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Volatile Organic Compounds in Indoor Air: A Review of Concentrations Measured in North America Since 1990

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Abstract

Central tendency and upper limit concentrations of volatile organic compounds (VOCs) measured in indoor air are summarized and reviewed. Data were obtained from published cross-sectional studies of residential and office buildings conducted in North America from 1990 through 2001. VOC concentrations in existing residences reported in 12 studies comprise the majority of the data set. Central tendency and maximum concentrations are compared between new and existing residences and between existing residences and office buildings. Historical changes in indoor VOC concentrations since the Clean Air Act Amendments of 1990 are explored by comparing the current data set with two published reviews of previous data obtained primarily in the 1980s. These historical comparisons suggest average indoor concentrations of some toxic air contaminants, such as 1,1,1-trichloroethane have decreased.

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Introduction

Consideration of indoor exposures to air pollutants is critical to accurate assessments of the health risks associated with these chemicals because people spend a large fraction of their time indoors where concentrations of many airborne pollutants often tend to exceed ambient levels.

A California statewide activity pattern survey conducted in 1987-88 showed that individuals spent, on average, 87% of their time indoors (Jenkins *et al.*, 1992). This was broken down into 65% of the time spent in a residence and 21% of the time spent in other indoor locations. The National Human Activity Pattern Survey conducted in 1992-94 produced similar results (Klepeis *et al.*, 2001). Again, the mean percentage of time spent indoors was 87%. This was broken down into 69% of time spent in a residence and 18% of the time spent in other indoor locations.

It is widely recognized that airborne concentrations of many toxic volatile organic compounds (VOCs) in residences, office buildings and some other indoor environments are higher than concentrations in outdoor air (*e.g.*, Pellizzari *et al.*, 1986; Wallace, 1987; Daisey *et al.*, 1994). This occurs in part because there are numerous indoor sources of VOCs and because the relatively low rates of outdoor air ventilation typically used in residences and offices prevent the rapid dispersal of airborne contaminants. The many consumer products used in residences and offices contain and emit numerous VOCs. Such products include cleaners, air fresheners, and insect repellents. Combustion processes, in particular smoking, are indoor sources of complex mixtures of VOCs. Attached garages are a potential source of gasoline vapors due to evaporative and exhaust emissions. Materials and products used in new construction, remodeling, and redecorating are other major contributors to indoor VOC concentrations in residences and offices.

In the U.S. and elsewhere, the decade since 1990 has witnessed increased concern about the environmental consequences and adverse health effects of air pollution. Most significantly, the U.S. 1990 Clean Air Act (CAA) Amendments established Federal and State programs to regulate the emissions of a large number of air pollutants associated with cancer, reproductive harm, other serious illnesses as well as environmental damage. These are classified as hazardous air pollutants (HAPs). A list of 189 HAPs was included in the 1990 CAA, and the U.S. Environmental Protection Agency (EPA) was given authority to add new chemicals to the list or to remove chemicals (U.S. EPA, 1994). Source categories also were defined. Both large and small area sources are regulated and now must reduce their emissions of HAPs through curtailment and use of control technologies. Cleaner fuels and engines have been mandated to reduce emissions of HAPs from mobile sources. In 1998, the EPA promulgated national VOC emissions standards for certain categories of consumer products as authorized under a section of the 1990 CAA. It is possible that concentrations of some HAPs to which people are exposed in buildings have been reduced due to reductions in outdoor air pollution and reformulation of materials and products.

Indoor VOC data from about 1978 through 1990 were summarized in several reviews. In the late 1980’s, Shah and Singh (1988) updated and analyzed a VOC database for the U.S. Most of the available measurements of VOCs in ambient air and in residential and commercial buildings were gathered, with data accepted in all forms. The final database included 66 VOCs measured indoors. Average, median and upper and lower quartile concentrations were presented for 35 indoor VOCs. Brown *et al.* (1994) reviewed the literature and summarized the data on concentrations of VOCs measured indoors in different building categories (*i.e.*, residences, offices, schools and hospitals). These included measurements from 50 studies, primarily in North America and Western Europe. Data were obtained for 90 VOCs occurring in residences. Considerably fewer data were available for other building types. Holcomb and Seabrook (1995) compiled the data from 30 studies of houses and public places in North America and the United Kingdom, all conducted prior to 1990. Average concentrations were presented by environment for 18 of 85 identified VOCs.

In this paper, we have compiled and summarized the data on the central tendency and upper limit indoor VOC concentrations measured from 1990 through 2001. We focused exclusively on measurements made in North America. Much of the available data are from studies of residential studies. Data from existing (*i.e.*, not newly constructed) residences, new residences and primarily large office buildings were separately treated. VOC concentrations in other environments such as small offices, schools, retail stores and health care facilities generally have not been characterized and were not included. We also did not attempt to summarize indoor/outdoor concentration ratios. Our primary objective was to generate a database of typical and maximum VOC concentrations that can be used by others as a comparative basis for evaluating measured concentrations.

In a companion paper (Hodgson and Levin, Submitted), we assessed VOC concentrations in residences and office buildings summarized herein with respect to odor thresholds, derived sensory irritation levels for the general population and non-cancer chronic health risks. Our objective was to identify and broadly classify VOCs that are most likely to result in comfort and/or health concerns in buildings.

Methods

We defined VOCs as chemical compounds with carbon chains or rings and vapor pressures greater than ~1 Pa at room temperature. Carbon monoxide, carbon dioxide, carbonic acid, metallic carbides, carbonate salts, and C_1-C_3 hydrocarbons were excluded.

Papers were gathered from the scientific journal literature with several exceptions. Papers were sought reporting measurements made in North American residences, both new and existing, and office buildings from 1990 through 2001. Only cross-sectional studies that investigated five or more buildings were considered. Investigations of unusual environments or pollutant sources were excluded. One important probability-based study of residences was obtained as an agency report (Sheldon *et al*., 1991). A probability-based study of office buildings was obtained from the proceedings of an international conference (Girman *et al*., 1999). Finally, several recent studies were obtained from the proceedings of Indoor Air 2002, the 9th International Conference on Indoor Air Quality and Climate (Foster *et al.*, 2002; Kurtz *et al.*, 2002). In total, we identified 13 papers presenting the results of 12 studies of existing residences, two papers presenting results for new residences, and three papers presenting results for office buildings. Basic information regarding these studies is summarized by building type in Tables 1-3.

For existing residences, there were five probability-based studies. One (Sheldon *et al.*, 1992) provided population statistics including geometric means (GMs) and frequency distributions. More commonly, the existing residence studies presented central tendencies as median values or arithmetic averages. Upper concentration ranges most frequently were given as a maximum value and sometimes as 90th and/or 95th percentile values. For three existing residence studies (Heavner *et al.*, 1995 and 1996; Mukerjee *et al.*, 1997) in which the data were segmented (*i.e.*, smoking and non-smoking residences or spring and summer seasons), GM concentrations weighted by the numbers of housing units in each segment were calculated for the entire study as described by Brown *et al.* (1994).

Only two studies of new residences encompassing 20 single-family houses were identified. The measurements were made within the first six months after the houses were completed. For one study (Hodgson *et al*., 2000), GM concentrations and ranges were presented for manufactured and site-built houses. GMs for the combined set were summarized as weighted averages. For the other study (Lindstrom *et al.*, 1995), the individual concentration measurements for pre- and post-occupancy phases were presented. These data were combined and summarized as GMs. The office building data were used as reported. For one study (Girman *et al.*, 1999), the median and 95th percentile values were extracted from a Log-scale plot.

Limited data editing was performed. Environmental tobacco smoke specific compounds (*e.g.*, 3-ethenylpyridine and nicotine) reported by two studies (Heavner *et al.*, 1995 and 1996) were excluded. Mukerjee *et al*. (1997) reported data for 70 volatile and very volatile, predominantly hydrocarbon compounds. Twenty-five of these were included; a number very volatile hydrocarbons, compounds with low occurrence, and branched alkane hydrocarbon isomers were excluded. Van Winkle *et al.* (2001) reported data for 37 volatile and very volatile compounds. Only the 17 ubiquitous and often-found VOCs were included. Acrolein data reported by Lindstrom *et al*. (1995) were excluded as the method used likely underestimated the mass of this compound (Tejada, 1986).

All reported data were entered into a relational database (Microsoft Access). Concentrations given as mass per unit volume, *i.e.*, µg m^{-3} (the majority of studies) were converted to molar volume concentrations (ppb) assuming normal indoor temperature of (25^{o} C, 298^{o} K) and one atmospheric pressure (101 kPa). This conversion facilitates the inter-comparison of compounds with respect to health effects. Data summaries for individual studies were prepared as described above. In the tables, the compounds are grouped into 16 chemical classes and then, within each class, listed by decreasing volatility as indicated by boiling point.

Results

Table 4 lists 106 VOCs for which concentration data were obtained along with µg/m3 to ppb conversion factors and other pertinent data. The EPA classifies 35 of these as HAPs. Five additional compounds are classified by the California EPA as Toxic Air Contaminants (Cal/EPA, 1999).

For existing residences, central tendency data were reported for 57 VOCs. These data are summarized in Table 5, which lists reported GM, median, and average concentrations. For compounds with data from two or more studies, concentrations were summarized as unweighted GMs. A best estimate of central tendency concentration for a compound was calculated as the unweighted GM of reported GM and median concentrations, with the GM selected to represent a study if both of these statistics were reported. The majority of VOCs (37) had best estimate concentrations below 1 ppb. These included the HAPs, n-hexane, 1,3-butadiene, styrene, isopropylbenzene (cumene), naphthalene, vinyl chloride, chloroform, carbon tetrachloride, trichloroethene, and 1,4-dioxane.

Measured VOC concentrations in buildings have wide distributions. A number of the residential studies reported standard deviations for arithmetic average concentrations that were approximately the same magnitude as the average values. Typical geometric standard deviations for distributions of VOC concentrations in both residences and office buildings were approximately 2.0-2.2 based on several studies reporting this statistic (Daisey *et al*., 1994; Shields *et al*., 1996, Hodgson *et al*., 2000, Foster *et al*., 2002).

For existing residences, upper concentration ranges were reported for 48 VOCs. These data are summarized in Table 6, which lists the reported 90th and 95th percentiles and maximum concentrations. For compounds with data from three or more studies, ranges are shown and maximum values were summarized as unweighted GMs. All upper concentration measures for seven of the VOCs including the HAPs, naphthalene, vinyl chloride, carbon tetrachloride, chlorobenzene, and bromomethane, were less than 1 ppb. VOCs with maximum concentrations of 50 ppb or more included acetic acid, formaldehyde, toluene, m/p-xylene, 1,4-dichlorobenzene, dichloromethane, 1,1,1-trichloroethane, and 2-propanone.

Geometric mean and maximum concentration data from the two studies of new single-family houses are presented in Table 7. Data were reported for 69 VOCs. VOC concentrations reported by both studies are summarized as unweighted GMs. For 25 compounds including all nine halogenated compounds, GM concentrations were less than 1 ppb. VOCs with maximum concentrations of 50 ppb or more in the new houses included acetic acid, formaldehyde, acetaldehyde, hexanal, toluene, ethylene glycol, 1,2-propanediol, 2-propanone, and α-pinene.

Central tendency (GMs or medians) and maximum concentration data from the three studies of office buildings are presented in Table 8. Data were reported for 67 VOCs. VOC concentrations reported by multiple studies were summarized as unweighted GMs. For 31 compounds, central tendency values were less than 1 ppb. These included the HAPs, n-hexane, ethylbenzene, o-xylene, styrene, 1,4-dichlorobenzene, dichloromethane, and tetrachloroethene. For nine of the VOCs, including the HAPs, 1,2,4-trichlorobenzene, carbon tetrachloride, and chlorobenzene, the maximum concentrations also were less than 1 ppb. VOCs with maximum concentrations of 50 ppb or more in the office buildings included ethanol, 2-propanol, n-octane, toluene, dichloromethane, 1,1,1-trichloroethane, and 2-propanone.

Discussion

Data Limitations

Published data are available for only a fraction of the VOCs that are known or suspected to occur in indoor air. The uncharacterized VOCs likely include a number of compounds important with respect to human health, sensory irritation and odor that have not been measured because they are inadequately collected or analyzed by conventional methods (Wolkoff *et al*., 1997; Wolkoff and Nielsen, 2001).

Several important indoor environments are inadequately represented. In particular, almost no published data were found for small office buildings where the majority of office workers are located, schools, retail stores, other non-office commercial environments, and institutionalized housing.

The estimates of central tendency and upper limit concentrations might not be representative of indoor exposure concentrations for various reasons. Some of the studies were conducted in the early 1990's and might not represent current levels. For some VOCs, only a small number of building units was represented. Only a fraction of the studies were probability based. The studies might have treated values below reporting limits differently. This would affect the central tendencies for VOCs with relatively high frequencies of non-detectable values. Most of the residential studies obtained only short-term samples and no study sampled a given environment more than a few times. Such strategies are dictated by practical considerations but might result in substantial misrepresentations of long-term indoor exposure concentrations and inadequate characterization of peak concentrations. In addition, personal breathing zone exposures, which typically were not measured, can be substantially higher than indoor area concentrations (Rodes, 1990). This predominance of personal exposures was well demonstrated by the U.S. EPA TEAM studies (Wallace, 2001). Finally, very few studies measured building ventilation rates, which directly influence VOC concentrations and might vary substantially with time within buildings.

Comparisons Among Building Types

Concentrations of VOCs emitted by interior building materials are expected to be higher initially in newly constructed buildings. Figure 1 compares central tendency and maximum VOC concentrations for occupied existing residences with values for unoccupied new residences. Only VOCs with substantial differences are shown. Values for n-decane were also indicative of results for n-undecane, n-dodecane and n-tridecane (not shown). Central tendency concentrations of several aldehydes (acetaldehyde, propionaldehyde, and benzaldehyde), normal alkane hydrocarbons and terpene hydrocarbons (α-pinene and d-limonene) were more than three times (i.e., one-half order of magnitude) higher in the new houses than in the existing houses. Maximum concentrations of propionaldehyde, pentanal, acetic acid and 1,2-dichlorobenzene were more than three times higher in the new houses. Acetaldehyde, pentanal, and terpenes are emitted by composite wood products used for cabinetry and subfloors (Hodgson *et al.*, 2002). Wood products probably also are a large source of acetic acid. Chloroform concentrations were lower in the new houses. This is expected, as these houses were unoccupied except for the final phase of one study (Lindstrom *et al*., 1995) with little domestic water use, a primary source of this compound. Some of the other lower values of chlorinated hydrocarbons in new houses also may be attributable to the occupancy difference.

The sources of some VOCs may differ between residences and office buildings. Figure 2 compares central tendency and maximum VOC concentrations for existing residences with values for office buildings. Only VOCs with substantial differences are shown. Central tendency concentrations of n-dodecane, 1,1,1-trichloroethane, trichloroethene and tetrachloroethene were more than three times higher in the office buildings. Dodecane is a component of an isoparaffinic solvent that was used in once prevalent wet-process photocopiers (Hodgson *et al.*, 1991). The chlorinated solvents may be used in various office and janitorial products. The office buildings had lower central tendency concentrations of pentanal, α-pinene, d-limonene, 1,4-dichlorobenzene, and dichloromethane. A lower prevalence of wood products in office buildings versus residences probably accounts for the lower pentanal and terpene concentrations. 1,4-Dichlorobenzene was once widely used in residences as a moth control agent. Maximum concentrations of the six aromatic hydrocarbons were more than three times lower in office buildings.

Historical Trends

Changes in the production and use of environmentally harmful and toxic chemicals resulting from increased global awareness and the enactment in the U.S. of the 1990 CAA are expected to impact indoor concentrations and exposures to targeted HAPs in two ways. General reductions in the emissions, production, and use of HAPs should decrease the ambient concentrations of these compounds in ventilation and infiltration air entering buildings. Changes in industrial processes to use less toxic compounds in consumer products and other materials used indoors should directly reduce indoor concentrations of the targeted HAPs. These latter changes, in particular, can result in substantial decreases in overall population exposures as shown by Lai *et al.* (2000). Using the concept of inhalation transfer factors, emissions of pollutants indoors were estimated to result, on average, in three orders of magnitude higher exposures than equivalent emissions occurring outdoors in an urban air basin.

Potential historical changes in VOC concentrations were explored by comparing central tendency VOC concentrations from this review with results from the U.S. EPA TEAM studies. The TEAM studies measured concentrations of toxic VOCs in outdoor air, indoor air, personal exposure air and breath samples for communities in several states (*i.e.*, NC, LA, TX, NJ and CA) from 1980 through 1984. Indoor samples were collected overnight at each residence and were analyzed for up to 30 VOCs. The indoor, residential median and maximum VOC concentrations were presented by Pellizzari *et al.* (1986). Because the measurements were probability based, limited to the U.S., and employed a consistent methodology, they provide a good benchmark for exploring potential historical changes in HAP concentrations. In Figure 3, the median and GM concentrations from the current review summarized as unweighted GMs are compared with the TEAM study's central tendency concentrations for 17 VOCs from nine studies also summarized as unweighted GMs. The 1,1,1-trichloroethane concentration in the current review is more than three times lower than the TEAM study value. Other compounds that are approximately one-half order of magnitude lower in the current review are benzene, 1,2-dichloroethane and tetrachloroethene.

These changes likely are due to increased regulations. The 1990 London Amendment to the Montreal Protocol established timelines for global phase out of the production and consumption of CFCs, halons, 1,1,1-trichloroethane, and carbon tetrachloride. By 1995, the production and consumption of 1,1,1-trichloroethane in the U.S. were down by more than 80% relative to 1989 with substantially larger decreases in subsequent years (Oberthur, 2001). The U.S. EPA estimated that nationwide tetrachloroethene emissions dropped 67% from 1990 to 1996 (U.S. EPA, 2001). Measurements of benzene at urban monitoring sites throughout the U.S. showed an average 40% reduction in benzene levels from 1994 to 1999 coincident with the phase-in of “tier 1” emissions standards for cars and increased regulation of oil refineries and chemical processes (*ibid.*). Other aromatic hydrocarbons associated with benzene may exhibit similar reductions.

Conclusions

There are few health-based guidelines for VOC concentrations in non-industrial indoor environments. Thus, summaries of indoor VOC concentrations typically measured in houses and offices provide one means for evaluating measured VOC concentrations. Although the available data were limited in a number of aspects, the summary of these data fills an important gap by covering the decade since the substantial 1990 revision of the Clean Air Act in the U.S. A comparison of the concentrations reviewed here with data from the previous decade suggests average indoor concentrations of some toxic indoor air contaminants, such as benzene, 1,1,1-trichloroethane and tetrachloroethene, have decreased. Despite this trend, indoor exposures to commonly occurring VOCs undoubtedly still dominate overall population exposures to these compounds.

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Table 1. Residential studies included in review. Probability-based studies are listed first.

Reference (ID)	Parameter	Data
Sheldon *et al*. (s) 1992	Study type	Stratified probability sample
	Loc. & Date	Woodland, CA; Jun 1990
	No. units	128 Residences
	Data source	Tbls. 9-13, 9-14, 9-18
Otson *et al*. (o) 1994	Study type	Probability sample
	Loc. & Date	Canada; Date not specified
	No. units	757 Housing units
	Data source	Tbl. 1, p. 3564
Clayton *et al*. (c) 1999	Study type	Stratified, 4-stage probability sample
	Loc. & Date	IL, OH, MI, MN, WI; Jul 1995 - May 1997
	No. units	~170 Housing units, sampled up to 3 times
	Data source	Tbl. 7, p. 387
Gordon *et al*. (g) 1999	Study type	Stratified, 3-stage probability sample
	Loc. & Date	AZ; Date not specified
	No. units	~190 Housing units
	Data source	Tbls. 10 & 11, pp. 467-468
Adgate *et al*. (a) 2002	Study type	Stratified probability sample; units with children
	Loc. & Date	MN; May - Aug 1997
	No. units	~290 Housing units
	Data source	Tbl. 2 & Fig. 1, Vol. 1, pp. 205-206
Zhang *et al*. (za, zb) 1994a & b	Study type	Convenience sample
	Loc. & Date	NJ; Jun - Aug, 1992
	No. units	6
	Data source	Tbl. 1, p. 148; Tbl. 2, p. 32
Heavner *et al*. (ha) 1995	Study type	Convenience sample; units with married non-smoking females
	Loc. & Date	Columbus, OH; Feb 1991
	No. units	24 Non-smoking units, 25 smoking units
	Data source	Tbl. 1, p. 7
Heavner *et al*. (hb) 1996	Study type	Convenience sample; units with married non-smoking females
	Loc. & Date	Mt. Laurel, NJ; Nov 1992
	No. units	61 Non-smoking units, 32 smoking units
	Data source	Tbl. 4, p. 169
Mukerjee *et al*. (m) 1997	Study type	Convenience sample
	Loc. & Date	Brownsville, TX; 1993
	No. units	3 City units, 6 rural agricultural units
	Data source	Tbl. 8, pp. 668-669

Table 1. Continued.

Reference (ID)	Parameter	Data
Van Winkle *et al*. (v) 2001	Study type	Convenience sample of non-smoking units
	Loc. & Date	Chicago, IL; 1994 - 1995
	No. units	10 Units sampled monthly or quarterly
	Data source	Tbl. 1, pp. 52-53
Kurtz & Folkes (k) 2002	Study type	Convenience sample
	Loc. & Date	Denver, CO; 1998 - 2001
	No. units	120 Single-family residences in Redfield Rifle Scope site
	Data source	Tbl. 1, Vol. 1, p. 923
Foster *et al*. (f) 2002	Study type	Convenience sample
	Loc. & Date	Denver, CO; 1996 - 2001
	No. units	21 Single-family resid., 8 town house; 12 apart.bldg.
	Data source	Tbl. 2, Vol. 1, p. 935

Table 2. Studies of new residences included in review.

Reference (ID)	Parameter	Data
Lindstrom *et al*. (l) 1995	Study type	Convenience sample
	Loc. & Date	Denver, CO; Dec 1992 - May 1993
	No. units	6 Experimental & 3 conventional single-family houses
	Data source	Tbls. 6, 8, 9 & 11, pp. 262, 265 & 267
Hodgson *et al*. (ho) 2000	Study type	Convenience sample
	Loc. & Date	FL & east, southeast U.S.; 1997 - 1998
	No. units	4 Manufactured houses; 7 site-built single-family houses
	Data source	Tbls. 3 & 4, pp. 668-669

Table 3. Office building studies included in review.

Reference (ID)	Parameter	Data
Daisey *et al*. (d) 1994	Study type	Convenience sample
	Loc. & Date	San Francisco Bay Area, CA; Jun - Sep 1990
	No. units	12 Public buildings (3 natural vent., 3 mech. vent., 6 mech. vent. with AC)
	Data source	Tbl. 2, p. 3559
Shields *et al*. (sh) 1996	Study type	Convenience sample
	Loc. & Date	U.S.; Mar - Apr 1991
	No. units	11 Telco administrative offices
	Data source	Tbl. 3, p. 8
Girman *et al*. (gi) 1999	Study type	Stratified probability sample
	Loc. & Date	U.S., 1995 - 1998
	No. units	56 Public & private buildings
	Data source	Tbl. 1 & Fig. 1; Vol. 2, pp. 462 & 464

Table 4. VOCs reported in existing and new residences and in office buildings ordered by chemical class and increasing boiling point within class. Factors for µg/m^3 to ppb concentration conversions are shown. Presence on U.S. EPA Hazardous Air Pollutant (H) and California EPA Toxic Air Contaminant (T) lists is indicated.

Compound	CAS No.	Chem. Class[a]	BP (°C)	µg/m^3 to ppb	Toxic Cat.
Ethanol	64-17-5	Alc	78	0.530	
2-Propanol	67-63-0	Alc	82	0.407	
1-Butanol	71-36-3	Alc	118	0.330	T
Phenol	108-95-2	Alc	182	0.260	H,T
2-Ethyl-1-hexanol	104-76-7	Alc	183	0.188	
1-Octanol	111-87-5	Alc	195	0.188	
Butylated hydroxytoluene	128-37-0	Alc	265	0.111	
t-Butyl methyl ether	1634-04-4	Ethr	20	0.277	H,T
1,4-Dioxane	123-91-1	Ethr	101	0.278	H,T
Ethylene glycol	107-21-1	Gly	19	0.394	H,T
2-Butoxyethanol	111-76-2	Gly	171	0.207	H,T
1,2-Propanediol	57-55-6	Gly	188	0.321	
2-(2-Butoxyethoxy)ethanol	112-34-5	Gly	231	0.151	H,T
2-Propanone	67-64-1	Ket	56	0.421	
2-Butanone	78-93-3	Ket	80	0.339	H,T
4-Methyl-2-pentanone	108-10-1	Ket	117	0.244	H,T
Cyclohexanone	108-94-1	Ket	156	0.249	
1-Phenylethanone	98-86-2	Ket	202	0.203	H,T
Formaldehyde	50-00-0	Ald	-19	0.815	H,T
Acetaldehyde	75-07-0	Ald	20	0.554	H,T
Propionaldehyde	127-38-6	Ald	48	0.421	
Acrolein	107-02-8	Ald	53	0.436	H,T
Butanal	123-72-8	Ald	75	0.339	
3-Methylbutanal	590-86-3	Ald	90	0.284	
Pentanal	110-62-3	Ald	103	0.284	
Hexanal	66-25-1	Ald	128	0.244	
Heptanal	111-71-7	Ald	153	0.214	
2-Furaldehyde	98-01-1	Ald	162	0.254	
Octanal	124-13-0	Ald	174	0.191	
Benzaldehyde	100-52-7	Ald	179	0.230	
Nonanal	124-19-6	Ald	195	0.172	
Ethyl acetate	141-78-6	Estr	77	0.278	
Butyl acetate	123-86-4	Estr	126	0.210	
TMPD-MIB[b]	25265-77-4	Estr	244	0.113	
TMPD-DIB[c]	6846-50-0	Estr	280	0.085	
Diethyl phthalate	84-66-2	Estr	298	0.110	

Table 4. Continued.

Compound	CAS No.	Chem. Class[a]	BP (^oC)	$\mu g/m^3$ to ppb	Toxic Cat.
Formic acid	64-18-6	Acid	100	0.532	
Acetic acid	64-19-7	Acid	118	0.408	
Hexanoic acid	142-62-1	Acid	206	0.147	
n-Pentane	109-66-0	Alka	36	0.339	
2-Methylpentane	107-83-5	Alka	60	0.284	
3-Methylpentane	96-14-0	Alka	64	0.284	
n-Hexane	110-54-3	Alka	69	0.284	H,T
3-Methylhexane	589-34-4	Alka	91	0.244	
n-Heptane	142-82-5	Alka	98	0.244	
2,2,5-Trimethylhexane	3522-94-9	Alka	124	0.191	
n-Octane	111-65-9	Alka	126	0.214	
n-Nonane	111-84-2	Alka	151	0.191	
n-Decane	124-18-5	Alka	174	0.172	
n-Undecane	1120-21-4	Alka	196	0.156	
n-Dodecane	112-40-3	Alka	216	0.144	
n-Tridecane	629-50-5	Alka	236	0.133	
n-Tetradecane	629-59-4	Alka	252	0.123	
n-Pentadecane	629-62-9	Alka	270	0.115	
n-Hexadecane	544-76-3	Alka	287	0.108	
Methylcyclopentane	96-37-7	Cycl	72	0.290	
Cyclohexane	110-82-7	Cycl	81	0.290	T
Methylcyclohexane	108-87-2	Cycl	100	0.249	
Propylcyclohexane	1678-92-8	Cycl	155	0.194	
Butylcyclohexane	1678-93-9	Cycl	178	0.174	
1,3-Butadiene	106-99-0	Alke	-5	0.452	H,T
Isoprene	78-79-5	Terp	34	0.359	
α-Pinene	7785-70-8	Terp	155	0.180	
Camphene	5794-04-7	Terp	160	0.180	
3-Carene	13466-78-9	Terp	165	0.180	
β-Pinene	18172-67-3	Terp	166	0.180	
d-Limonene	5989-27-5	Terp	177	0.180	
p-Cymene	99-87-6	Terp	177	0.182	
Benzene	71-43-2	Arom	80	0.313	H,T
Toluene	108-88-3	Arom	111	0.265	H,T
Ethylbenzene	100-41-4	Arom	136	0.230	H,T
m/p-Xylene		Arom	139	0.230	
o-Xylene	95-47-6	Arom	143	0.230	H,T
Styrene	100-42-5	Arom	145	0.235	H,T

Table 4. Continued.

Compound	CAS No.	Chem. Class[a]	BP (^{o}C)	µg/m^3 to ppb	Toxic Cat.
Isopropylbenzene (cumene)	98-82-8	Arom	153	0.203	H,T
3/4-Ethyltoluene		Arom	159	0.203	
Propylbenzene	103-65-1	Arom	159	0.203	
4-Ethyltoluene	622-96-8	Arom	162	0.203	
2-Ethyltoluene	611-14-3	Arom	164	0.203	
1,3,5-Trimethylbenzene	108-67-8	Arom	165	0.203	
1,2,4-Trimethylbenzene	95-63-6	Arom	169	0.203	T
1,2,3-Trimethylbenzene	526-73-8	Arom	175	0.203	
Butylbenzene	104-51-8	Arom	183	0.182	
Naphthalene	91-20-3	Arom	218	0.191	H,T
4-Phenylcyclohexene	4994-16-5	Arom	252	0.155	
Chlorobenzene	108-90-7	ClAro	132	0.217	H,T
1,4-Dichlorobenzene	106-46-7	ClAro	174	0.166	H,T
1,2-Dichlorobenzene	95-50-1	ClAro	180	0.166	
1,2,4-Trichlorobenzene	120-82-1	ClAro	213	0.135	H,T
Vinyl chloride	75-01-4	Halo	-13	0.391	H,T
Bromomethane	74-83-9	Halo	4	0.258	H,T
Trichlorofluoromethane	75-69-4	Halo	24	0.178	T
Dichloromethane	75-09-2	Halo	40	0.288	H,T
Trichlorotrifluoroethane	76-13-1	Halo	48	0.130	T
Chloroform	67-66-3	Halo	62	0.205	H,T
1,1,1-Trichloroethane	71-55-6	Halo	74	0.183	H,T
Carbon tetrachloride	56-23-5	Halo	77	0.159	H,T
1,2-Dichloroethane	107-06-2	Halo	83	0.247	H,T
Trichloroethene	79-01-6	Halo	87	0.186	H,T
Tetrachloroethene	127-18-4	Halo	121	0.147	H,T
Carbon disulfide	75-15-0	Misc	46	0.321	H,T
Acrylonitrile	107-13-1	Misc	77	0.460	H,T
Pyridine	110-86-1	Misc	115	0.309	
d4 Siloxane[d]	556-67-2	Misc	175	0.082	
d5 Siloxane[e]	541-02-6	Misc	210	0.066	
Benzothiazole	95-16-9	Misc	231	0.181	

a. Alc = alcohol; Ethr = ether; Gly = glycol ether; Ket = ketone; Ald = aldehyde; Estr = acetates and other esters; Acid = carboxylic acid; Alka = alkane HC; Alke = alkene HC; Cycl = cyclic HC; Terp = terpene HC; Arom = aromatic HC; ClAro = chlorinated aromatic HC; Halo = halogenated aliphatic HC; Misc = miscellaneous category

b. 2,2,4-Trimethyl-1,3-pentanediol monisobutyrate (combined isomers 1 & 3)

c. 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate

d. Octamethylcyclotetrasiloxane

e. Decamethylcyclopentasiloxane

Table 5. Geometric mean (GM), median and mean VOC concentrations in existing residences. For multiple studies, concentrations were summarized as unweighted GMs. Best estimates were calculated as unweighted GMs of reported GM and median concentrations. Numbers of residential units comprising best estimates are shown..

		Concentration (ppb) Value or GM (No. Studies)			Best Estimate		
Compound	Chem. Class	GM	Median	Mean	Conc. (ppb)	No. Units	Study ID[a]
1,4-Dioxane	Ethr	0.03		0.39	0.03	128	s
2-Propanone	Ket		15	30	15	93	hb
Formaldehyde	Ald		17	55	17	190	g,za
Acetaldehyde	Ald			3.0			za
Propionaldehyde	Ald			1.2			za
Acrolein	Ald	1.8			1.8	128	s
Butanal	Ald			0.66			za
3-Methylbutanal	Ald			0.41			za
Pentanal	Ald			0.91			za
2-Furaldehyde	Ald			0.27			za
Benzaldehyde	Ald			0.38			za
Formic acid	Acid			8.8			za
Acetic acid	Acid			24			za
2-Methylpentane	Alka		0.56		0.56	9	m
3-Methylpentane	Alka		0.33		0.33	9	m
n-Hexane	Alka		0.51	0.28	0.51	9	m,o
n-Heptane	Alka		0.26		0.26	9	m
n-Octane	Alka		0.24 (2)	0.70	0.24	19	m.v
n-Nonane	Alka		0.25 (3)	0.78 (2)	0.25	151	ha,hb,m
n-Decane	Alka		0.44 (2)	0.97 (2)	0.44	142	ha,hb
n-Undecane	Alka		0.28 (2)	1.3 (2)	0.28	142	ha,hb
n-Dodecane	Alka		0.17 (2)	0.55 (2)	0.17	142	ha,hb
n-Tridecane	Alka		0.14 (2)	0.31 (2)	0.14	142	ha,hb
Cyclohexane	Cycl		0.18		0.18		m
Methylcyclohexane	Cycl		0.40		0.40		m
1,3-Butadiene	Alke		0.23 (4)	0.31 (2)	0.23	302	g,hb,m,v
Isoprene	Terp		0.54 (2)	6.5	0.54	102	hb,m
α-Pinene	Terp			4.1			o
d-Limonene	Terp			3.6			o
p-Cymene	Terp			0.18			o
Benzene	Arom	1.0 (2)	0.87 (7)	1.5 (7)	0.90	980	a,c,f,g,ha,hb, m,o,s,v
Toluene	Arom		3.3 (6)	6.7 (5)	3.3	641	a,g,ha,hb,m, o,v
Ethylbenzene	Arom		0.53 (4)	1.4 (4)	0.53	160	ha,hb,m,o,v,

Table 5. Continued.

Compound	Chem. Class	Concentration (ppb) Value or GM (No. Studies) GM	Median	Mean	Best Estimate Conc. (ppb)	No. Units	Study ID[a]
m/p-Xylene	Arom	1.0	1.4 (3)	2.9 (3)	1.3	437	a,m,s,v
o-Xylene	Arom	0.44	0.53 (5)	1.1 (6)	0.51	579	a,ha,hb,m,o,s,v
Styrene	Arom	0.18	0.25 (5)	0.35 (6)	0.23	579	a,ha,hb,m,o,s,v
Isopropylbenzene	Arom		0.07 (2)	0.12 (2)	0.07	142	ha,hb
Propylbenzene	Arom		0.11 (2)	0.25 (2)	0.11	142	ha,hb
4-Ethyltoluene	Arom		0.55		0.55	9	m
2-Ethyltoluene	Arom		0.45		0.45	9	m
1,3,5-Trimethylbenz	Arom		0.25 (3)	0.51 (3)	0.25	151	ha,hb,m,o
1,2,4-Trimethylbenz	Arom		0.79	2.4	0.79	9	m,o
1,2,3-Trimethylbenz	Arom		0.20	0.42	0.20	142	ha,hb
Butylbenzene	Arom		0.03 (2)	0.06 (2)	0.03	142	ha,hb
Naphthalene	Arom		0.09	0.35 (2)	0.09	10	o,v
4-Phenylcyclohexene	Arom			0.02			hb
1,4-Dichlorobenzene	ClAro	0.18	0.08 (4)	1.3 (6)	0.09	570	a,ha,hb,o,s,v
1,2-Dichlorobenzene	ClAro			11			v
Vinyl chloride	Halo	0.01 (2)	<0.01		0.01	161	f,k
Dichloromethane	Halo	0.88 (2)	2.1 (2)	6.4 (4)	1.4	299	f,k,o,s,v
Chloroform	Halo	0.43	0.19 (5)	0.37 (5)	0.22	613	a,c,f,hb,m,o,v
1,1,1-Trichloroethane	Halo	0.26 (3)	0.36 (4)	2.4 (3)	0.35	598	a,f,k,m,s,v,
Carbon tetrachloride	Halo	0.09	0.09 (2)	0.09 (2)	0.09	147	m,s,v
1,2-Dichloroethane	Halo	0.01 (2)	0.01	0.06 (3)	0.01	161	f,ha,hb,k,o
Trichloroethene	Halo	0.04 (3)	0.08 (8)	0.23 (7)	0.07	1100	a,c,f,g,ha,hb,k,m,o,s,v
Tetrachloroethene	Halo	0.13 (3)	0.15 (7)	0.41 (6)	0.14	910	a,c,f,ha,hb,k,m,s,v
Pyridine	Misc		0.17 (2)	0.54 (2)	0.17	142	ha,hb

a. IDs of all studies reporting values are indicated; study IDs defined in Table 1

Table 6. Upper percentile (90th and 95th) and maximum VOC concentrations in existing residences. Values are shown as ranges for compounds reported by three or more studies. Maximum concentrations for multiple studies were summarized as unweighted GMs.

		Concentration (ppb)				
	Chem.	Value or Range (No. Studies)			GM	Study
Compound	Class	90%ile	95%ile	Max	Max	ID[a]
1,4-Dioxane	Ethr	0.18		39		s
2-Propanone	Ket			280		hb
Formaldehyde	Ald	37		100, 330	180	za,g
Acetaldehyde	Ald			16		za
Propionaldehyde	Ald			5.6		za
Acrolein	Ald	9.2		13		s
Butanal	Ald			2.4		za
3-Methylbutanal	Ald			1.2		za
Pentanal	Ald			2.0		za
2-Furaldehyde	Ald			1.5		za
Benzaldehyde	Ald			1.3		za
Formic acid	Acid			19		zb
Acetic acid	Acid			81		zb
n-Octane	Alka	2.4		3.6		v
n-Nonane	Alka			3.2, 14	6.7	ha,hb
n-Decane	Alka			7.9, 20	13	ha,hb
n-Undecane	Alka			9.2, 39	19	hb,ha
n-Dodecane	Alka			4.1, 18	8.7	hb,ha
n-Tridecane	Alka			2.1, 5.2	3.3	ha,hb
1,3-Butadiene	Alke	0.17, 0.53		0.27-5.5 (4)	1.7	g,hb,s,v
Isoprene	Terp			24		hb
Benzene	Arom	1.9-4.1 (4)	4.0	8.4-41 (7)	18	a,c,f,g,ha,hb, s,v
Toluene	Arom	7.8, 13		12-240 (5)	47	a,g,ha,hb,v
Ethylbenzene	Arom	3.0		5.9-40 (3)	11	ha,hb,v
m/p-Xylene	Arom	2.8, 13	5.0	28-120 (3)	67	a,s,v
o-Xylene	Arom	1.3, 3.7	1.6	7.9-43 (5)	14	a,ha,hb,s,v
Styrene	Arom	0.50, 0.89	0.56	1.7-33 (5)	5.5	a,ha,hb,s,v
Isopropylbenzene	Arom			0.66, 2.1	1.2	ha,hb
Propylbenzene	Arom			2.0, 6.1	3.5	ha,hb
1,3,5-Trimethylbenz	Arom			3.1, 14	6.5	ha,hb
1,2,3-Trimethylbenz	Arom			2.2, 7.9	4.2	ha,hb
Butylbenzene	Arom			0.3, 2.3	0.80	ha,hb
Naphthalene	Arom	0.41		0.95		v
4-Phenylcyclohexene	Arom			0.29		hb
Chlorobenzene	ClAro			0.11		s

Table 6. Continued.

Compound	Chem. Class	Concentration (ppb) Value or Range (No. Studies) 90%ile	95%ile	Max	GM Max	Study ID[a]
1,4-Dichlorobenzene	ClAro	0.34, 4.7	0.57	16-50 (5)	26	a,ha,hb,s,v
1,2-Dichlorobenzene	ClAro	0.04		0.09		v
Vinyl chloride	Halo		0.04	0.13, 0.20	0.16	f,k
Bromomethane	Halo			0.72		s
Dichloromethane	Halo	46, 150	4.6	3.5-490 (4)	74	f,k,s,v
Chloroform	Halo	0.83, 1.3	1.2	1.2-4.3 (4)	2.6	a,c,f,hb,v
1,1,1-Trichloroethane	Halo	2.2, 12	1.4, 3.2	2.6-180 (5)	28	a,f,k,s,v
Carbon tetrachloride	Halo	0.11, 0.15		0.20, 0.41	0.29	s,v
1,2-Dichloroethane	Halo		0.04	0.10-2.4 (4)	0.26	f,ha,hb,k
Trichloroethene	Halo	0.21-0.42 (4)	0.13, 0.26	0.58-5.0 (7)	1.9	a,c,f,g,ha,hb,k,s,v
Tetrachloroethene	Halo	0.34-1.0 (3)	0.72, 1.0	0.76-65 (7)	7.0	a,c,f,ha,hb,k,s,v
Pyridine	Misc			1.5, 2.7	2.0	hb,ha
Acrylonitrile	Misc			12		s

a. IDs of all studies reporting values are indicated; study IDs defined in Table 1

Table 7. Geometric mean (GM) and maximum VOC concentrations in new single-family houses. Concentrations reported by both studies were summarized as unweighted GMs.

Compound	Chem. Class	Concentration (ppb) GM	Concentration (ppb) Maximum	Study ID[a]
1-Butanol	Alc	7.7	21	ho
Phenol	Alc	1.8	5.8	ho
2-Ethyl-1-hexanol	Alc	<1.5		ho
1-Octanol	Alc	<1.5		ho
BHT	Alc	<0.5		ho
Ethylene glycol	Gly	48	490	ho
2-Butoxyethanol	Gly	2.9	12	ho
1,2-Propanediol	Gly	4.8	360	ho
DEGBE	Gly	<1.5		ho
2-Propanone	Ket	28	210	l
2-Butanone	Ket	6.4	37	ho,l
4-Methyl-2-pentanone	Ket	<0.5		ho
Cyclohexanone	Ket	<0.5		ho
1-Phenylethanone	Ket	<1.5		ho
Formaldehyde	Ald	32	62	ho,l
Acetaldehyde	Ald	14	43	ho,l
Propionaldehyde	Ald	4.4	19	l
Butanal	Ald	0.30	2.0	l
Pentanal	Ald	2.5	9.8	l
Hexanal	Ald	15	36	ho,l
Heptanal	Ald	1.9	4.9	ho
2-Furaldehyde	Ald	<1.5		ho
Octanal	Ald	2.6	7.2	ho
Benzaldehyde	Ald	1.3	3.7	l
Nonanal	Ald	3.1	7.6	ho
Ethyl acetate	Estr	<0.5		ho
Butyl acetate	Estr	1.4	14	ho
TMPD-MIB[b]	Estr	5.6	25	ho
TMPD-DIB[c]	Estr	1.3	7.2	ho
Acetic acid	Acid	71	280	ho
Hexanoic acid	Acid	1.1	5.5	ho
n-Heptane	Alka	<1.5		ho
n-Nonane	Alka	<1.5		ho
n-Decane	Alka	3.9	22	ho
n-Undecane	Alka	2.3	9.1	ho
n-Dodecane	Alka	3.6	11	ho
n-Tridecane	Alka	5.2	21	ho
n-Tetradecane	Alka	<5.0		ho

Table 7. Continued.

Compound	Chem. Class	Concentration (ppb) GM	Maximum	Study ID[a]
n-Pentadecane	Alka	<0.5		ho
n-Hexadecane	Alka	<0.5		ho
Methylcyclohexane	Cycl	<1.5		ho
Propylcyclohexane	Cycl	<0.5		ho
Butylcyclohexane	Cycl	<0.5		ho
α-Pinene	Terp	23	60	ho
Camphene	Terp	<1.5		ho
3-Carene	Terp	4.1	15	ho
β-Pinene	Terp	8.0	26	ho
d-Limonene	Terp	4.3	12	ho
Benzene	Arom	0.47	6.1	l
Toluene	Arom	8.5	68	ho,l
Ethylbenzene	Arom	0.32	2.1	l
m/p-Xylene	Arom	2.1	11	ho,l
o-Xylene	Arom	0.64	4.4	l
Styrene	Arom	0.59	7.8	ho,l
1,3,5-Trimethylbenzene	Arom	<0.5		ho
1,2,4-Trimethylbenzene	Arom	<1.5		ho
Naphthalene	Arom	<1.5		ho
4-Phenylcyclohexene	Arom	<0.5		ho
Chlorobenzene	ClAro	0.17	0.32	l
1,2-Dichlorobenzene	ClAro	0.22	0.54	l
Trichlorofluoromethane	Halo	0.55	1.3	l
Dichloromethane	Halo	0.29	2.3	l
Trichlorotrifluoroethane	Halo	0.17	1.2	l
Chloroform	Halo	0.06	0.47	l
1,1,1-Trichloroethane	Halo	0.46	2.3	l
Trichloroethene	Halo	0.06	0.43	l
Tetrachloroethene	Halo	0.06	0.29	l
Benzothiazole	Misc	<0.5		ho

a. Study IDs defined in Table 2

b. 2,2,4-Trimethyl-1,3-pentanediol monisobutyrate (combined isomers 1 & 3)

c. 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate

Table 8. Central tendency (GM or median) and maximum VOC concentrations in office buildings. Concentrations reported by multiple studies were summarized as unweighted GMs.

		Central Tendency		Maximum	
Compound	Chem. Class	Conc. (ppb)	Study ID[a]	Conc. (ppb)	Study ID[a]
Ethanol	Alc	19	d	130	d
2-Propanol	Alc	2.3	d	62	d
1-Butanol	Alc			5.0	gi
Phenol	Alc			2.5	gi
2-Ethyl-1-hexanol	Alc			9.0	gi
t-Butyl methyl ether	Ethr			8.3	gi
2-Butoxyethanol	Gly	0.65	d,gi,sh	14	d,gi,sh
2-Propanone	Ket	7.4	d,gi	33	d,gi
2-Butanone	Ket			6.1	gi
4-Methyl-2-pentanone	Ket			6.8	gi
1-Phenylethanone	Ket	1.0	d	2.8	d,gi
Pentanal	Ald	0.17	d	1.3	d,gi
Hexanal	Ald	0.47	d,gi	2.4	d,gi
Benzaldehyde	Ald	0.47	d	1.5	d
Nonanal	Ald	0.52	gi	1.4	gi
Ethyl acetate	Estr	0.34	d	7.4	d,gi
Butyl acetate	Estr	0.21	d	3.9	d,gi
TMPD-MIB[b]	Estr	0.06	sh	3.2	gi
TMPD-DIB[c]	Estr	0.20	sh	0.88	gi,sh
Diethyl phthalate	Estr	<0.01	sh	0.66	sh
n-Pentane	Alka	2.5	d	8.9	d
3-Methylpentane	Alka			4.5	gi
n-Hexane	Alka	0.62	d,gi	3.1	d,gi
3-Methylhexane	Alka	0.34	d	0.71	d
n-Heptane	Alka	0.40	d	0.72	d
2,2,5-Trimethylhexane	Alka	0.14	d	0.31	d
n-Octane	Alka	0.11	d,sh	13	d,gi
n-Nonane	Alka	0.36	d	5.6	d,gi
n-Decane	Alka	0.69	d,sh	5.8	d,gi
n-Undecane	Alka	0.65	d	10	d,gi
n-Dodecane	Alka	0.86	d,gi,sh	16	d,gi
n-Tetradecane	Alka	1.4	sh		
n-Pentadecane	Alka	1.5	sh		
n-Hexadecane	Alka	1.2	sh		
Methylcyclopentane	Cycl	0.45	d	1.2	d
Methylcyclohexane	Cycl	0.38	d	0.76	d
α-Pinene	Terp	0.04	sh	1.5	gi

Table 8. Continued.

Compound	Chem. Class	Central Tendency Conc. (ppb)	Central Tendency Study ID[a]	Maximum Conc. (ppb)	Maximum Study ID[a]
d-Limonene	Terp	1.2	d,gi,sh	12	d,gi
Benzene	Arom	1.0	d,gi	3.8	d,gi
Toluene	Arom	2.1	d,gi,sh	40	d,gi
Ethylbenzene	Arom	0.48	d,sh	2.6	d,gi
m/p-Xylene	Arom	1.4	d,gi,sh	10	d,gi
o-Xylene	Arom	0.66	d	3.5	d,gi
Styrene	Arom	0.40	d	1.2	d,gi
3/4-Ethyltoluene	Arom	0.75	d	1.7	d
4-Ethyltoluene	Arom			2.2	gi
2-Ethyltoluene	Arom	0.48	d	0.98	d
1,3,5-Trimethylbenzene	Arom	0.38	d	1.1	d,gi
1,2,4-Trimethylbenzene	Arom	0.88	d,sh	2.9	d,gi
1,2,3-Trimethylbenzene	Arom	0.29	d	1.1	d
Naphthalene	Arom			1.9	gi
4-Phenylcyclohexene	Arom			0.09	gi
Chlorobenzene	ClAro			0.15	gi
1,4-Dichlorobenzene	ClAro	0.03	sh	7.0	gi,sh
1,2-Dichlorobenzene	ClAro			2.2	gi
1,2,4-Trichlorobenzene	ClAro			0.16	gi
Trichlorofluoromethane	Halo	0.75	d	13	d,gi
Dichloromethane	Halo	0.40	d	65	d,gi
Trichlorotrifluoroethane	halo			3.0	gi
Chloroform	Halo			2.0	gi
1,1,1-Trichloroethane	Halo	1.6	d,gi	77	d,gi
Carbon tetrachloride	Halo			0.62	gi
Trichloroethene	Halo	1.8	d	4.8	d,gi
Tetrachloroethene	Halo	0.47	d,sh	3.8	d,gi
Carbon disulfide	Misc			5.8	gi
d4 Siloxane[d]	Misc	0.84	sh		
d5 Siloxane[e]	Misc	2.6	sh		

a. Study IDs defined in Table 3
b. 2,2,4-Trimethyl-1,3-pentanediol monisobutyrate (combined isomers 1 & 3)
c. 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate
d. Octamethylcyclotetrasiloxane
e. Decamethylcyclopentasiloxane

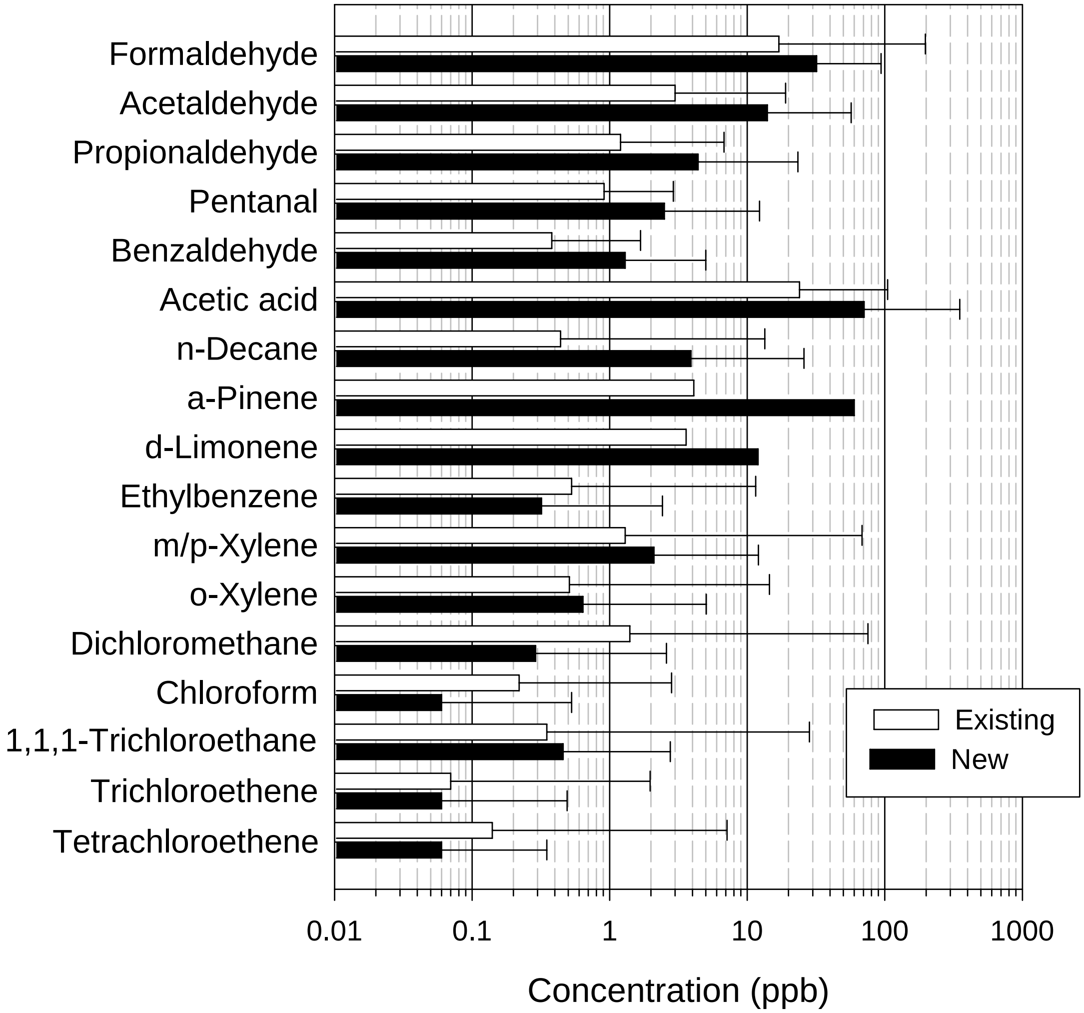

Figure 1. Comparison of central tendency and maximum VOC concentrations between occupied existing and unoccupied new residences. Bars indicate central tendency values; whiskers indicate maximum concentrations.

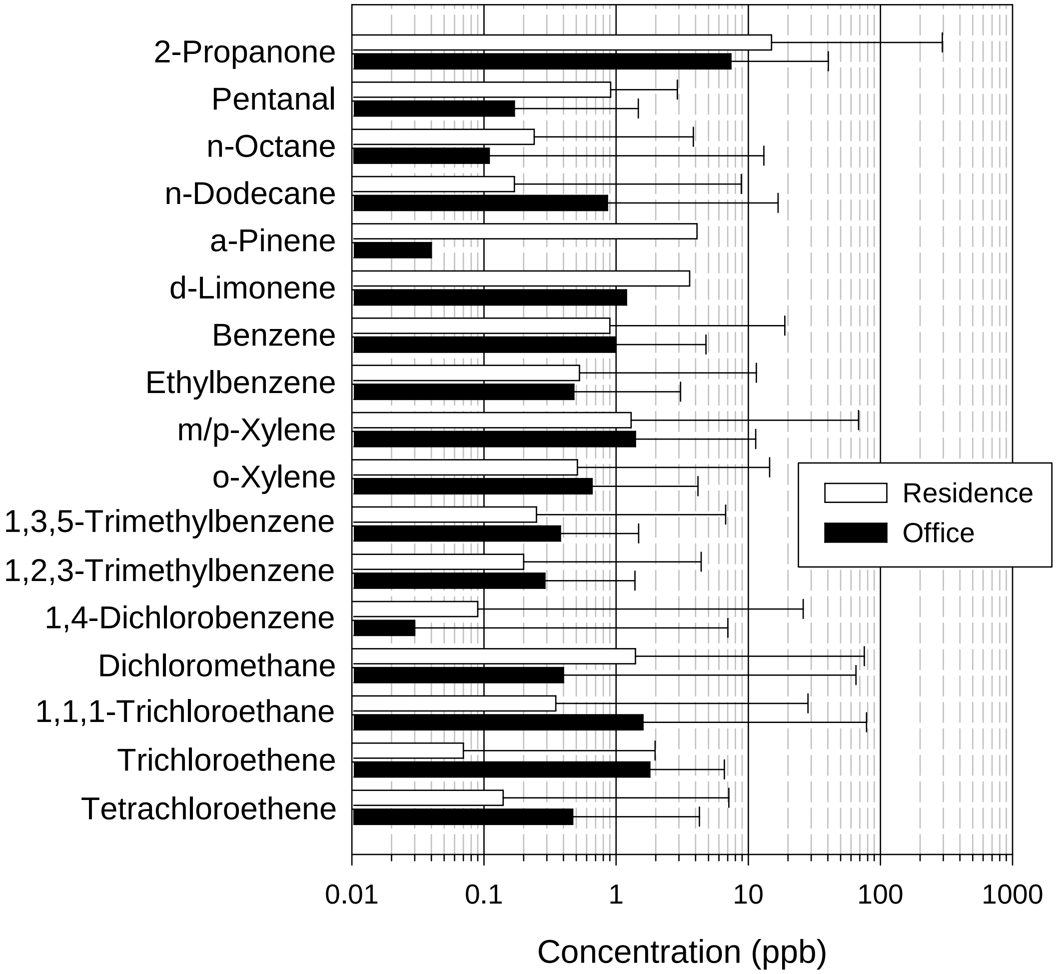

Figure 2. Comparison of central tendency and maximum VOC concentrations between existing residences and office buildings. Bars indicate central tendency values; whiskers indicate maximum concentrations.

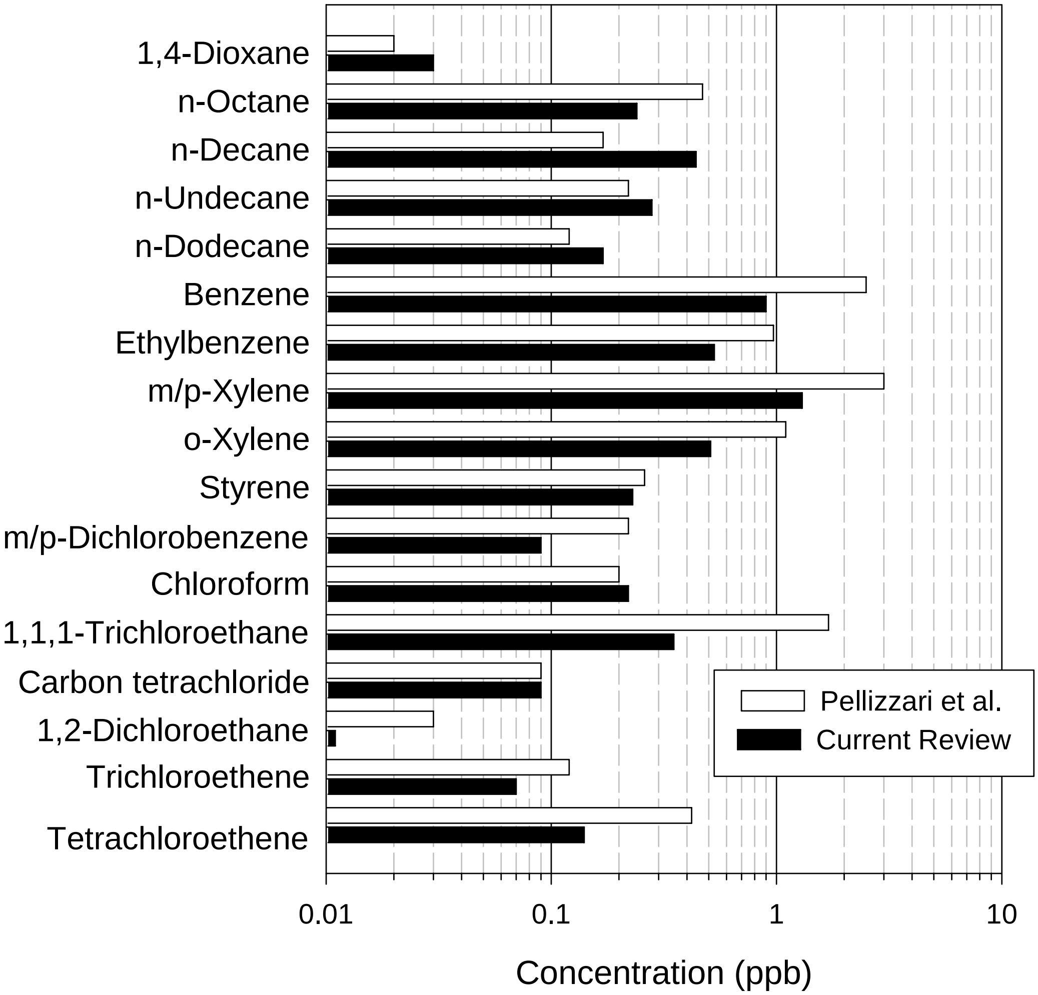

Figure 3. Comparison of unweighted GM VOC concentrations from the 1980-84 U.S. EPA TEAM studies (Pellizzari *et al*., 1986) with central tendency VOC concentrations in existing residences from current review.