BACKGROUND LEVELS OF VOLATILE ORGANIC CHEMICALS IN HOMES: A REVIEW OF RECENT LITERATURE

Introduction

For over 20 years, it has been known that many volatile organic chemicals are present in the indoor air of homes (Wallace 1986). While small contributions from outdoor air concentrations of volatiles may occur, indoor levels are typically higher (Sexton et al. 2004, Weisel et al. 2005). This is due to indoor sources of these chemicals, including the use of consumer products, the presence of home furnishings, carpeting or other building materials, the use of construction materials and fuels, and activities such as smoking and cooking. Also, vapors from gasoline, other fuels, and other chemicals may invade the indoor air space from an attached garage (Weisel et al. 2008). For this reason, when investigating the possibility of vapor intrusion occurring in homes and other buildings, it should be evaluated whether or not volatile contaminant concentrations measured in homes are present due to these sources, rather than from vapor intrusion from underlying contaminated ground water or soil.

The previous version of this guidance reviewed several past studies, dating back to the 1980s, that measured indoor background concentrations of volatile organic chemicals. It has been observed, however, that indoor contaminant concentrations from more recent studies have tended to be lower than those from earlier studies, due to a decrease of some of these contaminants in consumer products, construction materials, etc. (Hodgson and Levin 2003, Zhu et al. 2005). Therefore, this updated literature review focuses on studies that have been conducted from the late 1990s to the present. The studies are briefly summarized below.

New Jersey Department of Environmental Protection study

The NJDEP developed its own database of indoor air background concentrations in residential buildings. Since many past indoor air studies have focused on urban centers in the United States, it was desired to conduct this study on suburban and rural portions of the state, to see if indoor air concentrations were lower than in urban areas. The study was conducted by the University of Medicine and Dentistry of New Jersey. One hundred homes were sampled in this study, scattered across 13 counties in the state (Weisel et al. 2008, 2006). The homes were single family or semi attached buildings. Almost all of the sampling was conducted in 2004 and 2005, in all seasons. Candidate homes were cross-checked against geographic information system databases of known contaminated ground water and soil sites to ensure that indoor air contaminant concentrations were not influenced by local contamination. Method TO-15 was used, with a 24-hour sample collection time. Smokers were not excluded in this study, but there were only a few smokers in the homes selected. Residents were instructed that during sampling, they should keep windows closed, avoid actively ventilating the homes, not store or use gasoline or kerosene in the home (except in a garage), not use fireplaces, and avoid painting a week before sampling. Samples were collected on the ground floor.

Massachusetts study

This study was conducted by Haley and Aldrich, Inc. and Alpha Analytical Laboratories, with oversight by the Massachusetts Department of Environmental Protection and USEPA Region I (Rago et al. 2005). Samples were collected in 2004 and 2005 in 100 residences from throughout the state (urban, suburban and rural). Method TO-15 was used, and 24-hour samples were collected in early spring and late fall with the windows closed.

New York study

Between 1997 and 2003, the New York State Department of Health conducted a study of the occurrence of volatile organic chemicals in the indoor air of homes that heat with fuel oil (NYSDOH 2006). Basement and living space samples were taken from 104 single family homes during all seasons of the year. Homes were selected from across the state (except for New York City), but the majority of homes were from the Albany, New York area. Prospective residences were required to have no past oil spills, and no hobbies or home business that regularly use products containing VOCs. Two-hour samples were collected and analyzed via Method TO-15.

Denver, Colorado study

As part of an investigation and remediation of a large area of VOC-contaminated ground water underlying several hundred residences in Denver, CO, multiple indoor air background samples were collected for approximately 100 homes after vapor intrusion was mitigated with radon-type subslab ventilation systems (Folkes and Kurtz 2002a). Data were collected only from homes where the ventilation systems removed all VOC impacts from subsurface sources. The contaminants determined were several halogenated volatile organic compounds. Twenty four-hour SUMMA® canister samples were collected between 1998 and 2001, and analyzed by Method TO-15 in the selective ion monitoring mode. Detection limits were much lower for this study than for most other studies.

Minneapolis, Minnesota study

As part of a larger study on personal, indoor and outdoor exposures to hazardous air pollutants, indoor air samples were taken from 132 homes in three urban neighborhoods in Minneapolis and Saint Paul, Minnesota (Sexton et al. 2004). The study was a joint effort of the University of Minnesota, the Minnesota Pollution Control Agency, and the University of Texas. Smokers were not included in this study. Samples were taken for 48 hours and collected in the spring, summer and fall of 1999. Charcoal-based passive air samplers were used.

Ottawa, Canada study

During the winter of 2002-2003, Health Canada sampled 75 residences from urban, suburban, and the rural fringe areas of Ottawa, Canada (Zhu et al. 2005). The homes were mostly single family homes, but a few row homes and semi-detached homes were also sampled. Ten homes were occupied by smokers. Active adsorbent tubes were used, and the ground floor of each of the residences was sampled. The sampling time was 100 minutes, during which ten liters of air was sampled.

RIOPA (Relationship of Indoor, Outdoor and Personal Air) study

A study entitled Relationship of Indoor, Outdoor and Personal Air (RIOPA) was conducted between 1999-2001 that entailed sampling personal, outdoor, indoor air and air in vehicles (Weisel et al. 2005). One hundred homes each in Houston, Texas, Los Angeles County, California, and Elizabeth, New Jersey were each sampled twice using passive vapor monitors for 48 hour exposure periods. Houses with smokers were excluded. Sampling locations in Los Angeles County and Houston were biased to areas in which known outdoor sources of air toxics exist (freeways in Los Angeles, petrochemical industries in Houston). Homes were sampled in all seasons, in the main living area.

Survey of Post-1990 studies

In 2009, Dawson and McAlary published a survey of indoor air studies conducted after 1990. It is included here for completeness. It includes the studies listed above, plus additional earlier studies conducted as early as 1990.

Summary of Indoor Background Levels

With the exception of the New Jersey RIOPA data, the studies presented here represent an entirely new dataset compared to the 2005 version of the NJDEP Vapor Intrusion Guidance. They represent the most current information available, with samples being collected from 1997-2006. (The survey from Dawson and McAlary includes some studies dating back to 1990). More than 800 homes in the United States are represented, as well as 75 homes in Canada. While it is possible that some of these studies may have inadvertently included a few homes that were located above soil or ground water contaminated with volatiles, the likelihood of this is small. Use of the median and 90th percentile statistics largely avoids the effect of such outlier homes, as well as the occasional occurrence of an unusual indoor source of a particular contaminant. The median, 90th percentile, and maximum value from the reviewed studies, are reported here.

Many earlier studies were designed as personal air monitoring studies and employed compact sampling devices that could be worn by the subject. Either adsorbent cartridges or passive adsorption badges were typically used. Many of the recent studies, on the other hand, have used the current regulatory method for indoor air sampling, specifically USEPA Method TO-15, which employs the use of SUMMA® canisters. Thus, the results from these studies are directly comparable to sample analyses conducted during vapor intrusion investigations.

The volatiles subject to NJDEP guidance for the vapor intrusion pathway were surveyed for available indoor air background information. Tables G-1, G-2 and G-3 indicate median, 90th percentile, and maximum concentrations from the various studies, and a summary of these results are given in Table G-4. Compared to the 2005 version of Table G-4, it can be seen that the ranges of concentrations reported for several chemicals are somewhat lower in the more recent studies. Also apparent is that the New Jersey suburban/rural study yielded results that were not significantly different from those studies focused on urban areas, indicating that the major source of these chemicals was indoors or in an attached garage.

For several chemicals, the agreement in reported concentrations between studies is striking. For example, median benzene concentrations were tightly clustered around 2 $\mu g/m^3$ (Table G-1). Other chemicals where median values showed very similar results between studies include 2-butanone, carbon tetrachloride, chloroform, ethylbenzene, methylene chloride, styrene, toluene and xylene. For this reason, representative median concentrations can be selected and are shown in Table G-4.

Sources of these chemicals have been reported by many investigators over the years but have recently been summarized by Weisel et al. (2008). The aromatic compounds, alkanes and MTBE are frequently correlated with each other and originate from gasoline vapors, sometimes due to storage of gasoline or the presence of a vehicle in an attached garage. MTBE occurrence is expected to decline significantly with the recent phase out of MTBE in New Jersey gasoline. Aromatic compounds may also result from smoking and combustion processes. Acetone and 2-butanone are components in nail polish remover and other cosmetics. Fluorinated organics originate from leakages in air conditioning and refrigeration units. Compounds such as methylene chloride, 1,4-dichlorobenzene, 1,1,1-trichloroethane and other halogenated chemicals may result from cleaning products, paint strippers, fragrances and deodorizers. PCE is a dry cleaning compound, but may also occur in paint strippers and paint thinners. Chloroform originates from disinfected drinking water and bleach. Other sources of contaminants are carpeting, furniture, plastics, paints, rubber, adhesives, building materials and other consumer products.

Compound-specific Occurrence Data and Selection of Median Indoor Background Concentrations

Chemicals were separated into five groups, depending on their occurrence pattern in the studies surveyed. For commonly occurring chemicals with adequate data, median concentrations were determined.

Group 1 Compounds commonly detectable via Method TO-15

Several compounds were frequently detected in indoor air at μg/m^3 concentrations using Method TO-15. For these chemicals, median concentrations were reviewed in order to select representative values (Table G-4). Generally, the New Jersey suburban/rural median concentrations were used because 1) they are New Jersey specific, 2) the study is among the most recent, and 3) median concentrations from this study were often similar to those from other studies.

Acetone – Median concentrations ranged from 6-34 μg/m^3, with the New Jersey RIOPA study near the low end and the New Jersey suburban/rural study at the high end. The New Jersey suburban/rural study used the required regulatory method (Method TO-15), which is among the most recent studies, and is specific to the State. Furthermore, health-based concentrations for this chemical in air are much higher than this range. Considering all these factors, the median background concentration for acetone was set at 34 μg/m^3.

Benzene – All studies surveyed included this chemical, with all but one yielding median concentrations above the reporting limit. These median concentrations were tightly clustered between 1.8 and 3.1 μg/m^3. The Massachusetts study indicated a median concentration that was below the reporting limit of 1.6 μg/m^3, but the 75th percentile value was 1.9 μg/m^3. Both the suburban/rural and the RIOPA New Jersey studies gave nearly the same median values (1.8 and 1.65 μg/m^3, respectively), and appear to be very representative of median benzene concentrations in indoor air. The New Jersey suburban/rural study used Method TO-15, and the rounded median value from this study (2 μg/m^3) was selected as the median background concentration.

2-Butanone (MEK) – Median concentrations reported for this chemical were also tightly clustered over a narrow range (1.5-3.5 μg/m^3). Leaving out the Canadian result, the three studies remaining are all TO-15 studies and exhibit an even narrower range of median values (2.7-3.5 μg/m^3). The value from the New Jersey suburban/rural study was at the high end of the range, but is among the most recent studies and is specific to the state. This value was rounded to 4 μg/m^3 and used as the median background concentration.

Chloromethane – Median concentrations ranged from 0.5 to 1.4 μg/m^3. For reasons similar to those for 2-butanone and acetone, the rounded value from the New Jersey suburban/rural study (1 μg/m^3) was selected as the median background concentration.

Dichlorodifluoromethane – The New Jersey suburban/rural study yielded a median concentration of 3.3 μg/m^3, while the other two studies that included this compound did not detect it at reporting limits that were lower and higher than this value. In lieu of additional information, the rounded suburban/rural New Jersey median value (3 μg/m^3) was selected as the median background concentration.

Ethyl benzene – All studies surveyed included this chemical, with all but two studies yielding median values above the reporting limit. For these studies, the measured median values were tightly clustered from 1-1.7 μg/m^3. The other two studies (the New Jersey suburban/rural study and the Massachusetts study) had higher reporting limits (2.2 μg/m^3), and median values were below this level. However, the New Jersey suburban/rural study had a lowered detection limit midway through the study which resulted in greater than 50% samples with detectable levels overall, and the median concentration for the samples run using the lower reporting limit (51 samples) was 1.1 μg/m3. Since all medians in the various studies except one were less than 1.5, a round value of 1 μg/m^3 is appropriate as the median background concentration.

n-Hexane – Three studies reported median values of 2.8, less than 3.5 and 1.6 μg/m^3. The New Jersey suburban/rural study value was 2.8 μg/m^3 and the rounded value of 3 μg/m^3 appears appropriate as a median value.

MTBE – Concentrations of this chemical are expected to decrease with time due to its phase-out in gasoline. However, for the present time, the NJDEP suburban/rural rounded median value of 3 μg/m^3 is recommended. This is somewhat lower than the three RIOPA urban studies (5-7 μg/m^3), but it is more recent, and it may reflect the decreasing use of this chemical. Furthermore, it is midrange between the three RIOPA studies and the median values observed in Massachussetts and New York (less than 2 and 0.8 μg/m^3, respectively). The Ottawa, Canada value is much lower due to historical limited MTBE use in Canada.

Toluene – Toluene median values were reported in every study and have a narrow range, from about 8-13 μg/m^3. The New Jersey suburban/rural value of 13 is at the high end of this range but it was selected because it is a New Jersey-specific value and health-based permitted air concentrations are much higher.

Trichlorofluoromethane – Three TO-15 studies investigated this chemical. Two of them (including the New Jersey study) reported a median below the detection limit of 2.8 μg/m^3. The third reported a median of 2.9 μg/m^3. Similar to the situation with ethyl benzene, the New Jersey suburban/rural study had a reporting limit decrease midway through the study to 1.1 μg/m^3. This resulted in a overall detection rate of 76% of the 100 samples. After the reporting limit change, all samples except one yielded reportable levels, with a median value of 2.1 μg/m^3. The selected median value for this chemical in indoor air is 2 μg/m^3.

Xylene – This chemical was reported in all studies. Median concentrations for m & p-xylene (combined) ranged from 1.5-5.5 μg/m^3. The New Jersey suburban/rural rounded value (4 μg/m^3) is in the middle of this range and appropriate for use as a background concentration. The results for o-xylene yielded median background levels of 1.1-1.6 μ/m^3. The New Jersey study yielded less than 2.2μg/m^3 overall, but after the detection limit was lowered to 0.87 μg/m^3 midway through the study, the median concentration was 1.4 μg/m^3, in the middle of the range reported for the other studies. Therefore, a reasonable rounded median background level for o-xylene is 1 μg/m^3.

Group 2 Compounds commonly detected with methods more sensitive than Method TO-15

The following compounds were very commonly detected at sub-μg/m^3 concentrations through the use of passive vapor monitors or carbon adsorption tubes. They were also detected with Method TO-15 in the New York and Denver, Colorado studies, for which lower reporting limits were developed than those used by New Jersey and Massachusetts. As New Jersey Method TO-15 detection limits decrease, these compounds are expected to be commonly detected. When possible, representative median values were selected for these compounds and are shown in Table G-4.

Carbon tetrachloride – Several studies in Table G-1 indicate a median background concentration of about 0.6 μg/m^3.

Chloroform – Chloroform should be frequently detected as the Method TO-15 reporting limit drops below 1 μg/m^3. Other studies indicate a median indoor air concentration of about 1 μg/m^3. This would be expected in homes with chlorinated drinking water supplies.

Cyclohexane – This chemical was detected in nearly half the homes in the New Jersey suburban/rural study. Based on the last 51 samples (after the detection limit was lowered to 0.69 μg/m^3), the median concentration of this chemical indoors is about 0.7 μg/m^3. This agrees well with the New York value of 0.8 μg/m^3.

1,2-, 1,3- and 1,4-Dichlorobenzene – Data from Minneapolis and the RIOPA studies seem to suggest median indoor background concentrations are greater than 0.1 μg/m^3 for 1,4-dichlorobenzene.

The data are too scattered to suggest a representative median concentration. The other two isomers are less common but were observed greater than 10% of the time in the New York study, which had lower reporting limits.

Methylene chloride – This chemical was detected in almost half of the samples from the New Jersey suburban/rural study. Data from other studies suggest a median background concentration of 0.4-1.5 µg/m3 in the United States, with a central tendency of 1 µg/m^3. The New Jersey study detection limits were just above this range (1.7 µg/m^3).

4-Methyl-2-pentanone – Median concentrations appear to be approximately 0.2 µg/m^3 based on data from New York and Ottawa Canada, but not enough data exist to select a representative value with confidence.

Styrene – Median concentrations from studies that had lower detection limits indicate a median concentration of 0.3-0.7 µg/m^3 with 0.5 µg/m^3 as a central value.

Tetrachloroethene (PCE) – Median concentrations appear to lie between 0.3 and 1.7 µg/m^3. The center of this range is 1 µg/m^3, but data appear too scattered to select a representative median at this time.

1,1,1-Trichloroethane – Two studies report medians of 0.3 and 0.9 µg/m^3. Insufficient data are available to judge an appropriate median value.

1,1,2-Trichloro-1,2,2-trifluoromethane – The New York study indicates a possible median of about 0.5 µg/m^3, but data are insufficient to select this value.

Trichloroethene – This compound appears to occur with a median concentration of under 0.5 µg/m^3, but there are only two studies reporting median values, so no median value was selected. It is expected to commonly be found as detection limits drop below 0.5 µg/m^3.

Group 3 The following chemicals were observed in at least 10% of homes of at least one study as shown in Table G-2, but in less than 50% of homes of all studies (Table G-1). Since no median values for these chemicals are available, median background concentrations were not developed. They are not commonly detected with current New Jersey reporting limits. Only 1,3-butadiene, carbon disulfide, and 1,2-dichloroethane were detected in the New Jersey suburban/rural study.

Bromomethane – detected in greater than 10% of some New York samples
1,3-Butadiene – detected in greater than 10% of Ottawa samples
Carbon disulfide – detected in greater than 10% of Ottawa samples
1,1-Dichloroethene – detected in greater than 10% of Ottawa samples
1,2-Dichloroethane – detected in greater than 10% of Denver samples
Hexachlorobutadiene – detected in greater than 10% of New York samples.
1,2,4-Trichlorobenzene – detected in greater than 10% of New York samples

Group 4 The following chemicals were occasionally detected, but in less than 10% of homes from any study, as indicated by their listings in Tables G-2 and G-3. Only 2-chlorotoluene and *cis*-1,2-dichloroethene were detected in the New Jersey suburban/rural study.

Chlorobenzene
Chloroethane
3-Chloropropene
2-Chlorotoluene
1,2-Dibromoethane
1,1-Dichloroethane
cis-1,2-dichloroethene
1,2-Dichloropropane

1,3-Dichloropropene
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
Vinyl chloride

Group 5 The following chemicals were never detected in any of the studies surveyed (as indicated in Table G-3), based on current regulatory or research reporting limits:

Bromodichloromethane
Bromoethene
Bromoform
Chlorodibromomethane
trans-1,2-dichloroethene
Tertiary butyl alcohol

Table G-1
Median Concentrations of Volatile Contaminants in Background Indoor Air Samples (µg/m^3)

Chemical	CAS No.	New Jersey suburban/rural study, 100 homes sampled 2003-2006, Method TO-15	Massachusetts study, 100 homes sampled 2004-2005, Method TO-15	New York fuel oil homes, 104 homes sampled 1997-2003, Method TO-15	Denver, Colorado, approximately 100 remediated homes sampled 1998-2001, Method TO-15	Minneapolis, Minnesota, 132 homes sampled in 1999, passive vapor monitors	Ottawa Canada, 75 homes sampled 2002-2003, adsorbent tubes	RIOPA study, Elizabeth, New Jersey, 100 homes sampled 1999-2001, passive vapor monitors	RIOPA study, Los Angeles, California, 100 homes sampled 1999-2001, passive vapor monitors	RIOPA study, Houston, Texas, 100 homes sampled 1999-2001, passive vapor monitors	EPA 2009 survey of studies since 1990
Acetone (2-Propanone)	67-64-1	34.5	26.45	21	-	-	28.48	7.04	6.3	12.9	-
Benzene	71-43-2	1.8	<1.6	2.1	-	1.9	2.15	1.65	2.05	3.06	2.5
Bromodichloromethane (Dichlorobromomethane)	75-27-4	<1.3	<3.35	-	-	-	-	-	-	-	-
Bromoethene (Vinyl bromide)	593-60-2	<0.87	-	-	-	-	-	-	-	-	-
Bromoform	75-25-2	<2.1	<5.16	-	-	-	-	-	-	-	-
Bromomethane (Methyl bromide)	74-83-9	<0.78	<1.94	<0.25	-	-	-	-	-	-	-
1,3-Butadiene	106-99-0	<1.1	<2	-	-	-	<0.32	-	-	-	-
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	3.5	2.66	3.4	-	-	1.48	-	-	-	-
Carbon disulfide	75-15-0	<1.6	<1.56	-	-	-	0.13	-	-	-	-
Carbon tetrachloride	56-23-5	<1.3	<3.14	<0.25	-	0.5	-	0.63	0.58	0.62	0.5
Chlorobenzene	108-90-7	<0.92	<2.3	<0.25	-	-	<0.01	-	-	-	-
Chlorodibromomethane (Dibromochloromethane)	124-48-1	<1.7	<4.26	-	-	-	-	-	-	-	-
Chloroethane	75-00-3	<1.3	<1.32	<0.25	-	-	-	-	-	-	-
Chloroform	67-66-3	<2.4	<2.44	<0.25	-	0.9	1.19	0.74	0.92	1.32	1.1
Chloromethane (Methyl chloride)	74-87-3	1.4	1.22	0.5	-	-	-	-	-	-	-
3-Chloropropene (Allyl chloride)	107-05-1	<1.6	<1.56	-	-	-	-	-	-	-	-
2-Chlorotoluene (o-Chlorotoluene)	95-49-8	<1.3	-	-	-	-	-	-	-	-	-
Cyclohexane	110-82-7	0.7[a]	<1.72	0.8	-	-	4.51	-	-	-	-
1,2-Dibromoethane	106-93-4	<1.5	<3.84	<0.25	-	-	<0.02	-	-	-	-
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	<1.2	<3.00	<0.25	-	-	<0.02	-	-	-	-
1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1	<1.2	<3.00	<0.25	-	-	0.15	-	-	-	-
1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	<3	<3.00	<0.25	-	0.2	-	<1.44	0.76	2.02	-
Dichlorodifluoromethane (Freon 12)	75-71-8	3.3	<4.94	<0.25	-	-	-	-	-	-	-
1,1-Dichloroethane	75-34-3	<0.81	<2.02	<0.25	<0.08	-	-	-	-	-	<RL
1,2-Dichloroethane	107-06-2	<0.81	<2.02	<0.25	<0.04	-	<0.02	-	-	-	<RL
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	<0.79	<1.98	<0.25	<0.04	-	<0.01	-	-	-	<RL
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	<0.79	<1.98	<0.25	-	-	-	-	-	-	<RL
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	<0.79	<1.98	-	-	-	-	-	-	-	<RL
1,2-Dichloroethene (total)	540-59-0	-	-	-	-	-	-	-	-	-	-
1,2-Dichloropropane	78-87-5	<0.92	<2.31	<0.25	-	-	<0.04	-	-	-	-
1,3-Dichloropropene	542-75-6	<0.91(cis);<0.91(trans)	<2.27(cis);<2.27(trans)	<0.25(cis);<0.25(trans)	-	-	-	-	-	-	-
Ethylbenzene	100-41-4	1.1[a]	<2.17	1	-	1.4	1.05	1.29	1.45	1.68	2
Hexachloro-1,3-butadiene	87-68-3	<2.1	<5.33	<0.25	-	-	-	-	-	-	-
n-Hexane	110-54-3	2.8	<3.52	1.6	-	-	-	-	-	-	-
Mercury (elemental)	7439-97-6	-	-	-	-	-	-	-	-	-	-
Methylene chloride (Dichloromethane)	75-09-2	<1.7	<3.47	1.4	0.88	1.1	1.87	<1.68	0.84	0.44	1.1
4-Methyl-2-pentanone (MIBK)	108-10-1	<2.0	<2.05	0.3	-	-	0.16	-	-	-	-
MTBE (tert-Butyl methyl ether)	1634-04-4	3.45	<2	0.8	-	-	<0.05	5.03	7.44	5.82	1.2
Styrene	100-42-5	<2.1	<2.13	0.3	-	0.5	0.46	<0.34	0.49	0.67	-
Tertiary butyl alcohol (TBA)	75-65-0	<15	-	-	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	79-34-5	<1.4	<3.43	<0.25	-	-	<0.02	-	-	-	-
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	<3.4	<3.39	0.3	1	0.6	0.47	<1.12	1.66	0.29	0.9
Toluene	108-88-3	13	7.62	9.6	-	12.3	5.53	9.74	10.6	10.3	13
1,2,4-Trichlorobenzene	120-82-1	<3.7	<3.71	<0.25	-	-	-	-	-	-	-
1,1,1-Trichloroethane	71-55-6	<2.7	<2.72	0.3	0.86	-	-	-	-	-	1.9
1,1,2-Trichloroethane	79-00-5	<2.7	<2.72	<0.25	-	-	-	-	-	-	-
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	<2.7	<2.68	<0.25	<0.26	0.2	<0.02	0.43	<0.22	<0.24	<RL
Trichlorofluoromethane (Freon 11)	75-69-4	2.1[a]	<2.81	2.9	-	-	-	-	-	-	-
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon TF)	76-13-1	<1.9	<2.72	0.5	-	-	-	-	-	-	0.5
Vinyl chloride	75-01-4	<0.51	<1.28	<0.25	<0.02	-	-	-	-	-	-
Xylenes (total)	1330-20-7	3.80(m,p);1.4(o)[a]	2.99(m,p);<2.17(o)	1.5(m,p);1.1(o)	-	4.8(m,p);1.6(o)	3.59(m,p);1.22(o)	3.18(m,p);1.18(o)	4.16(m,p);1.64(o)	4.55(m,p);1.53(o)	5.5(m,p);2.2(o)

[a]last 51 samples only (see text)
- = not analyzed
< RL = below reporting limit

Table G-2
90th Percentile Concentrations of Volatile Contaminants in Background Indoor Air Samples ($\mu g/m^3$)

Chemical	CAS No.	New Jersey suburban/rural study, 2003-2006, 100 homes	Massachusetts study, 100 homes sampled 2004-2005, Method TO-15	New York fuel oil homes, 104 homes sampled 1997-2003, Method TO-15	Denver, Colorado, approximately 100 remediated homes sampled 1998-2001, Method TO-15	Minneapolis, Minnesota, 132 homes sampled in 1999, passive vapor monitors	Ottawa Canada, 75 homes sampled 2002-2003, adsorbent tubes	EPA 2009 survey of studies since 1990
Acetone (2-Propanone)	67-64-1	91	61.59	110	-	-	76.4	-
Benzene	71-43-2	10	6.8	15	-	15.3	5.21	10
Bromodichloromethane (Dichlorobromomethane)	75-27-4	<3.4	<3.35	-	-	-	-	-
Bromoethene (Vinyl bromide)	593-60-2	<2.2	-	-	-	-	-	-
Bromoform	75-25-2	<5.2	<5.16	-	-	-	-	-
Bromomethane (Methyl bromide)	74-83-9	<1.9	<1.94	0.6	-	-	-	-
1,3-Butadiene	106-99-0	<1.1	<2	-	-	-	1.64	-
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	12.1	9.65	16	-	-	6.66	-
Carbon disulfide	75-15-0	<1.6	<1.56	-	-	-	0.86	-
Carbon tetrachloride	56-23-5	<3.1	<3.14	0.8	-	0.9	-	0.8
Chlorobenzene	108-90-7	<2.3	<2.3	<0.25	-	-	<0.01	-
Chlorodibromomethane (Dibromochloromethane)	124-48-1	<4.3	<4.26	-	-	-	-	-
Chloroethane	75-00-3	<1.3	<1.32	<0.25	-	-	-	-
Chloroform	67-66-3	2.62	2.46	1.4	-	3.4	4.39	3.9
Chloromethane (Methyl chloride)	74-87-3	2	1.75	3.3	-	-	-	-
3-Chloropropene (Allyl chloride)	107-05-1	<1.6	<1.56	-	-	-	-	-
2-Chlorotoluene (o-Chlorotoluene)	95-49-8	<2.6	-	-	-	-	-	-
Cyclohexane	110-82-7	4.53	2.78	8.1	-	-	15.1	-
1,2-Dibromoethane	106-93-4	<3.8	<3.84	<0.25	-	-	<0.02	-
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	<3.0	<3.00	0.7	-	-	<0.02	-
1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1	<3.0	<3.00	0.6	-	-	1.05	-
1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	3.77	<3.00	1.3	-	1.5	-	-
Dichlorodifluoromethane (Freon 12)	75-71-8	9.56	4.98	15	-	-	-	-
1,1-Dichloroethane	75-34-3	<2.0	<2.02	<0.25	-	-	43.21	<RL
1,2-Dichloroethane	107-06-2	<2.0	<2.02	<0.25	0.1	-	<0.02	0.15
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	<2.0	<1.98	<0.25	-	-	0.83	<RL
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	<2.0	<1.98	<0.25	-	-	-	<RL
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	<2.0	<1.98	-	-	-	-	<RL
1,2-Dichloroethene (total)	540-59-0	-	-	-	-	-	-	-
1,2-Dichloropropane	78-87-5	<2.3	<2.31	<0.25	-	-	<0.04	-
1,3-Dichloropropene	542-75-6	<2.3(cis);<2.3(trans)	<2.27(cis);<2.27(trans)	<0.25(cis);<0.25(trans)	-	-	-	-
Ethylbenzene	100-41-4	9.64	5.25	7.3	-	8.9	4.76	8.6
Hexachloro-1,3-butadiene	87-68-3	<5.3	<5.33	4.6	-	-	-	-
n-Hexane	110-54-3	16.2	14.23	18	-	-	-	-
Mercury (elemental)	7439-97-6	-	-	-	-	-	-	-
Methylene chloride (Dichloromethane)	75-09-2	6.74	10.53	22	10	11.5	43	10
4-Methyl-2-pentanone (MIBK)	108-10-1	<2.0	<2.05	2.2	-	-	0.8	-
MTBE (tert-Butyl methyl ether)	1634-04-4	40.7	38.31	26	-	-	<0.05	26
Styrene	100-42-5	<2.1	<2.13	1.3	-	1.4	1.49	-
Tertiary butyl alcohol (TBA)	75-65-0	<15	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	79-34-5	<3.4	<3.43	<0.25	-	-	<0.02	-
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	4.39	<3.39	2.9	4.5	3.8	3.25	4
Toluene	108-88-3	60.8	42.51	58	-	53.8	25.47	51
1,2,4-Trichlorobenzene	120-82-1	<3.7	<3.71	3.4	-	-	-	-
1,1,1-Trichloroethane	71-55-6	2.81	<2.72	3.1	5.1	-	-	5.5
1,1,2-Trichloroethane	79-00-5	<2.7	<2.72	<0.25	-	-	-	-
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	<2.7	<2.68	0.5	0.3	0.8	0.19	0.9
Trichlorofluoromethane (Freon 11)	75-69-4	6.25	3.56	17	-	-	-	-
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon TF)	76-13-1	<3.8	3.83	1.8	-	-	-	1.8
Vinyl chloride	75-01-4	<1.3	<1.28	<0.25	-	-	-	0.03
Xylenes (total)	1330-20-7	30.2(m,p);11.1(o)	20.52(m,p);6.78(o)	12(m,p);7.6(o)	-	36.9(m,p);11.4(o)	16.35(m,p);6.48(o)	27(m,p);10(o)

- = not analyzed
<RL = below reporting limit

Table G-3
Maximum Concentrations of Volatile Contaminants in Background Indoor Air Samples (µg/m^3)

Chemical	CAS No.	New Jersey suburban/rural study, 2003-2006, 100 homes	Massachusetts study, 100 homes sampled 2004-2005, Method TO-15	New York fuel oil homes, 104 homes sampled 1997-2003, Method TO-15	Denver, Colorado, approximately 100 remediated homes sampled 1998-2001, Method TO-15	Ottawa Canada, 75 homes sampled 2002-2003, adsorbent tubes
Acetone (2-Propanone)	67-64-1	2900	257	690	-	456
Benzene	71-43-2	42	28.1	460	-	21
Bromodichloromethane (Dichlorobromomethane)	75-27-4	<3.4	<3.35	-	-	-
Bromoethene (Vinyl bromide)	593-60-2	<2.2	-	-	-	-
Bromoform	75-25-2	<5.2	<5.16	-	-	-
Bromomethane (Methyl bromide)	74-83-9	<1.9	<1.94	23	-	-
1,3-Butadiene	106-99-0	4.4	2.05	-	-	3.65
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	150	11.2	180	-	16.45
Carbon disulfide	75-15-0	4.4	<1.56	-	-	3.29
Carbon tetrachloride	56-23-5	<3.1	<3.14	4.2	-	-
Chlorobenzene	108-90-7	<2.3	<2.3	0.6	-	0.04
Chlorodibromomethane (Dibromochloromethane)	124-48-1	<4.3	<4.26	-	-	-
Chloroethane	75-00-3	1.3	5.4	4.5	-	-
Chloroform	67-66-3	5.9	8.26	25	-	8.23
Chloromethane (Methyl chloride)	74-87-3	6.2	4.21	260	-	-
3-Chloropropene (Allyl chloride)	107-05-1	1.6	<1.56	-	-	-
2-Chlorotoluene (o-Chlorotoluene)	95-49-8	6.2	-	-	-	-
Cyclohexane	110-82-7	52	9.45	510	-	54
1,2-Dibromoethane	106-93-4	<3.8	<3.84	1.1	-	<0.02
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	16	<3.00	4.9	-	0.11
1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1	<3.0	<3.00	2.5	-	16.19
1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	270	34.2	770	-	-
Dichlorodifluoromethane (Freon 12)	75-71-8	160	82.2	300	-	-
1,1-Dichloroethane	75-34-3	<2.0	<2.02	4.4	0.16	-
1,2-Dichloroethane	107-06-2	3.5	2.76	4.9	0.72	0.71
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	<2.0	<1.98	430	<0.04	4.05
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	2.9	<1.98	7.4	-	-
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	<2.0	<1.98	-	-	-
1,2-Dichloroethene (total)	540-59-0	-	-	-	-	-
1,2-Dichloropropane	78-87-5	<2.3	<2.31	34	-	<0.04
1,3-Dichloropropene	542-75-6	<2.3(cis);<2.3(trans)	<2.27(cis);<2.27(trans)	3.5(cis);<0.25(trans)	-	-
Ethylbenzene	100-41-4	39	24.5	340	-	201
Hexachloro-1,3-butadiene	87-68-3	<5.3	<5.33	51	-	-
n-Hexane	110-54-3	270	38.5	950	-	-
Mercury (elemental)	7439-97-6	-	-	-	-	-
Methylene chloride (Dichloromethane)	75-09-2	94	146	2100	180	408
4-Methyl-2-pentanone (MIBK)	108-10-1	9.8	11.2	36	-	1.4
MTBE (tert-Butyl methyl ether)	1634-04-4	470	155	340	-	3.32
Styrene	100-42-5	5.1	3.24	50	-	6.53
Tertiary butyl alcohol (TBA)	75-65-0	<15	-	-	-	-
1,1,2,2-Tetrachloroethane	79-34-5	<3.4	<3.43	2.7	-	<0.02
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	540	27.6	51	440	9.23
Toluene	108-88-3	160	944	510	-	113
1,2,4-Trichlorobenzene	120-82-1	<3.7	<3.71	37	-	-
1,1,1-Trichloroethane	71-55-6	9.3	21.3	110	210	-
1,1,2-Trichloroethane	79-00-5	<2.7	<2.72	6.2	27	-
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	13	110	25	-	0.87
Trichlorofluoromethane (Freon 11)	75-69-4	62	162	190	-	-
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon TF)	76-13-1	2.1	4.35	7.4	-	-
Vinyl chloride	75-01-4	<1.3	<1.28	1	0.5	-
Xylenes (total)	1330-20-7	91(m,p);38(o)	81.9(m,p);27.8(o)	550(m,p);310(o)	-	139(m,p);205(o)

- = not analyzed

Table G-4
Summary of Ambient Indoor Levels and New Jersey Median Background Concentrations of Volatile Contaminants in Homes (µg/m3)[a]

Chemical	CAS No.	Range of median values	Representative median indoor air concentrations	Range of 90th percentile values
Acetone (2-Propanone)	67-64-1	6-34	34	62-110
Benzene	71-43-2	<1.6-3.1	2	5.2-15
Bromodichloromethane (Dichlorobromomethane)	75-27-4	<RL		<RL
Bromoethene (Vinyl bromide)	593-60-2	<RL		<RL
Bromoform	75-25-2	<RL		<RL
Bromomethane (Methyl bromide)	74-83-9	<RL		0.6[c]
1,3-Butadiene	106-99-0	<RL		1.6[b]
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	1.5[b];2.7-3.5[d]	4	6.7[b];9.6-16[d]
Carbon disulfide	75-15-0	0.13[b]		0.86[b]
Carbon tetrachloride	56-23-5	<0.25-0.6	0.6[f]	0.8-0.9
Chlorobenzene	108-90-7	<RL		<RL
Chlorodibromomethane (Dibromochloromethane)	124-48-1	<RL		<RL
Chloroethane	75-00-3	<RL		<RL
Chloroform	67-66-3	<0.25-2.4	1	1.4-3.4[d];4.4[b]
Chloromethane (Methyl chloride)	74-87-3	0.5-1.4	1	1.8-3.3
3-Chloropropene (Allyl chloride)	107-05-1	<RL		<RL
2-Chlorotoluene (o-Chlorotoluene)	95-49-8	<RL		<RL
Cyclohexane	110-82-7	0.7-0.8[d];4.5[b]	0.7	2.8-8.1[d];15[b]
1,2-Dibromoethane	106-93-4	<RL		<RL
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	<RL		0.7[c]
1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1	0.15[b]		0.6-1
1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	0.2-2		1.3-3.8
Dichlorodifluoromethane (Freon 12)	75-71-8	<0.25-3.3	3	5-15
1,1-Dichloroethane	75-34-3	<RL		<RL
1,2-Dichloroethane	107-06-2	<RL		0.1[e]
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	<RL		0.83[b]
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	<RL		<RL
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	<RL		<RL
1,2-Dichloroethene (total)	540-59-0	-		-
1,2-Dichloropropane	78-87-5	<RL		<RL
1,3-Dichloropropene	542-75-6	<RL		<RL
Ethylbenzene	100-41-4	1.0-1.7	1	4.8[b];5.2-9.6[d]
Hexachloro-1,3-butadiene	87-68-3	<RL		4.6[c]
n-Hexane	110-54-3	1.6-2.8	3	14-18
Mercury (elemental)	7439-97-6	-		-
Methylene chloride (Dichloromethane)	75-09-2	0.44-1.9	1[f]	6.7-22[d], 43[b]
4-Methyl-2-pentanone (MIBK)	108-10-1	0.16-0.3		0.8-2.2
MTBE (tert-Butyl methyl ether)	1634-04-4	<0.05[b];0.8-7.4[d]	3	<0.05[b];26-41[d]
Styrene	100-42-5	0.3-0.7	0.5[f]	1.3-1.5
Tertiary butyl alcohol (TBA)	75-65-0	<RL		<RL
1,1,2,2-Tetrachloroethane	79-34-5	<RL		<RL
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	0.3-1.7		2.9-4.5
Toluene	108-88-3	5.5[b];7.6-13[d]	13	25[b];42-61[d]
1,2,4-Trichlorobenzene	120-82-1	<RL		3.4[c]
1,1,1-Trichloroethane	71-55-6	0.3-0.9		<2.7-5.1
1,1,2-Trichloroethane	79-00-5	<RL		<RL
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	<0.02[b];0.2-0.4[d]		0.2[b];0.3-0.8[d]
Trichlorofluoromethane (Freon 11)	75-69-4	2.1-2.9	2	3.6-17
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon TF)	76-13-1	0.5[c]		1.8-3.8
Vinyl chloride	75-01-4	<RL		<RL
Xylenes (total)	1330-20-7	1.5-5(m,p);1.1-1.6(o)	4(m,p);1(o)	12-37(m,p);6-11(o)

[a]EPA study not included
[b]Ottawa, Canada study only
[c]New York study only
[d]United States studies only
[e]Denver study only
[f]Below New Jersey reporting limit
<RL= less than reporting limit