Health Risk Evaluation of Site Specific Ambient Air Measurements in Garfield County, Colorado (October – December 2017)

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Executive Summary

Garfield County Public Health (GCPH) collected air samples between October to December 2017 to measure multiple volatile organic compounds (VOCs) near a newly developed oil and gas well in Battlement Mesa. GCPH requested the Oil and Gas Health Information and Response (OGHIR) program at the Colorado Department of Public Health and Environment (CDPHE) to conduct a health risk evaluation of these VOC air samples.

Although these data are limited, the main findings from this evaluation suggest:

- All air concentrations of individual and combined VOCs were below long-term non-cancer health guideline values established by state and federal agencies (Table 2). Five of the 56 detected VOCs did not have health guideline values and therefore, were not evaluated.
- Cancer risks estimates for benzene and ethylbenzene individually and combined were within the US EPA generally acceptable risk range of $1x10^{-6}$ to $1x10^{-4}$ (Table 4).
- Comparisons for upwind and downwind samples could not be assessed due to equipment malfunctions and insufficient upwind samples.

Overall, the evaluation of the air samples during this time indicates a low risk of cancer and long-term non-cancer health effects due to VOC exposure in the vicinity of this oil and gas operation.

Background

Garfield County Public Health (GCPH) is conducting an ongoing evaluation of the air quality near a newly developed oil and gas well in Battlement Mesa, operated by URSA Operating Company, LLC. GCPH requested the Oil and Gas Health Information and Response (OGHIR) Program at the Colorado Department of Public Health and Environment (CDPHE) to conduct a health risk evaluation of the measured VOCs in the third quarter air samples.

Purpose

The purpose of this assessment was to evaluate the health risks from the measured volatile organic compounds.

Methods

VOC air sampling

GCPH contracted Air Resource Specialists (ARS) to design and build a conditional sampler to collect air samples south of the URSA well pad in Battlement Mesa. One sample per month from October to November 2017 was collected over a week long period with the conditional sampler designed to collect ambient air samples when prevailing winds were coming from the direction of the well-pad (termed downwind). An upwind sample was simultaneously collected to provide background measurements (termed upwind). According to ALS, a leak in the updwind canister portion was discovered and these samples were invalidated for November. Two grab samples were then collected in November, and one grab sample was collected in December (Table 1). Samples were analyzed for VOC's following EPA's Method TO-12. Details of the VOC sampling study area available via GCPH/ARS.

Table 1. Sampler operational timeline conducted by ALS from October to December of 2017

Month/Year	*Upwind Canister Total Sampling Time*	*Downwind Canister Total Sampling Time*
October 2017	491 minutes	493 minutes
November 2017	Invalid	441 minutes
November 2017	Two grab samples (11/21/17 & 11/28/17)	
December 2017	One grab sample (12/19/17)	

Health risk evaluation

A screening level health risk evaluation was performed in accordance with the US Environmental Protection Agency guidance[1].

1. Exposure Evaluation
   Because these samples as taken with the conditional sampler were collected over approximately 1-2 weeks, they more likely represent long-term average exposures rather than short-term (i.e. one hour or less) exposures. Although the emissions from the monitored oil and gas site during the current phase of operation will be much less than a lifetime of exposure, long-term exposure assumes a person lives or stays near a given monitoring location for 24

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

hours per day, 365 days per year, for a lifetime (i.e., 70 years). It also assumes the measured concentrations of the VOCs in the air remain constant over the entire 70-year exposure period.

2. Health Effect Evaluation

Non-cancer health effects: A non-cancer health guideline value (HGV) is defined 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. The HGV for each VOC is expressed as a concentration in units of parts per billion. Long-term (chronic) HGVs were used to compare to the air measurements. There were no long-term HGV's for 1-nonene, 1-octene, 2-methyl-1-butene, n-tridecane and therefore, these VOCs were not evaluated in this health risk assessment. Ethane is considered an asphyxiant at extremely high exposures with no other toxicological effects and was not evaluated.

Cancer health effects: For VOCs that could cause cancer, VOC concentrations associated with $1x10^{-6}$ (one in one million) to $1x10^{-4}$ (one in ten thousand) excess 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. 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".

3. Risk Characterization

Non-cancer health effects

Individual VOCs: A hazard quotient (HQ) was determined for each individual VOC that had an established HGV. This ratio is a risk estimate that compares the maximum or average air concentration for each VOC to long-term HGV. 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 non-cancer risk for exposure to all of the VOCs.

HQs and His are calculated as follows:

$$HQ = \frac{\text{air measurement}}{HGV}$$

HQ = Hazard Quotient
HGV = Health Guideline Value

$$HI = HQ1+HQ2+HQ3+\ldots.$$

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 recommended.

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.

Results

- All air concentrations of VOCs were below long-term non-cancer health guideline values (Table 2).
  - Benzene and 1,3-Butadiene concentrations in November had the highest hazard estimates of 0.18 and 0.11 respectively, as measured in the downwind conditional sampler. No upwind samples were available for comparisons in November (Table 3).
    - Benzene and 1,3-Butadiene were approximately 6-9 times below standard long-term non-cancer health guideline values.
    - Although 1,3-Butadiene has not been detected in previous quarters and has been detected in 3 out of the 6 samples in this sampling period, comparisons cannot be made due to insufficient upwind sampling
  - All other VOCs were at least 100 times below their respective non-cancer long-term health guideline value.
- Cancer risks estimates for benzene and ethylbenzene individually or together were within the acceptable risk range of $1x10^{-6}$ to $1x10^{-4}$ (Table 4).

Limitations

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

- This air sampling represents a "snapshot" of VOC concentrations from all emission sources in the area during separate week long periods or grab samples. This sampling technique may not accurately capture peak exposures and samples collected under different conditions and times could have different results.
- Other substances may be emitted from oil and gas that were not sampled in this study and exposure to these substances may result in additional health risk.
- Comparisons for upwind and downwind samples could not be assessed due to equipment malfunctions and insufficient upwind samples.

Conclusions

Although these data are limited, the evaluation of the air samples during this time indicates a low risk of long-term harmful health effects due to VOC exposure in the vicinity of this oil and gas operation.

Table 2. Air measurements compared to non-cancer long-term (chronic) health guideline values (HGV). All values are in ppbV.

Substance*	October (downwind)	October (upwind)	November (grab sample 1)	November (grab sample 2)	November (downwind)	December (grab sample)	Chronic HGV
1,2,3-Trimethylbenzene	ND	ND	ND	ND	0.11	0.02	12 [I]
1,2,4-Trimethylbenzene	0.08	0.08	0.03	0.06	0.61	0.15	12 [I]
1,3,5-Trimethylbenzene	0.05	0.04	0.02	0.04	0.69	0.17	12 [I]
1,3-Butadiene	0.03	ND	ND	0.03	0.10	ND	0.9 [I]
1-Hexene	0.03	0.01	ND	ND	0.01	ND	50 [T]
1-Pentene	0.05	0.02	0.01	0.03	0.03	0.01	560 [T]
2,2-Dimethylbutane	0.08	0.07	0.02	0.11	0.19	0.18	100 [T]
2,3,4-Trimethylpentane	ND	ND	ND	ND	0.01	ND	390 [R]
2,3-Dimethylbutane	0.12	0.11	0.03	0.20	0.44	0.39	99 [R]
2,3-Dimethylpentane	0.08	0.07	0.02	0.09	0.44	0.29	2200 [T]
2,4-Dimethylpentane	0.05	0.04	0.01	0.07	0.27	0.19	2200 [T]
2-Methylheptane	0.14	0.12	0.04	0.11	1.64	0.83	380 [T]
2-Methylhexane	0.28	0.24	0.06	0.28	1.39	0.98	2200 [T]
2-Methylpentane	0.55	0.43	0.12	0.77	1.62	1.41	90 [T]
3-Methylheptane	0.11	0.10	0.03	0.08	1.24	0.64	380 [T]
3-Methylhexane	0.23	0.20	0.05	0.24	1.35	0.93	2200 [T]
3-Methylpentane	0.29	0.25	0.07	0.42	1.04	0.90	100 [T]
Acetylene	0.54	0.35	0.21	0.85	0.57	0.42	2500 [T]
a-Pinene	ND	0.02	ND	ND	ND	ND	63 [T]
Benzene	0.37	0.34	0.14	0.41	1.67	0.83	9.39 [I]
cis-2-Butene	0.01	ND	ND	0.02	ND	ND	700 [T]
Cyclohexane	0.54	0.50	0.14	0.75	3.32	2.35	1743 [I]
Cyclopentane	0.07	0.06	0.02	0.12	0.25	0.22	120 [T]
Ethylbenzene	0.11	0.10	0.09	0.11	0.37	0.12	230 [I]
Ethylene	1.45	0.90	0.37	1.93	1.84	1.57	5300 [T]
Isobutane	2.36	2.04	0.54	5.70	2.68	4.40	10000 [T]
Isopentane	ND	ND	ND	3.34	2.90	3.22	8000
Isoprene	0.02	0.02	ND	ND	0.02	ND	2 [T]
Methylcyclohexane	1.10	0.99	0.26	1.17	9.86	5.71	400 [T]
Methylcyclopentane	0.42	0.38	0.11	0.59	2.02	1.56	75 [T]
m-Ethyltoluene	0.07	0.06	0.01	0.03	0.35	0.10	25 [T]
m-Xylene/p-Xylene	0.29	0.25	0.09	0.22	3.98	1.40	23 [T]
n-Butane	2.39	2.09	0.63	5.88	3.55	4.90	10000 [T]
n-Decane	0.09	0.08	0.03	0.05	1.47	0.34	175 [T]

n-Dodecane	0.02	0.03	0.01	ND	0.10	0.02	**210** [R]
n-Heptane	0.40	0.36	0.10	0.44	3.33	2.20	**2200** [T]
n-Hexane	0.62	0.54	0.17	0.95	2.77	2.35	**198** [I]
n-Nonane	0.16	0.14	0.05	0.09	2.89	0.90	**38** [P]
n-Octane	0.36	0.33	0.11	0.27	4.86	2.26	**75** [T]
n-Pentane	0.93	0.79	0.23	1.86	2.36	2.40	**8000** [T]
n-Propylbenzene	ND	ND	ND	ND	0.09	0.03	**203** [P]
n-Undecane	0.04	0.04	0.02	ND	0.41	0.08	**55** [T]
o-Ethyltoluene	0.02	ND	ND	0.02	0.31	0.08	**25** [T]
o-Xylene	0.14	0.13	0.11	0.13	0.68	0.20	**23** [T]
p-Ethyltoluene	ND	ND	ND	ND	0.31	0.09	**25** [T]
Propane	9.77	8.43	2.66	22.40	9.83	18.67	**8000** [T]
Propylene	0.40	0.26	0.13	0.41	0.47	0.11	**1743** [C]
Styrene	ND	ND	0.02	ND	ND	ND	**235** [I]
Toluene	1.15	1.89	0.29	0.58	4.26	1.94	**1327** [I]
trans-2-Butene	0.11	ND	ND	0.03	ND	ND	**700** [T]
trans-2-Pentene	0.02	0.01	ND	ND	ND	ND	**560** [T]

*Only substances that were above the detection limit in at least one sample and had a health guideline value are reported in the table. I = US EPA; A = ATSDR (US Agency for Toxic Substances 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); R = Read Across; ND= Substance was not measured above the detection limit.

Table 3. Non-cancer long-term risk estimates for individual VOCs for both downwind and upwind samples. The risk estimate is the ratio that compares the air concentration for each VOC to long- term HGV (see Table 1). A value below 1 indicates that the air concentration was below the HGV.

Substance*	October (downwind)	October (upwind)	November (grab sample 1)	November (grab sample 2)	November (downwind)	December (grab sample)
1,2,3-Trimethylbenzene	ND	ND	ND	ND	0.0090	0.0018
1,2,4-Trimethylbenzene	0.0065	0.0063	0.0029	0.0052	0.0509	0.0128
1,3,5-Trimethylbenzene	0.0039	0.0035	0.0015	0.0032	0.0571	0.0141
1,3-Butadiene	0.0305	ND	ND	0.0381	0.1125	ND
1-Hexene	0.0005	0.0002	ND	ND	0.0002	ND
1-Pentene	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000
2,2-Dimethylbutane	0.0008	0.0007	0.0002	0.0011	0.0019	0.0018
2,3,4-Trimethylpentane	ND	ND	ND	ND	0.0000	ND
2,3-Dimethylbutane	0.0012	0.0011	0.0003	0.0020	0.0044	0.0040
2,3-Dimethylpentane	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001
2,4-Dimethylpentane	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
2-Methylheptane	0.0004	0.0003	0.0001	0.0003	0.0043	0.0022
2-Methylhexane	0.0001	0.0001	0.0000	0.0001	0.0006	0.0004
2-Methylpentane	0.0061	0.0047	0.0013	0.0085	0.0180	0.0157
3-Methylheptane	0.0003	0.0003	0.0001	0.0002	0.0033	0.0017
3-Methylhexane	0.0001	0.0001	0.0000	0.0001	0.0006	0.0004
3-Methylpentane	0.0029	0.0025	0.0007	0.0042	0.0104	0.0090
Acetylene	0.0002	0.0001	0.0001	0.0003	0.0002	0.0002
a-Pinene	ND	0.0003	ND	ND	ND	ND
Benzene	0.0398	0.0362	0.0146	0.0437	0.1775	0.0879
cis-2-Butene	0.0000	ND	ND	0.0000	ND	ND
Cyclohexane	0.0003	0.0003	0.0001	0.0004	0.0019	0.0013
Cyclopentane	0.0006	0.0005	0.0002	0.0010	0.0021	0.0019
Ethylbenzene	0.0005	0.0004	0.0004	0.0005	0.0016	0.0005
Ethylene	0.0003	0.0002	0.0001	0.0004	0.0003	0.0003
Isobutane	0.0002	0.0002	0.0001	0.0006	0.0003	0.0004
Isopentane	ND	ND	ND	0.0004	0.0004	0.0004
Isoprene	0.0096	0.0087	ND	ND	0.0082	ND
Methylcyclohexane	0.0028	0.0025	0.0007	0.0029	0.0246	0.0143
Methylcyclopentane	0.0056	0.0050	0.0015	0.0079	0.0269	0.0208
m-Ethyltoluene	0.0029	0.0023	0.0006	0.0013	0.0139	0.0039

m-Xylene/p-Xylene	0.0000	0.0000	0.0000	0.0000	0.0004	0.0001
n-Butane	0.0002	0.0002	0.0001	0.0006	0.0004	0.0005
n-Decane	0.0005	0.0005	0.0002	0.0003	0.0084	0.0019
n-Dodecane	0.0001	0.0001	0.0001	ND	0.0005	0.0001
n-Heptane	0.0002	0.0002	0.0000	0.0002	0.0015	0.0010
n-Hexane	0.0031	0.0027	0.0008	0.0048	0.0140	0.0119
n-Nonane	0.0042	0.0037	0.0014	0.0023	0.0760	0.0236
n-Octane	0.0048	0.0043	0.0014	0.0036	0.0648	0.0302
n-Pentane	0.0001	0.0001	0.0000	0.0002	0.0003	0.0003
n-Propylbenzene	ND	ND	ND	ND	0.0005	0.0001
n-Undecane	0.0007	0.0007	0.0003	ND	0.0075	0.0015
o-Ethyltoluene	0.0009	ND	ND	0.0007	0.0125	0.0033
o-Xylene	0.0060	0.0055	0.0046	0.0058	0.0293	0.0088
p-Ethyltoluene	ND	ND	ND	ND	0.0126	0.0035
Propane	0.0012	0.0011	0.0003	0.0028	0.0012	0.0023
Propylene	0.0002	0.0002	0.0001	0.0002	0.0003	0.0001
Styrene	ND	ND	0.0001	ND	ND	ND
Toluene	0.0009	0.0014	0.0002	0.0004	0.0032	0.0015
trans-2-Butene	0.0002	ND	ND	0.0000	ND	ND
trans-2-Pentene	0.0000	0.0000	ND	ND	ND	ND

*Only substances that were above the detection limit in at least one sample and had a health guideline value are reported in the table.
ND= Substance was not measured above the detection limit.

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

Substance	Range of 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]	0.34 - 1.67	0.041[2]	0.41[2]	4.1[2]
Ethylbenzene[4]	0.09 - 0.36	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]Range of air measurements of all samples (Canister 1 and 2).
[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 $\mu g/m^3$.