individual (Table 2) and combined (Table 4) VOCs were below long-term non-cancer health guideline values (Figure 3).
- Cancer risks estimates for the two carcinogenic VOCs (benzene and ethylbenzene) individually (Table 3) or combined (Table 4) were less than one in one hundred thousand, which is below the midpoint of EPA's "acceptable' excess cancer risk range of $1x10^{-6}$ to $1x10^{-4}$.

Odor Concerns

- The maximum short-term (1 hour sample) air concentrations of 1,3,5-trimethylbenzene, ethylbenzene, xylenes, diethylbenzenes, butane, and toluene 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 or other nearby facilities 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.
- 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 substances.

Conclusions

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

In response to these concerns, OGHIR deployed the Colorado Air Monitoring Mobile Laboratory (CAMML) and collected multiple single air samples between July 27 – August 22 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 indicated 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. Although the air measurements identified a large number of VOCs related to oil and gas emissions, there may be other substances that were not measured that may contribute to the reported health symptoms and odors.

These risk assessment methods evaluate if the measured VOCs are at levels that could cause short and long-term harmful health effects, but do not necessarily reflect the risk for reversible health symptoms due to odors. Based on the measurements of multiple substances that can produce odors and documented sporadic odors detected by the residents during times when health symptoms occur, it is clear that some people have experienced physical symptoms related to odors from the site. Typically, these symptoms have resolved as the odor decreased.

Next Steps

OGHIR continues to monitor health concerns in the vicinity of the Pratt and Waste Connections sites and will be conducting additional air monitoring during the next phases of operation. Individuals with ongoing health concerns are encouraged to contact OGHIR by phone (303) 389-1687 or online www.colorado.gov/oghealth.

Figure 3. Short-term and long-term risk estimates (hazard quotients – HQ) for individual and combined ("All") VOCs for non-cancer effects from the CAMML air data. "All" represents the risk estimate for non-cancer health effects to occur from all substances combined. If HQ 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.

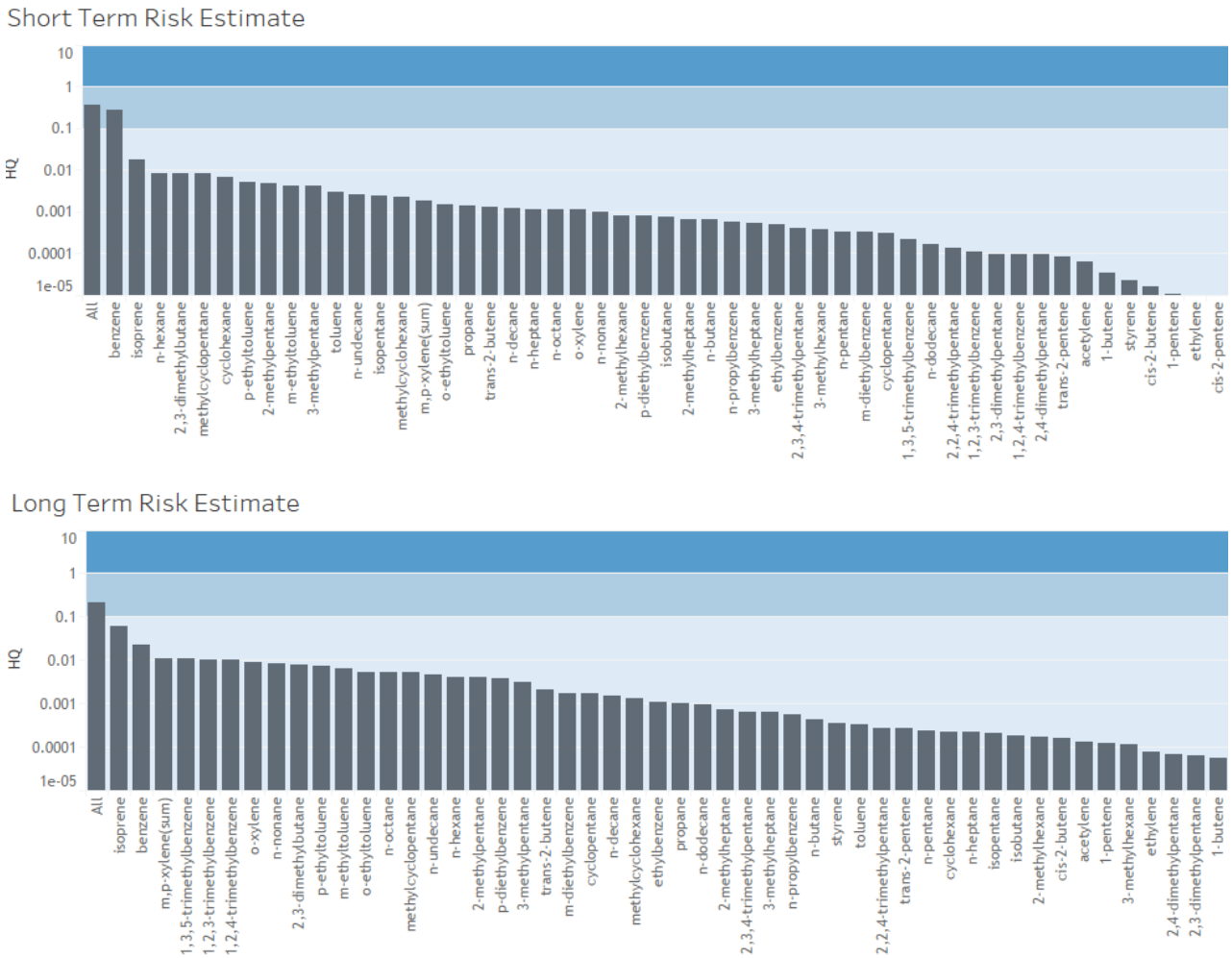


Table 2. Air measurements of VOCs from CAMML and single grab samples compared to non-cancer health guideline values. All values are in ppbV. See Table 1 for description of location for each sample.

Substance	CAMML		Grab Samples					Health Guidelines	
	18-day Average	Maximum (1-hr)	1	2	3	4	5	Short-Term	Long-Term
1,2,3-Trimethylbenzene	0.13	0.33	0.07	ND	ND	0.12	ND	**3000 [T]**	**12 [I]**
1,2,4-Trimethylbenzene	0.12	0.29	0.06	ND	ND	0.09	ND	**3000 [T]**	**12 [I]**
1,3,5-Trimethylbenzene	0.13	0.67	0.15	0.06	ND	0.21	ND	**3000 [T]**	**12 [I]**
1-Butene	0.13	0.92	ND	ND	ND	ND	ND	**27000 [T]**	**2300 [T]**
1-Pentene	0.07	0.13	ND	ND	ND	ND	ND	**12000 [T]**	**560 [T]**
2,2,4-Trimethylpentane	0.11	0.54	ND	ND	ND	ND	ND	**4100 [T]**	**390 [T]**
2,3,4-Trimethylpentane	0.25	1.67	ND	ND	ND	ND	ND	**4100 [R]**	**390 [R]**
2,3-Dimethylbutane	0.80	8.28	ND	ND	ND	ND	ND	**990 [T]**	**99 [R]**
2,3-Dimethylpentane	0.14	0.82	ND	ND	ND	ND	ND	**8300 [R]**	**2200 [T]**
2,4-Dimethylpentane	0.15	0.78	0.20	0.07	ND	ND	ND	**8300 [T]**	**2200 [T]**
2-Methylheptane	0.28	2.77	0.37	0.11	0.07	0.24	0.06	**4100 [T]**	**380 [T]**
2-Methylhexane	0.38	6.91	0.81	0.33	0.15	0.27	0.11	**8300 [T]**	**2200 [T]**
2-Methylpentane	0.36	4.76	0.65	0.36	0.16	0.23	0.12	**990 [T]**	**90 [T]**
3-Methylheptane	0.24	2.22	0.33	0.16	0.07	0.23	0.07	**4100 [T]**	**380 [T]**
3-Methylhexane	0.25	3.20	0.37	0.15	0.07	0.14	0.05	**8300 [T]**	**2200 [T]**
3-Methylpentane	0.32	4.27	0.60	0.28	0.13	0.21	0.09	**1000 [T]**	**100 [T]**
Acetylene	0.33	1.56	ND	ND	ND	ND	ND	**25000 [T]**	**2500 [T]**
Benzene	0.20	2.46	0.67	0.49	0.16	0.18	0.12	**9 [A]**	**9.3 [I]**
Cis-2-butene	0.12	0.25	ND	ND	ND	ND	ND	**15000 [T]**	**700 [T]**
Cis-2-pentene	ND	ND	ND	ND	ND	ND	ND	**12000 [T]**	**560 [T]**
Cyclohexane	0.40	6.82	0.75	0.29	0.16	0.24	0.12	**1000 [T]**	**1743 [I]**
Cyclopentane	0.21	1.81	0.19	0.10	0.06	0.08	ND	**5900 [T]**	**120 [T]**
Ethane	12.21	93.90	ND	ND	ND	ND	ND	**NA**	**NA**
Ethylbenzene	0.24	2.54	ND	ND	ND	0.25	0.07	**5000 [A]**	**230 [I]**
Ethylene	0.40	1.79	ND	ND	ND	ND	ND	**500000 [T]**	**5300 [T]**
Isobutane	1.83	24.51	ND	ND	ND	ND	ND	**33000 [T]**	**10000 [T]**
Isopentane	1.70	19.69	ND	ND	ND	ND	ND	**8100 [T]**	**8000 [T]**
Isoprene	0.12	0.35	ND	ND	ND	ND	ND	**20 [T]**	**2 [T]**
m,p-Xylene	0.26	3.13	1.09	0.20	0.17	1.40	0.28	**1700 [A]**	**23 [T]**
m-Diethylbenzene	0.08	0.15	ND	ND	ND	ND	ND	**460 [T]**	**46 [T]**
Methylcyclohexane	0.53	8.87	1.08	0.51	0.29	0.59	0.23	**4000 [T]**	**400 [T]**
Methylcyclopentane	0.39	6.12	0.69	0.35	0.17	0.29	0.14	**750 [T]**	**75 [T]**
m-Ethyltoluene	0.17	1.08	0.25	0.12	0.05	0.34	0.12	**250 [T]**	**25 [T]**
n-Butane	4.33	58.93	ND	ND	ND	ND	ND	**92000 [T]**	**10000 [T]**
n-Decane	0.26	2.08	0.44	0.12	0.10	0.57	0.19	**1750 [T]**	**175 [T]**
n-Dodecane	0.20	0.78	0.28	ND	ND	0.35	0.09	**4500 [D]**	**210 [R]**
n-Heptane	0.49	9.84	1.18	0.51	0.25	0.49	0.19	**8300 [T]**	**2200 [T]**
n-Hexane	0.81	14.73	1.73	0.90	0.41	0.60	0.31	**1700 [T]**	**198 [I]**
n-Nonane	0.32	3.08	0.64	0.17	0.11	0.86	0.24	**3000 [T]**	**38 [P]**
n-Octane	0.39	4.77	0.81	0.29	0.17	0.64	0.18	**4100 [T]**	**75 [T]**
n-Pentane	1.87	23.26	3.44	1.91	1.04	1.16	0.61	**68000 [T]**	**8000 [T]**
n-Propylbenzene	0.12	0.30	0.08	ND	ND	0.10	ND	**510 [T]**	**203 [P]**
n-Undecane	0.25	1.40	0.38	0.14	0.07	0.49	0.16	**550 [T]**	**55 [T]**
o-Ethyltoluene	0.13	0.37	0.10	0.08	ND	0.15	ND	**250 [T]**	**25 [T]**
o-Xylene	0.21	1.97	0.52	0.30	0.08	0.68	0.14	**1700 [T]**	**23 [T]**
p-Diethylbenzene	0.10	0.20	0.06	ND	ND	0.07	ND	**250 [T]**	**25 [T]**
p-Ethyltoluene	0.19	1.34	0.05	ND	ND	0.08	ND	**250 [T]**	**25 [T]**
Propane	8.37	97.15	ND	ND	ND	ND	ND	**68000 [T]**	**8000 [T]**
Propylene	0.12	0.50	ND	ND	ND	ND	ND	**NA**	**1743 [C]**
Styrene	0.08	0.11	ND	ND	ND	ND	ND	**5000 [A]**	**235 [I]**
Toluene	0.45	5.82	1.33	0.42	0.23	0.63	0.20	**2000 [A]**	**1327 [I]**
Trans-2-butene	1.46	20.13	ND	ND	ND	ND	ND	**15000 [T]**	**700 [T]**
Trans-2-pentene	0.15	0.99	ND	ND	ND	ND	ND	**12000 [T]**	**560 [T]**

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 cancer risk estimates for individual cancer causing substances. The air measurements are compared to air concentrations at each risk level within the generally "acceptable"[1] risk range ($1x10^{-4}$ to $1x10^{-6}$).

Substance	Average Air Measurement[2] (ppbV)	Cancer Risk Estimate		
		Air Concentration at $1x10^{-6}$ (ppbV)	Air Concentration at $1x10^{-5}$ (ppbV)	Air Concentration at $1x10^{-4}$ (ppbV)
Benzene[3]	0.20	0.041[2]	0.41[2]	4.1[2]
Ethylbenzene[4]	0.24	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 18 days of continuous sampling.
[3]Determined using the US EPA inhalation unit risk of 7.8 $x10^{-6}$ per $\mu g/m^3$.
[4]Determined using the CalEPA inhalation unit risk of $2.5x10^{-6}$ per $\mu g/m^3$.

Table 4. Summary of cancer and non-cancer risk estimates for combined exposures to all measured VOCs from each sampling site

Location	Combined Cancer Risk	Acute HI	Chronic HI
CAMML	7.6×10^{-6}	0.37	0.22
Walking Path SE	NA	0.08	0.30
Walking Path SW		0.02	0.23
Playground		0.02	0.04

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

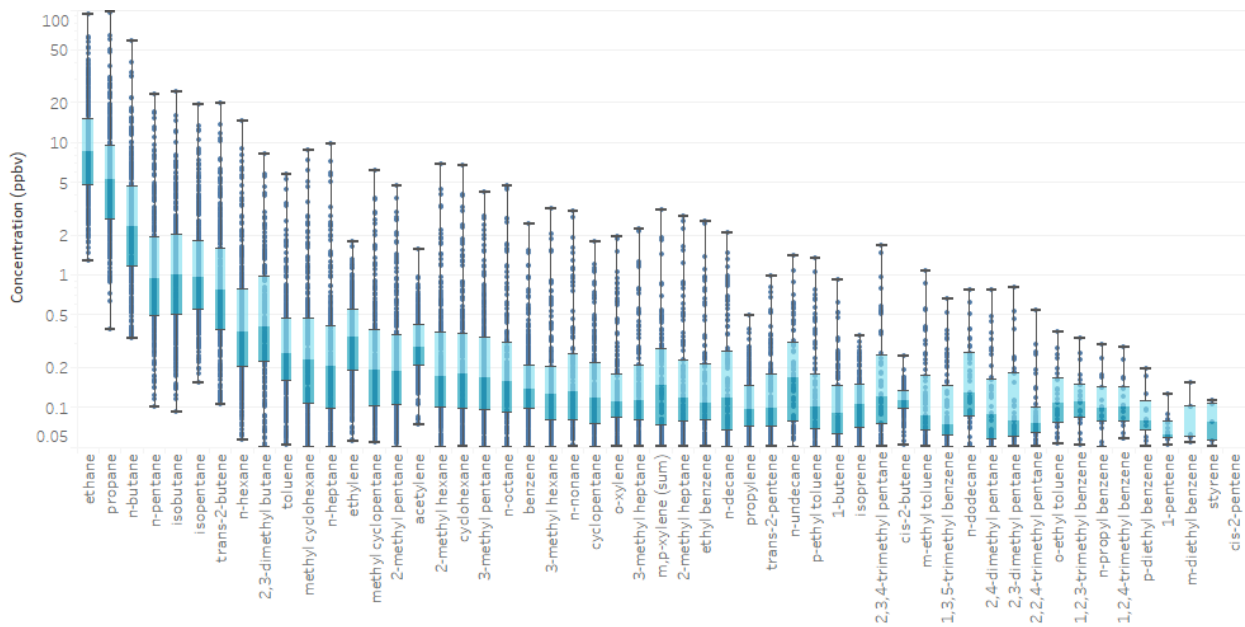
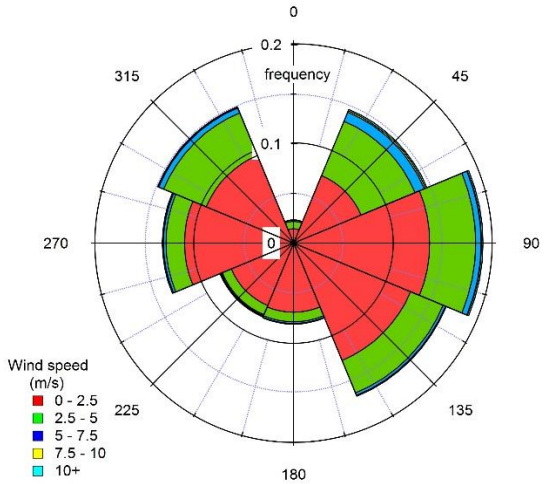
Table 5. Comparison of maximum air concentrations detected across all samples with odor threshold values

Substance*	Maximum Concentration (ppbV)	Odor Threshold (ppbV)	Odor Characteristic
1,2,3-Trimethylbenzene	0.33	6	aromatic
1,2,4-Trimethylbenzene	0.29	6	aromatic
1,3,5-Trimethylbenzene	0.67	6	aromatic
1-Butene	0.92	362	petroleum
1-Pentene	0.13	100	gasoline
2,2,4-Trimethylpentane	0.54	660	gasoline, oil
2,3,4-Trimethylpentane	1.67	660	gasoline, oil
2,3-Dimethylbutane	8.28	426	gasoline
2,3-Dimethylpentane	0.82	410	gasoline
2,4-Dimethylpentane	0.78	410	gasoline
2-Methylheptane	2.77	660	gasoline
2-Methylhexane	6.91	410	gasoline
2-Methylpentane	4.76	426	gasoline
3-Methylheptane	2.22	660	gasoline
3-Methylhexane	3.2	410	gasoline
3-Methylpentane	4.27	426	gasoline
Acetylene	1.56	226000	gassy, garlic
Benzene	2.46	470	aromatic, sweet, solvent
Cis-2-butene	0.25	362	petroleum
Cis-2-pentene	ND	190	gasoline
Cyclohexane	6.82	520	pungent
Cyclopentane	1.81	NA	NA
Ethane	93.9	20328000	NA
Ethylbenzene	2.54	<2	oily, solvent
Ethylene	1.79	1700	grassy
Isobutane	24.51	421	natural gas
Isopentane	19.69	13000	sweet, gasoline
Isoprene	0.35	47	aromatic
m,p-Xylene	3.13	12	sweet, creosote/burnt organic matter
m-Diethylbenzene	0.15	0.38	NA
Methylcyclohexane	8.87	149	petroleum
Methylcyclopentane	6.12	NA	NA
m-Ethyltoluene	1.08	NA	NA
n-Butane	58.93	421	natural gas
n-Decane	2.08	620	gasoline
n-Dodecane	0.78	5310	gasoline
n-Heptane	9.84	410	gasoline
n-Hexane	14.73	1500	gasoline
n-Nonane	3.08	2300	gasoline
n-Octane	4.77	660	gasoline, oil
n-Pentane	23.26	1290	sweet
n-Propylbenzene	0.3	NA	NA
n-Undecane	1.4	110	hydrocarbon
o-Ethyltoluene	0.37	NA	NA
o-Xylene	1.97	12	sweet, creosote/burnt organic matter
p-Diethylbenzene	0.2	0.38	NA
p-Ethyltoluene	1.34	NA	NA
Propane	97.15	1497000	natural gas
Propylene	0.5	10100	gassy, aromatic
Styrene	0.11	2.8	sharp, sweet
Toluene	5.82	21	sour, burnt
Trans-2-butene	20.13	362	petroleum
Trans-2-pentene	0.99	190	gasoline

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

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 by the Colorado Air Monitoring Mobile Laboratory (Deployment dates: July 27- August 14, 2017). The mobile lab is represented by the center of the dial, and the Pratt site is located at approximately 45 degrees (north-east). The length of the spoke corresponds to the frequency and speed of the wind blowing *from* the indicated direction. For example, the wind was blowing at low and high speeds *from* the east, for a large proportion of the time.