Typical Indoor Air Concentrations of Volatile Organic Compounds in Non-Smoking Montana Residences Not Impacted by Vapor Intrusion

A Montana Indoor Air Quality Investigation

Prepared by the Montana Department of Environmental Quality

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1.0 INTRODUCTION

Vapor intrusion, the migration of volatile chemicals from a subsurface source to the indoor air of overlying or adjacent buildings, is a rapidly evolving science that has far-reaching implications to the investigation and remediation of sites impacted with volatile organic compounds (VOCs). A common confounding factor in the evaluation of data collected in vapor intrusion investigations is the separation of "background" (i.e. from typical activities and chemicals inside buildings) indoor air VOC concentrations from VOCs that may be present in indoor air due to subsurface vapor intrusion. This is especially difficult when background indoor air concentrations of VOCs exceed screening levels, such as the Environmental Protection Agency Regional Screening Levels (EPA RSLs) for contaminants of concern (COCs) during the course of vapor intrusion investigations. This scenario may result in additional sampling and data evaluation, and in difficulty explaining the investigation results to the building occupants, when ultimately the agency may determine that no vapor intrusion issue exists.

Numerous studies have documented the ubiquitous presence of some VOCs in indoor air due to human activities. Indoor sources of VOCs include consumer products (e.g., cleaners, solvents, strippers, polish, adhesives, water repellants, lubricants, air fresheners, aerosols, mothballs, scented candles, insect repellants, plastic products); combustion processes (e.g., smoking, cooking, home heating); fuels in attached garages; dry cleaned clothing or draperies; municipal tap water; or occupant activities (e.g., craft hobbies)[1]. In addition, sources of VOCs in outdoor air or attached garages may affect indoor air quality as the typical building experiences multiple exchanges of indoor air with attached garage or outdoor air each day.[2] The Montana Department of Environmental Quality (DEQ) does note that some sites investigated for vapor intrusion have demonstrated outdoor air concentrations of some VOCs greater than that observed in the indoor air.

In order to improve the understanding of typical concentrations of VOCs in the indoor air of residential homes in the state of Montana, the Department of Environmental Quality (DEQ) conducted indoor air sampling at 50 non-smoking residences in Montana that represent a cross section of "typical" residential building use (in the absence of smoking) in both urban and rural settings. Study participants were recruited based on the inclusion criteria presented in the Experimental Methods section. The goal of this study was to calculate tolerance limits and 25^{th}, 50^{th}, 75^{th}, 90^{th}, and 95^{th} percentiles for the expected concentrations of VOCs in residential households, as measured by laboratory methods TO-15, TO-15 Selective Ion Monitoring (SIM), and hydrocarbon fractions measured by Massachusetts Air-Phase Petroleum Hydrocarbons (Mass APH).

The benefits of this study may include:

- Allowing for better evaluation of data obtained from vapor intrusion investigations by comparing measured indoor air concentrations of VOCs to the expected indoor air concentrations reported from this study;

- Providing possible alternate generic screening levels (DEQ currently uses the most current EPA RSLs) if it is found that some compounds are ubiquitously present above these EPA RSLs in indoor air;

- Providing possible alternate generic screening levels for EPA RSLs that are analytically unachievable;

- Eliminating the need to conduct more expensive TO-15 SIM analysis for some or all contaminants if it is found that these contaminants are ubiquitously present in indoor air at concentrations above standard TO-15 detection limits;

- Allowing DEQ and other environmental professionals to better explain measured indoor air concentrations of VOCs to the public by using the data obtained from this study as representative of typical concentrations of VOCs found in indoor air in Montana residences;

- Providing typical indoor air concentrations of VOCs that could be used as possible cleanup criteria for buildings requiring mitigation of subsurface vapor intrusion.

This study is not the first of its kind. Similar studies conducted to measure concentrations of VOCs in the indoor air of residential buildings include:

- Batterman et al. (2007)[2] – This study sampled the indoor air and garage air of 15 single family homes in southeast Michigan;

- Heroux et al. (2010)[3] – This study sampled the indoor air of 106 homes in the winter and 111 homes in summer of 2007 in Regina, Saskatchewan, Canada;

- Weisel et al. (2008)[4] – This study sampled the indoor air of 100 homes located in suburban and rural areas of New Jersey which were not expected to be impacted by vapor intrusion;

- Environmental Protection Agency (2011)[1] – The EPA reviewed a total of 18 studies of VOCs in the indoor air of residences of North America and developed summary ranges of VOCs present in background indoor air of North American residences between 1990 and 2005 from this compilation;

- Massachusetts Department of Environmental Protection (Mass DEP) (2008)[5] –Mass DEP developed criteria for reviewing available studies for inclusion in an updated 50th, 75th, and 90th percentile calculation of indoor air VOCs.

- New York State Department of Health (NYDOH) (2006)[6] – Appendix C of NYDOH's *Guidance for Evaluating Soil Vapor Intrusion in the State of New York* is a summary of five studies conducted between 1988 and 2005 with VOC concentration percentiles presented in this appendix.

While this study was conducted as a Montana-specific study, its findings may have application to other locations with similar urban development, building construction and building occupant habits. This study is limited only in the size of the sample (n=50). A larger sample size may provide a better range of expected indoor air concentrations of VOCs. Additionally, buildings that do not meet the inclusion criteria for the study (i.e. occupied by smokers, recent building renovations, commercial buildings, etc.) may have background concentrations of VOCs above the values calculated in this study.

2.0 DATA QUALITY OBJECTIVES

Data Quality Objectives (DQOs) of this study were presented in Table 2.0 of the *Sampling, Analysis, and Quality Assurance Project Plan: Typical Indoor Air Concentrations of Volatile Organic Compounds in Non-Smoking Residences Not Impacted by Subsurface Vapor Intrusion*[7] Step 2, *Identifying the Decisions* of the DQOs is summarized as follows:

- Data from this study will be used to determine whether indoor air concentrations of VOCs in non-smoking residences not impacted by subsurface vapor intrusion typically exceed risk-based screening levels;
- The data will be used to determine whether alternate screening/cleanup levels for certain VOCs are appropriate because concentrations in background indoor air are higher;
- The data will be used to determine whether more costly analytical methods are necessary for site-specific vapor intrusion investigations;
- The data will be used to show members of the public who are concerned about vapor intrusion what concentrations of certain compounds are typically present in residences not impacted by vapor intrusion.

Section 5.1 provides further discussion regarding the data quality objectives.

3.0 EXPERIMENTAL METHODS

3.1 Participant Selection Criteria

The selection of residential buildings to include in this study was of critical importance as buildings with abnormally high levels of VOCs (i.e. cigarette smoking indoors or recent building renovations) have the potential to skew the data. This study sought to sample indoor air at a representative population of residential households according to the following criteria:

- The building must not be occupied by smokers currently, or in the past 12 months;
- The building must not have undergone any form of remodeling (including painting, wood treatment or finishing, new tile, new carpeting, etc.) within the past 12 months;
- The building must be a primary residence and occupied 12 months out of the year;
- The building must be in "sound condition" (no broken windows, missing doors, inadequate building heating, etc.);

- The building must not be used as a place of business;
- The building must not be located within ¼ mile of any known DEQ site, facility, or otherwise known VOC contamination existing in groundwater or subsurface soils.

Additional considerations in selecting the study participants were:

- A representation of buildings located in both urban and rural areas (as outdoor air VOC concentrations or building use patterns may differ between rural and urban areas);
- A representation of buildings located geographically across Montana;
- The sample population should contain a variety of building construction styles (slab on grade, subsurface basement, above ground crawlspace, etc.) and ages;
- The sample population should represent a variety of heating sources (indoor heating oil tank and furnace, natural gas fired stoves or furnaces, propane fired stove or furnace, wood stoves, etc.) as different heat sources may pose varying potential VOC impacts to indoor air;
- The sample population should include a significant population of buildings that have a garage attached to the living space. The presence of an attached garage has been identified as a major source of indoor air VOC contamination.[2] This study sought to include structures with attached garages due to the frequency of this type of building construction in Montana;
- Potential indoor air VOC sources were not removed from the buildings prior to the collection of indoor air samples as this study sought to quantify the impact to indoor air from these common household VOC sources.

This study employed a convenience sampling strategy; a non-probability based sampling that involves the selection of samples from a population readily available. It is believed that the population selected by convenience sampling is representative of the population as a whole.

3.2 Laboratory Methods and Constituents Analyzed

Columbia Analytical Services (CAS) of Simi Valley, California was the sole laboratory for the study. CAS provided all of the 100% individually certified clean (for the entire constituent list) six-liter Summa canisters for sample collection. Table 3.2.1 lists the individual VOCs analyzed and provides their respective generic screening levels and laboratory detection limits.

Table 3.2.1: Selected VOCs Analyzed, Generic Screening Levels (RSLs), and Laboratory Reporting Limits (RLs)

Analyte	Chemical Abstract Services Number	Key - carcinogen (c) or non-carcinogen (n)	EPA BASED RSL* (residential air) (µg/m^3)	TO-15 RL (µg/m^3)	TO-15 SIM RL (µg/m^3)
1,1,1-Trichloroethane (TCA)	71-55-6	n	520	0.54	0.054
1,1,2,2-Tetrachloroethane	79-34-5	c	0.042	0.69	0.14
1,1,2-Trichloroethane	79-00-5	n	0.015	0.54	0.11
1,1-Dichloroethane (1,1-DCA)	75-34-3	c	1.5	0.40	0.081
1,1-Dichloroethene (1,1-DCE)	75-35-4	n	21	0.40	0.040
1,2,4-Trimethylbenzene	95-63-6	n	0.73	0.49	
1,2-Dibromoethane	106-93-4	c	0.0041	0.77	
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	76-14-2		No value	0.70	
1,2-Dichlorobenzene	95-50-1	n	21	0.60	
1,2-Dichloroethane	107-06-2	c	0.094	0.40	0.081
1,2-Dichloropropane	78-87-5	c	0.24	0.46	
1,3,5-Trimethylbenzene	108-67-8		No value	0.49	
1,3-Butadiene	106-99-0	c	0.081	0.22	
1,3-Dichlorobenzene	541-73-1		No Value	0.60	
1,4-Dichlorobenzene	106-46-7	c	0.22	0.60	
2-Butanone (MEK)	78-93-3	n	520	1.5	
2-Hexanone	591-78-6	n	3.1	2.0	
4-Ethyltoluene	622-96-8		No value	0.49	
4-Methyl-2-pentanone	108-10-1	n	310	0.41	
Acetone	67-64-1	n	3200	1.2	
Benzene	71-43-2	c	0.31	0.32	0.16
Bromochloromethane	74-97-5	n	4.2		
Bromodichloromethane	75-27-4	c	0.066	0.67	
Bromoform	75-25-2	c	2.2	1.0	
Bromomethane	74-83-9	n	0.52	0.39	
Carbon Disulfide	75-15-0	n	73	1.6	
Carbon Tetrachloride	56-23-5	c	0.41	0.63	
Chlorobenzene	108-90-7	n	5.2	0.46	
Chloroethane (ethyl chloride)	75-00-3	n	1000	1.3	
Chloroform	67-66-3	c	0.11	0.49	
Chloromethane	74-87-3	n	9.4	0.21	
Cyclohexane	110-82-7	n	630	0.34	
Dibromochloromethane	124-48-1	c	0.09	0.81	
Dichlorodifluoromethane (CFC 12)	75-71-8	n	10	0.49	
Dichloromethane (methylene chloride)	75-09-2	c	96	0.69	

Analyte	Chemical Abstract Services Number	Key - carcinogen (c) or non-carcinogen (n)	EPA BASED RSL* (residential air) (μg/m^3)	TO-15 RL (μg/m^3)	TO-15 SIM RL (μg/m^3)
Ethylbenzene	100-41-4	c	0.97	0.43	0.087
Methyl tert-Butyl Ether	1634-04-4	c	9.4	0.36	0.36
Styrene	100-42-5	n	100	0.42	
Tetrachloroethene (PCE)	127-18-4	c	9.4	0.68	0.14
Tetrahydrofuran (THF)	109-99-9		210	1.5	
Toluene	108-88-3	n	520	0.38	
Trichloroethene (TCE)	79-01-6	n	0.43	0.54	0.11
Trichlorofluoromethane (CFC 11)	75-69-4	n	73	0.56	
Vinyl Chloride	75-01-4	c	0.16	0.26	0.026
cis-1,2-Dichloroethene	156-59-2		No value	0.40	0.079
cis-1,3-Dichloropropene (2)	10061-01-5	c	0.61	0.45	
m,p-Xylenes (1)	179601-23-1	n	10	0.43	0.17
n-Heptane	142-82-5		No value	0.41	
n-Hexane	110-54-3	n	73	0.35	
o-Xylene	95-47-6	n	10	0.43	0.087
trans-1,2-Dichloroethene	156-60-5	n	6.3	0.40	0.40
trans-1,3-Dichloropropene (2)	10061-02-6	c	0.61	0.45	
2-Propanol	67-63-0	n	730	1.2	
Ethanol	64-17-5		No value	0.94	
Hexachlorobutadiene	87-68-3	c	0.11	0.81	
Naphthalene	91-20-3	c	0.072		0.16
Cumene (isopropylenzene)	98-82-8	n	42	0.49	
3-Chloropropene	107-05-1		No value	1.6	
2,2,4-trimethylpentane	540-84-1		No value	2.3	
1,4-Dioxane	123-91-1	c	0.32	0.36	
Propylbenzene	103-65-1		No value	0.49	
1,2,4-Trichlorobenzene	120-82-1	n	2.1	3.7	

Notes:

* = DEQ divides non-carcinogenic RSLs by 10 to ensure a total hazard index of 1 or less. Carcinogenic RSLs are not modified

1 – m,p xylenes are listed separately in the 2012 EPA RSL table

2 – DEQ adjusted EPA RSL is for 1,3-dichloropropene

μg/m^3 – micrograms per cubic meter

Shaded compounds have RSLs that are less than the lowest practicable reporting limit

Table 3.2.2 lists the hydrocarbon fractions analyzed and provides their respective generic screening level and laboratory detection limits:

Table 3.2.2: Hydrocarbon Fractions Analyzed by Massachusetts Air-Phase Petroleum Hydrocarbons (Mass APH), DEQ Screening Levels, and Laboratory Reporting Limits

Analyte	CAS Number	DEQ Screening Level (residential air) (µg/m^3)	Reporting Limit (µg/m^3)
C_5-C_8 Aliphatic Hydrocarbons	Not Available	62.6	27
C_9–C_{12} Aliphatic Hydrocarbons	Not Available	10.4	13
C_9-C_{10} Aromatic Hydrocarbons	Not Available	10.4	6.7

Notes:
SHADED compounds have RSLs that are less than the lowest practicable reporting limit
µg/m^3 – micrograms per cubic meter

3.3 Field Sampling Methodology

All samples were collected in laboratory supplied, individually certified clean six-liter Summa canisters with a dedicated vacuum gauge and flow regulator set to collect the sample over a 24-hour period. All Summa canisters were tested with a digital vacuum gauge upon receipt from the laboratory to verify that the canisters had adequate initial negative pressure (between -24” Hg and -29” Hg, adjusted for feet above sea level).

All samples were collected between March 5 and March 31, 2012. Samples were collected during a cold weather time period in order to collect samples during what has been identified as a potential worst case time period for indoor air quality.[8] Additionally, sampling during a cold weather time period ensured that the results from this study seasonally correlated with most results from vapor intrusion investigations in Montana.

One indoor air sample was collected per building. The placement of the Summa canister for collection of the indoor air sample adhered to the following selection criteria:

- Summa canisters were placed in a central location on what the building occupant or DEQ determined to be the main living floor of the building (central gathering or food preparation areas used most frequently by occupants of the building);
- Summa canisters were not placed in kitchens when possible so as to not preferentially sample VOCs generated by cooking activities;
- Summa canisters were placed so that the intake to the Summa canister was located between three and five feet above the floor to collect the indoor air sample from the typical breathing zone area;
- Summa canisters were not placed in closets or similar storage areas to avoid preferentially sampling common locations of VOC-containing household products;

- Summa canisters were not placed in a breezeway, doorway, or close to any other opening to the outdoors or other ventilation; and
- Summa canisters were not placed in a workshop, garage, or hobby room.

At the time of the sampling, participants were asked to complete DEQ's Occupied Building Questionnaire (Reference 8, Attachment A) which describes building construction, heat sources, occupant habits, and consumer product storage. Sampling teams assisted participants with the completion of the questionnaire when necessary and also completed indoor air sampling forms (http://deq.mt.gov/StateSuperfund/viguide.mcpx) documenting sampling equipment serial numbers, initial and final vacuums, weather conditions, building layout, building GPS coordinates, sample location within the building, and any other relevant field observations for each location.

The sample teams were instructed to avoid using perfumes, colognes, hair spray, fueling vehicles before the collection or deployment of samples, smoking at any time during the sampling event, or engaging in any other activity that may introduce VOCs to indoor air.

Following collection, all samples were shipped back to the laboratory in their original packages under chain of custody. No more than ten days elapsed between sample collection and shipment (sample hold time is 30 days). Samples remained under DEQ custody at all times prior to shipment to the laboratory.

4.0 RESULTS

Data from the 50 samples, plus five field duplicates, were validated using DEQ protocols.[9] In brief, all data, some with qualification, are usable for the purpose of this study. In addition, all the data are assumed to be representative for the purpose of the study given that each building sampled met the previously identified selection criteria. Therefore, no outliers are assumed to be present in the data.

Data from all 50 residential buildings for each of the 77 VOCs were input into EPA ProUCL software (version 4.1.01). The 25^{th}, 50^{th}, 75^{th}, 90^{th}, and 95^{th} percentiles were calculated using raw data for each VOC. This means that non-detect values were included at the reporting limit; no conversion or substitution of data occurred to determine percentiles. For cases where non-detect values constituted an entire percentile, the statistic is presented as less than the reporting limit at the specified percentile. For example, the 50^{th} percentile for C9-C10 aromatics is "<9.2 μg/m^3."

In addition to percentiles, upper tolerance limits (UTLs) on the median (i.e., 50^{th} percentile) with 95% confidence (95%UTL-50^{th}) were calculated for VOCs with detected values for at least 50 percent of each data set. In other words, if non-detect values constituted at least 50 percent of the data set for a specific VOC, then a 95%UTL-50^{th} statistic was not calculated. A UTL is a statistic of proportion for a data set; therefore, it is a useful metric for estimating an upper limit of a percentile of a population. In particular, the 95%UTL-50^{th} parametric is pertinent for a study of "typical" indoor air concentrations because the metric represents a statistically-based upper limit on the median of expected indoor air concentrations.

50 percent was utilized as the limit of allowable non-detect values in a data set for calculating 95%UTL-50th statistics because when calculating a statistically-based upper limit for a proportion, i.e., median, the data set should desirably contain quantified results within the respective proportion to validate the statistic. In other words, a 95%UTL-50th statistic for a data set that has 50 percent or more qualified values, i.e., non-detect values, has no quantified measurements to confirm the statistic.

In other words, DEQ calculated the average indoor air concentration of each VOC (the 50th percentile value). For those VOCs that had a non-detect value as the average (or 50th percentile) concentration, no additional statistics could be performed since the average concentration was an unquantified value (i.e <0.84 µg/m^3). For VOCs with a quantified value as the 50th percentile (i.e. benzene 50th percentile = 0.90 µg/m^3) DEQ calculated the upper tolerance limit (UTL) of this value. The UTL is an estimate of what the highest value that a calculated average could be in reality, if one were to sample the entire population. The UTL typically is calculated with a level of confidence. For this study a 95% level of confidence was used when calculating the UTL. This 95%-UTL value is an estimation for what the highest real value that the calculated averages could be, with a 95% certainty. For example, the 95%-UTL-50th for benzene (1.3 µg/m^3) is the estimate of the highest value that the average concentration of benzene found in the 50 houses sampled in this study (0.90 µg/m^3) could be if one were to sample a much larger population.

Table 3 contains percentiles for all 77 VOCs and 95%UTL-50th statistics for the 21 VOCs that had less than 50 percent non-detect values.

Table 4.0.1: Concentration Percentiles

Compounds	**Frequency of Non-Detects**	**25th Percentile (µg/m^3)**	**50th Percentile (µg/m^3)**	**75th Percentile (µg/m^3)**	**90th Percentile (µg/m^3)**	**95th Percentile (µg/m^3)**	**95% UTL on 50th Percentile (µg/m^3)**
1,1,1-Trichloroethane	96%	<0.77	<0.84	<0.93	<1.0	<1.7	NA
1,1,2-Trichloroethane	100%	<0.15	<0.17	<0.19	<0.20	<0.25	NA
1,1,2-Trichlorotrifluoroethane	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
1,1-Dichloroethane	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
1,1-Dichloroethene	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
1,2,4-Trichlorobenzene	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
1,2,4-Trimethylbenzene	52%	<0.86	<1.1	1.9	4.9	8.7	NA
1,2-Dibromo-3-chloropropane	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
1,2-Dibromoethane	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
1,2-Dichlorobenzene	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
1,2-Dichloroethane	0%	0.11	0.17	0.48	0.82	1.2	0.23
1,2-Dichloropropane	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
1,3,5-Trimethylbenzene	82%	<0.78	<0.87	<0.97	2.0	2.9	NA
1,3-Butadiene	98%	<0.77	<0.84	<0.93	<0.99	<1.3	NA
1,3-Dichlorobenzene	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA

Compounds	**Frequency of Non-Detects**	**25th Percentile (µg/m^3)**	**50th Percentile (µg/m^3)**	**75th Percentile (µg/m^3)**	**90th Percentile (µg/m^3)**	**95th Percentile (µg/m^3)**	**95% UTL on 50th Percentile (µg/m^3)**
1,4-Dichlorobenzene	96%	<0.77	<0.84	<0.93	<1.1	<2.6	NA
1,4-Dioxane	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
2-Butanone	86%	<7.7	<8.5	<9.6	13	18	NA
2-Hexanone	90%	<0.77	<0.84	<0.93	<0.98	1.5	NA
2-Propanol	0%	11	27	46	77	95	29
Allyl Chloride	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
4-Ethyltoluene	86%	<0.78	<0.87	<0.97	2.0	2.9	NA
4-Methyl-2-pentanone	74%	<0.78	<0.88	1.0	2.1	2.3	NA
Acetone	0%	31	46	65	83	103	51
Acetonitrile	94%	<0.77	<0.84	<0.93	<1.0	1.8	NA
Acrolein	84%	<3.1	<3.5	<3.9	4.8	6.8	NA
Acrylonitrile	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
alpha-Pinene	4%	1.7	3.8	5.5	13	25	4.7
Benzene	2%	0.52	0.90	2.5	8.4	12	1.3
Benzyl Chloride	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
Bromodichloromethane	94%	<0.77	<0.84	<0.93	<1.0	1.7	NA
Bromoform	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
Bromomethane	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
C5 - C8 Aliphatics	10%	46	81	160	224	414	94
C9 - C12 Aliphatics	16%	22	33	73	100	196	44
C9 - C10 Aromatics	60%	<8.4	<9.2	12	24	38	NA
Carbon Disulfide	100%	<7.7	<8.3	<9.3	<9.8	<13	NA
Carbon Tetrachloride	92%	<0.77	<0.85	<0.93	<1.0	1.5	NA
Chlorobenzene	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
Chloroethane	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
Chloroform	64%	<0.82	<0.93	1.7	2.7	3.6	NA
Chloromethane	94%	<0.77	<0.84	<0.93	<1.0	1.3	NA
cis-1,2-Dichloroethene	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
cis-1,3-Dichloropropene	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
Cyclohexane	76%	<1.6	<1.8	<2.2	3.8	5.1	NA
Dibromochloromethane	98%	<0.77	<0.84	<0.93	<1.0	<1.4	NA
Dichlorodifluoromethane (CFC 12)	2%	1.9	2.0	2.1	2.2	2.2	2.1
Methylene Chloride	62%	<0.78	<0.93	1.5	9.0	29	NA
d-Limonene	0%	11	16	28	46	95	22
Ethanol	0%	288	625	1,375	2,020	2,930	769
Ethyl Acetate	10%	3.8	6.3	15	25	31	8.6
Ethylbenzene	6%	0.41	0.78	2.1	4.0	6.0	1.1
Hexachlorobutadiene	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
Cumene	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
m,p-Xylenes	34%	<1.7	2.7	6.6	8.9	24	3.6
Methyl Methacrylate	96%	<1.5	<1.7	<1.9	<2.0	<2.5	NA
Methyl tert-Butyl Ether	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
Naphthalene	20%	0.21	0.36	0.51	0.82	1.3	0.39
n-Butyl Acetate	38%	<0.85	1.3	2.5	4.4	5.7	1.5
n-Heptane	38%	<0.87	1.1	3.2	5.0	6.0	1.6
n-Hexane	38%	<0.91	1.5	3.2	11	16	1.9
n-Nonane	62%	<0.80	<0.93	1.8	3.0	4.0	NA
n-Octane	60%	<0.82	<0.93	1.2	2.0	2.3	NA

Compounds	Frequency of Non-Detects	25th Percentile (µg/m^3)	50th Percentile (µg/m^3)	75th Percentile (µg/m^3)	90th Percentile (µg/m^3)	95th Percentile (µg/m^3)	95% UTL on 50th Percentile (µg/m^3)
n-Propylbenzene	88%	<0.77	<0.85	<0.93	1.5	1.8	NA
o-Xylene	58%	<0.82	<0.94	2.4	5.2	7.6	NA
Propene	4%	2.2	6.0	8.7	18	35	6.5
Styrene	66%	<0.82	<0.93	1.2	2.2	2.4	NA
Tetrachloroethene	16%	0.061	0.099	0.24	2.3	2.8	0.14
Tetrahydrofuran	70%	<0.80	<0.90	1.6	3.2	4.2	NA
Toluene	2%	5.0	8.3	25	49	60	13
trans-1,2-Dichloroethene	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
trans-1,3-Dichloropropene	100%	<0.77	<0.83	<0.93	<0.98	<1.3	NA
Trichloroethene	56%	<0.042	<0.048	0.096	0.58	1.3	NA
Trichlorofluoromethane (CFC 11)	10%	1.1	1.2	1.8	2.7	3.6	1.3
Vinyl Acetate	98%	<7.7	<8.4	<9.3	<10	<15	NA
Vinyl Chloride	98%	<0.038	<0.042	<0.046	<0.049	<0.064	NA

5.0 DISCUSSION

5.1 Data Quality Objectives Discussion

The results of this study provide useful additional lines of evidence in evaluating the vapor intrusion pathway, particularly in terms of comparison of measured indoor air results from vapor intrusion investigations to the percentiles calculated from this study. The results of this study are discussed in terms of the study's data quality objectives (DQOs) as follows:

Data from this study will be used to determine whether indoor air concentrations of VOCs in non-smoking residences not impacted by subsurface vapor intrusion typically exceed risk-based screening levels.

Twenty-seven of 77 VOCs had non-detect values for all 50 samples (100% non-detect). For these 27 VOCs, it may be assumed that these should not normally be detected in residential indoor air. These VOCs include many compounds that are not typically contaminants of concern (COCs) in vapor intrusion investigations (i.e. bromoform, hexachlorobutadiene); however, some compounds that may be COCs for a vapor intrusion investigation (methyl tert-butyl ether (MTBE) or 1,2-dichlorobenzene) are also included in this group.

Twenty-nine of the 77 VOCs had non-detect values for greater than 50% of the samples collected, but were detected in a minimum of one sample. Together with the 27 VOCs that were not detected in any sample (discussed above), these 56 VOCs were not able to have 95%UTL-50th statistics calculated due to the fact that the 50th percentile for these compounds represents a non-detect result and not a quantified indoor air concentration.

Six of the 56 VOCs are compounds for which no screening level exists.

Twenty-nine of the 56 compounds have estimated 50th percentiles below a detection limit that are also below the respective screening level for each VOC; for these VOCs, typical indoor air concentrations in Montana residences are not expected to exceed screening levels. Of particular note in this set of 29 VOCs are C9-C10 aromatics, trichloroethene (TCE), and vinyl chloride, which are frequently compounds of potential concern for vapor intrusion investigations.

The remaining 21 VOCs from the set of 56 have estimated 50th percentiles below a detection limit that is above the respective screening levels for each VOC. This study provides the least utility for these 21 VOCs because typical indoor air concentrations in Montana residences cannot be quantified for these compounds and the qualified values of the 50th percentiles do not allow for a meaningful comparison to generic risk screening levels. The most useful finding for these 21 VOCs is that they should not typically be measured in indoor air unless they are related to subsurface contamination or they have an indoor or ambient source not usually present in the 50 residences sampled during this study.

Table 5.1.1 below summarizes the 56 VOCs that were not able to have 95%UTL-50th statistics calculated due to the fact that the 50th Percentile for these compounds represents a non-detect result and not a quantified indoor air concentration.

Table 5.1.1 VOCs with Non-Detect Value as 50th Percentile

Compounds	DEQ-ADJUSTED EPA RSL* (residential air) (μg/m^3)	50th Percentile (μg/m^3)
1,1,1-Trichloroethane	520	<0.84
1,1,2-Trichloroethane	0.15	<0.17
1,1,2-Trichlorotrifluoroethane	No value	<0.83
1,1-Dichloroethane	1.5	<0.83
1,1-Dichloroethene	21	<0.83
1,2,4-Trichlorobenzene	0.21	<0.83
1,2,4-Trimethylbenzene	0.73	<1.1
1,2-Dibromo-3-chloropropane	0.00016	<0.83
1,2-Dibromoethane	0.0041	<0.83
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	No value	<0.83
1,2-Dichlorobenzene	21	<0.83
1,2-Dichloropropane	0.24	<0.83
1,3,5-Trimethylbenzene	No value	<0.87
1,3-Butadiene	0.081	<0.84
1,3-Dichlorobenzene	No Value	<0.83
1,4-Dichlorobenzene	0.22	<0.84
1,4-Dioxane	0.32	<0.83
2-Butanone	520	<8.5
2-Hexanone	3.1	<0.84
Allyl Chloride	0.41	<0.83
4-Ethyltoluene	No value	<0.87
4-Methyl-2-pentanone	310	<0.88
Acetonitrile	6.3	<0.84
Acrolein	0.0021	<3.5
Acrylonitrile	0.036	<0.83
Benzyl Chloride	0.05	<0.83

Compounds	DEQ-ADJUSTED EPA RSL* (residential air) (µg/m^3)	50th Percentile (µg/m^3)
Bromodichloromethane	0.066	<0.84
Bromoform	2.2	<0.83
Bromomethane	0.52	<0.83
C9 - C10 Aromatics	10.4**	<9.2
Carbon Disulfide	73	<8.3
Carbon Tetrachloride	0.41	<0.85
Chlorobenzene	5.2	<0.83
Chloroethane	1000	<0.83
Chloroform	0.11	<0.93
Chloromethane	9.4	<0.84
cis-1,2-Dichloroethene	No value	<0.83
cis-1,3-Dichloropropene	0.61	<0.83
Cyclohexane	630	<1.8
Dibromochloromethane	0.09	<0.84
Methylene Chloride	96	<0.93
Hexachlorobutadiene	0.11	<0.83
Cumene	42	<0.83
Methyl Methacrylate	73	<1.7
Methyl tert-Butyl Ether	9.4	<0.83
n-Nonane	21	<0.93
n-Octane	No value	<0.93
n-Propylbenzene	No value	<0.85
o-Xylene	10	<0.94
Styrene	100	<0.93
Tetrahydrofuran	210	<0.90
trans-1,2-Dichloroethene	No value	<0.83
trans-1,3-Dichloropropene	0.61	<0.83
Trichloroethene	0.43	<0.048
Vinyl Acetate	21	<8.4
Vinyl Chloride	0.16	<0.042

Notes:

* = DEQ divides non-carcinogenic RSLs by 10 to ensure a total hazard index of 1 or less. Carcinogenic RSLs are not modified

**= The screening level for C9-C10 aromatic hydrocarbons is the DEQ residential air screening level.

µg/m^3 – micrograms per cubic meter

Shaded compounds have a 50th percentile non-detect value above their respective screening level.

The data will be used to determine whether alternate screening/cleanup levels for certain VOCs are appropriate because concentrations in background indoor air are higher

Twenty-one of the 77 VOCs measured had non-detect results constitute less than 50 percent of all results for each VOC, and therefore 95%UTL-50th statistics, as previously detailed, were calculated for these VOCs. The 95%UTL-50th statistics for these 21 VOCs may be used as a line of evidence for vapor intrusion investigations when considering typical indoor air concentrations in Montana residences. These 21 VOCs are summarized in Table 5.1.2:

Table 5.1.2 VOCs with Calculated 95% UTL-50th Percentile Statistics

Compounds	DEQ-ADJUSTED EPA RSL* (residential air) (µg/m³)	Calculated 95% UTL-50th Percentile (µg/m³)
1,2-Dichloroethane	0.094	0.23
2-Propanol	730	29
Acetone	3200	51
alpha-Pinene	No value	4.7
Benzene	0.31	1.3
C5 - C8 Aliphatics	62.6**	94
C9 - C12 Aliphatics	10.4**	44
Dichlorodifluoromethane (CFC 12)	10	2.1
d-Limonene	No value	22
Ethanol	No value	769
Ethyl Acetate	No value	8.6
Ethylbenzene	0.97	1.1
m,p-Xylenes	10***	3.6
Naphthalene	0.072	0.39
n-Butyl Acetate	No value	1.5
n-Heptane	No value	1.6
n-Hexane	73	1.9
Propene	310	6.5
Tetrachloroethene	9.4	0.14
Toluene	520	13
Trichlorofluoromethane (CFC 11)	73	1.3

Notes:

* = DEQ divides non-carcinogenic RSLs by 10 to ensure a total hazard index of 1 or less. Carcinogenic RSLs are not modified

**= The screening level for C5-C8 and C9-C12 aliphatics are the DEQ residential air screening levels.

***= m,p-Xylenes are listed separately in the 2012 EPA RSL table

µg/m³ – micrograms per cubic meter

Shaded compounds have a calculated 95% UTL-50th percentile value above their respective screening level.

Six VOCs (alpha-pinene, d-limonene, ethanol, ethyl acetate, n-butyl acetate, and n-heptane) in the group of 21 are compounds for which no EPA RSLs exist. These compounds are not usually COCs for vapor intrusion investigations. Regardless, the 95%UTL-50th statistics provide a reference for typical levels of these compounds in residential indoor air.

Nine VOCs (2-propanol, acetone, CFC-11, CFC-12, m&p-xylenes, n-hexane, propene, tetrachloroethene [PCE], and toluene) of these 21 VOCs have 95%UTL-50th statistics that are less than their respective RSLs; therefore, these VOCs are assumed to have common indoor and ambient sources, but typical indoor air concentrations in Montana residences related to these indoor and ambient sources are less than generic risk screening levels. Of particular note in this group of compounds are PCE, toluene, and m&p-xylenes, which are frequent COCs in vapor intrusion investigations.

For the remaining six VOCs of this group of 21 VOCs, the 95%UTL-50th statistics are greater than their respective screening levels. The six VOCs are 1,2-dichloroethane (1,2-DCA), benzene, C5-C8 aliphatics, C9-C12 aliphatics, ethylbenzene, and naphthalene. All of these compounds are common COCs in vapor intrusion investigations. These VOCs may be expected to normally be found above their generic screening levels in the indoor air of residential homes. These compounds are compared to their respective generic screening levels (RSLs) in Table 5.1.3 for clarity.

Table 5.1.3 VOCs with Calculated 95% UTL-50th Percentile Statistics Greater than Generic Screening Levels

Compounds	DEQ-ADJUSTED EPA RSL* (residential air) (µg/m^3)	Calculated 95% UTL-50th Percentile (µg/m^3)
1,2-Dichloroethane	0.094	0.23
Benzene	0.31	1.3
C5 - C8 Aliphatics	62.6**	94
C9 - C12 Aliphatics	10.4**	44
Ethylbenzene	0.97	1.1
Naphthalene	0.072	0.39

Notes:

* = DEQ divides non-carcinogenic RSLs by 10 to ensure a total hazard index of 1 or less. Carcinogenic RSLs are not modified

**= The screening level for C5-C8 and C9-C12 aliphatics are the DEQ residential air screening levels.

µg/m^3 – micrograms per cubic meter

The data will be used to determine whether more costly analytical methods are necessary for site-specific vapor intrusion investigations

If DEQ determines that as an outcome of this study, alternative screening levels may be appropriate for certain compounds (such as the six compounds discussed in the paragraph above and listed in table 5.1.3) then the use of the more expensive TO-15 SIM analysis could be eliminated for those compounds as long as standard TO-15 detection limits are below these alternative screening levels.

The data will be used to show members of the public who are concerned about vapor intrusion what concentrations of certain compounds are typically present in residences not impacted by vapor intrusion

By publishing the results of this study, DEQ provides the public with percentiles of measured indoor air concentrations of VOCs that may be expected in non-smoking, residential households that have not undergone recent remodeling. These percentiles may also be provided to members of the public who are involved in vapor intrusion investigations so that their measured indoor air results may be easily compared to results from residences known to not be impacted by subsurface vapor intrusion.

5.2 Additional Discussion

It is worth re-stating that evaluation of the vapor intrusion pathway requires multiple lines of evidence. The analytical results of this study demonstrate that typical indoor air concentrations in residences not impacted by subsurface vapor intrusion may vary by an order of magnitude, and measured concentrations sometimes exceed generic screening levels. As necessary, DEQ may consider the evaluation of each building as a unique situation, and allow for consideration of possibly higher typical indoor air concentrations as demonstrated by concentrations in the 75th, 90th and 95th percentiles of this study. Additionally, since the study design excluded residences that have undergone remodeling within 12 months, commercial structures, and residences occupied by smokers, these types of buildings may exhibit indoor air concentrations of VOCs equal to or greater than the upper percentiles of this study. However, variations in evaluating the vapor intrusion pathway should only occur after sufficient data have been collected for evaluation purposes and there are multiple lines of evidence indicating an indoor source.

Another line of evidence for which this study could be used is to determine whether certain building characteristics may significantly affect typical indoor air concentrations. A full analysis of this line of evidence has not been performed; however, DEQ did consider whether the presence of an attached garage affects the indoor air concentrations for the six VOCs (1,2-DCA, benzene, C5-C8 aliphatics, C9-C12 aliphatics, ethylbenzene, and naphthalene) with 95%UTL-50^{th} statistics greater than their respective screening levels. For each VOC, the full data set may be divided into data subsets for residences with attached garages (27 data points) and residences without attached garages (23 data points). The reasoning behind the data subdivision is that people generally store many products in garages (automobiles, power equipment, building supplies, household effects, etc) that are likely sources of the six VOCs identified above, and for residences with attached garages there is assumed air flow that occurs from the garage to the occupied living space that may impact indoor air quality.[2]

For each of the six VOCs, a hypothesis test was performed in ProUCL to determine whether a significant difference exists in the median concentration for the attached garage subset and no attached garage subset. A non-parametric Wilcoxon-Mann-Whitney test was utilized so that potential differences or uncertainty in the underlying distributions of the data subsets was not a concern. The results indicate that for 1,2-DCA, benzene, and ethylbenzene the 95%UTL-50^{th} statistic for the attached garage subset is significantly greater with 95% confidence than the no attached garage subset. For C5-C8 aliphatics, C9-C12 aliphatics, and naphthalene, there was no observed statistical difference at 95% confidence between the 95%UTL-50^{th} statistics of the attached garage and no attached garage subsets.

The 95%UTL-50^{th} statistics for 1,2-DCA, benzene, C5-C8 aliphatics, C9-C12 aliphatics, ethylbenzene, and naphthalene are identified above; however, in advanced situations involving multiple lines of evidence, DEQ may utilize the following 95%UTL-50^{th} statistics for 1,2-DCA, benzene, and ethylbenzene to accommodate the presence of an attached garage. Table 5.2.1 highlights the comparisons of percentiles and 95%UTL-50^{th} statistics between the full data set and attached garage and no attached garages data subsets for 1,2-DCA, benzene, and ethylbenzene. Lastly, it is noted that the 95%UTL-50th statistic for ethylbenzene for residences without an attached garage is less than the EPA RSL.

Table 5.2.1: Comparison of Data Subsets for Residences with Attached Garages and No Attached Garages

Compounds	Data Set	Frequency of Non-Detects	25th Percentile (µg/m^3)	50th Percentile (µg/m^3)	75th Percentile (µg/m^3)	90th Percentile (µg/m^3)	95th Percentile (µg/m^3)	95% UTL on 50th Percentile (µg/m^3)
1,2-DCA	Full	0%	0.11	0.17	0.48	0.82	1.2	0.23
	Attached Garage	0%	0.13	0.35	0.60	1.0	1.2	0.40
	No Attached Garage	0%	0.089	0.13	0.28	0.48	0.77	0.17
Benzene	Full	2%	0.52	0.90	2.5	8.4	12	1.3
	Attached Garage	0%	1.1	1.9	6.0	12	14	3.1
	No Attached Garage	4%	0.48	0.52	0.75	1.1	1.4	0.64
Ethylbenzene	Full	6%	0.41	0.78	2.1	4.0	6.0	1.1
	Attached Garage	0%	0.79	1.4	2.9	5.9	6.1	2.3
	No Attached Garage	13%	0.22	0.48	0.67	1.5	1.6	0.53

6.0 COMPARISON TO OTHER STUDIES

The Montana Vapor Intrusion Guide states that the range of indoor air concentrations for VOCs typically found in Montana is more narrow and falls at or below the low end of nationwide background ranges.[8] DEQ has previously supported this position by citing Montana's low population, rural conditions, small manufacturing base, and fewer contaminant sources of VOCs than locations predominantly included in other background studies. This indoor air study has provided data to empirically evaluate the issue.

Table 5 contains 50th percentiles from similar indoor air studies conducted in Massachusetts (2008), New York (2005), New Jersey (Weisel 2008), and an EPA (2011) compilation that combines indoor air data from 15 different studies (including the studies from Massachusetts, New York, and New Jersey) for which 50th percentiles were available from at least one other study.

Table 6.0.1: Comparison of Typical Montana Indoor Air Concentrations to Typical Indoor Air Concentrations from Other Studies

Compounds	Montana 50th Percentile (µg/m³)	MA DEP 50th Percentile[1] (µg/m³)	NYSDOH 50th Percentile[2] (µg/m³)	New Jersey 50th Percentile[3] (µg/m³)	EPA Background 50th Percentile[4] (µg/m³)
1,1,1-Trichloroethane	<0.84	0.5	0.33	<2.7	<RL - 5.9
1,1,2-Trichloroethane	<0.17	ND	<0.25	No Value	No Value
1,1,2-Trichlorotrifluoroethane	<0.83	No Value	0.54	No Value	<RL - 0.5
1,1-Dichloroethane	<0.83	ND	<0.25	No Value	<RL
1,1-Dichloroethene	<0.83	ND	<0.25	No Value	No Value
1,2,4-Trichlorobenzene	<0.83	ND	<0.25	No Value	No Value
1,2,4-Trimethylbenzene	<1.1	No Value	1.9	2.5	No Value
1,2-Dibromoethane	<0.83	No Value	<0.25	No Value	No Value
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	<0.83	No Value	<0.25	No Value	No Value
1,2-Dichlorobenzene	<0.83	ND	<0.25	No Value	No Value
1,2-Dichloroethane	0.17	ND	<0.25	No Value	<RL
1,2-Dichloropropane	<0.83	ND	<0.25	No Value	No Value
1,3,5-Trimethylbenzene	<0.87	No Value	0.64	<2.5	No Value
1,3-Butadiene	<0.84	No Value	No Value	<1.1	No Value
1,3-Dichlorobenzene	<0.83	ND	<0.25	No Value	No Value
1,4-Dichlorobenzene	<0.84	0.5	<0.25	3.0	No Value
1,4-Dioxane	<0.83	ND	No Value	No Value	No Value
2-Butanone	<8.5	3.4	3.4	3.5	No Value
4-Ethyltoluene	<0.87	No Value	No Value	<2.5	No Value
4-Methyl-2-pentanone	<0.88	No Value	No Value	<2.0	No Value
Acetone	46	26	21	35	No Value
alpha-Pinene	3.8	No Value	1.5	No Value	No Value
Benzene	0.90	2.3	2.1	1.8	<RL - 4.7
Bromodichloromethane	<0.84	ND	No Value	No Value	No Value
Bromoform	<0.83	ND	No Value	No Value	No Value
Bromomethane	<0.83	ND	<0.25	No Value	No Value
C5 - C8 Aliphatics	81	58	No Value	No Value	No Value
C9 - C12 Aliphatics	33	68	No Value	No Value	No Value
C9 - C10 Aromatics	<9.2	ND	No Value	No Value	No Value
Carbon Disulfide	<8.3	No Value	No Value	<1.6	No Value
Carbon Tetrachloride	<0.85	ND	<0.25	No Value	<RL - 0.68
Chlorobenzene	<0.83	ND	<0.25	No Value	No Value
Chloroethane	<0.83	No Value	<0.25	No Value	No Value
Chloroform	<0.93	1.9	<0.25	2.4	<RL - 2.4
Chloromethane	<0.84	No Value	0.50	1.4	No Value
cis-1,2-Dichloroethene	<0.83	ND	<0.25	No Value	<RL
cis-1,3-Dichloropropene	<0.83	ND	<0.25	No Value	No Value
Cyclohexane	<1.8	No Value	0.81	1.7	No Value
Dibromochloromethane	<0.84	ND	No Value	No Value	No Value
Dichlorodifluoromethane (CFC 12)	2.0	No Value	<0.25	3.3	No Value
Methylene Chloride	<0.93	1.4	1.4	<1.7	0.68 - 61

Compounds	Montana 50th Percentile (µg/m3)	MA DEP 50th Percentile[1] (µg/m3)	NYSDOH 50th Percentile[2] (µg/m3)	New Jersey 50th Percentile[3] (µg/m3)	EPA Background 50th Percentile[4] (µg/m3)
d-Limonene	16	No Value	2.8	No Value	No Value
Ethanol	625	No Value	160	No Value	No Value
Ethylbenzene	0.78	1.5	1.0	2.2	1 - 3.7
Hexachlorobutadiene	<0.83	ND	<0.25	No Value	No Value
Cumene	<0.83	No Value	<0.25	No Value	No Value
m,p-Xylenes	2.7	5.9	1.5	3.8	1.5 - 14
Methyl Methacrylate	<1.7	No Value	<0.25	No Value	No Value
Methyl tert-Butyl Ether	<0.83	3.5	0.79	3.45	0.025 - 3.5
Naphthalene	0.36	ND	No Value	No Value	No Value
n-Heptane	1.1	No Value	2.8	2.0	No Value
n-Hexane	1.5	No Value	1.6	2.8	No Value
n-Nonane	<0.93	No Value	1.3	No Value	No Value
n-Octane	<0.93	No Value	0.89	No Value	No Value
n-Propylbenzene	<0.85	No Value	<0.25	No Value	No Value
o-Xylene	<0.94	5.9	1.1	2.2	1.1 - 3.6
Styrene	<0.93	0.63	0.30	<2.1	No Value
Tetrachloroethene	0.099	1.4	0.34	<3.4	<RL - 2.2
Tetrahydrofuran	<0.90	No Value	<0.25	No Value	No Value
Toluene	8.3	11	9.6	13	4.8 - 24
trans-1,2-Dichloroethene	<0.83	ND	No Value	No Value	No Value
trans-1,3-Dichloropropene	<0.83	ND	<0.25	No Value	No Value
Trichloroethene	<0.048	0.29	<0.25	<2.7	<RL - 1.1
Trichlorofluoromethane (CFC 11)	1.2	No Value	2.9	2.8	No Value
Vinyl Chloride	<0.042	ND	<0.25	No Value	<RL

Notes:

ND = not detected (reporting limit unknown)
RL = reporting limit
µg/m3 – micrograms per cubic meter

The following list highlights the comparisons of significant VOCs for vapor intrusion investigations:

- 1,2,4-Trimethylbenzene – The Montana median concentration is non-detect at 1.1 µg/m^3, while New York’s and New Jersey’s are 1.9 and 2.5 µg/m^3, respectively.
- Benzene – The Montana median concentration is 0.90 µg/m^3, while Massachusetts’, New York’s, and New Jersey’s are 2.3, 2.1, and 1.8 µg/m^3, respectively. The range of 50th percentiles from the EPA compilation is less than the reporting limit (not identified) to 4.7 µg/m^3.
- Chloroform – The Montana median concentration is non-detect at 0.93 µg/m^3, while Massachusetts’, New York’s, and New Jersey’s are 1.9, non-detect at 0.25, and 2.4 µg/m^3, respectively. The range of 50th percentiles from the EPA compilation is less than the reporting limit (not identified) to 2.4 µg/m^3.
- Ethylbenzene – The Montana median concentration is 0.78 µg/m^3, while Massachusetts’, New York’s, and New Jersey’s are 1.5, 1.0, and 2.2 µg/m^3, respectively. The range of 50th percentiles from the EPA compilation is 1 to 3.7 µg/m^3.

- m,p-Xylenes – The Montana median concentration is 2.7 µg/m^3, while Massachusetts', New York's, and New Jersey's are 5.9, 1.5, and 3.8 µg/m^3, respectively. The range of 50th percentiles from the EPA compilation is 1.5 to 14 µg/m^3.
- n-Hexane – The Montana median concentration is 1.5 µg/m^3, while New York's and New Jersey's are 1.6 and 2.8 µg/m^3, respectively.
- o-Xylene – The Montana median concentration is non-detect at 0.94 µg/m^3, while Massachusetts', New York's, and New Jersey's are 5.9, 1.1, and 2.2 µg/m^3, respectively. The range of 50th percentiles from the EPA compilation is 1.1 to 3.6 µg/m^3.
- PCE – The Montana median concentration is 0.099 µg/m^3, while Massachusetts', New York's, and New Jersey's are 1.4, 0.34, and non-detect at 3.4 µg/m^3, respectively. The range of 50th percentiles from the EPA compilation is less than the reporting limit (not identified) to 2.2 µg/m^3.

In general, this comparison demonstrates that indoor air concentrations for VOCs typically found in Montana residences fall at or below the low end of nationwide background ranges; however, the results of this study do not allow a blanket statement that all typical indoor air quality in Montana residences is better than other more urbanized and industrial States. For instance, C5-C8 aliphatics, acetone, and ethanol are VOCs for which typical indoor air concentrations in Montana exceed levels from the other studies (though C5-C8 aliphatics and ethanol were only analyzed in one of the four studies referenced). Additionally, other background indoor air studies may not have utilized the same building selection criteria, and as such may include background indoor air VOC concentrations that represent a building use not captured by this background study (e.g., cigarette smoke in indoor air).

7.0 SUMMARY

DEQ undertook a study of typical concentrations of VOCs in the indoor air of non-smoking residential homes in Montana not impacted by subsurface vapor intrusion. The study design included building selection criteria to control potential variation in analytical results. The following key points are outcomes of the study:

- Typical indoor air concentrations in Montana residences for 56 out of the 77 VOCs evaluated in this study are expected to be less than normally achievable laboratory reporting limits;
- The study identified 21 VOCs for which 95%UTL-50^{th} statistics provide a useful line of evidence for vapor intrusion investigations when considering typical indoor air concentrations in Montana residences;
- Six VOCs (1,2-DCA, benzene, C5-C8 aliphatics, C9-C12 aliphatics, ethylbenzene, and naphthalene) exhibited 95%UTL-50^{th} statistics of typical indoor air concentrations in Montana residences above their respective EPA RSLs;
- For advanced, building-specific evaluations of the vapor intrusion pathway, Table 5.2.1 provides useful typical background indoor air concentrations of 1,2-DCA, benzene, and ethylbenzene based on whether a residence has an attached garage or not;
- The upper end of the percentiles (75^{th}, 90^{th} or 95^{th} percentiles) reported in Table 4.0.1 still represent concentrations of VOCs from sources other than vapor intrusion;
- The use of TO-15 SIM, depending on individual laboratory reporting limits, may not be necessary for 1,2-DCA, benzene, ethylbenzene, and naphthalene;

- DEQ will utilize the results of this study to inform the public involved in vapor intrusion assessments about typical indoor air concentrations in Montana residences not affected by vapor intrusion;
- DEQ will allow others (states, industries, consultants) access to the database for further evaluation of typical indoor air concentrations in Montana (e.g., evaluation of potential differences in typical indoor air concentrations based on heating fuel source);
- While additional data gathering has the potential to expand the evaluation for some VOCs or refine the evaluation of data subsets, the 50 samples collected during this study have provided a significant additional line of evidence for assessing the vapor intrusion pathway. No additional sampling is required to utilize the findings of this study.

8.0 REFERENCES

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