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Ventilation Relevant Contaminants of Concern in Commercial Buildings Screening Process and Results

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ABSTRACT

This report summarizes the screening procedure and its results for selecting contaminants of concern (COC), whose concentrations are affected by ventilation in commercial buildings. Many pollutants comprising criteria pollutants, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs) and biological contaminants are found in commercial buildings. In this report, we focus primarily on identifying potential volatile organic COC, which are impacted by ventilation. In the future we plan to extend this effort to inorganic gases and particles. Our screening considers compounds detected frequently in indoor air and compares the concentrations to health-guidelines and thresholds. However, given the range of buildings under consideration, the contaminant sources and their concentrations will vary depending on the activity and use of the buildings. We used a literature review to identify a large list of chemicals found in commercial-building indoor air. The VOCs selected were subject to a two stage screening process, and the compounds of greater interest are included in priority List A. Other VOCs that have been detected in commercial buildings are included in priority List B. The compounds in List B, were further classified into groups B1, B2, B3, B4 in order of decreasing interest.

INTRODUCTION

This report summarizes the screening procedure and its results for selecting contaminants of concern (COC), whose concentrations are affected by ventilation in commercial buildings. Pollutants of concern in commercial buildings include volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), biological contaminants, particulate matter, heavy metals (mercury, lead, nickel, chromium, etc.) and numerous inorganic gases (CO_2, CO, nitrogen oxides, sulfur oxides, O_3). Many of these pollutants all have well established health impacts, however, in this screening we focus on VOCs. VOCs, many with known or suspected adverse effects on occupants, are emitted by building materials, contents, and occupants, and can be reduced by ventilation as well as by source control and various air cleaning strategies. Some VOCs also have outdoor sources. Particulate matter has indoor sources and is brought into buildings with outdoor air; however, in most commercial buildings filtration is expected to play a larger role in controlling particulate matter concentrations compared to ventilation. Most of the biological contaminants of concern are particles. At this time, little is known about the concentrations of SVOCs in commercial buildings. The impacts of many SVOCs on health are also poorly understood. However, the current literature suggests that ventilation may not have a substantial effect on exposures to many SVOCs. SVOCs. Ventilation can indirectly affect some COC levels in buildings through its impact on humidity which can affect the risk of biological contamination and the emission rates of formaldehyde. The American Society of Heating, Refrigerating and Air-Conditioning Engineers has published a ventilation standards document 62.1-2010 (ASHRAE 2010), which classifies commercial buildings into the following types: Correctional facilities; educational facilities; food and beverage services; hotels, motels resorts, and dormitories; office buildings; miscellaneous spaces; public assembly spaces; retail stores; and sports and entertainment. Given the range of commercial buildings considered under this study, the contaminant sources and their concentrations could vary depending on many factors including human activities and use of the buildings.

As a first step in identifying the contaminants of concern, we carried out and summarize here a literature review. We searched for studies that report concentrations of VOCs in commercial

buildings in the U.S. (restricted to studies published after the 1990's). Details of this review are presented in Table 1 and the Appendix. The studies included in the literature review were carried out in a variety of commercial buildings: office buildings (BASE study, Daisey et al. 1994, SMCB 2010, East End 2006, Shields et al. 1996), retail buildings (Loh et al. 2006, Hotchi et al. 2006, Eklund et al. 2008) and schools (California Schools 2003, Godwin et al. 2006, Shendell et al. 2004, and Hodgson et al. 2004). Most of the reviewed studies were cross-sectional. However, Eklund et al. (2008) and East End (2006) followed the buildings over time to assess changes in VOC concentrations. Sampling times varied between studies, however, the studies mostly employed active sampling methods to measure VOC concentrations.

We created a master list of COCs, which included all the VOCs identified from the literature review, and split the list into two lists based on screening. The COCs of greater interest in the context of this study are included in List A. To identify List A COCs, we use a two-step screening process. In the two-step process, the first screening uses toxicity thresholds (non-cancer, reproductive, cancer) and perception of air quality (odor and pungency thresholds) to determine the compounds whose concentrations exceed any thresholds. The second screen makes use of a fugacity-based mass balance model to assess the impact of ventilation on concentration of compounds in buildings. *Compounds that pass the two screens are included in List A.* All other COCs on the master list, which do not pass the screens for List A, are included in List B. Additionally, the compounds in List B, were classified into groups B1, B2, B3 and B4.

List B1 compounds were found to exceed more than one toxicity/perception threshold, but their concentrations were not found to be impacted by the ventilation.

List B2 compounds were found to exceed exactly one toxicity/perception threshold, and their concentrations were not found to be impacted by ventilation.

List B3 compounds did not exceed any toxicity/perception threshold, however their concentrations were found to be impacted by ventilation.

List B4 comprised of remaining compounds, which did not exceed toxicity/perception thresholds, nor found to be impacted by ventilation.

METHODS OF SCREENING FOR CONTAMINANTS OF CONCERN

In order to identify contaminants of concern we applied three screening criteria. First we compared observed indoor concentrations to health-based concentration levels. The levels we used are those established to protect the general population from acute health hazards, reproductive toxicity, and cancer. Second we compared observed indoor concentrations to odor and pungency threshold levels. The third step is to sort the initial list of observed chemicals according to how effective ventilation can be in removing them from the indoor environment. In the sections below we describe this screen process in more detail.

Health-related thresholds for indoor VOC contaminants of concern - Overview

To determine which compounds pose a potential health concern for indoor spaces, we compared measured air concentrations of the compounds reported in various studies to the *most health*

protective standards set by cognizant authorities. Numerous agencies such as the federal Occupational Safety and Health Administration (OSHA), the California Office of Environmental Health Hazard Assessment (OEHHA), Agency for Toxic Substances and Disease Registry (ATSDR), and the United States Environmental Protection Agency (USEPA) have established health guidelines for various compounds. OSHA's permissible exposure limits (PELS) for workers, were largely adopted from the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values. They were adopted around 1968, and most of the numbers remain in effect till today, even though ACGIH has updated its TLVs. OSHA's PELs are geared towards protecting the *"healthy workers"* and do not account for variations in susceptibility and vulnerability in the population.

The California OEHHA has established risk-based Reference Exposure Levels (RELs) (OEHHA 2008), following guidelines in the National Academy of Sciences in its report "Science and Judgment in Risk Assessment". OEHHA has developed the REL numbers based on currently available toxicology and dose-response data applicable to the general population. The general population includes people who are especially susceptible to develop adverse health effects such as the very young, the elderly, pregnant women, and those with acute or chronic illnesses.

The USEPA (USEPA IRIS) has also applied the elements of classic risk assessment framework--(i) hazard identification, (ii) exposure assessment (iii) dose-response and (iv) risk characterization--in order to identify the reference inhalation concentrations (RfC), corresponding to calculated risk safe dose. The RfC is obtained from the no observed adverse effect levels (NOAELs) or lowest observed adverse effect levels (LOAELs) in toxicology experiments combined with safety/uncertainty factors and expected exposure factors. The ATSDR (2009) has also developed maximum recommended [exposure] levels (MRLs) for various compounds, using an approach similar to the USEPA. To make use of these data in our screening, we compiled and compared the non-cancer guidelines developed by these agencies and then selected the most limiting exposure based on a hazard ratio (the actual-dose/safe-dose ratio) to identify contaminants of concern (Table 2 and 3). The lowest chronic thresholds among limits provided by various regulatory agencies (OEHHA's RELs, ATSDR's MRLs, EPA's RfCs) were determined. We used intermediate and acute thresholds when chronic thresholds were not available.

To evaluate compounds on the basis of their potential for reproductive toxicity, we employed the maximum allowable dose level (MADL) developed under Proposition 65 by OEHHA (2010). The MADLs (µg/day) were converted to 24-hour concentrations (µg/m^3) by dividing them with assumed breathing rates (15 m^3/d, Layton 1993).

To address protection against cancer risk we used the No Significant Risk Level (NSRL) standards for inhalation (µg/day) provided under Proposition 65 by OEHHA (2010). Similar to MADLs, the NSRLs are converted to 24-hour concentrations (µg/m^3) by dividing them with breathing rates (15 m^3/d, Layton 1993) and compared to concentrations of interest.

Odor and pungency thresholds-Overview

Occupants of buildings are typically exposed to a wide array of VOCs, and they respond to the indoor levels of these substances based on their sensory perceptions of concentration. Pungency perception is a criteria used to determine *acceptability* of air quality indoors (ASHRAE 1999). According to Cain and Schmidt (2009) there are orders of magnitude variations among odor thresholds of compounds reported in numerous studies. Cain and Schmidt (2009) hypothesize

that systemic variations (experimental procedure, definition of odor threshold used by author) contribute to most of the variations in values compared to random variations. Schmidt and Cain (2010) report that odor thresholds determined using 'vapor delivery device 8' (VDD8), have been consistently found to be orders of magnitude lower than thresholds in current literature. The device allows for sampling of the actual concentration of vapor delivered to the subject, and does not allow for dilution by surrounding air hence reducing bias (see Schmidt and Cain 2010 for more details on VDD8).

However, odor thresholds have been established for very few compounds using the VDD8. Nagata (2003) employed a triangle bag odor method to establish a homogenous odor thresholds database for approximately 220 compounds. Cain and Schmidt (2009) found the odor thresholds of n- and tert-butyl acetate reported by Nagata (2003), to be closest to thresholds determined using the VDD8. Hodgson et al (2003a) conducted an analysis of odor and sensory irritation levels for substances that had been described in terms of odor/sensory irritation and non-cancer health guidelines in the archival literature. From their review, they developed a method to arrive at a reference concentration for both odor/sensor response and non-cancer health effects. These reference levels were compared to residential and office concentrations, which had been compiled earlier (Hodgson et al, 2003). Their analysis showed that some alcohols (1-octanol), carboxylic acids (acetic acid, hexanoic acid), higher molecular weight aldehydes (hexanal, heptanal, octanal, nonanal, 3-methyl butanal) were most odorous (OT<10 ppb). Acrolein, butylated hydroxy toluene, diethyl phthalate, acetic acid and 2-ethyl-1-hexanol had the lowest sensory irritation thresholds.

In the current study we rely primarily on odor and pungency thresholds reported in Cain and Schmidt. (2009), Hodgson et al. (2003a) and Nagata (2003). We selected the lowest thresholds among these studies to screen compounds of concern.

Toxicity, odor and pungency thresholds based screening

We have outlined the procedure followed to develop indices using health endpoints of concern for "safe/acceptable" air. Even though studies report different durations of short-term sampling measurements, we compared the concentrations to chronic thresholds since chronic thresholds are much lower than acute or 8- thresholds. A meta-analysis of VOC concentrations reported in various studies was first conducted to determine the representative concentration of each VOC to be used for screening. The concentrations were arrived at as follows (see Appendix Tables A and B):

- The measure of central tendency reported (mean/median) were compared across all the studies to determine the highest concentration
- If SD was reported along with maximum mean concentration, the 98^{th} percentile value was calculated.
- If 90^{th}/95^{th} percentile/maximum values were reported along with maximum median they were used for the analysis

The health endpoints of concern for "safe/acceptable" air used for screening are a) chronic, (or) intermediate (or), acute non-cancer toxicity thresholds b) cancer toxicity thresholds c) reproductive toxicity thresholds d) odor and pungency thresholds.

We determined whether any VOC concentration was within 90% of the threshold of interest, and developed various indices based on the formulae listed below. The results are tabulated in Table

4, and Tables A and B of the Appendix. If any index was found to exceed 0.1 (as in the case of 30 VOCs), they were subject to the ventilation-impact screen.

Formula	Index
$Conc._{voc}$ / (0.9 × Non-cancer toxicity threshold) =	Non-cancer tox. index
$Conc._{voc}$ / (0.9 × Reproductive toxicity threshold =	Reproductive tox. index
$Conc._{voc}$ / (0.9 × Cancer toxicity threshold) =	Cancer tox. index
$Conc._{voc}$ / (0.9 × Odor toxicity threshold) =	Odor index
$Conc._{voc}$ / (0.9 × Pungency toxicity threshold) =	Pungency index

Ventilation-impact screening

In the screening process it is important to distinguish chemicals based on how well they are removed from a commercial building or school by ventilation. Chemical properties are an important factor in this process. Chemicals with a high chemical affinity for carpets, walls, and furniture will not be effectively removed from the indoor environment by ventilation. In order to rank chemicals in terms of their capacity or recalcitrance for being removed by ventilation, we adapted the indoor mass-balance model of Bennett and Furtaw (2004). The model was modified so that it could be used for commercial environments rather than residential environments and we used it to make relative rankings rather than absolute determinations of chemical mass balance. The Bennett and Furtaw (2004) model is an indoor fugacity model that uses indoor sources or transfers of chemicals from outdoor sources to assess the relative partitioning of chemicals among the major indoor media--air, dust, and surfaces (carpets, vinyl floors, walls, and ceilings). Bennett and Furtaw (2004) showed good comparison of their results with measurements of chlorpyrifos in air and carpets from an independent study. The elements of the Bennett and Furtaw model that are important for our screening study are the model framework for mass balance and the data needed to determine the retention (fugacity) capacities of air, particles, and surfaces. The Bennett and Furtaw model includes mass transfer models, parameters, and materials properties needed to assess chemical partitioning for indoor air (both gas phase and aerosols), carpet, smooth flooring (vinyl), and walls. Although Bennett and Furtaw (2004) used six size fractions of particulate matter with different fate and transport properties, only one size category was used for the assessment here. The compartment-specific fugacity capacities and their mass transfer rate coefficients between compartments listed in Bennet and Furtaw (2004) were used. In order to apply the model to commercial building ventilation effectiveness, a continuous indoor source to air was introduced and only one significant loss mechanism—ventilation was assumed. In the Bennett and Furtaw model algorithms, the uptake and retention of organic chemicals on surfaces is strongly dependent on vapor pressure (VP) of the substances. The highest removal for ventilation regardless of other chemical properties is for a substance with a vapor pressure of 1 atmosphere (101,325 Pa). Simulations were run with a large range of vapor pressure values to rank the ventilation effectiveness of organic chemicals with VP below 101,325 Pa relative to one with a VP=101,325 Pa. The results are shown in Figure 1 where one can see that ventilation effectiveness rapidly falls with VP. Once the VP is below *7000 Pa (or approximately 50 mm Hg)*, the ventilation effectiveness is lower than 30% percent—indicating that the persistence of these substances indoors may only be weakly impacted by ventilation. The contaminants which pass this screen in addition to the toxicity screen, are included in List A.

RESULTS

The following tables provide the primary results of this analysis with more details provided in Tables 1-3 and the Appendix..

List A VOCs

Acetaldehyde*	Dichloromethane (methylene chloride)*
Benzene*	Formaldehyde*
1,3-Butadiene*	Propanal*
Carbon tetrachloride*	Trichloroethene (Trichloroethylene)*
Chloroform*	3-Methylbutyraldehyde*

*- Compounds which have significant indoor sources

List B1 VOCs

1,4-Dichlorobenzene	Ethylbenzene	Naphthalene	Toluene	mp-xylene

List B2 VOCs

Butylacetate	Nonanal	Tetrachloroethane	2-Heptanone
Decanal	Octanal	Tetrachloroethene	Hexanoic acid
Hexanal	Pentanal (valeraldehyde)	1,2,3-trichloropropane	Propylene Glycol
d-Limonene	α-pinene	2-Ethoxyethyl acetate	

List B3 VOCs

Acrolein	Carbon disulfide	Ethyl acetate	Tetrahydrofuran
Acrylonitrile	Chloromethane	n-Hexane	1,1,1-Trichloroethane (Methyl chloroform)
Bromomethane (methyl bromide)	Dichlorodifluoromethane	Methylcyclopentane	Trichlorofluoromethane
2-Butanone	1,2-Dichloroethane (ethylene dichloride)	3-Methylhexane	Trichlorotrifluoroethane
t-Butyl methyl ether (MTBE)	1,2-Dichloropropane	Pentane	1,2-dichloropropane
n-Butyraldehyde	Ethanol	2-Propanone (acetone)	Ethenyl acetate

List B4 VOCs

Acetophenone	n-Hexadecane	TMPD-DIB	1-Butoxy-2-Propanol
Benzaldehyde	Methylcyclohexane	TMPB-MIB	1-Piperidinecarboxaldehyde
1-Butanol	1-Methyl-2-pyrrolidinone	1,2,4-Trichlorobenzene	2-(2-Ethoxyethoxy) Ethanol
2-Butoxyethanol	4-methyl-2-pentanone (MIBK)	1,2,4-Trimethylbenzene	2-Ethyl-1-hexanoic Acid
p-Cymene	Nonane	1,2,3-Trimethylbenzene	Benzoic Acid
n-Decane	Octane	1,3,5-Trimethylbenzene	Longifolene
1,3-Dichlorobenzene	n-Pentadecane	2,2,5-Trimethylhexane	Menthol
Diethyl phthalate	Phenol	n-Undecane	N,N-Dibutyl Formamide
Di(ethylene glycol) butyl ether	β-pinene	o-xylene	N-butyl-1-Butanamine
Di(propylene glycol)methyl ethers (DPGME)	Styrene	1,2,3-trichlorobenzene	Nonanoic acid
Dodecane	D4 Siloxane	β-Methacrolein	Tridecane
2-Ethyl-1-hexanol	D5 siloxane	4-methylbenzaldehyde	
2-Ethyltoluene	Terpineols	op-tolualdehyde	
4-Ethyltoluene	n-Tetradecane	Caprolactam	

DISCUSSION:

This was a screening analysis to identify contaminants of concern in commercial buildings in California. The screening is largely based on studies which have reported VOC concentrations in office buildings in USA. Numerous guidelines were used for the screening assessment: non-cancer acute, intermediate and chronic toxicity, odor and irritancy thresholds, reproductive toxicity, and cancer potency. The most health protective guidelines issued were used. For the second screening process, a fugacity-based model was also used to assess the impact of ventilation on VOC concentration. The compounds were grouped into priority Lists A and B. Priority List A contains about 10 VOCs which have exceeded any health-based threshold, and whose indoor concentrations are expected to be substantially affected by ventilation. *In other words, List A compounds meet both of the two screening criteria used*. All other compounds (about 86) of interest which were reported in earlier studies were included in priority List B. They were classified into groups B1, B2, B3 and B4, based on whether they exceed odor/perception thresholds or how the concentrations are impacted by ventilation.

VOCs included on List A are sometimes present in commercial buildings at concentrations that may pose risks to health or degrade perceived air quality. These VOCs also have the physical characteristics that make their indoor concentration susceptible to changes in ventilation rates. However, their significance with respect to the setting of minimum ventilation standards will also depend on whether the primary sources are indoors, or the outdoor air. This factor will be considered in future phases of this work. Numerous compounds in indoor air may have not been

identified, and other compounds do not have established health thresholds. One of the limitations of this analysis is that, we have only looked at compounds which have been reported in previous studies, which makes the lists somewhat restrictive.

This analysis only considered gaseous or semi-volatile contaminants. Particulate contaminants and inorganic gaseous pollutants have not yet been considered. Particles emitted from indoor sources are expected to pose health risks. Much is known about the health impacts of outdoor air particles but relatively little is known about the magnitude of the risks from indoor-generated particles. In general, dilution ventilation will be a poor strategy for controlling indoor concentrations of indoor-generated particles in commercial buildings however local exhaust ventilation is often used to remove particles and other pollutants near strong indoor sources such as cooking and combustion. If the building has no particle filtration or only very low efficiency filtration, increased dilution ventilation will remove indoor-generated particles from the indoor air but bring in outdoor air particles. If a building has a moderate or high rate of particle filtration, which is common in commercial buildings, the ventilation rate will have a small impact on indoor concentrations of particles because particle removal by filtration dominates relative to particle removal by ventilation. Inorganic gaseous pollutants such as carbon monoxide, nitrogen oxides, ozone, and radon also pose health risks. In general, the sources of these pollutants are small in commercial buildings, with outdoor air as the primary sources for all, or for all except radon. Consequently, risks from these contaminants are not expected to be a factor that drives the selection of minimum ventilation rates in most commercial buildings. However, further analyses are needed to determine if there are exceptions in which these contaminants must be considered. Commercial buildings with combustion based cooking may be an exception – as the combustion processes may be a significant source of inorganic gaseous contaminants, and the effectiveness of any local exhaust ventilation may need to be considered.

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REFERENCES

1) American Society of Heating, Refrigerating and Air-Conditioning Engineers (2010). ANSI/ASHRAE Standard 62.1-2010, Ventilation for Acceptable Indoor Air Quality: ASHRAE, Atlanta.
2) Apte MG and Erdmann CA (2002). Associations of Indoor Carbon Dioxide Concentrations, VOCs, and Environmental Susceptibilities with Mucous Membrane and Lower Respiratory Sick Building Syndrome Symptoms in the BASE Study: Analyses if the 100 Building Dataset, LBNL-51570, Lawrence Berkeley National Laboratory, University of California, Berkeley, CA 94720.
3) ATSDR (2009). Agency for Toxic Substances and Disease Registry, Atlanta, GA. Minimum Risk Levels. December 2009. Web site: http://www.atsdr.cdc.gov/mrls/index.asp.
4) Cometto-Muñiz, J. E. and M. H. Abraham (2009). Olfactory detectability of homologous n-alkylbenzenes as reflected by concentration-detection functions in humans. Neuroscience 161(1): 236-248.
5) Daisey JM, Hodgson AT, Fisk WJ, Mendell MJ and Ten Brinke J. (1994). Volatile organic compounds in twelve California office buildings: classes, concentrations and sources. Atmospheric Environment. 28: 3557-3562.
6) BASE Website, http://www.epa.gov/iaq/largebldgs/index.html.
7) Bennett, D. H. and E. J. Furtaw (2004). Fugacity-Based Indoor Residential Pesticide Fate Model. Environmental Science & Technology 38(7): 2142-2152.
8) Bennett, Deborah, Apte, Michael, Wu, Xiangmei (May), Trout, Amber, Faulkner, Dave, Maddalena, Randy, Sullivan, Doug (University of California Davis). 2010. Indoor Environmental Quality and HVAC Survey of Small and Medium Size Commercial Buildings. California Energy Commission. Publication number: Pending.
9) Cain, W. S. and R. Schmidt (2009). "Can we trust odor databases? Example of t- and n-butyl acetate." Atmospheric Environment 43(16): 2591-2601.
10) Eklund, B.M., Burkes S, Morris P, and Mosconi L (2008). Spatial and temporal variability in VOC levels within a commercial retail building. Indoor Air 18: 365–374.
11) EPISUITE, U.S. EPA (2011). Estimation Programs Interface Suite™ for Microsoft® Windows, v 4.10. United States Environmental Protection Agency, Washington, DC, USA.
12) Godwin, C. and S. Batterman (2007). Indoor air quality in Michigan schools. Indoor Air 17(2): 109-121.
13) Hodgson, A.T., and Levin, H. (2003). Volatile organic compounds in indoor air: a review of concentrations measured in North America since 1990. Report LBNL-51715, Lawrence Berkeley National Laboratory, Berkeley, CA.
14) Hodgson AT, Levin H (2003a). Classification of measured indoor volatile organic compounds based on noncancer health and comfort considerations. LBNL technical paper, LBNL-53308, 38 pp.
15) Hodgson, A. T., D. G. Shendell, et al. (2004). Comparison of predicted and derived measures of volatile organic compounds inside four new relocatable classrooms. Indoor Air 14: 135-144.
16) Hotchi T, Hodgson AT, Fisk WJ (2006). Indoor air quality impacts of a peak load shedding strategy for a large retail building. LBNL technical paper LBNL-59293, 17 pp.
17) Layton, D.W. Metabolically consistent breathing rates for use in dose assessments. Health Physics 1993, 64, 23-36
18) Loh, M. M., E. A. Houseman, et al. (2006). Measured Concentrations of VOCs in Several Non-Residential Microenvironments in the United States. Environmental Science & Technology 40(22): 6903-6911.

19) Nagata, Y. Measurement of odor threshold by triangle odor bag method. Odor measurement review. Office of Odor, Noise and Vibration. Environmental Management Bureau, Ministry of Environment, Tokyo, Tokyo (2003), pp. 118–127.
20) OEHHA (2010). Office of Environmental Health Hazard Assessment, CA. PROP 65 Safe Habor Levels: No Significant Risk Levels for Carcinogens and Maximum Allowable Dose Levels for Chemicals Causing Reproductive Toxicity. Web site: http://oehha.ca.gov/prop65/pdf/2010NovemberStatus.pdf.
21) OEHHA (2008). Office of Environmental Health Hazard Assessment, CA. All OEHHA Acute, 8-hour and Chronic Reference Exposure Levels (chRELs) October 2008. Web site: http://www.oehha.ca.gov/air/allrels.html
22) Schmidt, R. and W. S. Cain Making Scents: Dynamic Olfactometry for Threshold Measurement. Chemical Senses 35(2): 109-120.
23) Shendell, D. G., A. M. Winer, et al. (2004). Evidence of inadequate ventilation in portable classrooms: results of a pilot study in Los Angeles County. Indoor Air 14(3): 154-158.
24) Shields HC, Fleischer DM and Weschler CJ. (1996). Comparisons among VOCs measured in three types of U.S. commercial buildings with different occupant densities. Indoor Air 6: 2-17.
25) U.S. EPA IRIS. Integrated Risk Information System. Office of Research and Development, National Center for Environmental Assessment, U.S. Environmental Protection Agency, Washington, DC. U.S. EPA IRIS web site: http://www.epa.gov/iriswebp/iris/.

TABLES:

Table 1: Details of key studies which report VOC measurements

Study	Number of buildings	Sample period
Apte et al (2002)	100 office buildings	1994 - 1998
Hotchi et al (2006)	1 retail store	October 2005
Daisey et al (1994)	12 office buildings	June - September, 1990
Eklund et al (2008)	1 strip mall	October 2002 - June 2005
Loh et al (2006)	12 Stores, dining	Summer 2004, Winter 2004, Winter 2005
SMCB (2010)	37 small and medium commercial buildings	2008-2010
Shields (1994)	60 Telecommunications offices, data centers and office building	March - April 1991
East End (2006)	5 office buildings	2002-2004
Godwin et al. (2006)	64 elementary and middle school classrooms	March – June 2003
Shendell et al. (2004)	13 portable classrooms and 7 traditional classrooms	June 2000-June 2001
California Schools (2004)	201 portable and traditional classrooms	2000-2003
Hodgson et al. (2004)	4 relocatable classrooms	Fall 2001

Table 2: VOCs of interest reported in previous studies, and their chemical properties

Compound	CAS No.	Chem. Class[1]	VP[2]	Mol.Wt[2]	Schools[3]	Other commercial buildings[4]
			mm Hg	g/mol		
Acetaldehyde	75-07-0	Ald	902	20	CAS,LAS, 4PC	L,B,T,S,EE
Acetic acid	64-19-7	Acid	16	118		
Acetophenone	98-86-2	Ket	0.4	120		T,D,Sh,EE
Acrolein	107-02-8	Ald	274	53		
Acrylonitrile	107-13-1	Misc	109	53		
Benzene	71-43-2	Arom	95	80	CAS,LAS, MS	L,B,D,Ek,S,EE
Benzaldehyde	100-52-7	AromAld	1	179	CAS	T,D,S,EE
Benzyl chloride	100-44-7	HaloAro	1	127		
Bromomethane (methyl bromide)	74-83-9	Halo	1620	95		
1,3-Butadiene	106-99-0	Alke	2110	54		L
1-Butanol	71-36-3	Alc	7	118		B,T,EE
2-Butanone	78-93-3	Ket	91	80	MS,4PC	B,T,Ek,EE
2-Butoxyethanol	111-76-2	Gly	1	171		B,T,D,Sh,S,EE
Butylacetate	123-86-4	Est	12	126		B,T,D,EE
Butylated hydroxytoluene	128-37-0	AromAlc	0.01	265		
Butylbenzene	104-51-8	Arom	1	134		
t-Butyl methyl ether (MTBE)	1634-04-4	Ethr	250	20	LAS,	L,Ek,EE
n-Butyraldehyde	123-72-8	Ald	111	72	CAS	EE
Carbon disulfide	75-15-0	Misc	359	76		
Carbon tetrachloride	56-23-5	Halo	115	154	CAS,LAS,	L,Ek,S
Chlorobenzene	108-90-7	HaloAro	12	113		
Chloroform	67-66-3	Halo	197	119	CAS,LAS, MS	L,Ek,S,EE
Chloromethane	74-87-3	Halo	4300	50		B,Ek
Cyclohexanone	108-94-1	Ket	4	156		
p-Cymene	99-87-6	Alke	2	177	MS	
n-Decane	124-18-5	Alka	1	174		B,T,D,Sh,EE
Decanal	112-31-2	Ald	0.1	156	4PC	S,EE
1,2-Dichlorobenzene	95-50-1	HaloAro	1	147		
1,3-Dichlorobenzene	541-73-1	HaloAro	2	147	MS	
1,4-Dichlorobenzene	106-46-7	HaloAro	2	147	LAS	L,B,T,S,EE
Dichlorodifluoromethane	75-71-8	HaloAro	4850	121		B,Ek
1,2-Dichloroethane (ethylene dichloride)	107-06-2	Halo	79	99		
Dichloromethane (methylene chloride)	75-09-2	Halo	435	85	LAS	L,T,D,Ek,S,EE
1,2-Dichloropropane	78-87-5	Halo	53	113		

Table 2: VOCs of interest reported in previous studies, and their chemical properties

Compound	CAS No.	Chem. Class[1]	VP[2]	Mol.Wt[2]	Schools[3]	Other commercial buildings[4]
			mm Hg	g/mol		
Diethyl phthalate	84-66-2	Est	0.002	298		S
Di(ethylene glycol) butyl ether	112-34-5	Est	0.02	162		T,EE
1,4-Dioxane	123-91-1	Ethr	38	101		
Di(propylene glycol)methyl ethers (DPGME)	34590-94-8	Ethr	1	148		T
Dodecane	112-40-3	Alka	0.1	216		B,T,D,Sh,EE
Ethanol	64-17-5	Alc	59	78		T,D,Ek
Ethyl acetate	141-78-6	Est	93	77		B,D,Ek,EE
Ethylbenzene	100-41-4	Arom	10	136	CAS,LAS, MS	L,B,D,Ek,Sh,S,EE
2-Ethyl-1-hexanol	104-76-7	Alc	0.1	183		B,T,EE
2-Ethyltoluene	611-14-3	Arom	3	120		D,H,EE
3/4-Ethyltoluene	620-14-4	Arom	3	120		EE
4-Ethyltoluene	622-96-8	Arom	3	120		B,EE
Ethylene glycol	107-21-1	Gly	0.1	19		EE
Formaldehyde	50-00-0	Ald	3890	30	CAS,LAS, 4PC	L,B,T,S,EE
n-Heptane	142-82-5	Alka	46	98		D,Ek,EE
n-Hexadecane	544-76-3	Alka	0	287		Sh,EE
n-Hexane	110-54-3	Alka	151	69		B,D,Ek,S,EE
Hexanal	66-25-1	Ald	11	128	CAS,4PC	B,T,D,S,EE
Isopropylbenzene	98-82-8	Arom	5	120		
d-Limonene	5989-27-5	Alke	1	177	LAS,MS	B,T,D,Sh,S,EE
Methylcyclohexane	108-87-2	Alke	46	100		D,H,EE
Methylcyclopentane	96-37-7	Alke	138	72		D,H
3-Methylhexane	589-34-4	Alke	62	91		D,H,EE
1-Methyl-2-pyrrolidinone	872-50-4	Misc	0.3	99	4PC	EE
4-methyl-2-pentanone (MIBK)	108-10-1	Ket	20	117	MS	B,T,Ek,EE
Naphthalene	91-20-3	Arom	0.1	128	MS,4PC	B,T,S,EE
Nonanal	124-19-6	Ald	0.4	195	4PC	B,S,EE
Nonane	111-84-2	Alka	4	151		B,T,D,EE
Octane	111-65-9	Alka	14	126		B,D,Sh,EE
Octanal	124-13-0	Ald	1	174		T,S,EE
n-Pentadecane	629-62-9	Alka	0.003	270		Sh,EE
Pentanal (valeraldehyde)	110-62-3	Ald	26	103	CAS	B,T,D,EE
Pentane	109-66-0	Alka	514	36		D
Phenol	108-95-2	Alc	0.4	182	MS,4PC	B,T,S,EE
4-Phenylcyclohexene	4994-16-5	Alke	0.05	158	4PC	

Table 2: VOCs of interest reported in previous studies, and their chemical properties

Compound	CAS No.	Chem. Class[1]	VP[2]	Mol.Wt[2]	Schools[3]	Other commercial buildings[4]
			mm Hg	g/mol		
α-pinene	80-56-8	Terp	5	155	LAS,MS	B,Sh,S,EE
β-pinene	127-91-3	Terp	3	166	LAS	
Propanal	123-38-6	Ald	317	58	CAS	EE
2-Propanol (isopropanol)	67-63-0	Alc	45	82		T,D,Ek,EE
2-Propanone (acetone)	67-64-1	Ket	232	56		B,T,D,Ek,S,EE
n-Propylbenzene	103-65-1	Arom	3	120		EE
Styrene	100-42-5	Arom	6	145	MS	L,B,D,Ek,S,EE
D4 Siloxane	556-67-2	Est	1	297		Sh,EE
D5 siloxane[7]	541-02-6	Est	0.2	371		T,Sh,S,EE
Terpineols	98-55-5	TerpAlc	0.04	154	4PC	S
Tetrachloroethane	79-34-5	Halo	13	168		D
Tetrachloroethene	127-18-4	Halo	19	166	CAS,LAS, MS	L,B,T,Ek,Sh,EE
n-Tetradecane	629-59-4	Alka	0.01	252		Sh,EE
Tetrahydrofuran	109-99-9	Misc	162	72	MS,	Ek
TMPD-DIB[5]	6846-50-0	Est	0.009	280		B,T,S,EE
TMPB-MIB[6]	25265-77-4	Est	0.010	244		B,EE
Toluene	108-88-3	Arom	28	111	CAS,LAS, MS,4PC	L,B,T,D,Ek,Sh,S,EE
1,2,4-Trichlorobenzene	120-82-1	HaloAro	0.5	181	MS	
1,1,1-Trichloroethane (Methyl chloroform)	71-55-6	Halo	124	133	CAS	B,T,D,S,EE
Trichloroethene (Trichloroethylene)	79-01-6	Halo	69	131	MS	L,D,Ek,S
Trichlorofluoromethane	75-69-4	Halo	803	137		T,D,Ek,EE
Trichlorotrifluoroethane	76-13-1	Halo	363	187		Ek
1,2,4-Trimethylbenzene	95-63-6	HaloAro	2	120	MS,4PC	B,T,D,Ek,Sh,EE
1,2,3-Trimethylbenzene	526-73-8	HaloAro	2	120		D,H,EE
1,3,5-Trimethylbenzene	108-67-8	HaloAro	2	120	MS	B,D,Ek,EE
Trimethylcyclohexenone	78-59-1	Misc	0.4	138		
2,2,5-Trimethylhexane	3522-94-9	Alka	17	124		D,H
2,2,4-Trimethylpentane	540-84-1	Alka	49	114		Ek
n-Undecane	1120-21-4	Alka	0.4	196		B,T,D,Sh,EE
o-xylene	95-47-6	Arom	8	106	CAS,LAS, MS	L,B,D,S,EE
mp-xylene	1330-20-7	Arom	8	106	CAS,LAS, MS	L,B,T,D,Ek,Sh,S,EE
1,2,3-trichlorobenzene	87-61-6	HaloAro	0.2	181	MS	
1,2,3-trichloropropane	96-18-4	Halo	4	147	MS	
β-Methacrolein	4170-30-3	Ald	30	70	CAS	
3-Methylbutyraldehyde	590-86-3	Ald	50	86	CAS	EE

Table 2: VOCs of interest reported in previous studies, and their chemical properties

Compound	CAS No.	Chem. Class[1]	VP[2]	Mol.Wt[2]	Schools[3]	Other commercial buildings[4]
			mm Hg	g/mol		
2,5-Dimethylbenzaldehyde	5779-94-2	Ald	0.1	134	CAS	
4-methylbenzaldehyde	620-23-5	Ald	0.4	120	CAS	
op-tolualdehyde	529-20-4	Ald	0.4	120	CAS	
Caprolactam	105-60-2	Ket	0.002	113	4PC	EE
1,2-dichloropropane	78-87-5	Halo	53	113		
Ethenyl acetate	108-05-4	Est	90	86	4PC	
1-Butoxy-2-Propanol	5131-66-8	Alc	0.4	132		EE
1-Piperidinecarboxaldehyde	2591-86-8	Ald	0.1	204		EE
2-(2-Ethoxyethoxy) Ethanol	111-90-0	Alc	0.1	134		EE
2-Ethoxyethyl acetate	111-15-9	Acid	2	132		EE
2-Ethyl-1-hexanoic Acid	149-57-5	Acid	0.0	144		EE
2-Heptanone	110-43-0	Ket	3.9	114		EE
Benzoic Acid	65-85-0	Acid	0.001	122		EE
Hexanoic acid	142-62-1	Acid	0.044	206		EE
Longifolene	475-20-7	Ket	0.02	204		EE
Menthol	89-78-1	Alc	0.06	156		EE
N,N-Dibutyl Formamide	761-65-9	Amine	0.03	157		EE
N-butyl-1-Butanamine	111-92-2	Amine	3	129		EE
Nonanoic acid	112-05-0	Acid	0.002	172		EE
Propylene Glycol	57-55-6	Alc	0.1	76		EE
Tridecane	629-50-5	Alka	0.1	184		EE

Notes: 1) 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.

2) Vapor pressure and molecular weight were generated using EPISUITE

3) CAS-CADPH (2004), MS-Godwin et al. (2007), LAS-Shendell et al. (2004), 4PC-Hodgson et al. (2004)

4) L-Loh et al. (2007), B-Apte et al. (2000), T-Hotchi et al. (2007), S-SMCB (2010), D-Daisey et al. (1994), Sh-Shields et al. (1992), Ek-Eklund et al. (2007), EE-East End (2003)

5) 2,2,4-Trimethyl-1,3-pentanediol monisobutyrate (combined isomers 1 & 3)

6) 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate

7) Decamethylcyclopentasiloxane

Table 3 - Toxicity, odor and pungency thresholds for VOCs of interest

Compound	Non-cancer Thresh.[1]	Level[2]	Source[3]	Rep. toxi. Thresh.[4]	Cancer Thresh.[4]	Source[5]	Odor Thresh.[6]	Source[7]	Pung. Thresh.	Source[7]
				µg/day	µg/day		ppb		ppb	
Acetaldehyde	0.009 mg/m^3	C	EPA		90	OEHHA	2	Na.		
Acetic acid							1	Ho.	130	Ho.
Acetophenone							360	Ho.	1000	Ho.
Acrolein	0.00002 mg/m^3	C	EPA				4	Na.	0.08	Ho.
Acrylonitrile	0.002 mg/m^3	C	EPA		0.7	OEHHA	8800	Na.		
Benzene	3 ppb	C	ATSDR	49	13	OEHHA	2700	Na.		
Benzaldehyde							42	Ho.		
Benzyl chloride	240 µg/m^3	A	OEHHA		4	OEHHA				
Bromomethane (methyl bromide)	0.005 mg/m^3	C	EPA	810		OEHHA				
1,3-Butadiene	0.002 mg/m^3	C	EPA		0.4	OEHHA	230	Na.		
1-Butanol							8	Ca.		
2-Butanone	5 mg/m^3	C	EPA							
2-Butoxyethanol	1.6 mg/m^3	C	EPA				340	Ho.		
Butylacetate							2	Ca.		
Butylated hydroxytoluene									22	Ho.
Butylbenzene							3	Ca.		
t-Butyl methyl ether (MTBE)	700 ppb	C	ATSDR							
Carbon disulfide	0.7 mg/m^3	C	EPA				96	Ho.		
Carbon tetrachloride	40 µg/m^3	C	OEHHA		5	OEHHA	4600	Na.		
Chlorobenzene	1000 µg/m^3	C	OEHHA							
Chloroform	20 ppb	C	ATSDR		40	OEHHA	3800	Na.		
Chloromethane	0.09 mg/m^3	C	EPA							
Cyclohexanone							710	Ho.		
p-Cymene							130	Ho.		
n-Decane							620	Na.		
Decanal							0.4	Na.		
1,2-Dichlorobenzene							72	Ho.	570	Ho.
1,4-Dichlorobenzene	10 ppb	C	ATSDR		20	OEHHA	48	Ho.	570	Ho.
1,2-Dichloroethane (ethylene dichloride)	400 µg/m^3	C	OEHHA		10	OEHHA				
Dichloromethane (methylene chloride)	400 µg/m^3	C	OEHHA		200	OEHHA				
1,2-Dichloropropane	0.004 mg/m^3	C	EPA		9.7	OEHHA				

Table 3 - Toxicity, odor and pungency thresholds for VOCs of interest

Compound	Non-cancer Thresh.[1]	Level[2]	Source[3]	Rep. toxi. Thresh.[4]	Cancer Thresh.[4]	Source[5]	Odor Thresh.[6]	Source[7]	Pung. Thresh.	Source[7]
				µg/day	µg/day		ppb		ppb	
Diethyl phthalate									55	Ho.
1,4-Dioxane	1000 ppb	C	ATSDR		30	OEHHA			830	Ho.
Dodecane							110	Na.		
Ethanol							331	Ca.		
Ethyl acetate							269	Ca.		
Ethylbenzene	1 mg/m^3	C	EPA		41	OEHHA	7	Ca.		
2-Ethyl-1-hexanol							240	Ho.	140	Ho.
2-Ethyltoluene							74	Na.		
3/4-Ethyltoluene							18	Na.		
4-Ethyltoluene							8	Na.		
Ethylene glycol	400 µg/m^3	C	OEHHA							
Formaldehyde	9 µg/m3	C	OEHHA		40	OEHHA	500	Na.	77	Ho.
n-Heptane							670	Na.		
n-Hexane	0.7 mg/m^3	C	EPA				1500	Na.		
Hexanal							8	Ho.		
Isopropylbenzene							8	Na.		
d-Limonene							16	Ca.		
3-Methylbutyraldehyde							0.1	Na.		
Methylcyclohexane							150	Na.		
Methylcyclopentane							1700	Na.		
3-Methylhexane							840	Na.		
1-Methyl-2-pyrrolidinone				3200		OEHHA				
4-methyl-2-pentanone (MIBK)	3 mg/m^3	C	EPA				170	Na.		
β-Methacrolein							23	Na.		
Naphthalene	0.003 mg/m^3	C	EPA		5.8	OEHHA	15	Ho.		
Nonanal							0.3	Na.		
Octane							1700	Na.		
Octanal							0.01	Na.		
Pentanal (valeraldehyde)							0	Na.		
Pentane							1400	Na.		
Phenol	200 µg/m^3	C	OEHHA				6	Na.		
α-pinene							18	Na.		
β-pinene							33	Na.		
Propanal							1	Na.		
2-Propanol (isopropanol)	7000 µg/m^3	C	OEHHA				26000	Na.		

Table 3 - Toxicity, odor and pungency thresholds for VOCs of interest

Compound	Non-cancer Thresh.[1]	Level[2]	Source[3]	Rep. toxi. Thresh.[4]	Cancer Thresh.[4]	Source[5]	Odor Thresh.[6]	Source[7]	Pung. Thresh.	Source[7]
				µg/day	µg/day		ppb		ppb	
2-Propanone (acetone)	13000 ppb	C	ATSDR				884	Ca.		
n-Propylbenzene							4	Na.		
Styrene	200 ppb	C	ATSDR				35	Na.		
Tetrachloroethane					3	OEHHA				
Tetrachloroethene	40 ppb	C	ATSDR		14	OEHHA	770	Na.		
Toluene	300 µg/m^3	C	OEHHA	7000		OEHHA	88	Ca.		
1,2,4-Trichlorobenzene									500	Ho.
1,1,1-Trichloroethane (Methyl chloroform)	1000 µg/m^3	C	OEHHA							
Trichloroethene (Trichloroethylene)	600 µg/m^3	C	OEHHA		80	OEHHA	3900	Na.		
1,2,3-Trichloropropane	0.0003 mg/m^3	C	EPA							
1,2,4-Trimethylbenzene							120	Na.		
1,3,5-Trimethylbenzene							170	Na.		
Trimethylcyclohexenone	2000 µg/m^3	C	OEHHA							
2,2,5-Trimethylhexane							900	Na.		
2,2,4-Trimethylpentane							670	Na.		
n-Undecane							870	Na.		
o-xylene	50 ppb	C	ATSDR				380	Na.		
mp-xylene	0.1 mg/m^3	C	EPA				41	Na.		
1-Butoxy-2-Propanol							160	Na.		
2-Ethoxyethyl acetate	140 µg/m^3	A	OEHHA	1400		OEHHA	49	Na.		
2-Heptanone							5	Ca.		
Hexanoic acid							1	Na.		
Propylene Glycol	9 ppb	I	ATSDR							

Notes: 1) Non-cancer Thresh. - Lowest available non-cancer threshold set by regulatory agencies.
2) Level: C-Chronic threshold, I-Intermediate threshold, A-Acute threshold.
3) Sources: EPA-U.S EPA IRIS, OEHHA-OEHHA (2008, 2010), ATSDR-ATSDR (2009).
4) Rep. toxi. Thresh. - Reproductive toxicity threshold (Maximum allowable daily limit) set by OEHHA.
5) Cancer Thresh. - Cancer toxicity threshold (No significant risk level) set by OEHHA.
6) Odor. Thresh. - Odor Thresholds for compounds.
7) Source: Ho.-Hodgson et al. (2003a), Na.-Nagata et al. (2003).

Table 4 : Results of screening and priority List A and B

Compound	Non-cancer toxi. Index	Rep. toxi. Index	Cancer toxi. Index	Odor Index	Pungency Index	Ventilation-impacted? VP>50 mm Hg	List A	List B
	>=0.1 ?							
Acetaldehyde	**x**		**x**	**x**		**x**	**x**	
Acetophenone								**x**
Benzene	**x**	**x**	**x**			**x**	**x**	
Benzaldehyde								**x**
1,3-Butadiene	**x**		**x**	**x**		**x**	**x**	
1-Butanol								**x**
2-Butanone						**x**		**x**
2-Butoxyethanol								**x**
Butylacetate				**x**				**x**
t-Butyl methyl ether (MTBE)						**x**		**x**
n-Butyraldehyde						**x**		**x**
Carbon tetrachloride			**x**			**x**	**x**	
Chloroform			**x**			**x**	**x**	
Chloromethane						**x**		**x**
p-Cymene								**x**
n-Decane								**x**
Decanal				**x**				**x**
1,3-Dichlorobenzene								**x**
1,4-Dichlorobenzene	**x**		**x**	**x**				**x**
Dichlorodifluoromethane						**x**		**x**
Dichloromethane (methylene chloride)			**x**			**x**	**x**	
Diethyl phthalate								**x**
Di(ethylene glycol) butyl ether								**x**
Di(propylene glycol)methyl ethers (DPGME)								**x**
Dodecane								**x**
Ethyl acetate						**x**		**x**
Ethylbenzene			**x**	**x**				**x**
2-Ethyl-1-hexanol								**x**
2-Ethyltoluene								**x**
4-Ethyltoluene								**x**
Formaldehyde	**x**		**x**		**x**	**x**	**x**	
n-Hexadecane								**x**
n-Hexane						**x**		**x**
Hexanal				**x**				**x**

Table 4 : Results of screening and priority List A and B

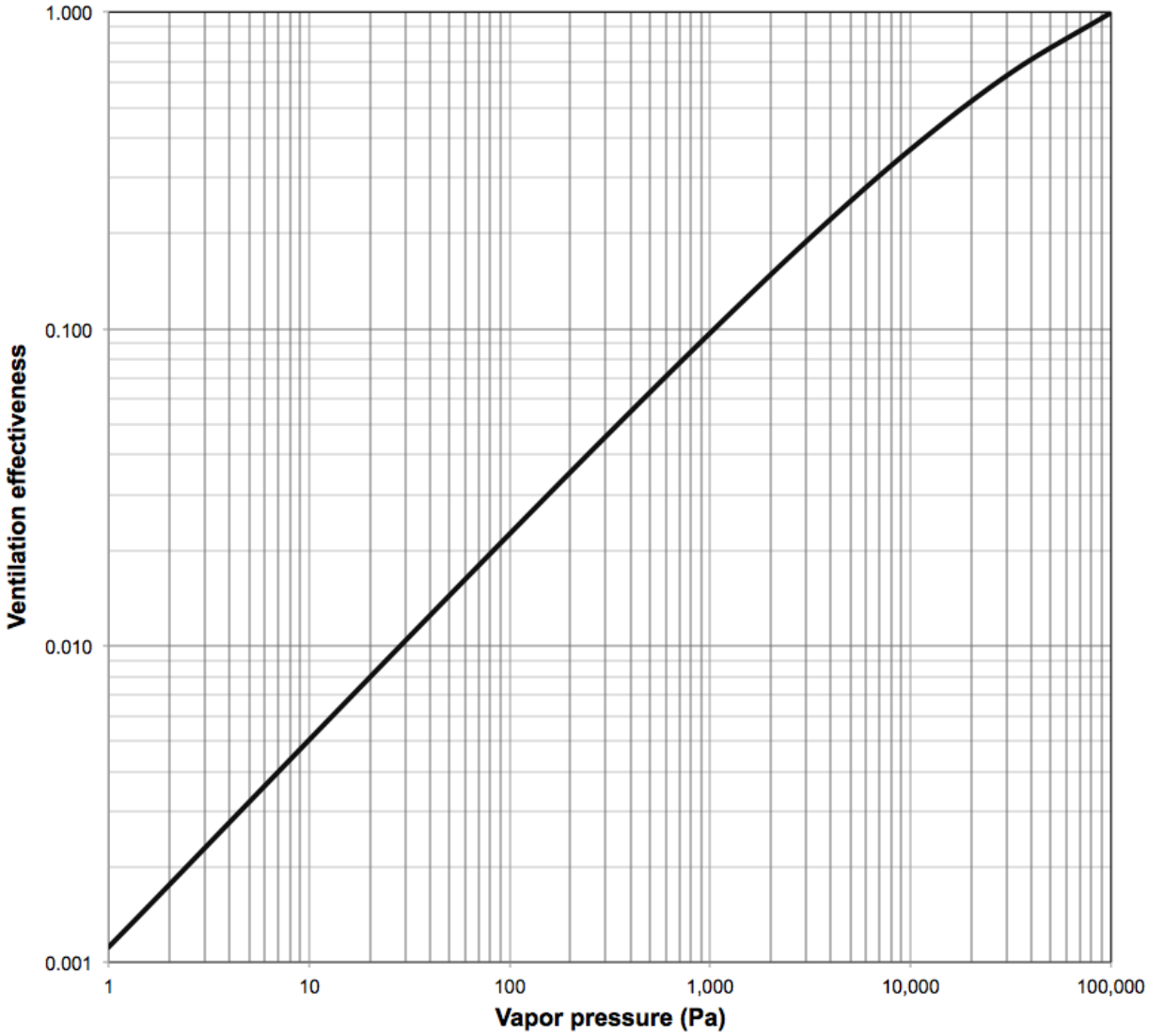
Compound	Non-cancer toxi. Index	Rep. toxi. Index	Cancer toxi. Index	Odor Index	Pungency Index	Ventilation-impacted? VP>50 mm Hg	List A	List B
	>=0.1 ?							
d-Limonene				**x**				**x**
Methylcyclohexane								**x**
Methylcyclopentane						**x**		**x**
3-Methylhexane						**x**		**x**
1-Methyl-2-pyrrolidinone								**x**
4-methyl-2-pentanone (MIBK)								**x**
Naphthalene	**x**		**x**	**x**				**x**
Nonanal				**x**				**x**
Nonane								**x**
Octane								**x**
Octanal				**x**				**x**
n-Pentadecane								**x**
Pentanal (valeraldehyde)				**x**				**x**
Pentane						**x**		**x**
Phenol								**x**
α-pinene				**x**				**x**
β-pinene								**x**
Propanal				**x**		**x**	**x**	
2-Propanone (acetone)						**x**		**x**
Styrene								**x**
D4 Siloxane								**x**
D5 siloxane								**x**
Terpineols								**x**
Tetrachloroethane			**x**					**x**
Tetrachloroethene			**x**					**x**
n-Tetradecane								**x**
Tetrahydrofuran						**x**		**x**
TMPD-DIB								**x**
TMPB-MIB								**x**
Toluene	**x**	**x**		**x**				**x**
1,2,4-Trichlorobenzene								**x**
1,1,1-Trichloroethane (Methyl chloroform)						**x**		**x**
Trichloroethene (Trichloroethylene)			**x**			**x**	**x**	
1,2,4-Trimethylbenzene								**x**
1,2,3-Trimethylbenzene								**x**

Table 4 : Results of screening and priority List A and B

Compound	Non-cancer toxi. Index	Rep. toxi. Index	Cancer toxi. Index	Odor Index	Pungency Index	Ventilation-impacted? VP>50 mm Hg	List A	List B
	>=0.1 ?							
1,3,5-Trimethylbenzene								**x**
2,2,5-Trimethylhexane								**x**
n-Undecane								**x**
o-xylene								**x**
mp-xylene	**x**			**x**				**x**
1,2,3-trichlorobenzene								**x**
1,2,3-trichloropropane	**x**							**x**
β-Methacrolein								**x**
3-Methylbutyraldehyde				**x**		**x**	**x**	
4-methylbenzaldehyde								**x**
op-tolualdehyde								**x**
Caprolactam								**x**
1-Butoxy-2-Propanol								**x**
1-Piperidinecarboxaldehyde								**x**
2-(2-Ethoxyethoxy) Ethanol								**x**
2-Ethoxyethyl acetate	**x**							**x**
2-Ethyl-1-hexanoic Acid								**x**
2-Heptanone				**x**				**x**
Benzoic Acid								**x**
Hexanoic acid				**x**				**x**
Longifolene								**x**
Menthol								**x**
N,N-Dibutyl Formamide								**x**
N-butyl-1-Butanamine								**x**
Nonanoic acid								**x**
Propylene Glycol	**x**							**x**
Tridecane								**x**

FIGURES

Figure 1: The figure shows the relative ventilation removal effectiveness at various vapor pressures compared to, ventilation removal effectiveness at 10^5 Pa or 1 atm



APPENDIX

Part A - Review of studies in the current literature

The following studies provide key references used to select the contaminants of concern in indoor air. The details of the studies are summarized in Table 1. Below we provide a short summary of each study.

Apte and Erdmann (2002), analyzed data from the United States Environmental Protection Agency (USEPA) Building Assessment Survey and Evaluation (BASE) study. The BASE study was carried out in 100 US office buildings that were randomly selected by the USEPA (BASE Website). Integrated 9-hour VOC samples representing a work day were collected in each building. Summary statistics (mean, median, minimum, maximum, standard deviation) were reported for 37 VOCs for which a complete dataset was available. For 73 VOCs that were measured, the BASE study also identified potential sources. The median formaldehyde concentration reported across all buildings (12 ppb), exceeded the Agency for Toxic Substances and Disease Registry (ATSDR) chronic and intermediate maximum recommended limits (MRLs) of 8 ppb. The maximum benzene concentration (10 ppb) was found to exceed the ASTDR intermediate MRL of 9 ppb.

Eklund et al. (2008) carried out sampling in 10 retail stores located in a New Jersey shopping mall. Over 130 eight-hr time integrated samples were collected over a 2-year period between 2002-2005. The types of stores sampled included: jeweler, hair/nail salon, restaurants, clothing rental store, dry-cleaner, video rental store and optician. Eklund et al. (2008) provided summary statistics for 28 VOCs detected in 10% or more of the samples. Concentrations of acetone (31), ethanol (28), tetrachloroethylene (12), isopropyl alcohol (8), ethyl acetate (5), toluene (5), methyl ethyl ketone (1), and tetrahydrofuran (1) exceeded 1000 $\mu g/m^{-3}$ in one or more samples—values in parentheses are the number exceeding 1000 $\mu g/m^{-3}$. Eklund et al. (2008) highlighted that VOC concentrations are widely variable in commercial spaces depending on the type of activity and indoor sources. High average (the arithmetic mean of all measurements) levels of acetone (27000 $\mu g/m^{-3}$), ethanol (1850 $\mu g/m^{-3}$), ethyl acetate (649 $\mu g/m^{-3}$), toluene (1150 $\mu g/m^{-3}$) and isopropyl alcohol (671 $\mu g/m^{-3}$) were detected in nail salons. High average concentrations of isopropyl alcohol were measured in the jewelers (6320 $\mu g/m^{-3}$) and the optician store (105 $\mu g/m^{-3}$). High concentrations of tetrachloroethylene were observed in the clothes rental stores (2540 $\mu g/m^{-3}$) and dry-cleaning establishment (1010 $\mu g/m^{-3}$). High average ethanol concentrations were measured in restaurants and the optician store. Large spatial variability was associated with VOCs such as acetone, toluene, ethanol and toluene indicating that their concentrations are influenced by significant indoor sources.

Loh et al. (2006) measured VOCs in several types of stores in Boston, using personal samplers. Sampling was carried out in a variety of stores, restaurants (1.5-h sampling) and on transportation (3-h sampling) during summer 2003 and winter 2004. Sampling was carried in a variety of stores such as hardware, multipurpose (7-h), grocery, drug stores, sporting goods, furniture stores, houseware stores, department stores, and electronics stores. Concentrations of formaldehyde were highest in houseware stores (GM=53 $\mu g/m^3$), highest levels were measured in multipurpose stores (GM=76 $\mu g/m^3$), restaurants had high concentrations of chloroform (GM=1.1 $\mu g/m^3$). Overall, stores had higher concentrations of formaldehyde, toluene, ethylbenzene, xylenes, styrene, chlorinated compounds. They also reported that benzene concentrations indoors were not found to be much higher than concentrations outdoors. Additionally, houseware stores also had high concentrations of compounds such as limonene,

and unsaturated hydrocarbons. Loh et al. also reported significant differences in formaldehyde and acetaldehyde concentrations during the summer and winter sampling events.

Hotchi et al. (2006) carried out VOC measurements in a Target store in San Francisco Bay Area. The goal was to determine whether turning off some air-handling units during load-shedding impacted VOC concentrations. They reported that formaldehyde, 2-butoxyethanol, DPGME, toluene, and D5 siloxane were found in highest concentrations at the sales area. Concentrations of compounds increased after the load-shedding events with fractional increases ranging from 0.11 to 1.28 times the pre-shedding concentrations. They sampled for about 34 VOCs, during the study. Formaldehyde and acetaldehyde concentrations were found to be similar to concentrations reported in the BASE study.

Daisey et al. (1994) measured concentrations of 39 VOCs in 12 office buildings in California along with outdoor concentrations adjacent to the buildings. The sampling included 3 naturally-ventilated, 3 mechanically-ventilated and 6 air-conditioned buildings. Daisey et al. (1994), reported that total VOC concentrations in the buildings were low, but noted that some buildings with photocopiers had higher levels of C10-C11 isoparaffinic compounds. They found no significant variation in total VOC concentration associated with the types of ventilation. They found oxidized hydrocarbons such as ethanol and chlorinated hydrocarbons to be the most abundant VOCs. An analysis of indoor and outdoor concentrations, helped associate compounds such as ethanol, isopropanol, acetone, n-dodecane, n-pentanal, n-hexanal, limonene, dichloromethane, trichloroethene, trichloroethane predominantly with indoor sources. The indoor to outdoor concentration ratio of these compounds was greater than 1.35. Other compounds such as benzene, xylenes, ethyltoluenes, trimethylbenzenes, pentane, 3-methylhexane, tetrachloroethylene, benzaldehyde, 1-phenylethanone, and n-decane were associated with outdoor sources. The ratio of indoor to outdoor concentrations of these compounds was lower than 1.35.

Shields et al. (1996) measured VOC concentrations in 50 sparsely occupied telecommunications offices, 9 variably occupied data centers and 11 densely occupied administrative offices. The study was carried out for six weeks during March and April 1991. Passive samplers were used which limited the VOCs that could be detected in the study. They found total VOC concentrations to be consistently higher indoors compared to outdoors. Telecommunications offices had the lowest indoor/outdoor concentration ratio (3.2), followed by administrative offices (5.3) and data centers (8.6). Administrative offices were better ventilated than data centers—thus indicating an association between ventilation rates and indoor concentrations. Compounds such as D4 siloxane, D5 siloxane, alkanes (n-C12 to n-C16), limonene and tetrachloroethylene varied across the building types and were strongly associated with occupant density. Concentrations of compounds such as toluene, xylenes, n-decane, n-undecane, and Texanol were fairly uniform across all buildings types.

Hodgson and Levin (2003) reviewed the published data on indoor concentrations of VOCs in residential buildings (existing and new) and office buildings (primarily large buildings) in North American starting from the year 1990. Their review excluded some compounds, such as very volatile compounds and compounds with low occurrence. Thirty-five of the compounds they summarized are classified as hazardous air pollutants (HAPs). VOCs with maximum concentrations of 50 ppb or more in office buildings, ethanol, 2-propanol, n-octane, toluene, dichloromethane, 1,1,1-trichloroethane, and 2-propanone. VOCs $\geq$ 50 ppb in existing residences included: acetic acid, formaldehyde, toluene, m/p-xylene, 1,4-dichlorobenzene, dichloromethane, 1,1,1-trichloroethane, and 2-propanone; in new houses, acetic acid,

formaldehyde, acetaldehyde, hexanal, toluene, ethylene glycol, 1,2-propanediol, 2-propanone, and alpha-pinene.

The small and medium commercial buildings study (SMCB 2010) measured concentrations of 30 VOCs in 37 California buildings. Sampling was carried out in the following types of buildings (the number of buildings is listed in parenthesis): beauty salons (2), public assembly (1), dentist offices (2), convenience stores (2) at gas stations, fitness centers (2), grocery stores (2), offices (2), restaurants (4), retailers (8), religious facility (2), and public assembly (1). The GM concentration of most compounds were well below the OEHHA intermediate and chronic exposure limits. Geometric means of formaldehyde concentrations in dentist offices, convenience stores, fitness centers, restaurants, retailers, religious facility, assembly, offices and beauty salons were found to exceed the OEHHA 8-hr and chronic RELs (9 ppb), and the ATSDR chronic REL (8 ppb). The mean tetrachloroethene concentrations exceeded the OEHHA 8-hr REL of 5 ppb at gas stations (17 ppb), dentist offices (17 ppb), and other spaces such as religious facilities or the public assembly spaces. The study provided insight into the variations in VOC concentrations in different types of buildings.

The state of California commissioned a 2006 study to assess indoor air quality in a newly constructed office-building complex (Capitol Area East End Complex, East End 2006). VOC and aldehyde sampling was carried out multiple times over 12 months in 5 buildings before and after they were occupied (21-site visits), allowing for an evaluation of temporal variations in concentrations. The study started with a target list of 110 chemicals. Samples were collected for 5-6 hours during each sampling event. Ventilation rates were also measured. The study reported that apart from formaldehyde and acetaldehyde, all other VOCs were found to be largely below target concentrations. The levels were compared to VOC concentrations reported in the BASE study, with few VOCs being detected in higher concentrations compared to BASE. Concentrations of chloroform, phenol, 1-ethyl-4-methyl-benzene, texanol, α-pinene, 1,2,4- and 1,3,5-trimethyl benzene were found to exceed the BASE concentrations by more than a factor of 2. Periodic sampling also allowed to researchers to compare increases in certain VOC concentration with activities in the buildings. Acetaldehyde, formaldehyde, caprolactam, naphthalene and nonanal were called building related compounds. Other compounds such as benzaldehyde, D5 siloxane, and d-limonene were linked to occupants.

The California Portable Classrooms study was carried out by the California Air Resources Board and the Department of Health Services between April 2001 and February 2002 (California Schools 2003). The study was carried out in two phases, the first phase included a mail survey sent to 1000 schools and the mailing of passive formaldehyde samplers to two-thirds of the schools. The second phase included site-specific samples (for aldehydes, VOCs, mold spores, pollen, biological pollutants, particle count, pesticides, metals, PAH's and allergens in floor dust) collected in 201 classrooms at 67 randomly selected schools in California. Phase II also involved monitoring environmental factors such as temperature, humidity, noise, ventilation and lighting. In both phases, two portable and one traditional classroom in each school were selected for the study. The passive formaldehyde sampling was carried out for 7-10 days in Phase I, and in Phase II 6-h sampling was carried out. The study was primarily carried out to assess conditions in California public school classrooms to develop and support various recommendations for improving indoor environmental conditions. Most of the schools were suburban. Elementary schools were sampled more than middle or high schools. The survey showed that portable classrooms were associated with greater number of complaints about issues such as water leaks, noise, mold, odor, indoor air quality, lighting and insects. Even though ventilation rates in both types of classrooms were not significantly

different (5% confidence level), the filter of HVAC units associated with portable classrooms were associated more strongly with presence of mold/mildew, clogging, dirty drain pans and standing water. The CO_2 levels in classrooms were also found to be significantly higher than outdoor levels.

Godwin et al. (2006) randomly selected four elementary schools and five middle schools in Michigan to undergo indoor pollutant sampling. A variety of rooms within each school were sampled (one art room, miscellaneous use room, general classrooms, science rooms, and clerical rooms). The also sampled both outdoors and indoors (in each room) for temperature, relative humidity, CO_2, VOCs and bioaerosols. Sampling was carried out over 3.5-4.5 days in the schools. Temperature, relative humidity and CO_2 were sampled every 5-minutes during the course of monitoring. VOCs were collected onto Tenax tubes and sampled in a gas chromatograph/mass spectrometer. The researchers made a visual inspection of the rooms and recorded the method of ventilation employed in the schools. The difference in CO_2 levels indoors and outdoors was used to estimate the air change rate in the rooms. Sampling was carried out in portable classrooms only in one school. Benzene, toluene, ethylbenzene, xylene, a-pinene and d-limonene were the most frequently detected compounds. With the exception of a-pinene and d-limonene, the researchers found concentrations of detected compounds to be below levels in schools reported earlier by Shendell et al. (2004). Indoor/outdoor concentration ratios for a-pinene, d-limonene, ethylbenzene, xylene, 2-butanone, methyl isooctane, toluene, chloroform, 1,2,4-trichlorobenzene, styrene, phenol, naphthalene were found to be reasonably high indicating the presence of indoor sources. Benzene had a much smaller indoor/outdoor ratio highlighting that outdoor sources were significant compared to indoor sources. The presence of swimming pools appeared to account for trace concentrations of chloroform, 1,2,3-trichlorobenzene, and trichloroethylene found in schools. High concentrations of toluene, phenol, MIBK, and 1,2,4-trichlorobenzene were found in art rooms. High concentrations of naphthalene, a-pinene were found in science rooms. The study did not find a significant difference in total VOC concentrations between middle schools and elementary schools, and total VOC concentrations were found to be fairly low. The ventilation in most schools was inadequate compared to the ASHRAE 62.1 standard of 8 L/person. The CO_2 levels also exceeded the 1000-ppm limit recommended by ASHRAE. Median biological pollutant concentrations measured in terms of counts/m^3 were found to be comparable to values in buildings. Regression analysis indicated that carpets and occupants were positively correlated to bioaerosol levels, and a-pinene was negatively correlated. The VOC concentrations were also found to be sensitive to changes in ventilation rates. The study highlighted the spatial variations of VOC concentrations due to the presence of localized sources in schools.

Shendell et al. (2004) carried out indoor air sampling in 7 schools in California. They sampled 20 classrooms (13 portable) for a range of VOCs. They used passive samplers with sampling times ranging from 1-day to 1-week and sampled during the winter and summer seasons. VOC concentrations were found to be lower during the winter compared to summer. Overall, concentrations of VOCs were found to be low in this study compared to previous studies. Acetaldehyde, formaldehyde, toluene, m,p-xylene, α-pinene and d-limonene were the most frequently detected compounds, however none of the concentrations were found to exceed regulatory thresholds. Shendell et al. (2004) also had technicians do walk-ins to identify potential indoor sources of VOCs. Cleaning products, personal care products, indoor furnishings and finish and teaching materials were identified as potential sources. In addition to successfully using passive samplers for measurements, the study also highlighted the need to carry out large-scale sampling in schools.

Hodgson et al. (2004) carried out VOC sampling in 4 portable classrooms located in California public schools. Two of the classrooms were built and furnished with materials that had low VOC emissions. The other two classrooms were used as controls. Hodgson et al. (2004) measured ventilation rates and made simultaneous outdoor sample measurements. HVAC units were operational during the studies. Outdoor sampling was simultaneously carried out in the locations. For all measurements they used 6-7 hour sampling. Hodgson et al. (2004) found that higher ventilation rates were associated with lower VOC concentrations. Of the 15 VOCs targeted in the study, the average concentrations observed were around 1 ppb. Only formaldehyde concentration was found to exceed 5 ppb.

Table A - Comparing concentrations in schools to health and odor-based thresholds.

Compound	Concentration Used	Source	Non-cancer Toxi. Index	Rep. toxi. Index	Cancer toxi. Index	Odor Index	Pungency Index
	ppb						
Acetaldehyde	11	CAS	**2.5E+00**		**3.7E+00**	**8.1E+00**	
Benzene	1.4	LAS	**5.2E-01**	**1.5E+00**	**5.7E+00**	5.8E-04	
Benzaldehyde	1	CAS				2.6E-02	
2-Butanone	0.4	4PC	2.6E-04				
t-Butyl methyl ether (MTBE)	3.1	LAS	4.9E-03				
n-Butyraldehyde	0.6	CAS					
Carbon tetrachloride	0.2	LAS	3.5E-02		**4.2E+00**	4.8E-05	
Chloroform	0.8	MS	4.4E-02		**1.6E+00**	2.3E-04	
p-Cymene	0.2	MS				1.7E-03	
1,3-Dichlorobenzene	0.1	MS					
1,4-Dichlorobenzene	0.5	LAS	5.6E-02		**2.5E+00**	1.2E-02	9.7E-04
Dichloromethane (methylene chloride)	0.5	LAS	4.8E-03		**1.4E-01**		
2,5-Dimethylbenzaldehyde		CAS					
Ethylbenzene	0.6	LAS	2.9E-03		**1.1E+00**	**1.0E-01**	
Formaldehyde	30	LAS	**4.5E+00**		**1.5E+01**	6.7E-02	4.3E-01
d-Limonene	14	MS				**9.7E-01**	
4-methylbenzaldehyde	5.1	CAS					
3-Methylbutyraldehyde	0.6	CAS				**6.7E+00**	
4-methyl-2-pentanone (MIBK)	2.6	MS	3.9E-03			1.7E-02	
β-Methacrolein	0.9	CAS				4.3E-02	
Naphthalene	3.2	MS	**6.2E+00**		**4.8E+01**	**2.4E-01**	
Pentanal (valeraldehyde)	0.4	CAS				**1.1E+00**	
α-pinene	6.1	LAS				**3.8E-01**	
β-pinene	1.3	LAS				4.4E-02	
Propanal	0.8	CAS				**8.9E-01**	
Styrene	0.4	MS	2.2E-03			1.3E-02	
Tetrachloroethene	0.3	LAS	8.3E-03		**2.4E+00**	4.3E-04	
Tetrahydrofuran	1.2	MS					
op-Tolualdehyde	4	CAS					
Toluene	5.6	LAS	7.8E-02	5.0E-02		7.1E-02	
1,2,3-Trichlorobenzene	0.09	MS					
1,2,4-Trichlorobenzene	1.2	MS					2.7E-03
Trichloroethene (Trichloroethylene)	0.09	MS	9.0E-04		**1.0E-01**	2.6E-05	
1,2,3-Trichloropropane	0.03	MS	**6.7E-01**				
1,3,5-Trimethylbenzene	0.06	MS				3.9E-04	
o-xylene	0.6	LAS	1.3E-02			1.8E-03	
mp-xylene	1.8	LAS	8.7E-02			4.9E-02	

Table B - Comparing concentrations in other commercial buildings to health and odor-based thresholds

Compound	Concentration Used ppb	Source	Non-cancer toxi. Index	Rep. toxi. Index	Cancer toxi. Index	Odor Index	Pungency Index
Acetaldehyde	54	L	**1.E+01**		**2.E+01**	**4.E+01**	
Acetophenone	0.9	S				3.E-03	1.E-03
Benzene	10	B	**4.E+00**	**1.E+01**	**4.E+01**	4.E-03	
Benzaldehyde	0.1	T				3.E-03	
Benzothiazole	0.05	T					
1,3-Butadiene	53	L	**7.E+01**		**5.E+03**	**3.E-01**	
1-Butanol	0.2	T				3.E-02	
2-Butanone	1.5	B	1.E-03				
2-Butoxyethanol	1.1	T	4.E-03			4.E-03	
Butylacetate	1.2	B				**7.E-01**	
t-Butyl methyl ether (MTBE)	0.2	L	3.E-04				
Carbon tetrachloride	0.01	L	2.E-03		**2.E-01**	2.E-06	
Chloroform	0.1	L	6.E-03		**2.E-01**	3.E-05	
Chloromethane	0.8	B	2.E-02				
n-Decane	0.1	S				2.E-04	
Decanal	0.2	S				**6.E-01**	
1,4-Dichlorobenzene	7.5	L	**8.E-01**		**4.E+01**	**2.E-01**	1.E-02
Dichlorodifluoromethane	5.5	B					
Dichloromethane (methylene chloride)	0.2	S	2.E-03		6.E-02		
Diethyl phthalate	0.002	S					4.E-05
Di(ethylene glycol) butyl ether	0.01	T					
Di(propylene glycol)methyl ethers (DPGME)	1	T					
Dodecane	0.05	S				5.E-04	
Ethyl acetate	1.7	B				7.E-03	
Ethylbenzene	3.3	L	2.E-02		**6.E+00**	**6.E-01**	
2-Ethyl-1-hexanol	0.3	B				1.E-03	2.E-03
2-Ethyltoluene	0.01	D				2.E-04	
4-Ethyltoluene	0.3	B				4.E-02	
Formaldehyde	43	S	**7.E+00**		**2.E+01**	1.E-01	**6.E-01**
n-Hexadecane	0.3	S					
n-Hexane	3.7	B	2.E-02			3.E-03	
Hexanal	1.3	S				**2.E-01**	
d-Limonene	1.8	S				**1.E-01**	
Methylcyclohexane	0.01	D				7.E-05	
Methylcyclopentane	0.03	D				2.E-05	
3-Methylhexane	0.01	D				1.E-05	
1-Methyl-2-pyrrolidinone	0.1	T		2.E-03			

Table B - Comparing concentrations in other commercial buildings to health and odor-based thresholds

Compound	Concentration Used ppb	Source	Non-cancer toxi. Index	Rep. toxi. Index	Cancer toxi. Index	Odor Index	Pungency Index
4-methyl-2-pentanone (MIBK)	1.8	B	3.E-03			1.E-02	
Naphthalene	9.4	EE	**2.E+01**		**1.E+02**	**7.E-01**	
Nonanal	16	EE				**5.E+01**	
Nonane	1	B					
Octane	0.02	S				1.E-05	
Octanal	0.1	S				**1.E+01**	
n-Pentadecane	0.05	S					
Pentanal (valeraldehyde)	0.05	T				**1.E-01**	
Pentane	0.4	D				3.E-04	
Phenol	0.2	S	4.E-03			4.E-02	
α-pinene	0.4	S				2.E-02	
2-Propanone (acetone)	43	S	4.E-03			5.E-02	
Styrene	1.1	L	6.E-03			3.E-02	
D4 Siloxane	0.002	S					
D5 siloxane	78	EE					
Terpineols	0.01	S					
Tetrachloroethane	0.01	D			**4.E-01**		
n-Tetradecane	0.07	S					
TMPD-DIB	0.003	T					
TMPB-MIB	0.7	B					
Toluene	16	L	**2.E-01**	**1.E-01**		**2.E-01**	
1,1,1-Trichloroethane (Methyl chloroform)	15	B	9.E-02				
Trichloroethene (Trichloroethylene)	0.06	D	6.E-04		**7.E-02**	2.E-05	
1,2,4-Trimethylbenzene	0.08	S				7.E-04	
1,2,3-Trimethylbenzene	0.02	D					
1,3,5-Trimethylbenzene	0.3	B				2.E-03	
2,2,5-Trimethylhexane	0.003	D				4.E-06	
n-Undecane	0.1	S				1.E-04	
o-xylene	1.3	L	3.E-02			4.E-03	
mp-xylene	13	L	**6.E-01**			**4.E-01**	
Caprolactam	21	EE					
1-Butoxy-2-Propanol	1.6	EE		2.E-02		1.E-02	
1-Piperidinecarboxaldehyde	1.3	EE					
2-(2-Ethoxyethoxy) Ethanol	3.8	EE					
2-Ethoxyethyl acetate	0.8	EE	**3.E-01**			2.E-02	
2-Ethyl-1-hexanoic Acid	0.9	EE					
2-Heptanone	3.9	EE				**9.E-01**	
Benzoic Acid	4	EE					

Table B - Comparing concentrations in other commercial buildings to health and odor-based thresholds

Compound	Concentration Used ppb	Source	Non-cancer toxi. Index	Rep. toxi. Index	Cancer toxi. Index	Odor Index	Pungency Index
Hexanoic acid	1	EE				**1.1.E+00**	
Longifolene	1.7	EE					
Menthol	0.9	EE					
N,N-Dibutyl Formamide	5.3	EE					
N-butyl-1-Butanamine	25	EE					
Nonanoic acid	0.9	EE					
Propylene Glycol	3.9	EE	**5.E-01**				
Tridecane	1.3	EE					