Groundwater Monitoring&Remediation

Indoor Air Background Levels of Volatile Organic Compounds and Air-Phase Petroleum Hydrocarbons in Office Buildings and Schools

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Abstract

A background indoor air study has been completed which includes the collection of indoor air samples from office buildings and schools. The anonymous study was designed with input from the U.S. Environmental Protection Agency and the Massachusetts Department of Environmental Protection. The sampling was implemented in 2013, 2014, and 2015 and included the collection of 25 school building samples and 61 office building samples. The study generated 14,668 new indoor air background data points, with samples collected from buildings located in 26 cities in 18 states, including Arizona, California, Connecticut, Indiana, Kansas, Maine, Massachusetts, Minnesota, Montana, New Hampshire, New Jersey, New York, Nevada, North Carolina, Ohio, Texas, Utah, and Washington. Indoor air background concentrations of target compound volatile organic compounds (VOCs) ranged from less than the laboratory method reporting limit of 0.044 µg/m^3 to concentrations up to 1190 µg/m^3, with hydrocarbon ranges from less than the reporting method limit of 10 µg/m^3 to concentrations up to 3000 µg/m^3. Some VOCs were identified ubiquitously in indoor air background, and some were identified at concentrations which exceeded risk-based regulatory screening levels. These study results provide useful and updated information on indoor air background and air quality in offices and schools and can be used in future regulatory guidance update considerations, for further examination of relationships between these data and residential study data, in human health risk assessments and risk communication, and in planning future studies.

Introduction

Indoor air background is considered to be comprised of contaminants that are present in indoor air due to indoor or outdoor sources and not due to a subsurface source (such as vapor intrusion) or otherwise related to a regulated discharge (Environmental Protection Agency [U.S. EPA] 2015). Indoor air background therefore differs from traditional definitions of background for soils or waters which refer to anthropogenic or naturally occurring sources (U.S. EPA 1989, 2002). Indoor air background can be the result of one or more sources such as household or building activities, consumer products, ambient air pollution, and building materials and furnishings (NJDEP 2018).

A wide range of VOCs have been identified in consumer products (Gorder and Dettenmaier 2011), including those with claims of being "green," "organic," and "fragrance-free," as well as air fresheners, laundry products, cleaners, and personal care products (Steinemann 2015). Indoor sources, consumer products, and tobacco smoke have been reported as the largest source of variability in levels of many VOCs in indoor air (Wallace 2001; Sexton et al. 2004). Products and materials that are used and stored in residential and nonresidential buildings have been demonstrated to impact indoor air with VOCs of environmental interest, including tetrachloroethene (tetrachloroethylene, PCE) from adhesives (Gorder and Dettenmaier 2011), trichloroethene (trichloroethylene, TCE) from a stored aerosol can (Beckley et al. 2016), and 1,2-dichloroethane (1,2-DCA) emanating from plastic holiday decorations (Doucette et al. 2010). VOC emissions have also been measured from markers commonly used in preschools, schools, and homes (Castorina et al. 2016). Additional information on VOC content for specific brands of consumer products such as auto products, pesticides, personal care, arts and crafts, home and home office, pet care, selected commercial/institutional products, and other commercially available products can be found in the Household Products Database (National Institute of Health 2013).

Relative to ambient air, VOCs can enter a building through infiltration, natural ventilation, and mechanical ventilation processes (U.S. EPA 1988). Building materials such as carpeting, fabrics and wallpapered gypsum board can act as "sinks" that retain indoor air pollutants and

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subsequently release them over a prolonged period of time (Won et al. 2001). VOCs have also been identified in new (finished and operational, but unoccupied) prefabricated and site-built houses (Hodgson et al. 2000).

There have been numerous studies of residential indoor air background (e.g., Clayton et al. 1999; Hippelein 2004; Rago et al. 2004; Weisel et al. 2005; NYSDOH 2006; MTDEQ 2012). Many of these and other residential studies have been compiled (Dawson and McAlary 2009; U.S. EPA 2011a) and demonstrate that VOCs are commonly identified in indoor air. These latter compilations also suggest that indoor air quality appears to have been improving over time in the United States and Canada, further citing several references (e.g., Hodgson and Levin 2003; Zhu et al. 2005; Massachusetts Department of Environmental Protection [MassDEP] 2008).

The (U.S. EPA 2015) and many state regulatory agencies provide guidance for comparing indoor air data to background concentration data to assess the vapor intrusion pathway at contaminated sites. In general, the background values currently being used were derived from previously cited residential indoor air background studies and compilations. These residential studies may not be well suited for current evaluation of indoor air quality in office buildings and schools, especially as it pertains to potential vapor intrusion. Nonresidential indoor air background may also differ from residential indoor air background in the types and ranges of VOCs detected (i.e., potential for higher halogenated aromatics in commercial settings and higher lineal and cyclic aliphatics in homes and schools) (Cometto-Muñiz and Abraham 2015). The usability of the available data for nonresidential studies of indoor air quality in office buildings (e.g., [Daisey et al. 1994; Girman et al. 1999] and schools [Adgate et al. 2004]) is further limited by the age of the data (some is over 20 years old) and use of inconsistent sampling and analytical methods (including multiple methods in the same study). Therefore, a need exists for a current indoor air background data set for samples collected from office buildings and schools using consistent sampling and analytical methods. These new data may be especially useful for practitioners since understanding indoor air background can be of strategic importance in vapor intrusion data review, focusing investigations, mitigation decision making, and risk communication.

Materials and Methods

The goal of this Study was to collect indoor air samples from offices/nonresidential buildings and schools across the United States that were unimpacted by any known subsurface sources and therefore representative of indoor air background conditions. Planning, volunteer identification and selection, and access arrangements began in 2012, and subsequently, 25 school indoor air background samples and 61 office/nonresidential indoor air background samples were collected in March 2013, April and May 2014, and March, April, and May 2015. Some schools and office/nonresidential buildings were relatively large buildings, and more than one sample was collected per location. For example, the 25 indoor air background samples were collected from 21 school buildings (three samples were collected from each of two larger school buildings), and the 61 indoor air background samples were collected from 42 office/nonresidential buildings (two samples were collected from each of 15 large buildings, and three samples were collected from one large building; in addition, one building was resampled as detailed below).

To identify and select potential anonymous Study volunteers for school indoor air background assessments, municipal officials (e.g., Departments of Education/school departments and town/city managers) were approached from one city and two suburban municipalities. In addition, the Environmental Health and Safety department of a large city university was approached. Collectively, access was obtained for indoor air sampling at elementary schools (e.g., kindergarten through fifth grade), middle schools (e.g., fifth through eighth grade), high schools, and teen centers in urban and suburban communities, as well as at university classroom settings. Based upon access and sampling coordination logistics and the physical location of the authors, the school sample population was focused on northeastern states Connecticut and Massachusetts.

To identify and select anonymous Study volunteers for office indoor air background assessments, the Study population consisting of members of the environmental professional practices industry was targeted, such as consultants, attorneys, and regulatory officials. This target population was selected for similar reasons used to enroll Study volunteers in the Nurses Health Study (NHS 2004): it was assumed that volunteers have the educational background and familiarity with indoor air quality and would be able to answer questions more accurately than the general public; based on volunteer's educational and professional backgrounds, they were more likely to be aware if a subsurface release had occurred near their office; volunteers were motivated to participate, and were familiar with and less likely to compromise the integrity of the sampling procedures; and, volunteers were located widely throughout the country, which increases the ability to obtain representative samples throughout the United States. The office building sampling group was also supplemented with access for sampling of two nonclassroom administrative office buildings as provided by the city university Environmental Health and Safety department. The Study authors completed all the sampling activities in these two locations. Collectively, this sampling group (e.g., consultants, attorneys, and/or regulatory official volunteers) comprised approximately two thirds of the office/nonresidential buildings in the indoor air background data set collected (43 of 61 samples, from 27 of 42 total office/nonresidential buildings).

Office/nonresidential Study volunteers were also solicited from town/city managers and other municipal officials. Collectively, access was obtained for indoor air sampling at two senior centers, two city hall buildings, a town hall building, a public library, a police department office, a fire department office, a department of health office, a department of public works office, a planning and engineering office, and other municipal buildings. The Study team completed all aspects of the sampling activities at these buildings, which comprise approximately one third of the office/nonresidential buildings in the indoor air background data

set collected (18 of 61 samples, from 15 of 42 total office/nonresidential buildings).

Since approximately two thirds of the Study volunteer office buildings were work locations for environmental professionals in private consulting, environmental law, or in a state regulatory capacity, the results of this nonresidential indoor air background study for office buildings may be biased-low. Some potential factors that may result in correspondingly lower detected concentrations of indoor air background VOCs for the offices portion of the Study dataset are similar to those discussed for other residential indoor air background study populations which focused largely on environmental professionals (e.g., Rago et al. 2004; McCafferty 2006) and include that

- the majority of Study volunteers should be more aware of potential inhalation risks associated using and storing chemical in the office workplace environment;
- the majority of Study volunteers may be more aware of and be motivated to obtain alternate products that may contain lower concentrations of VOCs and/or less toxic chemicals for their offices; and,
- potential volunteers that declined participation in the Study may have done so out of concern for identification of high levels of indoor air background constituents that may be present due to sources of VOCs that they may store and use in their offices.

Prior to approval of a volunteer building's suitability for this Study, an evaluation was performed to assess whether subsurface sources or other regulated discharge of VOCs may have impacted the indoor air of the building. To perform this for municipal and school buildings, available regulatory records were screened for building address and proximity and a phone interview was conducted. For the remaining office volunteer group, environmental consultants and attorneys and state regulatory officials familiar with vapor intrusion were considered competent to answer this query accurately. Collectively, two buildings were excluded from participation in the Study by this process.

A "Notice To Indoor Air Study Volunteers" was provided, which: (1) explained that the indoor air sample(s) collected in their building represented a 'snap-shot' of VOCs and air-phase petroleum hydrocarbons (APH), and that results may not be reproducible; (2) stated that the author's employers did not make claims as to the accuracy or representativeness of the data; (3) suggested that volunteers may need to independently decide how to respond or disclose the results received from this Study; and (4) advised volunteers to contact a third party to have their building retested if concerned about the reported results.

The notice also included a "Certification of Indoor Air Study Volunteers," wherein volunteers certified: (1) that they were participating in this Study on a voluntary basis; (2) that they do not have knowledge of releases of oil and/or hazardous materials to the environment that would impact the indoor air of the building tested; (3) that they understand that the detected VOCs and APH constituents, if any, may be the result of temporary or ongoing sources of VOCs and APH which may or may not originate from within the building; (4) that they understand that no additional follow on work associated with this Study would be conducted by the author's employers; and (5) that they agree to release and hold the author's employers harmless from all claims they may have arising from participating in this Study. The notice and certification was signed by all volunteers prior to acceptance in the Study.

All school and office buildings evaluated included conventional oil or gas forced air or baseboard heating systems and/or heating, ventilation, and air conditioning (HVAC) systems. HVAC parameters such as collection of air exchange rate data have been incorporated in some previous indoor air background studies (e.g., U.S. EPA 2003; Weisel et al. 2005), but were not collected for this study except as otherwise volunteered by a small group of participants. These data indicated that ventilation in these study buildings fell within U.S. EPA's published range of expected values of air changes per hour (ACH) for nonresidential buildings such as offices and educational facilities (0.3-4.1 ACH; U.S. EPA 2011b). Although not evaluated further herein, it is recognized that HVAC parameters can also be an important line of evidence in vapor intrusion assessments and that building ACH rates may be used to inform decision making at vapor intrusion sites (e.g., Shea et al. 2010; Reichman et al. 2017).

Sample locations were biased to where indoor air receptors (e.g., students or office workers) were assumed to be located and sampling near known building source areas (e.g., a school basement heating oil tank) was avoided. A list of the municipalities sampled is summarized in Table 1.

Table 1

List of Municipalities Sampled

State	Municipality	School Samples (%)	Office Samples (%)
AZ	Phoenix	0	3
CA	Costa Mesa, Fresno, Oakland, San Diego, San Jose, Walnut Creek	0	18
CT	Glastonbury, Rocky Hill	48	3
IN	Indianapolis	0	2
KA	Overland Park	0	2
MA	Boston, Cambridge, Watertown	52	33
ME	Portland	0	2
MN	Minneapolis	0	2
MT	Helena	0	3
NC	Raleigh	0	3
NH	Manchester	0	2
NJ	Parsippany	0	3
NV	Carson City	0	2
NY	Rochester	0	2
OH	Miamisburg	0	2
TX	Austin	0	13
UT	Salt Lake City	0	3
WA	Lacey	0	3

Laboratory Sampling and Analytical Procedures and Methods

To complete the sampling program, the laboratory provided 6-l fused silica lined canisters (Entech and Restek) and fused silica lined flow controllers equipped with digital gauges (Veriflo Restek 24238) calibrated to sample over a 24-h interval. Laboratory analysis of target compound VOCs was conducted via EPA Method TO-15 (full-scan mode) (U.S. EPA 1999b) with analytical reporting and quality control enhancements (MassDEP 2010). A subset of target compound VOCs was also acquired simultaneously in the Selected Ion Monitoring (SIM) mode, for which EPA Method TO-15 batch-certification was judged to be acceptable for these Study data. A laboratory control sample (LCS) with chromatographic conditions used is shown as Figure 1:

Method TO-15 volatile organics are defined as compounds having a vapor pressure greater than 10-1 Torr at 25 °C and 760 mmHg. EPA Method TO-15 documents the sampling and analytical procedures for measurement of subsets of the 97 VOCs that are included in the 189 hazardous air pollutants (Has) listed in Title III of the Clean Air Act Amendments of 1990. The Method TO-15 full scan reporting list herein varied slightly over the period of the study but included up to 105 target VOCs. Method TO-15 SIM mode target compound list also varied slightly over the period of the Study but included up to 58 target VOCs. All samples were also analyzed for MassDEP compendium analytical method for air-phase petroleum hydrocarbons (APH), which included redundant target compound list vocs 1,3-butadiene, methyl tert-butyl ether, benzene, toluene, ethylbenzene, p/m-xylene, o-xylene, naphthalene, as well as hydrocarbon ranges C5-C8 aliphatics, C9-C12 aliphatics, and C9-C10 aromatics.

Data Quality Assessment and Data Usability

Sampling information and analytical laboratory reports were reviewed, including initial and final canister vacuums, Chain of Custody forms, method blanks, LCS recoveries, GC/MS internal standard recoveries, and laboratory report narratives. Although minor QA/QC nonconformances were noted, the results were not qualified further and were judged to be representative and considered usable for this Study.

The MassDEP APH method includes the use of extracted ions to quantify ranges of hydrocarbons and includes an adjustment allowance for the analytical chemist to identify and remove nonpetroleum hydrocarbon peaks that elute in the aliphatic hydrocarbon ranges. For this study, all significant concentrations of nonpetroleum VOCs detected, target and nontarget, were subtracted from the corresponding. Hydrocarbon ranges by the analytical laboratory. Therefore, no false positive bias would be expected for the reported APH hydrocarbon results.

Data Management and Statistical Analysis

The laboratory provided analytical results via an electronic data deliverable (EDD) for each laboratory report. EDDs were imported into a relational database for processing. This provided a secure platform for managing, checking, and reporting the data. The Method TO-15 full scan data, Method TO-15 SIM data, and where applicable, the APH data were also reviewed for redundant target compounds and the reported results were determined to be comparable for detected values at the 95% confidence level. A merged data set was exported from the database by prioritizing the more sensitive Method TO-15 SIM over Method

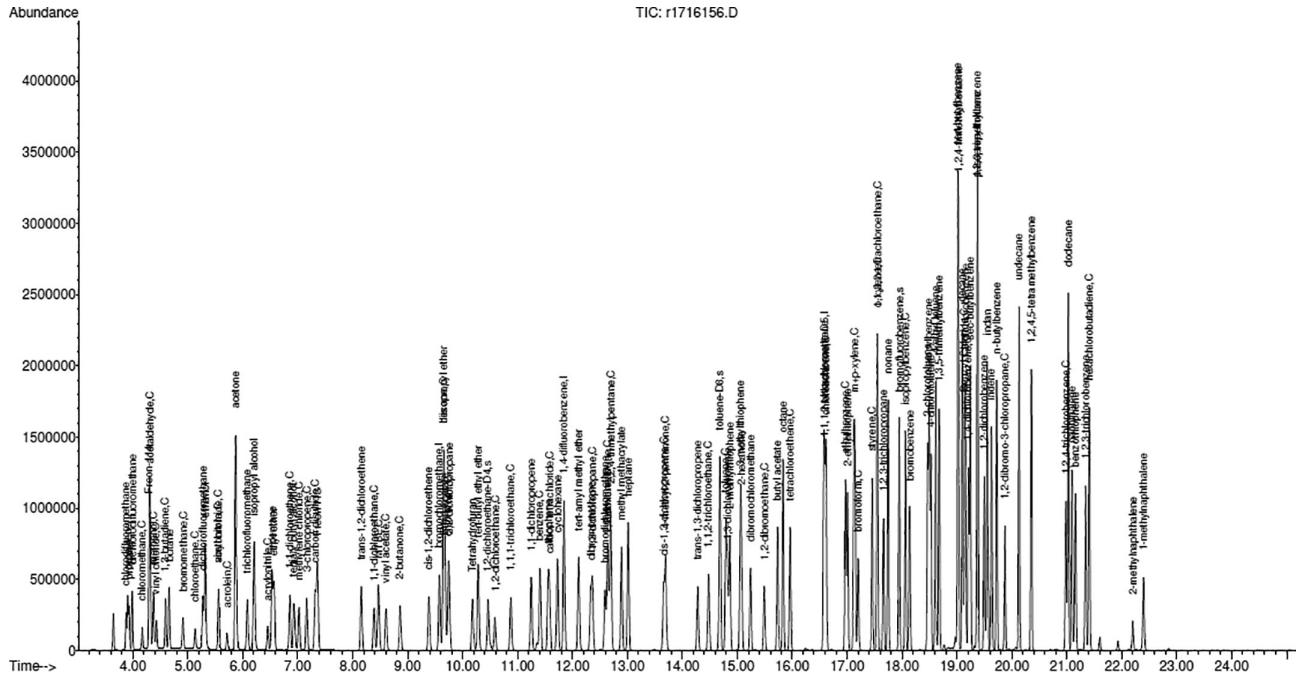


Figure 1. TO-15 LCS chromatogram (typical): chromatographic conditions: 25 °C for 5 min, 8.0 °C/min to 100 °C, 25 °C/min to 220 °C, hold 4 min; Column: Restek Rtx-1 (length = 60 M, 0.25 mm ID, film thickness [df] 1.0 µm). Instrumentation: Agilent 6890 GC/5975 MS with Entech 7100A Concentrator/7016CA Autosampler.

TO-15 full scan or the less sensitive APH analytical method for redundant target compounds. The merged VOC data sets for 86 samples (25 school samples and 61 office samples) were then examined using various graphical and statistical testing procedures using ProUCL 5.1 and Minitab 17 statistical software. The descriptive statistics for all merged data (all 86 samples), merged data for office samples only, and merged data for school samples only were evaluated separately for number of observations, number of detects, percentage of nondetects (ND), range of ND concentration, range of detected concentration, mean, percentile (10th, 25th, 50th [median], 75th, 90th, and 95th), variance, standard deviation, and coefficient of variation. For censored (nondetect) data, methods such as simple imputations and Kaplan-Meier (KM) estimations were used to calculate the descriptive statistics. The ND's were imputed with the whole reporting limit to calculate the percentiles. KM estimation was used to calculate mean, variance, standard deviation, and coefficient of variation. Refer to Supporting Information for these additional summary statistics.

Exploratory data analysis that includes outlier presence was examined using box plots. The box plots showed the presence of outliers in the data sets, but there was no conclusive evidence to remove the data. Therefore, all data were considered in this Study. Additional discussion of specific outliers is included in the Results discussion.

Discussion of Results

Target VOCs and the 3 Hydrocarbon ranges were detected in all school buildings and office/nonresidential buildings sampled, with 2487 detected results for 68 analytes (65 target VOCs and the 3 Hydrocarbon ranges) in the merged data set for the 86 office and school samples. This includes 1839 detected results for 66 analytes (63 target VOCs and the 3 Hydrocarbon ranges) for the 61 office building samples, and 728 detected results for 53 analytes (50 target VOCs and the 3 Hydrocarbon rages) for the 25 school building samples.

Statistical analysis was performed to assess the comparability between school building data sets and the office building dataset. The analysis was limited to frequently detected compounds Benzene, Toluene, and Ethylbenzene and suggests that the populations are different (unequal variance). However, an exhaustive evaluation of all compounds was not conducted and accordingly, the results presented herein include summary tables of all data as well as individual data presentations for offices and schools. The results summary tables presented below include percent (%) detection, range of detected concentrations, Kaplan-Meier mean, and the 10th, 25th, 50th, 75th, 90th, and 95th percentile values. The summary tables also include risk-based screening levels for comparison to the lower of the current cancer (1E-06 excess lifetime cancer risk) and noncancer (hazard index [HI] = 1) U.S. EPA Regional Screening Levels (RSLs) for residential and nonresidential air (U.S. EPA 2020). Tables 2 to 4 present merged data results for detected VOCs in all samples ($N = 86$), offices ($N = 61$), and schools ($N = 25$), respectively.

Indoor air background concentrations of target compound VOCs ranged from less than the laboratory method reporting limit of 0.044 µg/m^3 to concentrations up to 1190 µg/m^3, with hydrocarbon ranges from less than the reporting method limit of 10 µg/m^3 to concentrations up to 3000 µg/m^3. Hydrocarbons, ketones, halomethanes, alcohols, and chlorofluorocarbons (Freons) were the most reported of the 68 analytes detected, with hydrocarbons comprising approximately one half of the top 25 compounds detected:

- 100% frequency of detection: acetone, butane, carbon tetrachloride, ethyl alcohol, ethylbenzene, iso-propyl alcohol, methanol, o-xylene, p/m-xylene, toluene, and trichlorofluoromethane;
- 90% to 99% frequency of detection: 1,1,2-trichloro-1,2,2-trifluoroethane (Freon-113), chlorodifluoromethane, propane, chloromethane, dichlorodifluoromethane, C5-C8 aliphatics, 1,2,4-trimethylbenzene, benzene, and chloroform; and,
- 70% to 89% frequency of detection: Styrene, C9-C12 Aliphatics, 1,2-Dichloroethane, Acetaldehyde, and 2-Butanone.
- Since it is a compound of common environmental interest, it is noteworthy that Tetrachloroethene was detected in indoor air background in approximately two thirds of the samples (64%).

Many of these VOCs are likely to originate from indoor sources and activities, with potential sources of 1,2-Dichloroethane from plastics (Doucette et al. 2010), potential sources of Chloroform from tap water, bleach use (Odabasi 2008), or endogenous formation (Rezendes et al. 2012), and hydrocarbons, Freons, and alcohols simply from widespread use and storage.

Some VOCs (e.g. chloromethane [ATSDR 1998] and carbon tetrachloride [U.S. EPA 2017]) have been reported ubiquitously in ambient air monitoring at similar levels and may be present due to infiltration of outdoor air. Relative to outdoor air, study results for selected VOCs were qualitatively reviewed in consideration of the atmospheric background concentrations published by the National Oceanic and Atmospheric Administration (NOAA) Global Monitoring Laboratory for 2015 (NOAA 2020). Of the six analytes evaluated (chlorodifluoromethane, carbon tetrachloride, chloromethane, dichlorodifluoromethane, trichlorofluoromethane, and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113), the Study median results for five of the analytes were reported at concentrations that are within approximately 70-115% of the 2015 NOAA results for "long-term global trends of atmospheric trace gases". The Study median concentration for chlorodifluoromethane (Freon 22) of 2.16 µg/m^3 was more than twice the approximate 2015 NOAA values, potentially due to this VOC still being currently used as a propellant and refrigerant. The observed trend for Freon 22 in NOAA plotted atmospheric concentrations have increased approximately 2-fold since 1995.

The database population included many VOCs that were not detected in any of the samples (0% frequency of detection). Table 5 presents merged data results for nondetected VOCs in all samples ($N = 86$), offices ($N = 61$), and schools ($N = 25$), respectively. These VOCs may be compounds that are uncommon to consumer products and materials such as halopropanes and haloaromatics, but also included compounds

Table 2

Summary Statistics for Schools and Offices

Analytes	% Detection	Range of Detected Concentrations	KM Mean	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	Residential Air RSL	Industrial Air RSL
Volatile Organics (µg/m³)		**Minimum-Maximum**									
C5-C8 aliphatics, adjusted	97	14-3000	91.97	17.5	23	35	55.5	85.5	157.5	NA	NA
C9-C10 aromatics total	9	10–130	15.01	10	10	10	10	10	36.5	NA	NA
C9-C12 aliphatics, adjusted	83	15-990	76.97	14	19.25	35	65	140	327.5	NA	NA
1,1,1-Trichloroethane	9	0.153-0.611	0.131	0.109	0.109	0.109	0.109	0.162	0.272	5200 n	22000 n
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon-113)	99	0.468-1.49	0.608	0.529	0.544	0.575	0.651	0.701	0.739	5200 n	22000 n
1,1-Dichloroethane	5	0.134-0.194	0.0849	0.081	0.081	0.081	0.081	0.081	0.132	1.8 c	7.7 c
1,1-Dichloroethene	1	0.472-0.472	0.0836	0.079	0.079	0.079	0.079	0.079	0.079	210 n	880 n
1,2,3-Trimethylbenzene	8	1.12-8.11	1.262	0.983	0.983	0.983	0.983	0.983	1.086	63 n	260 n
1,2,4-Trimethylbenzene	97	0.098-32.7	1.448	0.128	0.176	0.313	0.54	1.425	7.2	63 n	260 n
1,2-Dichlorobenzene	2	0.132-0.186	0.121	0.12	0.12	0.12	0.12	0.12	0.129	210 n	880 n
1,2-Dichloroethane	79	0.081-0.704	0.158	0.081	0.085	0.113	0.166	0.283	0.338	0.11 c*	0.47 c*
1,2-Dichloropropane	3	0.092-0.166	0.0932	0.092	0.092	0.092	0.092	0.092	0.092	0.76 c**	3.3 c**
1,3,5-Trimethylbenzene	45	0.098-9.73	0.401	0.098	0.098	0.098	0.161	0.474	1.118	63 n	260 n
1,3-Butadiene	41	0.044-0.774	0.0714	0.044	0.044	0.044	0.0725	0.102	0.129	NA	NA
1,3-Dichlorobenzene	1	3.32-3.32	0.157	0.12	0.12	0.12	0.12	0.12	0.12	NA	NA
1,4-Dichlorobenzene	15	0.12-3.15	0.232	0.12	0.12	0.12	0.12	0.19	0.393	0.26 c	1.1 c
2,2,4-Trimethylpentane	9	0.986-83.6	1.992	0.934	0.934	0.934	0.934	0.988	2.878	NA	NA
2-Butanone	70	0.619-27	2.021	1.055	1.47	1.485	2.038	2.915	4.878	5200 n	22000 n
4-Methyl-2-pentanone	2	2.03-6.48	0.919	0.82	0.82	2.05	2.05	2.05	2.05	3100 n	13000 n
Acetaldehyde	77	6.43-35.7	18.32	5.465	9.235	18.7	26.95	32.9	34.33	1.3 c**	5.6 c**
Acetone	100	7.13-401	25.85	12.25	14.23	19.7	24.85	35.2	45.15	32000 n	140000 n
Acetonitrile	34	0.336-13.9	0.539	0.336	0.336	0.336	0.372	0.502	0.768	63 n	260 n
Acrolein	10	1.19-1.97	1.189	1.15	1.15	1.15	1.15	1.22	1.645	0.021 n	0.088 n
Benzene	94	0.319-24.8	0.921	0.331	0.406	0.617	0.745	0.913	1.405	0.36 c*	1.6 c*
Bromodichloromethane	2	0.409-0.422	0.141	0.134	0.134	0.134	0.134	0.134	0.15	0.076 c	0.33 c
Bromomethane	8	0.082-0.128	0.0801	0.078	0.078	0.078	0.078	0.0835	0.109	5.2 n	22 n
Butane	100	0.87-261	10.14	1.525	2.153	3.815	9.895	16.05	21.28	NA	NA
Butyl acetate	2	5.47-6.13	2.46	2.38	2.38	2.38	2.38	2.38	2.658	NA	NA
Carbon tetrachloride	100	0.327-0.66	0.445	0.384	0.409	0.434	0.477	0.519	0.576	0.47 c	2 c

Table 2. (Continued)

Analytes	% Detection	Range of Detected Concentrations	KM Mean	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	Residential Air RSL	Industrial Air RSL
Volatile Organics (µg/m³)		**Minimum-Maximum**									
Chlorodifluoromethane	99	0.806-151	12.21	1.15	1.403	2.16	8.073	23.55	80.8	52000 n	220000 n
Chloroethane	8	0.053-0.071	0.0538	0.053	0.053	0.053	0.053	0.053	0.0648	10000 n	44000 n
Chloroform	92	0.098-2.11	0.259	0.098	0.112	0.151	0.243	0.42	0.923	0.12 c	0.53 c
Chloromethane	98	1.02-1.67	1.315	1.12	1.2	1.31	1.41	1.53	1.598	94 n	390 n
cis-1,2-Dichloroethene	2	0.301-1.82	0.102	0.079	0.079	0.079	0.079	0.079	0.0888	NA	NA
Cyclohexane	24	0.702-29.3	1.253	0.688	0.688	0.688	0.699	1.475	2.315	6300 n	26000 n
Decane (C10)	33	1.18-80.9	3.503	1.16	1.16	1.16	1.498	4.75	8.685	NA	NA
Dichlorodifluoromethane	97	0.811-12.7	2.199	1.286	1.495	1.89	2.375	2.666	3.278	100 n	440 n
Dodecane (C12)	29	1.4-16.4	2.281	1.39	1.39	1.39	1.595	3.895	8.608	NA	NA
Ethyl acetate	19	1.85-16	2.386	1.8	1.8	1.8	1.8	3.26	6.098	73 n	310 n
Ethyl alcohol	100	13.7-1190	171.4	40.5	63.65	110	200	379	466.5	NA	NA
Ethyl ether	1	3.91-3.91	0.644	0.606	0.606	0.606	0.606	0.606	0.606	NA	NA
Ethylbenzene	100	0.109-45.6	1.05	0.159	0.191	0.3	0.562	1.21	1.69	1.1 c	4.9 c
Heptane	41	0.824-44.7	1.691	0.82	0.82	0.82	1.258	2.565	3.073	420 n	1800 n
iso-Propyl alcohol	100	1.64-136	20.91	4.265	5.963	12.3	25.53	42.85	50.83	210 n	880 n
Isopropylbenzene	1	3.31-3.31	1.011	0.983	0.983	0.983	2.46	2.46	2.46	420 n	1800 n
Methanol	100	9.42-169	41.17	18.65	25.48	34.45	50.13	68	75.88	21000 n	88000 n
Methyl tert butyl ether	1	0.151-0.151	0.0729	0.072	0.072	0.072	0.072	0.072	0.072	11 c	47 c
Methylene chloride	30	1.79-32.7	4.312	1.74	1.74	4.86	4.86	11.45	16.7	100 c**	1200 c**
Naphthalene	23	0.267-5.18	0.385	0.262	0.262	0.262	0.262	0.603	0.84	0.083 c*	0.36 c*
n-Hexane	41	0.705-106	2.2	0.705	0.705	0.705	0.895	1.54	2.973	730 n	3100 n
Nonane (C9)	8	1.1-28.3	1.625	1.05	1.05	1.05	1.05	1.05	1.89	21 n	88 n
n-Propylbenzene	5	1.87-6.83	1.103	0.983	0.983	0.983	0.983	0.983	1.648	1000 n	4400 n
Octane	13	0.943-15.2	1.175	0.934	0.934	0.934	0.934	1.14	1.815	NA	NA
o-Xylene	100	0.104-51.3	1.186	0.167	0.223	0.319	0.568	1.49	1.943	100 n	440 n
p/m-Xylene	100	0.243-157	3.354	0.4	0.553	0.81	1.688	4.24	5.298	NA	NA
Pentane	6	0.62-384	7.644	0.738	0.988	1.78	3.36	4.985	8.09	1000 n	4400 n
Propane	98	1.09-55.9	5.327	1.908	2.78	3.41	5.66	9.204	13.28	NA	NA
Propylene	8	0.874-3.48	0.96	0.861	0.861	0.861	0.861	0.868	1.625	3100 n	13000 n
Styrene	87	0.085-6.39	0.313	0.085	0.132	0.183	0.275	0.428	0.535	1000 n	4400 n
tert-Butyl alcohol	13	1.53-6.91	1.644	1.52	1.52	1.52	1.52	1.815	2.433	NA	NA

Table 2. (Continued)

Analytes	% Detection	Range of Detected Concentrations	KM Mean	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	Residential Air RSL	Industrial Air RSL
Volatile Organics (µg/m³)		**Minimum-Maximum**									
Tetrachloroethene	64	0.136-9.02	0.599	0.136	0.136	0.173	0.346	0.807	1.743	11 c**	47 c**
Tetrahydrofuran	6	0.702-11.9	0.9	0.59	0.59	1.47	1.47	1.47	1.47	2100 n	8800 n
Toluene	100	0.803-242	7.08	1.095	1.445	2.24	3.95	8.44	14.93	5200 n	22000 n
trans-1,2-Dichloroethene	1	0.095-0.095	0.0792	0.079	0.079	0.079	0.079	0.079	0.079	NA	NA
Trichloroethene	17	0.107-115	2.708	0.107	0.107	0.107	0.107	0.318	0.521	0.48 c**	3 c**
Trichlorofluoromethane	100	1.08-84.3	3.021	1.2	1.313	1.445	1.698	4.56	6.465	NA	NA
Undecane	22	1.3-57	2.922	1.28	1.28	1.28	1.28	2.245	7.83	NA	NA
Vinyl acetate	6	1.3-1.83	0.76	0.704	0.704	0.704	0.704	0.704	1.57	210 n	880 n

c, cancer; c*, n RSL < 100× c RSL; c**, n RSL < 10× c RSL; NA, not available; n, noncancer; µg/m³, microgram per cubic meter; RSL, USEPA Regional Screening Level, May 2020.

Table 3

Summary Statistics for Offices

Analytes	% Detection	Range of Detected Concentrations	KM Mean	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	Residential Air RSL	Industrial Air RSL
Volatile Organics (µg/m³)		**Minimum-Maximum**									
C5-C8 aliphatics, adjusted	95	14-3000	107.7	17	22	34	51	92	160	NA	NA
C9-C10 aromatics total	8	14-130	16.49	10	10	10	10	10	72	NA	NA
C9-C12 aliphatics, adjusted	80	15-990	84.15	14	16	29	69	150	350	NA	NA
1,1,1-Trichloroethane	11	0.153-0.611	0.138	0.109	0.109	0.109	0.109	0.17	0.273	5200 n	22000 n
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon-113)	100	0.506-1.49	0.616	0.537	0.544	0.567	0.659	0.705	0.728	5200 n	22000 n
1,1-Dichloroethane	7	0.134-0.194	0.0864	0.081	0.081	0.081	0.081	0.081	0.134	1.8 c	7.7 c
1,1-Dichloroethene	2	0.472-0.472	0.0854	0.079	0.079	0.079	0.079	0.079	0.079	210 n	880 n
1,2,3-Trimethylbenzene	6	8.11-8.11	1.428	0.983	0.983	0.983	0.983	0.983	2.765	63 n	260 n
1,2,4-Trimethylbenzene	98	0.098-32.7	1.708	0.128	0.162	0.29	0.541	1.34	11.8	63 n	260 n
1,2-Dichlorobenzene	3	0.132-0.186	0.121	0.12	0.12	0.12	0.12	0.12	0.132	210 n	880 n

Table 3. (Continued)

Analytes	% Detection	Range of Detected Concentrations	KM Mean	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	Residential Air RSL	Industrial Air RSL
Volatile Organics (µg/m³)		**Minimum-Maximum**									
1,2-Dichloroethane	80	0.081-0.704	0.171	0.081	0.085	0.121	0.182	0.324	0.498	0.11 c*	0.47c*
1,2-Dichloropropane	5	0.092-0.166	0.0937	0.092	0.092	0.092	0.092	0.092	0.092	0.76 c**	3.3 c**
1,3,5-Trimethylbenzene	41	0.103-9.73	0.482	0.098	0.098	0.098	0.162	0.501	2.72	63 n	260 n
1,3-Butadiene	43	0.047-0.774	0.0806	0.044	0.044	0.044	0.08	0.108	0.131	NA	NA
1,3-Dichlorobenzene	2	3.32-3.32	0.172	0.12	0.12	0.12	0.12	0.12	0.12	NA	NA
1,4-Dichlorobenzene	21	0.12-3.15	0.278	0.12	0.12	0.12	0.12	0.216	1.27	0.26 c	1.1 c
2,2,4-Trimethylpentane	11	0.986-83.6	2.409	0.934	0.934	0.934	0.934	0.99	3.2	NA	NA
2-Butanone	77	0.619-27	2.217	0.938	1.47	1.49	2.1	3.04	4.98	5200 n	22000 n
4-Methyl-2-pentanone	3	2.03-6.48	0.957	0.82	0.82	2.05	2.05	2.05	2.05	3100 n	13000 n
Acetaldehyde	63	6.43-35.7	14.8	4.5	7.848	10.16	25.73	34.25	34.73	1.3 c**	5.6 c**
Acetone	100	7.77-401	27.68	12.1	15.3	19.8	26.6	35.2	46.1	32000 n	140000 n
Acetonitrile	31	0.336-13.9	0.595	0.336	0.336	0.336	0.346	0.477	0.569	63 n	260 n
Acrolein	13	1.19-1.97	1.203	1.15	1.15	1.15	1.15	1.49	1.68	0.021 n	0.088 n
Benzene	93	0.319-24.8	1.019	0.326	0.358	0.527	0.725	0.895	1.81	0.36 c*	1.6 c*
Bromodichloromethane	3	0.409-0.422	0.143	0.134	0.134	0.134	0.134	0.134	0.155	0.076 c	0.33 c
Bromomethane	10	0.082-0.128	0.0802	0.078	0.078	0.078	0.078	0.085	0.097	5.2 n	22 n
Butane	100	0.87-261	11.55	1.36	2.07	3.85	8.68	15.9	22.4	NA	NA
Butyl acetate	2	6.13-6.13	2.441	2.38	2.38	2.38	2.38	2.38	2.38	NA	NA
Carbon tetrachloride	100	0.327-0.66	0.431	0.365	0.403	0.421	0.453	0.491	0.522	0.47 c	2 c
Chlorodifluoromethane	100	0.859-151	16.29	1.23	1.47	2.74	11.1	45.3	95.5	52000 n	220000 n
Chloroethane	8	0.053-0.071	0.0539	0.053	0.053	0.053	0.053	0.053	0.066	10000 n	44000 n
Chloroform	97	0.098-2.11	0.278	0.103	0.112	0.161	0.244	0.566	0.943	0.12 c	0.53 c
Chloromethane	98	1.09-1.66	1.332	1.16	1.23	1.32	1.43	1.54	1.59	94 n	390 n
cis-1,2-Dichloroethene	3	0.301-1.82	0.111	0.079	0.079	0.079	0.079	0.079	0.092	NA	NA
Cyclohexane	30	0.702-29.3	1.467	0.688	0.688	0.688	0.895	1.98	2.62	6300 n	26000 n
Decane (C10)	28	1.18-80.9	3.876	1.16	1.16	1.16	1.22	3.18	6.63	NA	NA
Dichlorodifluoromethane	100	0.811-11.7	2.105	1.231	1.493	1.82	2.268	2.546	2.647	100 n	440 n
Dodecane (C12)	31	1.47-12.7	2.226	1.39	1.39	1.39	1.64	3.92	4.97	NA	NA
Ethyl acetate	23	1.85-10.4	2.277	1.8	1.8	1.8	1.8	3.08	4.54	73 n	310 n
Ethyl alcohol	100	13.7-1190	159.5	42.6	59.5	103	196	339	405	NA	NA
Ethylbenzene	100	0.109-45.6	1.317	0.156	0.191	0.295	0.621	1.26	1.75	1.1 c	4.9 c

Table 3. (Continued)

Analytes	% Detection	Range of Detected Concentrations	KM Mean	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	Residential Air RSL	Industrial Air RSL
Volatile Organics (µg/m³)		**Minimum-Maximum**									
Heptane	36	0.897-44.7	1.757	0.82	0.82	0.82	1.18	1.78	2.22	420 n	1800 n
iso-Propyl alcohol	100	2.46-121	18.8	5.31	6.24	12.4	25.6	36.6	46.9	210 n	880 n
Isopropylbenzene	2	3.31-3.31	1.022	0.983	0.983	2.46	2.46	2.46	2.46	420 n	1800 n
Methanol	100	10.4-169	46.05	18.7	28.2	40.4	54.1	69.3	87.9	21000 n	88000 n
Methylene chloride	31	1.79-32.7	4.796	1.74	1.74	4.86	4.86	16	18.2	100 c**	1200 c**
Naphthalene	26	0.267-5.18	0.425	0.262	0.262	0.262	0.267	0.624	0.881	0.083 c*	0.36 c*
n-Hexane	43	0.705-106	2.712	0.705	0.705	0.705	0.899	1.38	3.16	730 n	3100 n
Nonane (C9)	8	1.43-28.3	1.845	1.05	1.05	1.05	1.05	1.05	1.68	21 n	88 n
n-Propylbenzene	7	1.87-6.83	1.151	0.983	0.983	0.983	0.983	0.983	1.87	1000 n	4400 n
Octane	10	1.1-15.2	1.239	0.934	0.934	0.934	0.934	0.934	1.39	NA	NA
o-Xylene	100	0.113-51.3	1.512	0.165	0.226	0.3	0.738	1.76	2.23	100 n	440 n
p/m-Xylene	100	0.278-157	4.323	0.4	0.547	0.821	1.89	4.78	5.78	NA	NA
Pentane	100	0.62-384	9.839	0.72	0.95	1.89	3.51	5.28	8.88	1000 n	4400 n
Propane	98	1.09-55.9	5.921	1.548	2.505	3.32	6.39	10.55	13.76	NA	NA
Propylene	11	0.874-3.48	1	0.861	0.861	0.861	0.861	1.01	1.72	3100 n	13000 n
Styrene	93	0.098-6.39	0.376	0.106	0.136	0.192	0.311	0.477	0.749	1000 n	4400 n
tert-Butyl alcohol	10	1.72-6.91	1.657	1.52	1.52	1.52	1.52	1.72	2.35	NA	NA
Tetrachloroethene	64	0.149-9.02	0.76	0.136	0.136	0.19	0.369	0.841	3.63	11 c**	47 c**
Tetrahydrofuran	8	0.702-11.9	1.027	0.59	0.59	1.47	1.47	1.47	1.47	2100 n	8800 n
Toluene	100	0.803-242	8.518	1.05	1.35	2.19	4.18	8.82	19.1	5200 n	22000 n
trans-1,2-Dichloroethene	2	0.095-0.095	0.0793	0.079	0.079	0.079	0.079	0.079	0.079	NA	NA
Trichloroethene	23	0.107-115	3.769	0.107	0.107	0.107	0.107	0.441	1.82	0.48 c**	3 c**
Trichlorofluoromethane	100	1.14-84.3	3.565	1.21	1.33	1.47	1.84	5.04	7.92	NA	NA
Undecane	23	1.3-57	3.364	1.28	1.28	1.28	1.28	2.4	9.53	NA	NA
Vinyl acetate	8	1.3-1.83	0.783	0.704	0.704	0.704	0.704	0.813	1.66	210 n	880 n

c, cancer; c*, n RSL < 100× c RSL; c**, n RSL < 10× c RSL; NA, not available; n, noncancer; µg/m³, microgram per cubic meter; RSL, USEPA Regional Screening Level, May 2020.

Table 4

Summary Statistics for Schools

Analytes	% Detection	Range of Detected Concentrations	KM Mean	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	Residential Air RSL	Industrial Air RSL
Volatile Organics (µg/m³)		**Minimum Maximum**									
C5-C8 Aliphatics, Adjusted	100	16-190	53.52	18.4	26	44	64	77.8	135.8	NA	NA
C9-C10 Aromatics Total	12	10-44	11.4	10	10	10	10	10	10.8	NA	NA
C9-C12 aliphatics, Adjusted	88	16-400	59.44	14.8	28	43	63	79.2	121.2	NA	NA
1,1,1-Trichloroethane	4	0.24-0.24	0.114	0.109	0.109	0.109	0.109	0.109	0.214	5200 n	22000 n
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon-113)	96	0.468-0.743	0.588	0.524	0.537	0.583	0.644	0.664	0.728	5200 n	22000 n
1,2,3-Trimethylbenzene	10	1.12-1.12	0.997	0.983	0.983	0.983	0.983	0.997	1.058	63 n	260 n
1,2,4-Trimethylbenzene	92	0.118-8.65	0.813	0.13	0.187	0.354	0.472	1.301	2.608	63 n	260 n
1,2-Dichloroethane	76	0.085-0.283	0.126	0.081	0.085	0.097	0.138	0.272	0.278	0.11 c*	0.47 c*
1,3,5-Trimethylbenzene	56	0.098-1.21	0.204	0.098	0.098	0.108	0.128	0.355	0.762	63 n	260 n
1,3-Butadiene	36	0.044-0.082	0.0486	0.044	0.044	0.044	0.047	0.0728	0.0816	NA	NA
2,2,4-Trimethylpentane	4	1.94-1.94	0.976	0.934	0.934	0.934	0.934	0.934	1.739	NA	NA
2-Butanone	52	1.33-2.82	1.669	1.47	1.47	1.47	1.96	2.592	2.776	5200 n	22000 n
Acetaldehyde	100	15.8-31.7	23.94	17.42	20.75	23.95	26.95	30.71	31.21	1.3 c**	5.6 c**
Acetone	100	7.13-74.1	21.37	12.52	13.7	19	22.9	28.5	34.86	32000 n	140000 n
Acetonitrile	40	0.346-1.07	0.405	0.336	0.336	0.336	0.408	0.611	0.992	63 n	260 n
Acrolein	4	1.25-1.25	1.154	1.15	1.15	1.15	1.15	1.15	1.23	0.021 n	0.088 n
Benzene	96	0.486-1.02	0.686	0.539	0.613	0.671	0.751	0.908	1.002	0.36 c*	1.6 c*
Bromomethane	4	0.124-0.124	0.0799	0.078	0.078	0.078	0.078	0.078	0.115	5.2 n	22 n
Butane	100	1.3-18.2	6.688	1.806	2.37	3.42	12.1	16.08	16.84	NA	NA
Butyl acetate	4	5.47-5.47	2.509	2.38	2.38	2.38	2.38	2.38	4.852	NA	NA
Carbon tetrachloride	100	0.403-0.616	0.478	0.424	0.434	0.453	0.503	0.574	0.609	0.47 c	2 c
Chlorodifluoromethane	96	0.806-9.9	2.236	0.98	1.21	1.47	2.16	4.002	8.102	52000 n	220000 n
Chloroethane	8	0.058-0.061	0.0535	0.053	0.053	0.053	0.053	0.056	0.0604	10000 n	44000 n
Chloroform	80	0.098-1.34	0.212	0.098	0.107	0.142	0.205	0.368	0.437	0.12 c	0.53 c
Chloromethane	96	1.02-1.67	1.272	1.098	1.17	1.26	1.36	1.484	1.58	94 n	390 n
Cyclohexane	12	0.73-1.15	0.728	0.688	0.688	0.688	0.688	0.976	1.148	6300 n	26000 n
Decane (C10)	44	1.22-17.4	2.593	1.16	1.16	1.16	1.95	4.94	8.636	NA	NA
Dichlorodifluoromethane	92	1.28-12.7	2.366	1.326	1.5	1.94	2.48	2.9	3.312	100 n	440 n
Dodecane (C12)	24	1.4-16.4	2.416	1.39	1.39	1.39	1.39	2.29	8.358	NA	NA

Table 4. (Continued)

Analytes	% Detection	Range of Detected Concentrations	KM Mean	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	Residential Air RSL	Industrial Air RSL
Volatile Organics (µg/m³)		**Minimum Maximum**									
Ethyl Acetate	8	8.72-16	2.645	1.8	1.8	1.8	1.8	4.416	8.208	73 n	310 n
Ethyl Alcohol	100	16.1-650	200.3	41.64	69.7	112	254	465.8	567	NA	NA
Ethyl ether	4	3.91-3.91	0.738	0.606	0.606	0.606	0.606	0.606	1.777	NA	NA
Ethylbenzene	100	0.113-2.11	0.396	0.164	0.191	0.321	0.452	0.603	0.62	1.1 c	4.9 c
Heptane	52	0.824-3.38	1.531	0.82	0.82	0.963	2.8	3.144	3.312	420 n	1800 n
iso-Propyl alcohol	100	1.64-136	26.04	2.99	5.09	7.6	23.3	82.76	127.2	210 n	880 n
Methanol	100	9.42-57.8	29.27	17.24	20.6	29.7	32.8	44.26	48.54	21000 n	88000 n
Methyl tert butyl ether	4	0.151-0.151	0.0753	0.072	0.072	0.072	0.072	0.072	0.135	11 c	47 c
Methylene chloride	28	2.41-10.9	3.12	1.74	1.74	4.86	4.86	8.172	10.25	100 c**	1200 c**
Naphthalene	16	0.267-0.613	0.285	0.262	0.262	0.262	0.262	0.359	0.566	0.083 c*	0.36 c*
n-Hexane	36	0.719-4.02	0.95	0.705	0.705	0.705	0.779	1.55	2.246	730 n	3100 n
Nonane (C9)	8	1.1-1.96	1.09	1.05	1.05	1.05	1.05	1.08	1.788	21 n	88 n
Octane	20	0.943-1.87	1.02	0.934	0.934	0.934	0.934	1.45	1.826	NA	NA
o-Xylene	100	0.104-0.943	0.389	0.171	0.222	0.33	0.539	0.673	0.831	100 n	440 n
p/m-Xylene	100	0.243-2.32	0.99	0.425	0.612	0.786	1.28	1.786	1.942	NA	NA
Pentane	96	0.62-12.1	2.294	0.838	1.1	1.71	2.33	3.612	4.412	1000 n	4400 n
Propane	100	1.86-11.6	4.377	2.488	3.12	3.84	5.3	6.5	7.392	NA	NA
Styrene	72	0.085-0.392	0.159	0.085	0.085	0.149	0.192	0.295	0.356	1000 n	4400 n
tert-Butyl alcohol	20	1.53-2.56	1.612	1.52	1.52	1.52	1.52	2.124	2.504	NA	NA
Tetrachloroethene	64	0.136-0.814	0.206	0.136	0.136	0.156	0.217	0.386	0.521	11 c**	47 c**
Toluene	100	1.04-15.2	3.572	1.194	1.69	2.35	2.71	6.766	12.67	5200 n	22000 n
Trichloroethene	4	0.419-0.419	0.119	0.107	0.107	0.107	0.107	0.107	0.315	0.48 c**	3 c**
Trichlorofluoromethane	100	1.08-5.79	1.694	1.164	1.28	1.4	1.5	2.026	3.882	NA	NA
Undecane	20	1.52-12.5	1.844	1.28	1.28	1.28	1.28	1.916	2.596	NA	NA

c, cancer; c*, n RSL < 100× c RSL; c**, n RSL < 10× c RSL; NA, not available; n, noncancer; µg/m³, microgram per cubic meter; RSL, USEPA Regional Screening Level, May 2020.

Table 5

Summary of Non-Detect VOCs in Merged Data Set in Offices and Schools

	Offices and Schools Combined		Offices Only[1]		Schools Only[2]	
Analytes	**Frequency of Detection (%)**	**Range of Reporting Limits for Non-Detects**	**Frequency of Detection (%)**	**Range of Reporting Limits for Non-Detects**	**Frequency of Detection (%)**	**Range of Reporting Limits for Non-Detects**
Volatile Organics (µg/m^3)						
1,1,1,2-Tetrachloroethane	0	0.137:0.469	0	0.137:0.214	0	0.137:0.469
1,1,2,2-Tetrachloroethane	0	0.137:0.469	0	0.137:0.214	0	0.137:0.469
1,1,2-Trichloroethane	0	0.109:0.373	0	0.109:0.17	0	0.109:0.373
1,1-Dichloropropene	0	0.908:3.1	0	0.908:1.41	0	0.908:3.1
1,2,3-Trichlorobenzene	0	0.371:1.27	0	0.371:0.576	0	0.371:1.27
1,2,3-Trichloropropane	0	1.21:4.12	0	1.21:1.87	0	1.21:4.12
1,2,4-Trichlorobenzene	0	0.371:1.27	0	0.371:0.576	0	0.371:1.27
1,2-Dibromo-3-chloropropane	0	1.93:6.6	0	1.93:3.01	0	1.93:6.6
1,2-Dibromoethane	0	0.154:0.525	0	0.154:0.239	0	0.154:0.525
1,2-Dichloro-1,1,2,2-tetrafluoroethane (Freon-114)	0	0.349:1.2	0	0.349:0.542	0	0.349:1.2
1,3-Dichloropropane	0	0.924:3.16	0	0.924:1.44	0	0.924:3.16
1,4-Dioxane	0	0.36:1.23	0	0.36:0.559	0	0.36:1.23
2,2-Dichloropropane	0	0.924:3.16	0	0.924:1.44	0	0.924:3.16
2-Hexanone	0	0.82:2.8	0	0.82:1.27	0	0.82:2.8
3-Chloropropene	0	0.626:2.14	0	0.626:0.973	0	0.626:2.14
4-Ethyltoluene	0	0.098:0.098	0	0.098:0.098	NA	–
Acrylonitrile	0	1.09:3.71	0	1.09:1.68	0	1.09:3.71
Benzyl chloride	0	1.04:3.54	0	1.04:1.61	0	1.04:3.54
Bromobenzene	0	0.793:2.71	0	0.793:1.23	0	0.793:2.71
Bromoform	0	0.207:0.706	0	0.207:0.322	0	0.207:0.706
Carbon disulfide	0	0.623:2.13	0	0.623:0.968	0	0.623:2.13
Chlorobenzene	0	0.092:0.315	0	0.092:0.143	0	0.092:0.315
cis-1,3-Dichloropropene	0	0.091:0.31	0	0.091:0.141	0	0.091:0.31
Dibromochloromethane	0	0.17:0.582	0	0.17:0.265	0	0.17:0.582
Dibromomethane	0	1.42:4.86	0	1.42:2.21	0	1.42:4.86
Dichlorofluoromethane	0	0.842:2.87	0	0.842:1.31	0	0.842:2.87
Ethyl-Tert-Butyl-Ether	0	0.836:2.85	0	0.836:1.3	0	0.836:2.85
Halothane	0	0.404:1.38	0	0.404:0.627	0	0.404:1.38
Hexachlorobutadiene	0	0.533:1.82	0	0.533:0.828	0	0.533:1.82
Isopropyl Ether	0	0.836:2.85	0	0.836:1.3	0	0.836:2.85
Methyl methacrylate	0	2.05:7	0	2.05:2.05	0	2.05:7
n-Butylbenzene	0	1.1:4.26	0	1.1:4.26	0	1.1:3.75
o-Chlorotoluene	0	1.04:3.54	0	1.04:1.61	0	1.04:3.54
p-Chlorotoluene	0	1.04:3.54	0	1.04:1.61	0	1.04:3.54
p-Isopropyltoluene	0	1.1:4.26	0	1.1:4.26	0	1.1:3.75
sec-Butylbenzene	0	1.1:4.26	0	1.1:4.26	0	1.1:3.75
tert-Butylbenzene	0	1.1:3.75	0	1.1:1.71	0	1.1:3.75
Tertiary-amyl methyl ether	0	0.836:2.85	0	0.836:1.3	0	0.836:2.85
trans-1,3-Dichloropropene	0	0.091:0.31	0	0.091:0.141	0	0.091:0.31
Vinyl bromide	0	0.874:2.99	0	0.874:1.36	0	0.874:2.99
Vinyl chloride	0	0.051:0.175	0	0.051:0.08	0	0.051:0.175

µg/m^3, microgram per cubic meter; NA, not analyzed.

[1]Ethyl ether and methyl tert butyl ether were not detected in the Office data set, however they were detected in the School data set.

[2]Sixteen compounds were not detected in the School data set, however these compounds were detected in the Office data set. This includes: 1,1-dichloroethane, 1,1-dichloroethene, 1,2-dichlorobenzene, 1,2-dichloropropane, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 4-methyl-2-pentanone, bromodichloromethane, cis-1,2-dichloroethene, isopropylbenzene, n-propylbenzene, propylene, tetrahydrofuran, trans-1,2-dichloroethene, trichloroethene, and vinyl acetate.

of common environmental interest such as several haloethanes and monoaromatics, 1,4-Dioxane, and Vinyl Chloride. Collectively, 41 VOCs were not detected in all samples, 43 VOCs were not detected in the office samples, and 57 VOCs were not detected in the school samples (several VOCs were detected in offices but not schools; Ethyl Ether and Methyl Tert-Butyl Ether [MTBE] were detected in schools but not offices).

Some outliers were evident in the data set. For example, using 100% detected ($N = 86$) compounds, the Ethylbenzene maximum detected concentration of 45.6 µg/m^3 or the Toluene maximum detected concentration of 242 µg/m^3 was not reflective of the remaining population as shown in the means/medians for these compounds of 1.05/0.3 µg/m^3 and 7.08/2.24 µg/m^3, respectively. Trichloroethene (TCE) was reported with a frequency of detection of 17% (15/86), ranging from 0.107 to 115 µg/m^3, with two >100 µg/m^3 outlier results identified in the same office building (subsequent resampling was offered in this building due to the high concentrations reported and since a potential source was identified, and these resampling results are also included within these Study data).

Indoor air background study maxima that differed greatly from the remaining population distribution are common as was shown in several studies of the U.S. EPA residential background compilation (Dawson and McAlary 2009; U.S. EPA 2011a), including a study of 100 residences in Massachusetts (Rago et al. 2004) wherein Trichloroethene was detected in only 2 of 100 residences, but with one location at a concentration of 110 µg/m^3 (a consumer product containing liquid Trichloroethene was stored in the home). In these cases, and in the case of this Study, the outliers support the individuality of a building's specific indoor air background: occupants of one building may episodically or regularly use and store aerosol lubricants containing petroleum hydrocarbons (e.g., 3000 µg/m^3 C5-C8 aliphatics) or an aerosol contact cleaner (e.g., 115 µg/m^3 trichloroethene) and many others may not.

Comparison to Risk Based Screening Levels and Risk Implications

Risk-based screening levels vary across regulatory jurisdictions. U.S. EPA screening values were used in this study to provide a point of comparison. A review of the Study results for Offices indicates that one or more samples exceeded the EPA RSLs (U.S. EPA 2020) for nonresidential indoor air for 1,2-dichloroethane, 1,4-dichlorobenzene, acetaldehyde, acrolein, benzene, bromodichloromethane, chloroform, ethylbenzene, naphthalene, and trichloroethene, with one or more samples also exceeding the EPA RSLs for residential indoor air for carbon tetrachloride and nonane, and with two samples exceeding commonly employed regulatory urgent response levels (HI = 3; approximately 24 µg/m^3) for trichloroethene. A review of the Study results for Schools indicates that one or more samples exceeded the EPA RSLs for nonresidential indoor air for acetaldehyde, acrolein, chloroform, and naphthalene, with one or more samples also exceeding the EPA RSLs for residential indoor air for 1,2-dichloroethane, benzene, carbon tetrachloride, and ethylbenzene.

Results for Offices and Schools for VOCs where concentrations exceeded RSLs (the lower of cancer (1E-06 excess lifetime cancer risk) and noncancer (HI = 1) are summarized in Table 6 and Table 7, respectively.

These findings suggest that indoor air background concentrations in offices and schools may pose potential human health risks to building occupants. Potential health risks from VOCs in nonresidential settings have been described by others (e.g., Çankaya et al. 2018), and may be especially relevant since residential indoor air background may contain higher concentrations of VOCs compared to nonresidential indoor air background (Adgate et al. 2004) and since relative health risks may be accordingly higher in residences relative to those in offices or schools (Rago et al. 2017).

Table 6

Comparison to Risk Based Screening Levels for Office

Analyte	Range of Detected Concentrations	Residential Air RSL	Frequency of Exceedances Residential Air RSL	Industrial Air RSL	Frequency of Exceedances Industrial Air RSL
Volatile Organics (µg/m^3)	**Minimum-Maximum**				
1,2-Dichloroethane	0.081-0.704	0.11 c*	34/61	0.47 c*	4/61
1,4-Dichlorobenzene	0.12-3.15	0.26 c	5/61	1.1 c	4/61
Acetaldehyde	6.43-35.7	1.3 c**	10/16	5.6 c**	10/16
Acrolein	1.19-1.97	0.021 n	8/61	0.088 n	8/61
Benzene	0.319-24.8	0.36 c*	44/61	1.6 c*	4/61
Bromodichloromethane	0.409-0.422	0.076 c	2/61	0.33 c	2/61
Carbon tetrachloride	0.327-0.66	0.47 c	11/61	2 c	0/61
Chloroform	0.098-2.11	0.12 c	43/61	0.53 c	7/61
Ethylbenzene	0.109-45.6	1.1 c	11/61	4.9 c	2/61
Naphthalene	0.267-5.18	0.083 c*	16/61	0.36 c*	14/61
Nonane (C9)	1.43-28.3	21 n	1/61	88 n	0/61
Trichloroethene	0.107-115	0.48 c**	5/61	3 c**	3/61

c, cancer; c*, n RSL < 100× c RSL; c**, n RSL < 10× c RSL; n, noncancer; µg/m^3, microgram per cubic meter; RSL, USEPA Regional Screening Level, May 2020.

Table 7

Comparison to Risk Based Screening Levels for Schools

Analyte	Range of Detected Concentrations	Residential Air RSL	Frequency of Exceedances Residential Air RSL	Industrial Air RSL	Frequency of Exceedances Industrial Air RSL
Volatile Organics (µg/m³)	**Minimum-Maximum**				
1,2-Dichloroethane	0.085-0.283	0.11 c*	11/25	0.47 c*	0/25
Acetaldehyde	15.8-31.7	1.3 c**	10/10	5.6 c**	10/10
Acrolein	1.25-1.25	0.021 n	1/25	0.088 n	1/25
Benzene	0.486-1.02	0.36 c*	24/25	1.6 c*	0/25
Carbon tetrachloride	0.403-0.616	0.47 c	12/25	2 c	0/25
Chloroform	0.098-1.34	0.12 c	16/25	0.53 c	1/25
Ethylbenzene	0.113-2.11	1.1 c	1/25	4.9 c	0/25
Naphthalene	0.267-0.613	0.083 c*	4/25	0.36 c*	2/25

c, cancer; c*, n RSL < 100× c RSL; c**, n RSL < 10× c RSL; n, noncancer; µg/m³, microgram per cubic meter; RSL, USEPA Regional Screening Level, May 2020.

Comparison to Other Studies

Previous Nonresidential Indoor Air Background Studies—Offices and Schools

Although there are numerous published residential indoor air background studies, there are relatively fewer nonresidential indoor air background studies available in literature, and these vary widely in focus and methodology. Relative to offices, six nonresidential studies were considered for consideration of comparison to this study. These include the EPA Building Assessment Survey and Evaluation (BASE) Study (U.S. EPA 1999a) and the California Health Buildings Study (Daisey et al. 1994), as well as several others summarized below.

EPA BASE Study (Offices)

The EPA BASE Study was conducted over a 5-year period, 1994 to 1998. Investigators evaluated 100 public and commercial office buildings in the United States, with samples collected in 37 cities in 25 states. In addition to the availability of study information at the parent reference (U.S. EPA 1999a), individual papers reference study planning (Johnston et al. 2002; U.S. EPA 2003) and data for VOCs as relative to this study (Girman et al. 1999).

The study addressed three areas: environmental and comfort measurements, building and heating, ventilation, and air-conditioning (HVAC) systems characterization, and building occupant demographics, symptoms, and perceptions, with a goal "to address a significant data gap that existed regarding baseline IAQ [indoor air quality] and occupant perceptions in large public and commercial office buildings" (Girman et al. 1999).

The study examined a variety of parameters such as particulates (PM10, PM2.5), VOCs, Formaldehyde, bioaerosols, Radon, temperature, relative humidity, Carbon Dioxide, Carbon Monoxide, sound, and light. Generally, three indoor sampling locations and one outdoor sampling location were collected. Relative to VOCs, samples were collected using both multi-sorbent samplers and SUMMA canisters and analyzed by gas chromatography/mass spectrometry (GC/MS). Censored data were managed by assigning ½ of the laboratory reporting limit to nondetect values. Selected data are presented for percentiles (5th, 50th, and 95th), arithmetic mean, and indoor air:outdoor air (I/O) ratios. Data from this study are further considered for comparison herein.

California Health Buildings Study (Offices)

This study evaluated for total volatile organic compounds (TVOCs) and 39 individual VOCs in 12 office buildings in the San Francisco Bay Area of California, targeting city and county office buildings (and excluding jails, hospitals, police stations, and fire stations). VOCs were collected using multi-sorbent samplers (thermal desorption tubes) over eight-hour intervals and analyzed by gas chromatography/flame ionization detector (GC/FID) and via GC/MS. This study presents limited data that may be used for comparison, but there are some uncertainties with the sampling method used (e.g., unspecified sample volumes and flow rates versus compound specific breakthrough volumes). Therefore, data from this study were not further considered for comparison herein.

Other Office Studies Reviewed

Several other studies of offices were reviewed but were not carried forward for evaluation in this study. These included:

- a study that focused on 70 telecommunications offices, data centers and administrative offices, with testing limited to passive diffusive samplers (3 M OVM 3500) and analysis of largely nontarget compound hydrocarbons (Shields et al. 2004);
- a study that focused on coffee shops, libraries, pharmacies, offices, gymnasiums, newspaper stands, hair salons, restaurants, and supermarkets in southern Italy, with testing limited to passive diffusive samplers (Radiello) and analysis of a limited target compounds list of VOCs (Bruno et al. 2008);
- a study that focused on 56 office buildings in 9 European countries during the winter heating season of 1993 to 1994, with samples collected on Tenax-TA and analysis of total VOCs via thermal desorption GC-FID and additional GC/MS VOC identification (not quantification) of

a limited target compounds list of VOCs (Bluyssen et al. 2017); and,
- a study that focused on VOC concentrations and whole building emission rates in 37 small- and medium-sized commercial buildings in California, with active sampling using multibed thermal desorption tubes and acidified 2,4-dinitrophenylhydrazine-coated silica gel cartridges for the analysis of a limited target compounds list of VOCs (EPA Method TO-17) and aldehydes (EPA Method TO-11) (Wu et al. 2011).

These studies were not carried forward for comparison herein due to sampling methods, study, and group applicability concerns, and/or lack of study target compound list comparability.

Relative to schools, four studies were identified for consideration of comparison to this study, which also vary widely in focus and methodology. These include:

- a study that included evaluation of indoor air at two inner-city schools (SHIELD Study) in Minneapolis, Minnesota (Adgate et al. 2004);
- a study of exposures to "urban air toxics" to high school students in inner-city neighborhoods (TEACH Study) of New York City, New York and Los Angeles, California (Kinney et al. 2002);
- a two-part article series published in the newspaper USA Today called "The Smokestack Effect" (Heath and Morrison 2008; Morrison and Heath 2008); and,
- a study of one university building in Germany (Solomon et al. 2008).

These studies are further described below.

SHIELD Study (Schools)

The School Health Initiative: Environment, Learning, and Disease (SHIELD) study (University of Minnesota Research Subjects' Protection Program Institutional Review Board: Human Subjects Committee) assessed school children exposures to VOCs and other chemical and biological agents in Minneapolis, Minnesota. Study design is described in (Sexton et al. 2000) and (Sexton et al. 2003). Investigators measured VOC exposures for children during sampling events in winter 2000 (January-February) and spring 2000 (April to mid-May). Air samples were collected using 3M 3520 Organic Vapor Monitors for a target compound list of 15 VOCs at 4 discrete locations (outdoors [O], indoors at school [S], indoors at home [H], and personal [P] samples). Sample intervals varied, with H and P samples collected for 48 continuous hours; S samples collected for 31 h over 5 school days; and O air measurements collected at school from Monday morning to Friday afternoon, over a period of 103 h. The study provided data for percent detected, median, and 10th and 90th percentiles for Benzene, Carbon tetrachloride, Chloroform, 1,4-Dichlorobenzene, Ethylbenzene, d-Limonene, Methylene chloride, α-Pinene, β-Pinene, Styrene, Tetrachloroethene, Toluene, Trichloroethene, and m/p-Xylene, and o-Xylene, and examined whether certain VOC patterns were associated with racial/ethnic groups. Data from this study are further considered for comparison herein.

TEACH Study (Schools)

The TEACH (Toxic Exposure Assessment, A Columbia/Harvard) study was designed to characterize levels of and factors influencing personal exposures to urban air toxics among high school students living in inner-city neighborhoods of New York City and Los Angeles. The study (Kinney et al. 2002) examined personal, indoor, and outdoor air for 17 VOCs but does not present indoor air data from the schools of the 46 high school students and was not carried forward for comparison herein.

"USA Today Study" (Schools)

In December 2008, USA Today published a two-part report entitled "The Smokestack Effect—Toxic Air and America's Schools." USA Today partnered with researchers from the University of Massachusetts-Amherst Political Economy Research Institute, who used EPA's Risk-Screening Environmental Indicators model and Industrial Source Complex Long Term (ISCLT) air dispersion model, and with Johns Hopkins University and the University of Maryland, who conducted confirmatory ambient air monitoring at 95 schools in 30 states with badges and active sampling methods. The report provided a ranking of the schools with the highest toxic levels in a searchable database of 127,800 schools, although specific data are not provided, and this study was not carried forward for comparison herein.

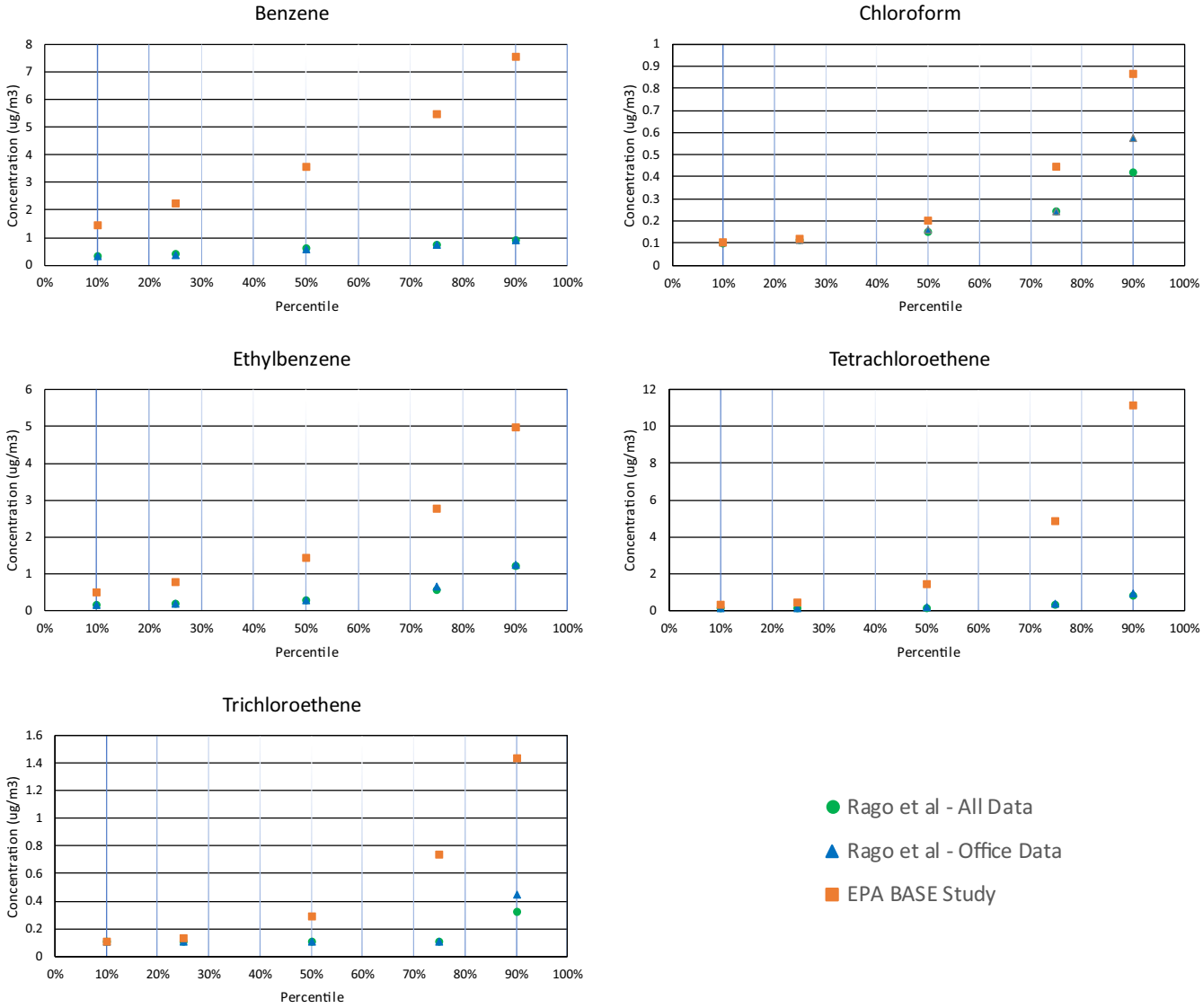
University of Bremen Study

A school study was also reviewed which focused on VOC concentrations in the 5-story Department of Physics and Electrical Engineering building at the University of Bremen, Germany, with 14-day continuous sampling and analysis of a limited target compounds list of hydrocarbon and carbonyl VOCs via proton-transfer mass spectrometry (Solomon et al. 2008). Based on the inconsistency of sampling methods and target list VOCs with this Study, this study was not carried forward for comparison herein.

Selected Study Data Comparisons

This Study compares results for schools to those presented for the SHIELD Study (Adgate et al. 2004), and compares results for offices to those presented for the EPA BASE Study (e.g., Girman et al. 1999). The SHIELD Study only reported the 10th, 50th and 90th percentiles for selected VOCs, and the EPA BASE Study parent website only reports the mean, fifth, 50th and 95th percentiles. The mean values were omitted from the comparison as the data distribution (high percentage of nondetects, skewed data distribution, and extreme observations) provided inaccurate estimation of means. Therefore, only order statistics (10th, 25th, 50th, 75th, 90th, and 95th) were used to compare the three studies. The missing percentile statistics for the SHIELD Study and EPA BASE Study were estimated by fitting appropriate distributions using Monte Carlo simulation (Oracle Crystal Ball 11.1.2.4 software).

The data for all samples and office samples was compared to the EPA BASE Study data. The data for all samples and



All data is in µg/m³: microgram per cubic meter

Figure 2. Comparison of Rago et al. Office Data Set to EPA BASE Study.

school samples was compared to the SHIELD Study winter and spring data. Figures 2 and 3 below present the comparison plots for Benzene, Chloroform, Ethylbenzene, Tetrachloroethene, and Trichloroethene. These VOCs were selected because they were common to the studies being compared and because they are of broad environmental interest.

The comparison plots for offices suggest that the Study data are generally comparable to EPA BASE Study data at lower percentiles and diverge with relatively higher concentrations reflected at higher percentiles for the EPA Base Study. The comparison plots for schools suggest that the Study data are generally comparable with SHIELD Study data, with these Study data lower than SHIELD Study winter percentiles for commonly detected VOCs. The lower results are also likely reflective of general decreasing trends in indoor air VOC concentrations over time as described in literature (e.g. [A. Hodgson and Levin 2003; Weschler 2009; Dawson and McAlary 2009; U.S. EPA 2011a]).

Summary and Conclusions

The Study generated 14,668 new indoor air background data points for offices and schools from buildings located in 26 cities in 18 states across the United States. Indoor air background concentrations of target compound VOCs ranged from less than the laboratory method reporting limit of 0.044 µg/m³ to concentrations up to 1190 µg/m³, with hydrocarbon ranges from less than the reporting method limit of 10 µg/m³ to concentrations up to 3000 µg/m³. VOCs such as hydrocarbons, ketones, alcohols, Freons, and some chlorinated solvents were identified ubiquitously in indoor air background. A review of the Study results for Schools indicates that one or more samples exceeded the EPA RSLs for nonresidential indoor air for Acetaldehyde, Acrolein, Chloroform, and Naphthalene, with one or more samples also exceeding the EPA RSLs for residential indoor air for 1,2-dichloroethane, benzene, carbon tetrachloride, and ethylbenzene. A review of the Study results for Offices indicates that one or more samples exceeded the EPA RSLs for

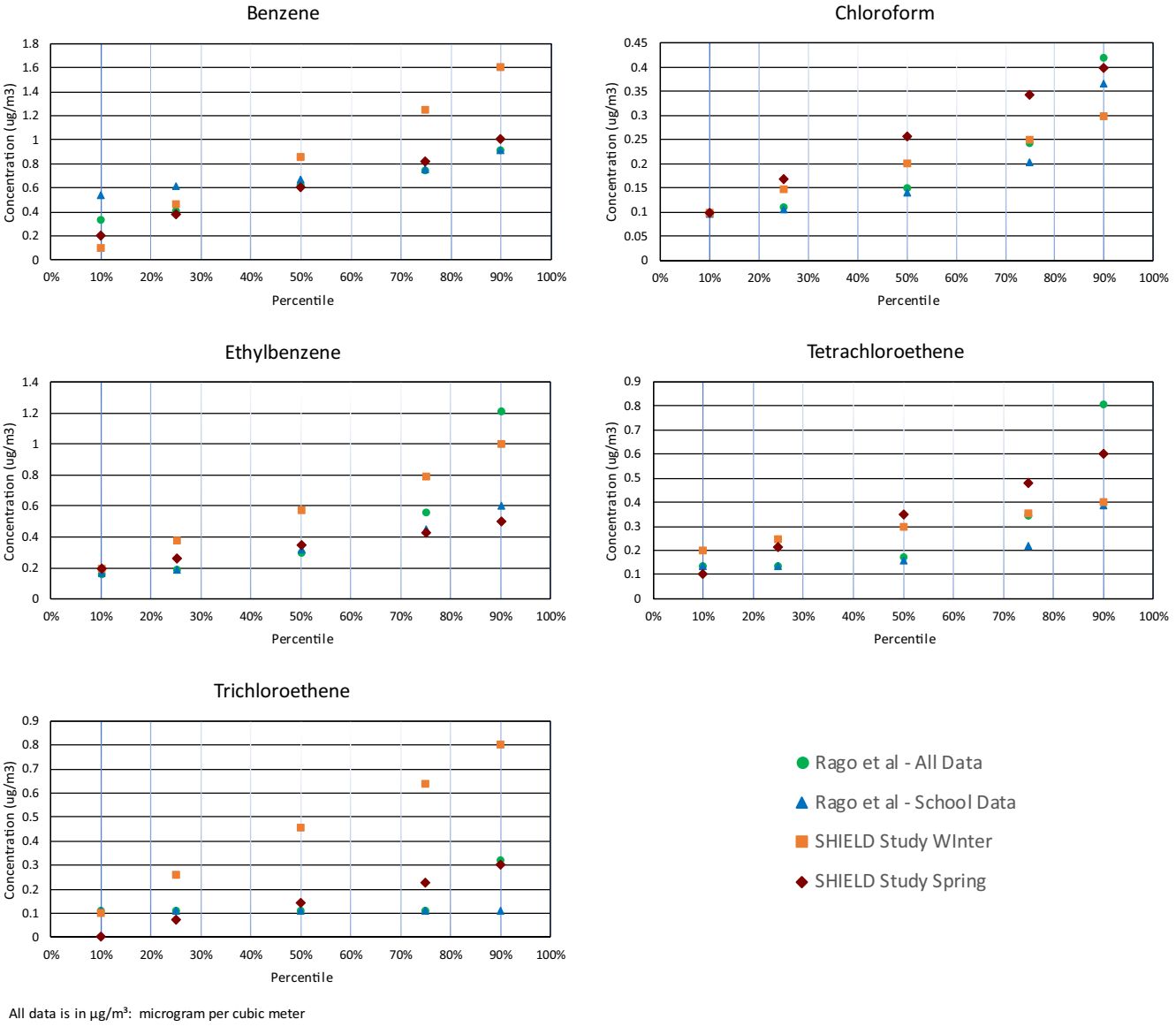


Figure 3. Comparison of Rago et al. School Data Set to SHIELD Study.

nonresidential indoor air for 1,2-dichloroethane, 1,4-dichlorobenzene, acetaldehyde, acrolein, benzene, bromodichloromethane, chloroform, ethylbenzene, naphthalene, and trichloroethene, with one or more samples also exceeding the EPA RSLs for residential indoor air for carbon tetrachloride and nonane, and with two samples exceeding commonly employed regulatory rapid action levels (HI = 3; approximately 24 µg/m^3) for Trichloroethene. This is significant since chlorinated VOCs such as Trichloroethene are still common to commercially available consumer products.

State and federal guidance documents may vary greatly in their approaches to vapor intrusion (Eklund et al. 2018), but nearly all recognize that indoor air background can confound vapor intrusion investigations. Nuanced and iterative strategies such as those developed on behalf of the United States Navy (NAVFAC 2011) may be needed to make determinative vapor intrusion pathway evaluations when contribution from indoor air background is suspected. These may include comparison with site-specific or published background values, review of constituent ratios between media, and methods such as differential pressure monitoring, pressure cycling, tracer compound analyses, and real-time monitoring, including continuous monitoring of spatial and time series concentration data patterns combined with confirmation using discrete sampling and analysis (e.g., Kram et al. 2019, 2020). If it is determined that these methods are not conclusive, environmental forensic analysis may be needed (e.g., Plantz et al. 2008; Beckley et al. 2016).

Understanding indoor air background data can be of strategic importance in vapor intrusion data review, focusing investigations, mitigation decision making, and risk communication. Since indoor air background is building-specific and since commercial product formulations can and do change over time, practitioners are cautioned to carefully review background studies for focus, relationships, and detected concentration ranges, and not to simply rely on "bright lines" such as medians or upper fence values.

Study Design and Funding

The study was designed and implemented by Richard Rago of Haley & Aldrich and Andrew Rezendes of Alpha Analytical Labs, with initial planning support and input from EPA and Massachusetts Department of Environmental Protection. The study was funded entirely by Haley & Aldrich, Inc., and Alpha Analytical Labs, except for the $5000 Wesley E. Stimpson Grant awarded from the Massachusetts Licensed Site Professionals Association (LSPA) in 2014.

Authors' Note

The authors declare no competing interests.

Supporting Information

Additional Supporting Information may be found in the online version of this article. Supporting Information is generally not peer reviewed.

Table S1: Summary statistics for offices and schools (all samples), expanded to include frequency of detection, range of reporting limits for nondetects, and descriptive statistics (Kaplan-Meier variance, standard deviation, and coefficient of variance).

Table S2: Summary statistics for offices, expanded to include frequency of detection, range of reporting limits for nondetects, and descriptive statistics (Kaplan-Meier variance, standard deviation, and coefficient of variance).

Table S3: Summary statistics for schools, expanded to include frequency of detection, range of reporting limits for nondetects, and descriptive statistics (Kaplan-Meier variance, standard deviation, and coefficient of variance).

Figure S1: Comparison of Rago et al. Office Data Set to EPA BASE Study, expanded to include carbon tetrachloride, methylene chloride, 1,4-dichlorobenzene, toluene, p/m-xylene, and o-xylene.

Figure S2: Comparison of Rago et al. Office Data Set to EPA BASE Study, expanded to include carbon tetrachloride, methylene chloride, 1,4-dichlorobenzene, toluene, p/m-xylene, and o-xylene.

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