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Indoor Air Quality Guidelines and Standards

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Consortium for Material Emissions and Indoor Air Quality Modelling II (CMEIAQ-II)

In 2000, the Institute for Research in Construction, National Research Council Canada (IRC/NRC) launched the second phase of the Material Emissions and Indoor Air Quality Modelling project (CMEIAQ-II). The second phase of this project is the direct result of the support and suggestions from the first phase's consortium members for continued work on this research topic. In the second phase, the research is directed towards two principal objectives. The first is to develop the knowledge and tools needed to estimate concentrations of volatile organic compounds (VOCs) generated by the emissions from building materials and furnishings in order to gain a better understanding of the effects of those products on indoor air quality (IAQ). The second is to provide the scientific bases needed to enhance indoor air quality guidelines for office and residential buildings. An important addition to the project in this phase was the Health and End Users Advisory Committee, which was tasked to provide much needed input from the health sector and advice to help tailor the project outputs to better meet the needs of end-users.

Phase II Tasks

The specific tasks of the phase II research were:

- To assemble a target VOC list on which to focus our efforts for the analysis of the emission test results. The list includes chemicals which are known to be emitted from various materials, and, especially, chemicals known to have health effects;
- To determine the ranges of variation of the emissions from selected materials, which may result from material variability or environmental influences;
- To expand the database to include a total of 69 materials, and to re-analyze the existing data to cover as many VOCs on the new target list as possible;
- To refine the Material Emission DataBase and Indoor Air Quality (MEDB-IAQ) simulation program to make it more user-friendly;
- To develop and validate empirical and mass-transfer based source models; and
- To develop a best practice guide for managing VOCs/IAQ in office buildings.

Significance of the Project

A recent report by a multidisciplinary group of European scientists (EUROVEN) based on existing and limited literature, recommends that outdoor air supply rates need to be increased to 30 L/s per person from the current ASHRAE recommendation of 10 L/s per person to improve indoor air quality for health, comfort, and productivity concerns. On the other hand, a previous NRC experimental study indicates that increasing the ventilation rate to speed up the removal of air-borne VOCs, even when energy use is not a concern, is not effective. The most efficient strategy to maintain indoor air quality is to remove the contaminants at the source (source control) and then to rely on ventilation (dilution) to remove the air-borne VOCs.

This research contributes to improved indoor air quality by developing knowledge and tools for effectively applying source control to reduce ventilation needs (and hence, save energy). The work provides the relative contribution by a given product to up to 90 VOC concentrations

(some of which are known to have adverse health effects), allowing intelligent, informed choices of building materials and indoor consumer products. Product manufacturers will benefit by learning how their products can be improved with respect to VOC emissions, and where their products stand relative to others in simulations of their actual use. The information collected in Phase II will also make it easier for investigators to diagnose possible IAQ problems in buildings, and explore trade-offs between increased ventilation and source control.

The consortium for Phase II (which has a Steering Committee, a Technical Advisory Committee, and a Health & End Users Advisory Committee) was established to set the research priorities and help fund the project. Members of the consortium include: Public Works & Government Services Canada, Natural Resources Canada, Canada Mortgage and Housing Corporation, Health Canada and the National Research Council. In addition, the following organizations have made significant in-kind contributions to the consortium project through close research collaboration with the IRC/NRC project team: Canadian Composite Panel Association, Carleton University, Chemical Manufactures Association (Rohm & Haas), Dalhousie University, Gypsum Board Association, Saskatchewan Research Council, Syracuse University, University of Calgary, University of Miami, U.S. Environmental Protection Agency (EPA), U.S. National Institute of Standards and Technology (NIST), and Virginia Polytechnic Institute & State University.

The CMEIAQ-II final research reports include:

Report 1.1	Target VOC list
Report 1.2	Methodology for Analysis of VOCs in Emission Testing of Building Materials
Report 2.1	Specimen Variability: A Case Study
Report 2.2	Effects of Environmental Factors on VOC Emissions from a Wet Material
Report 2.3	Effects of Material Temperature on VOC Emissions from a Dry Building Material
Report 3.1	Material Emission Data: Small Environmental Chamber Tests
Report 3.2	MEDB-IAQ Version 4.1 Beta
Report 4.1	Model Development for VOC Emissions from Wet Building Materials
Report 4.2	Validation of a Mass-transfer Model for VOC Emissions from Wet Building Materials
Report 4.3	Validation of Empirical Models with Long-term Emission Testing Data
Report 5.1	Indoor Air Quality Guidelines and Standards
Report 5.2	Managing VOCs and Indoor Air Quality in Office Buildings: An Engineering Approach

Reports 1.1 and 1.2 provide the information on the Target VOC list and the analysis method for the VOCs on the list. Reports 2.1 and 2.2 present research outcomes on both inherent and environmental factors inducing variability in material emissions. Report 2.3 discusses VOC emissions as a function of surface temperatures, which can be applied to emissions from a radiant floor heating system. Report 3.1 provides material emission testing data and the resulting coefficients for empirical emission models for the expansion of MEDB-IAQ simulation software. Report 3.2 is a user manual for the revised MEDB-IAQ. Reports 4.1 and 4.2 deal with the development of a mass-transfer based model for wet building materials and the validation of the model with experimental data. Report 4.3 compares empirical models based on short-term emission testing data with those based on long-term data. Report 5.1 contains summaries of existing guidelines and standards associated with indoor air quality. Report 5.2 is a manual for property managers and building operators for their duties in managing VOCs in office buildings.

Indoor Air Quality Guidelines and Standards

Summary

This report summarizes some of the most well-established guidelines and standards relating to indoor air quality, including those that are used most frequently in North America. The report is divided into four sections, detailing the applicable standards and guidelines for:

- ventilation rates (commercial/institutional buildings, low-rise residential buildings)
- common indoor contaminants (11 contaminants, 10 agencies);
- organic compounds (546 compounds, 7 agencies); and
- labeling schemes for low-VOC emitting materials (12 schemes)

For each section, descriptions of the agencies that developed the guidelines and standards are provided, along with the required or recommended criteria.

The guidelines and standards provided in this summary differ with respect to their derivation. Some standards are based on the results of scientific studies, whereas others are derived from practical experience, or consensus based on available knowledge. Some of the standards focus on acceptable levels for occupant comfort and the avoidance of odour irritation, whereas others are based on health concerns. Some of the guidelines and standards were developed for industrial settings, where contaminant concentrations are likely to be relatively high, whereas others were created for non-industrial settings, such as offices and residences. Some of the standards and guidelines presented in this report are legally enforced, but others are recommended criteria which can be voluntary adhered to. These differences are noted in each section of the summary.

Practical guidance on designing indoor environments to achieve these standards and guidelines is beyond the scope of this report. However, further information can be gained from the cited standards, and from the CMEIAQ-II Report 5.2 *Managing VOCs and Indoor Air Quality in Office Buildings: An Engineering Approach* (Shaw et al., 2004).

It is important to note that this report is simply a summary of the available standards. The requirements and recommendations set by standards agencies have not been critically examined in this report to determine how appropriate the cited criteria are. In addition, because this report provides a summary, more detailed information (e.g. exactly how to measure the indoor environment to assess conformity, exceptions and limitations to stated criteria) is not included. Therefore, readers are strongly encouraged to consult the cited standards and guidance documents before applying these criteria.

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Indoor Air Quality Guidelines and Standards

1. Introduction

The concentration of indoor contaminants found indoors can affect occupants' comfort and health. Many different contaminants exist, the effects of which are varied. In order to design acceptable indoor environments, practitioners refer to standards and guidelines developed by a variety of agencies. This report summarizes some of the most well-established recommendations that relate to indoor air quality, including those that are used most frequently in North America. The organizations cited in this document are shown in Table 1.

Table 1. Standards and Guidelines Organizations

Acronym	Organization
ACGIH	American Conference of Governmental Industrial Hygienists
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
	Association of Environmentally Friendly Carpets (Germany)
	Building Information Foundation (Finland)
CRI	Carpet and Rug Institute
CSA	Canadian Standard Association
DFG	Deutsche Forschungs Gemeinschaft (Germany)
DSIC	Danish Society of Indoor Climate (Denmark)
EPA	U.S. Environmental Protection Agency
GEI	GreenGuard Environmental Institute
	Green Seal
GEV	Gemeinschaft Emissionskontrollierter Verlegewerkstoffe (Germany)
	Federal Environmental Agency (Germany), Indoor Air Hygiene Commission (IRK)
HRSDC	Human Resources and Skill Development Canada
MHLW	Ministry of Health, Labour and Welfare (Japan)
	Nordic Council of Ministries
NFICL	Norwegian Forum of Indoor Climate Labeling (Norway)
NIOSH	National Institute for Occupational Safety and Health
OEHHA	Office of Environmental Health Hazard Assessment (California EPA)
OSHA	Occupational Health and Safety Administration
SCS	Scientific Certification Systems
	TerraChoice Environmental Services
	The Government of the Hong Kong Special Administrative Region (Hong Kong)
WHO	World Health Organization

This report is divided into four sections, detailing the applicable standards and guidelines for ventilation, common indoor contaminants, organic compounds, and labeling schemes for low-VOC emitting materials. For each section, descriptions of the agencies that developed the guidelines and standards are provided, along with the required or recommended criteria. Where an agency based its recommendations on another available standard, or simply refers readers to another document, this is noted in the tables below.

The standards and guidelines provided in this summary differ with respect to their derivation. Some standards are based on the results of scientific studies, whereas others are derived from practical experience, or consensus based on available knowledge. Some of the standards focus on acceptable levels for occupant comfort and the avoidance of odour irritation, whereas others are based on health concerns. Some of the guidelines and standards were developed for industrial settings, where contaminant concentrations are likely to be relatively high, whereas others were created for non-industrial settings, such as offices and residences. Some of the standards and guidelines presented in this report are legally enforced, but others are recommended criteria which can be voluntary adhered to. These differences are noted in each section of the summary.

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It is important to note that this report is simply a summary of the available standards. The requirements and recommendations set by standards agencies have not been critically examined in this report to determine how appropriate the cited criteria are. In addition, because this report provides a summary, more detailed information (e.g. exactly how to measure the indoor environment to assess conformity, exceptions and limitations to stated criteria) is not included. Therefore, readers are strongly encouraged to consult the cited standards and guidance documents before applying these criteria.

2. Ventilation Standards and Guidelines

Indoor air quality is closely related to ventilation. Assuming outdoor air is less contaminated than indoor air, fresh outdoor air replaces indoor air through ventilation, thus removing and diluting contaminants generated indoors. The focus of this section is to summarize standards and guidelines for ventilation requirements that are commonly used in North America.

Standardization of ventilation requirements has a long history, dating back to as early as the 18th century. The guidelines specify ventilation rates that are linked to the minimum acceptable pollutant concentrations. For many years, ventilation standards and guidelines were based on the metabolic CO_2 concentration. The recent ventilation guidelines take into account both occupant-generated contaminants (e.g., CO_2 or odours) and non-occupant sources (e.g., VOCs from building materials and furnishings).

2.1 Ventilation Guidelines for Commercial and Institutional Buildings

In general, two different procedures are prescribed in the ventilation guidelines to achieve acceptable indoor air quality in commercial and institutional buildings.

2.1.1 Ventilation Rate Procedure

This procedure is a prescriptive method, which prescribes the amount of fresh air that should be delivered to a space in terms of air volume per unit time and per person for different types of spaces (Olesen, 2004; Avgelis and Papadopoulos, 2004). This provides an indirect solution to the control of indoor air contaminants through prescribing required ventilation rates (ASHRAE, 2004). ASHRAE Standard 62.1 and European CR 1752 include this procedure. While ASHRAE Standard 62.1 is a minimum standard, CR 1752 includes the possibility of designing for different levels of perceived air quality (PAQ) by adopting three classes of PAQ (Class A with ~15% perceived dissatisfied, Class B with ~20%, & Class C with ~30%) (Olesen, 2004).

To determine design ventilation rates, ASHRAE 62.1 recommends the following equation, which is based on both occupant-related and area-related sources:

$$V_{bz} = R_P P_z + R_a A_z \quad \textbf{(1)}$$

where:

V_{bz}: breathing zone outdoor airflow (L/s)
A_z: zone floor area, i.e., the net occupiable floor area in the zone (m^2)
P_z: zone population, i.e., the largest number of people expected to occupy the zone during typical usage (person).
R_p: outdoor airflow rate required per person (L/s person)
R_a: outdoor airflow rate required per unit area (L/s m^2).

Table 2 summarizes the minimum ventilation rates (outdoor air supply rates) that are commonly used in North America for selected spaces of commercial and institutional buildings. The default ventilation rate (Q_v, L/s person) recommended in ASHRAE 62.1 is based on the following equation using the default value of occupant density (D_p, person/m^2).

$$Q_v = R_p + \frac{R_a}{D_p} \quad \textbf{(2)}$$

Therefore, the breathing zone outdoor airflow (V_{bz}) has the following relationship with the default ventilation rate (Q_v) and occupant density (D_p) in Table 2.

$$V_{bz} = Q_v D_p A_z \quad \textbf{(3)}$$

In theory, the minimum ventilation rates specified in ASHRAE 62.1 can vary based on the occupant density. Olesen (2004) presents different ventilation rates for different occupational densities from those in Table 2.

Table 2. Recommended Outdoor Air Supply Rates

values given are in litres per second per person (L/s.p)

Type of Space	ASHRAE 62.1 (2004)[a]		CSA Z412 (2000)[b]	COHS (2002)	CFR (2002) 10.435.107
	default occupant density (#/100 m^2)	default outdoor air rate	10	refers readers to ASHRAE 62.	refers readers to ASHRAE 62.
office space	5	8.5	10		
reception areas	30	3.5	8		
telephone/data entry	60	3.0	10		
main entry lobbies	10	5.5	---		
conference rooms			10		

Notes:
a: the default outdoor air rates given assume a ventilation system with a zone air distribution effectiveness (E_z) of 1.0, and a system ventilation efficiency (E_v) of 1.0. If the ventilation system does not meet these assumptions, readers should refer to Section 6.2 of ASHRAE's *Standard 62.1-2004* to determine appropriate outdoor air supply rates. The default outdoor air rates also assume that outdoor air meets the requirements of the US EPA's National Primary Ambient Air Quality Standards (NAAQS), or that appropriate measures are taken to remove excess contaminants in the incoming air.
b: based on ASHRAE *Standrad-62-2001*.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). (2004). *ANSI/ASHRAE Standard 62.1-2004: Ventilation for Acceptable Indoor Air Quality*. Atlanta, GA: ASHRAE.

Canadian Standards Association (CSA). (2000). *Guideline on office ergonomics* (CSA Z412-00 – updated June 2003). Toronto, Canada: CSA.

Canadian Occupational Health and Safety (COHS) (2002). Part II: Permanent structures, Division III: HVAC systems. In *Regulations respecting occupational health and safety made under part II of the Canada Labour Code.* Ottawa, Canada: COHS. [Available at: http://laws.justice.gc.ca/en/L-2/SOR-86-304/31290.html]

U.S. Code of Federal Regulations (CFR) (2002). *Heating, ventilation, and air-conditioning (HVAC) systems* (U.S. Department of Energy) (10.435.107). Washington, DC: National Archives and Records Administration, Office of the Federal Register.

2.1.2 Air Quality Procedure

This procedure is an alternative performance based approach, which does not just determine the fresh airflow that must be provided into a space, but it is based on measuring potential air contaminants, analyzing air pollution sources and acceptable IAQ goals. This method allows decreasing the amount of outdoor air to levels of below those recommended by the ventilation rate procedure, if other measures (e.g., recirculation with air cleaning) are taken to achieve the IAQ requirements (Avgelis and Papadopoulos, 2004; ASHRAE, 2004). The levels of acceptable of air pollutants are discussed in Sections 3 and 4.

2.2 Ventilation Guidelines for Low-Rise Residential Buildings

ASHRAE Standard 62.2 is specifically designed for single-houses and multifamily structures of three stories or fewer above grade, including manufactured and modular house (ASHRAE, 2003b). The standard specifies ventilation requirements as well as requirements related to controlling certain pollutant sources that could be reasonably expected to be present.

2.2.1 Ventilation Rates for Whole House Ventilation

The minimum outdoor airflow rate for whole house ventilation can be calculated based on the floor area of the conditioned space and number of bedrooms using the following equation:

$$Q_{fan} = 0.05\, A_{floor} + 3.5\,(N_{br} + 1) \qquad \textbf{(4)}$$

Where:

Q_{fan}: fan flow rate (L/s)
A_{floor}: floor area (m^2)
N_{br}: number of bedrooms (not to be less than one)

Table 3 summarizes resulting ventilation rate requirements for whole building ventilation, which is intended to bring fresh air into the general environment to dilute the pollutants that cannot be effectively controlled at the source. The values in Table 3 are also based on default values of occupant density, which are two persons in a studio or one-bedroom dwelling unit and an additional person for each additional bedroom. For higher occupant densities, the rate should be increased accordingly.

Table 3. Ventilation Air Requirements (L/s) for Low-Rise Residential Dwellings

Floor Area (m^2)	Bedrooms				
	0-1	2-3	4-5	6-7	>7
<139	14	21	28	35	42
139.1-279	21	28	35	42	50
279.1-418	28	35	42	50	57
418.1-557	35	42	50	57	64
557.1-697	42	50	57	64	71
>697	50	57	64	71	78

2.2.2 Ventilation Rates for Local Ventilation

ASHRAE 62.2 also provides the exhaust airflow rates for local ventilation, which is intended to exhaust pollutants from specific rooms before they enter the general environment. Table 4 summarizes intermittent and continuous local ventilation exhaust airflow rates.

Table 4. Local Ventilation Exhaust Airflow Rates

Application	Airflow	
	Intermittent Local Ventilation	Continuous Local Ventilation
Kitchen	50 L/s [a]	5 air change per hour [b]
Bathroom	25 L/s	10 L/s

a: Vented range hood (including appliance-range hood combinations) required if exhaust fan flow rate is less than 5 kitchen air changes per hour.

b: Base on kitchen volume

3. Standards and Guidelines for Common Indoor Contaminants

This section summarizes standards and guidelines for a number of contaminants commonly found indoors, which can be used as acceptable indoor air quality levels. Eleven contaminants are detailed, including carbon dioxide, carbon monoxide, ozone, lead, and particulates. Formaldehyde, the most well-known volatile organic compound, is also included, but recommended concentrations for other volatile organic compounds (VOCs) are summarized separately in section 3. Recommended concentrations are provided from ten different agencies.

The standards and guidelines for these common indoor contaminants are presented in Table 5. The majority of recommendations come from an excellent summary of indoor contaminants, provided by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) in *ASHRAE/ANSI Standard-62.1-2004* (ASHRAE, 2004). This summary, previously provided as *Addenda ad to ASHRAE/ANSI Standard 62-2001* (ASHRAE, 2003a) is available online at http://www.ashrae.org/template/AssetDetail/assetid/30205

In most cases, the primary objective in setting recommended limits was to minimize health risks to the general public, or to sectors of the public, such as industrial workers or sensitive individuals. It is important to note that lower limits might be needed to avoid occupant dissatisfaction, discomfort, unacceptable odours, and sensory irritation. It is also impractical to assume that maintaining contaminant concentrations below these recommended levels will guarantee the absence of all adverse health effects for all occupants.

As the standards and guidelines given in Table 5 differ in terms of the criteria used to set limits, the population focused on, and the context for application, readers are strongly advised to consult the source documents before applying these recommendations.

3.1 Description of Sources

The standards and guidelines featured in Table 5 are described below.

3.1.1 NAAQS/EPA

The National Ambient Air Quality Standards (NAAQS) were developed by the U.S. Environmental Protection Agency (EPA) under the Clean Air Act (last amended in 1990). These enforceable standards were developed for outdoor air quality, but they are also applicable for indoor air contaminant levels. The concentrations are set conservatively in order to protect the most sensitive individuals, such children, the elderly, and those with asthma. By law, these regulatory values must be reviewed every five years (ASHRAE, 2004; USEPA, 2005). Further details of this standard can be found at: http://www.epa.gov/ttn/naaqs/

3.1.2 OSHA

The U.S. Occupational Health and Safety Administration (OSHA) developed enforceable maximum exposures for industrial environments. The standards were developed through a formal rule-making process, and the permissible limits can only be changed by reopening this

process. The Permissible Exposure Limits (PELs) given in Table 5 are designed to protect the average industrial worker, but do not take into account the possible reactions of sensitive individuals (ASHRAE, 2004; OSHA, 2005). More information on these standards can be found at: http://www.osha.gov/SLTC/pel

3.1.3 MAK

MAK levels were developed in Germany by Deutsche Forschungs Gemeinschaft (DFG), an insitution similar to the U.S. National Institutes of Health and the U.S. National Institute for Occupational Safety and Health (NIOSH). These levels are set on a regular basis and receive annual reviews. The limits are enforceable in Germany, and are set for the general population (ASHRAE, 2004; DFG, 2005). More information is available at: http://www.dfg.de/en/dfg_profile/structure/statutory_bodies/senate/senate_commissions_and_committees/investigation_health_hazards/

3.1.4 Canadian

The Canadian maximum exposures shown in Table 5 were developed in 1987, and reaffirmed in 1995, by a committee of provincial members of the Canadian federal government. The guidelines were developed on a consensus basis. These recommended, but not enforced, exposures were developed for air quality in residences (ASHRAE, 2004; Health Canada, 1995). For more information, see: http://www.hc-sc.gc.ca/hecs-sesc/air_quality/index.htm

3.1.5 WHO/Europe

The World Health Organization's (WHO) Office for Europe, based in Denmark, developed guidelines to be used in non-industrial settings. These guidelines were developed in 1987 and updated in 1999. They are intended for application to both indoor and outdoor exposures, but are guidelines rather than an enforceable standard (ASHRAE, 2004; WHO, 2000). Further details of these guidelines can be found at:http://www.euro.who.int/document/e71922.pdf

3.1.6 NIOSH

Recommended maximum exposures for industrial environments have also been developed by the U.S. National Institute for Occupational Safety and Health (NIOSH). These guidelines are published in a set of criteria documents, which contain a review of relevant literature and Recommended Exposure Limits (RELs). These non-enforceable recommendations are not reviewed regularly, and in some cases levels are set above those needed for health reasons because commonly available industrial hygiene practices do not reliably detect substances at lower levels (ASHRAE, 2004, NIOSH, 2005). More information is available at: http://www.cdc.gov/niosh/81-123.html

3.1.7 ACGIH

The American Council of Governmental Industrial Hygienists recommends Threshold Limit Values (TLV®) as maximum exposures for industrial environments. The TLVs are set by

committee, who review the existing scientific literature and recommend a guideline concentrations. The recommendations are applicable for normal industrial working conditions (i.e. 40 hours a week), and for single contaminant exposure. These recommendations are guidelines, rather than enforceable standards, and are not selected to protect the most sensitive workers (ASHRAE, 2004; ACGIH, 2005). Further information is available at: http://www.acgih.org

3.1.8 COSHR

The Canadian Occupational Safety and Health Regulations (COSHR) establish requirements for maintaining a healthy and safe working environment, and form part of the Canadian Labour Code (HRSDC, 2005). Within the context of indoor air quality, COSHR requires that indoor contaminant concentrations be kept within the limits set by the ACGIH. The Canadian Labour Code and COSHR are requirements for Canadian Federal Government organizations, and are recommendations for other Canadian institutions. More information is available at: http://www.hrsdc.gc.ca/asp/gateway.asp?hr=/en/lp/lo/ohs/publications/overview.shtml&hs=oxs

3.1.9 Hong Kong

The Government of the Hong Kong Special Administrative Region established two levels of IAQ guideline values (8-hour average) that can be used to certify the indoor air quality of offices and public places. The guideline values were set for 6 individual chemicals, TVOC, PM_{10}, airborne bacteria for Excellent Class and for Good Class IAQ (Hong Kong, 2003). More information is available at: http://www.iaq.gov.hk/cert/doc/CertGuide-eng.pdf.

3.1.10 German

Between 1996 and 2004, an ad hoc working group of members of the Federal Environmental Agency's Indoor Air Hygiene Commission (IRK) and the Working Group of the Health Ministries of the Länder (AOLG) of Germany established indoor air quality guideline values for 11 individual substances and TVOC for non-industrial settings including residences, offices, and schools. The guidelines consist of two levels: Guide Value II (RW II) and Guide Value I (RW I).

Guide Value II (RW II) is based on current toxicological and epidemiological knowledge of a substance. It is the concentration of a substance that, if reached or exceeded, requires immediate action as this concentration could pose a health hazard, especially for sensitive people who reside in these spaces over long periods of time. Guide Value I (RW I) is the concentration of a substance in indoor air for which, when considered individually, there is no evidence at present that even life-long exposure is expected to bear any adverse health impacts. Values exceeding this are associated with a higher-than-average exposure that is undesirable for health reasons. For the sake of precaution, there is also need for actions in the concentration range between RW I and RW II. RW I is derived from RW II by introducing an additional factor (usually 10) (Um Umwelt Bundes Amt, 2005). More information is available at: http://www.umweltbundesamt.de/uba-info-daten-e/daten-e/irk.htm#4 and http://www.umweltbundesamt.de/uba-info-daten/daten/irk.htm.

Table 5. Standards and Guidelines for Common Indoor Contaminants

Unless otherwise specified, values are given in parts per million (ppm)
Number in brackets [ ] refers to either a ceiling or to averaging times of less than or greater than eight hours (min=minutes; hr=hours; yr=year; C=ceiling; L=long term. Where no time is specified, the averaging time is eight hours.

	NAAQS/EPA (2000)[a]	OSHA [a]	MAK (2000) [a]	Canadian (1995) [a]	WHO/ Europe (2000) [a]	NIOSH (1992) [a]	ACGIH (2001) [a]	COSHR	Hong Kong (2003) [i]	German [j]
Carbon dioxide		5,000	5,000 10,000 [1 hr]	3,500 [L]		5,000 30,000 [15 min]	5,000 30,000 [15 min]	refers readers to ACGIH recommend-ations	800 / 1,000 [8 hr]	
Carbon monoxide	9[d] 35 [1hr][d]	50	30 60 [30 min]	11 [8 hr] 25 [1 hr]	90 [15 min] 50 [30 min] 25 [1 hr] 10 [8 hr]	35 200 [C]	25		1.7 / 8.7 [8 hr]	52 / 5.2 [0.5 h] 13 / 1.3 [8 h]
Formaldehyde	(see note e)	0.75 2 [15 min]	0.3 1.0[g]	0.1 [L] 0.05 [L][h]	0.081 (0.1 mg/m^3) [30 min]	0.016 0.1 [15 min]	0.3 [C]		0.024 / 0.081 [8 hr]	
Lead	1.5 µg/m^3 [3 months]	0.05 mg/m^3	0.1 mg/m^3 1 mg/m^3 [30 min]	minimize exposure	0.5 µg/m^3 [1 yr]	0.1 mg/m^3 [10 hr]	0.05 mg/m^3			
Nitrogen dioxide	0.05 [1 yr]	5 [C]	5 10 [5 min]	0.05 0.25 [1 hr]	0.1 [1 hr] 0.004 [1 yr]	1.0 [15 min]	3 5 [15 min]		0.021 / 0.08 [8 hr]	0.19 [0.5 h] 0.03 [1 wk]
Ozone	0.12 [1 hr][d] 0.08	0.1	carcinogen – no maximum value established	0.12 [1 hr]	0.064 (120 µg/m^3) [8 hr]	0.1 [C]	0.05 – heavy work 0.08 – moderate work 0.1 – light work 0.2 – any work (2hr)		0.025 / 0.061 [8 hr]	
Particles[b] <2.5 µm MMAD[c]	15 µg/m^3 [1 yr][f] 65 µg/m^3 [24 hr][f]	5 mg/m^3	1.5 mg/m^3 for <4 µm	0.1 mg/m^3 [1 hr] 0.04 mg/m^3 [L]			3 mg/m^3			
Particles[b] <10 µm MMAD[c]	50 µg/m^3 [1 yr][f] 150 µg/m^3 [24 hr][f]		4 mg/m^3				10 mg/m^3		0.02 / 0.18 mg/m^3 [8 hr]	
Radon	4 pCi/L [1 yr]				2.7 pCi/L [1 yr]				4.1 / 5.4 pCi/L [8 hr]	
Sulfur dioxide	0.03 [1 yr] 0.14 [24 hr][d]	5	0.5 1.0[g]	0.38 [5 min] 0.019	0.048 [24 hr] 0.012 [1 yr]	2 5 [15 min]	2 5 [15 min]			
Total particles[b]		15 µg/m^3								

Notes for Table 5:
a: As reported in: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). (2004). *ANSI/ASHRAE Standard-62.1-2004: Ventilation for Acceptable Indoor Air Quality*. Atlanta, GA: ASHRAE.
b: Nuisance particles not otherwise classified (PNOC), not known to contain significant amounts of asbestos, lead, crystalline silica, known carcinogens, or other particles known to cause significant adverse health effects.
c: MMAD = mass median aerodynamic diameter in microns (micrometers). Less that 3.0 um is considered respirable; less than 10 um is considered inhalable.
d: Not to be exceeded more than once per year
e: The U.S. Department of Housing and Urban Development adopted regulations concerning formaldehyde emissions from plywood and particleboard intended to limit the airborne concentration of formaldehyde in manufactured homes to 0.4 ppm (24 CFR Part 3280, HUD Manufactured Home Construction and Safety Standards).
f: 62 FR38652 – 38760, July 16, 1997.
g: Never to be exceeded.
h: Target level is 0.05 ppm because of its potential carcinogenic effects. Total aldehydes limited to 1 ppm.
i: Guideline value for Excellent Class / Guideline value for Good Class of IAQ (Hong Kong, 2003)
j: Guide Vale II / Guide Value I; Values are converted from mg/m^3 to ppm at 25 ^oC and 1 atm.

Source Documents:
(NAAOS/EPA)- U.S. Environmental Protection Agency. (2000). *Code of Federal Regulations*, Title 40, Part 50. National Ambient Air Quality Standards. [Online at: http://www.epa.gov/ttn/naaqs/]

(OSHA) - U.S. Department of Labor, Occupational Safety and Health Administration. *Code of Federal Regulations,* Title 29, Part 1910.1000-1910.1450. [Online at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992]

(MAK) – *Maximum Concentrations at the Workplace and Biological Tolerance Values for Working Materials 2000.* Commission for the Investigation of Health Hazard of Chemical Compounds in the Work Area, Federal Republic of Germany.

(Canadian) – Health Canada (1995). *Exposure Guidelines for Residential Indoor Air Quality: A Report of the Federal-Provincial Advisory Committee on Environmental and Occupational Health.* Ottawa: Health Canada.

(WHO/Europe) – World Health Organization (2000). *Air Quality Guidelines for Europe* (2nd Edn.). World Health Organization Regional Publications, European Series No. 91. World Health Organization, Regional Office for Europe, Copenhagen. [online at: http://www.euro.who.int/document/e71922.pdf]

(NIOSH) – NIOSH. (1992). *NIOSH Recommendations for Occupational Safety and Health – Compendium of Policy Documents and Statements.* National Institute for Occupational Safety and Health, January. [Online at: http://www.cdc.gov/niosh/chem-inx.html]

(ACGIH) – ACGIH. (2001) *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices.* American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, 6500 Glenway, Building D-7, Cincinnati, OH, 45240-1630.

(COSHR) - Canadian Occupational Safety and Health Regulations (COSHR) Part X: Hazardous Substances. In *Regulations respecting occupational health and safety made under part II of the Canada Labour Code.* Ottawa, Canada: COSH [online at: http://laws.justice.gc.ca/en/L-2/SOR-86-304/31739.html#rid-31844]

(Hong Kong) – The Government of the Hong Kong Special Administrative Region, *A Guide on Indoor Air Quality Certification Scheme, 2003* [online at: http://www.iaq.gov.hk/cert/doc/CertGuide-eng.pdf]

(German) – Umwelt Bundes Amt (German Federal Environmental Agency). "Guideline Value for Indoor Air." [Online] 03 March 2005. <http://www.umweltbundesamt.de/uba-info-daten-e/daten-e/irk.htm#4 and http://www.umweltbundesamt.de/uba-info-daten/daten/irk.htm>

4. Standards and Guidelines for Organic Compounds

This section details standards and guidelines for concentrations of organic compounds. Table 6 summarizes guideline values for various organic compounds for acute and/or chronic exposures mainly through inhalation, from seven different agencies. PELs and TLVs are regulatory and voluntary limits for industrial settings, respectively. The other five levels are recommended guideline values for non-industrial (office and residential) settings. PELs, TLVs, Hong Kong, and German guideline values are for short-term exposures with the averaging time of 8 hours for most substances. WHO guidelines cover both short-term (30 minutes to 1 week) and long-term (1 year) exposures depending on individual compounds. CRELs and MHLW guideline values are for long-term exposures producing chronic health effects.

4.1 Description of Sources

The standards and guidelines featured in Table 6 are described below.

4.1.1 Threshold Limit Value (TLV)

As mentioned in section 2.1.7, Threshold Limit Values (TLVs) are the guideline values set by the American Conference of Governmental Industrial Hygienists (ACGIH) to minimize workers' exposure to hazardous concentrations as much as possible. The TLVs are published annually for more than 700 chemical substances and physical agents (ACGIH, 2005). TLVs for ~ 500 organic compounds are summarized in Table 6.

4.1.2 Permissible Exposure Level (PEL)

Exposure limits usually represent the maximum amount (concentration) of a chemical that can be present in the air without presenting a health hazard. Permissible exposure limits (PELs) are set by Office of Safety and Health Administration (OSHA) to protect workers against the health effects of exposure to hazardous substances. PELs are regulatory limits on the amount or concentration of a substance in the air (see section 2.1.2). PEL may be either a time-weighted-average (TWA) exposure limit (8 hour), a 15-minute short term exposure limit (STEL), or a ceiling (C) (OSHA, 2005). PELs have been set for about 500 substances (OSHA, 2005). Table 6 summarizes PELs for ~290 organic chemicals.

4.1.3 Chronic Reference Exposure Level (CREL)

A chronic reference level is an airborne level that would pose no significant health risk to individuals indefinitely exposed to that level. CRELs are based solely on health considerations, and are developed from the best available data in the scientific literature by State of California (OEHHA, 2003). Among 79 substances endorsed by August 2003 (OEHHA, 2005), 58 organic compounds are summarized in Table 6.

Section 01350 developed by State of California requires that the modeled indoor air concentration of any chemical at 96-hr not exceed 50% of the CRELs, with the exception of formaldehyde. The 50% concentration limit of CRELs for each building material was based on

the fact that each CREL is the recommended airborne level from all sources and not just from a single source.

4.1.4 WHO Air Quality Guidelines

The World Health Organization (WHO) provided health-based guidelines for 55 airborne inorganic and organic compounds for carcinogenic and non-carcinogenic health endpoints. The non-carcinogenic endpoints include development toxicity, reproduction toxicity, respiratory toxicity, neurotoxicy, hepatoxicity, hematoxicity, eye/nose/throat irritation, and odor annoyance. The lowest concentration at which effects are observed in humans, animals, and plants was used as a staring point for the non-carcinogenic endpoints. Uncertainty factors determined through scientific judgment in consensus and averaging time were also taken into account in determining the health endpoint for non-carcinogenic compounds. The classification by the international Agency for Research on Cancer (IARC) was used to determine a chemical as a carcinogen. The endpoint of carcinogen was determined by linear extrapolation from the high dose level, which is characteristic of animal experiments or occupation exposure with cancer responses (WHO, 1999).

4.1.5 Japan - IAQ Guidelines

The Ministry of Health, Labour and Welfare of Japan produced guideline values for 14 organic compounds and TVOC in indoor air. The guideline values are the levels at which no adverse health effects would be caused in humans with the lifetime exposure. The guideline values are mainly based on chronic toxicity via a long-term exposure, except that of formaldehyde, which is given as a 30-minute average value based on toxicity via a short-term exposure. The value of TVOC is not based on toxicological information, but it is set to be as low as reasonably achievable as the result of investigations on indoor VOC concentration in Japan (MHLW, 2004).

4.1.6 Hong Kong – IAQ Guidelines

Table 6 presents the guideline values for TVOC and 9 volatile organic compounds set by the Government of the Hong Kong Special Administrative Region (see Section 2.1.9). The guideline values are to achieve Good Class of IAQ. More information can be found in Section 2.1.9 and the reference therein.

4.1.7 Germany – IAQ Guidelines

The ad hoc committee of IRK/AOLG of Germany also set IAQ guideline values for organic chemicals found in indoor air of non-industrial settings. Table 6 summarizes two guideline values (Guide Value I and II) for 8 organic compounds. More detailed information is available at the two websites cited in Section 2.1.10.

Table 6. Guideline Values for Organic Chemicals in Indoor Air (industrial and non-industrial settings)

#	Substances	CAS #	ACGIH [1] mg/m^3	OSHA [2] mg/m^3	OEHHA[3] mg/m^3	WHO [4] mg/m^3	Japan [5] mg/m^3	HK [6] mg/m^3	Germany [7] mg/m^3
1	Acetaldehyde	75-07-0	(C)45	360	0.009	0.05 [1 yr]	0.048		
2	Acetic acid	64-19-7	25	25					
3	Acetic anhydride	108-24-7	21	20					
4	Acetone	67-64-1	1188	2400		n.p.			
5	Acetone cyanohydrin	75-86-5	(C)5						
6	Acetonitrile	75-05-8	34	70					
7	2-Acetylaminofluorene	53-96-3		Carcinogen					
8	Acetophenone	98-86-2	49						
9	Acetylene	74-86-2	207640						
10	Acetylene tetrabromide	79-27-6	14	14					
11	Acetylsalicylic acid	50-78-2	5						
12	Acrolein	107-02-8	(C)0.23	0.3	0.00006	0.05 [30 min]			
13	Acrylamide	79-06-1	0.03	0.3					
14	Acrylic acid	79-10-7	6						
15	Acrylonitrile	107-13-1	4	4	0.005				
16	Adipic acid	124-04-9	5						
17	Adiponitrile	111-69-3	9						
18	Aldrin	309-00-2	0.3	0.3					
19	Allyl alcohol	107-18-6	1	5					
20	Allyl chloride	107-05-1	3	3					
21	Allyl glycidyl ether	106-92-3	5	(C)45					
22	Allyl propyl disulfide	2179-59-1	3	12					
23	4-Aminodiphenyl	92-67-1	A1	Carcinogen					
24	2-Aminopyridine	504-29-0	2	2					
25	Amitrole	61-82-5	0.2						
26	Ammonium perfluorooctanoate	3825-26-1	0.01						
27	tert-Amyl methyl ether [TAME]	994-05-8	84						
28	Aniline	62-53-3	8	19					
29	o-Anisidine	90-04-0	0.5	0.5					
30	p-Anisidine	104-94-9	0.5	0.5					
31	ANTU	86-88-4	0.3	0.3					
32	Arsenic, organic compounds (as As)	7440-38-2		0.5					
33	Atrazine	1912-24-9	5						
34	Azinphos-methyl	86-50-0	0.2	0.2					
35	Benz[a]anthracene	56-55-3	A2						
36	Benzene	71-43-2	2	32	0.06	n.v.		0.0161	
37	Benzidine	92-87-5	A1	Carcinogen					
38	Benzo[b]fluoranthene	205-99-2	A2						
39	Benzo[a]pyrene	50-32-8	A2						
40	Benzotrichloride	98-07-7	0.8						
41	Benzoyl chloride	98-88-4	(C)3						
42	Benzoyl peroxide	94-36-0	5	5					
43	Benzyl acetate	140-11-4	61						
44	Benzyl chloride	100-44-7	5	5					
45	Biphenyl	92-52-4	1	1					
46	Bis(2-dimethylaminoethyl) ether [DMAEE]	3033-62-3	0.3						
47	Bromacil	314-40-9	10						

Table 6 (continued)

#	Substances	CAS #	ACGIH [1]	OSHA [2]	OEHHA [3]	WHO [4]	Japan [5]	HK [6]	Germany [7]
			mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3
48	1,3-Butadiene	106-99-0	4	2	0.02				
49	Butane	106-97-8	2378						
50	n-Butanol	71-36-3	61	300					
51	see-Butanol	78-92-2	303	450					
52	tert-Butanol	75-65-0	303	300					
53	2-Butoxyethanol	111-76-2	97	240		13.1 [1 wk]			
54	2-Butoxyethyl acetate	112-07-2	131						
55	n-Butyl acetate	123-86-4	713	710					
56	see-Butyl acetate	105-46-4	951	950					
57	tert-Butyl acetate	540-88-5	951	950					
58	n-Butyl acrylate	141-32-2	10						
59	n-Butylamine	109-73-9	(C)15	(C)15					
60	Butylated hydroxytoluene [BHT]	128-37-0	2						
61	tert-Butyl chromate (as CrO3)	1189-85-1	(C)0.1	(C)0.1					
62	n-Butyl glycidyl ether [BGE]	2426-08-6	133	270					
63	n-Butyllactate	138-22-7	30						
64	n-Butyl mercaptan	109-79-5	2	35					
65	o-sec-Butylphenol	89-72-5	31						
66	p-tert-Butyltoluene	98-51-1	6	60					
67	Camphor - Synthetic	76-22-2	12	2					
68	Caprolactam	105-60-2	5						
69	Captafol	2425-06-1	0.1						
70	Captan	133-06-2	5						
71	Carbaryl	63-25-2	5	5					
72	Carbofuran	1563-66-2	0.1						
73	delta-3-Carene [3,7,7-Trimethyl bicyclohep-3-ene]	13466-78-9	112						
74	Catechol	120-80-9	23						
75	Chlordane	57-74-9	0.5	0.5					
76	Chlorinated camphene	8001-35-2	0.5	0.5					
77	o-Chlorinated diphenyl oxide	31242-93-0	0.5						
78	Chloroacetaldehyde	107-20-0	(C)3	(C)3					
79	Chloroacetone	78-95-5	(C)4						
80	2-Chloroacetophenone	532-27-4	0.3	0.3					
81	Chloroacetyl chloride	79-04-9	0.2						
82	Chlorobenzene	108-90-7	46	350	1	0.5 [1 yr]			
83	o-Chlorobenzylidene malononitrile	2698-41-1	(C)0.4	0.4					
84	Chlorobromomethane	74-97-5	1059	1050					
85	Chlorodifluoromethane [FC-2]	75-45-6	3539						
86	Chlorodiphenyl (42% chloride)	53469-21-9	1	1					
87	Chlorodiphenyl (54% chloride)	11097-69-1	0.5	0.5					
88	Chloroform	67-66-3	49	(C)240	0.3			0.163	
89	bis(Chloromethyl) ether	542-88-1	0.005	Carcinogen					
90	Chloromethyl methyl ether	107-30-2	A2	Carcinogen					

Table 6 (continued)

#	Substances	CAS #	ACGIH [1] mg/m^3	OSHA [2] mg/m^3	OEHHA[3] mg/m^3	WHO [4] mg/m^3	Japan [5] mg/m^3	HK [6] mg/m^3	Germany [7] mg/m^3
91	1-Chloro-1-nitropropane	600-25-9	10	100					
92	Chloropentafluoroethane	76-15-3	6321						
93	Chloropicrin	76-06-2	0.7	0.7	0.0004				
94	beta-Chloroprene	126-99-8	36	90					
95	1-Chloro-2-propanol	127-00-4	4						
96	2-Chloro-1-propanol	78-89-7	4						
97	2-Chloropropionlc acid	598-78-7	0.4						
98	o-Chlorostyrene	2039-87-4	284						
99	o-Chlorotoluene	95-49-8	259						
100	Chlorpyrifos	2921-88-2	0.1				0.0001 (children), 0.001 (others)		
101	Chrysene	218-01-9	A3						
102	Clopidol	2971-90-6	10						
103	o-Cresol	95-48-7	22						
104	m-Cresol	108-39-4	22						
105	p-Cresol	106-44-5	22						
106	Cresol - Mixture of isomers	1319-77-3	22	22	0.6				
107	Crotonaldehyde	4170-30-3	(C)0.9	6					
108	Crufomate	299-86-5	5						
109	Cumene	98-82-8	246	245					
110	Cyanamide	420-04-2	2						
111	Cyanogen	460-19-5	21						
112	Cyanogen chloride	506-77-4	(C)0.8						
113	Cyclohexane	110-82-7	344	1050					
114	Cyclohexanol	108-93-0	205	200					
115	Cyclohexanone	108-94-1	80	200					
116	Cyclohexene	110-83-8	1008	1015					
117	Cyclohexylamine	108-91-8	41						
118	Cyclonite	121-82-4	0.5						
119	Cyclopentadiene	542-92-7	203	200					
120	Cyclopentane	287-92-3	1722						
121	Cyhexatin	13121-70-5	5						
122	2,4-D [2,4-Dichlorophenoxyacetic acid	94-75-7	10	10					
123	DDT [Dichlorodiphenyltrichloroethane]	50-29-3	1	1					
124	Demeton	8065-48-3	0.05	0.1					
125	Demeton-S-methyl	919-86-8	0.05						
126	Diacetone alcohol	123-42-2	238	240					
127	Diazinon	333-41-5	0.01				0.00029		
128	Diazomethane	334-88-3	0.3	0.4					
129	1,2-Dibromo-3-chloropropane (DBCP)	96-12-8		0.010					
130	2-N-Dibutylaminoethanol	102-81-8	4						
131	Dibutyl phenyl phosphate	2528-36-1	4						
132	Dibutyl phosphate	107-66-4	9	5					
133	Dibutyl phthalate	84-74-2	5	5			0.22		
134	Dichloroacetylene	7572-29-4	(C)0.4						

Table 6 (continued)

#	Substances	CAS #	ACGIH [1]	OSHA [2]	OEHHA [3]	WHO [4]	Japan [5]	HK [6]	Germany [7]
			mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3
135	o-Dichlorobenzene	95-50-1	150	(C)300				0.5	
136	p-Dichlorobenzene	106-46-7	60	450	0.8	1 [1 yr]	0.24	0.2	
137	3,3' -Dichlorobenzidine	91-94-1	A3	Carcinogen					
138	1,4-Dichloro-2-butene	764-41-0	0.03						
139	Dichlorodifluoromethane [FC-12]	75-71-8	4948	4950					
140	1,3-Dichloro-5,5-dimethyl hydantoin	118-52-5	0.2	0.2					
141	1,1-Dichloroethane	75-34-3	405	400					
142	1,2-Dichloroethylene, cis-isomer	156-59-2	794						
143	1,2-Dichloroethylene, sym-isomer	540-59-0	794	790					
144	1,2-Dichloroethylene, trans-isomer	156-60-5	794						
145	Dichloroethyl ether	111-44-4	29	(C)90					
146	Dichlorofluoromethane [FC-21]	75-43-4	42	4200					
147	Dichloromethane	75-09-2	174	87	0.4	3 [24 hr]			2 / 0.2 [24 h]*
148	1,1-Dichloro-1-nitroethane	594-72-9	12	(C)60					
149	1,3-Dichloropropene	542-75-6	5						
150	2,2-Dichloropropionic acid	75-99-0	5						
151	Dichlorotetrafluoroethane [Cryofluorane]	76-14-2	6995	7000					
152	Dichlorvos [DDVP]	62-73-7	0.1	1					
153	Dicrotophos	141-66-2	0.05						
154	Dicyclopentadiene	77-73-6	27						
155	Dieldrin	60-57-1	0.3	0.3					
156	Diesel fuel - Vapor & aerosol	68334-30-5	100						
157	Diesel fuel No.2 - Vapor & aerosol	68476-34-6	100						
158	Diesel fuel No.4 (Marine disel) - Vapour & Aerosol	77650-28-3	100						
159	Diethanolamine	111-42-2	2		0.003				
160	Diethylamine	109-89-7	15	75					
161	2-Diethylaminoethanol	100-37-8	10	50					
162	Diethylene triamine	111-40-0	4						
163	Di(2-ethylhexyl)phthalate [DEHP]	117-81-7	5	5			0.12		
164	Diethyl ketone	96-22-0	705						
165	Diethyl phthalate	84-66-2	5						
166	Difluorodibromomethane	75-61-6	859	860					
167	Diglycidyl ether [DGE]	2238-07-5	0.5	(C)2.8					
168	Diisobutyl ketone	108-83-8	146	290					
169	Diisopropylamine	108-18-9	21	20					
170	N,N-Dimethylacetamide	127-19-5	36	35					
171	Dimethylamine	124-40-3	9	18					
172	Dimethylaniline	121-69-7	25	25					
173	4-Dimethylaminoazo-benzene	60-11-7		Carcinogen					
174	2,2-Dimethylbutane	75-83-2	1763						
175	2,3-Dimethylbutane	79-29-8	1763						

Table 6 (continued)

#	Substances	CAS #	ACGIH [1]	OSHA [2]	OEHHA [3]	WHO [4]	Japan [5]	HK [6]	Germany [7]
			mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3
176	Dimethyl carbamoyl chloride	79-44-7	A2						
177	Dimethylethoxysilane	14857-34-2	2						
178	Dimethylformamide	68-12-2	30	30	0.08				
179	1,1-Dimethylhydrazine	57-14-7	0.02	1					
180	Dimethyl phthalate	131-11-3	5	5					
181	Dimethyl sulfate	77-78-1	0.5	5					
182	Dimethyl sulfide	75-18-3	25						
183	Dinitolmide	148-01-6	5						
184	o-Dinitrobenzene	528-29-0	1	1					
185	m-Dinitrobenzene	99-65-0	1	1					
186	p-Dinitrobenzene	100-25-4	1	1					
187	Dinitro-o-cresol	534-52-1	0.2	0.2					
188	Dinitrotoluene	25321-14-6	0.2	2					
189	1,4-Dioxane	123-91-1	72	360	3				
190	Dioxathion	78-34-2	0.1						
191	1,3-Dioxolane	646-06-0	61						
192	Diphenylamine	122-39-4	10						
193	Dipropyl ketone	123-19-3	234						
194	Diquat	2764-72-9	0.5						
195	Diquat	2764-72-9	0.1						
196	Disulfiram	97-77-8	2						
197	Disulfoton	298-04-4	0.05						
198	Diuron	330-54-1	10						
199	Divinyl benzene	1321-74-0	53						
200	Dodecyl mercaptan	112-55-0	0.8						
201	Endosulfan	115-29-7	0.1						
202	Endrin	72-20-8	0.1	0.1					
203	Enflurane	13838-16-9	566						
204	Epichlorohydrin	106-89-8	2	19	0.003				
205	EPN	2104-64-5	0.1	0.5					
206	Epoxybutane (1,2-)	106-88-7			0.02				
207	Ethane	74-84-0	1231						
208	Ethanol	64-17-5	1885	1900					
209	Ethanolamine	141-43-5	7	6					
210	Ethion	563-12-2	0.05						
211	2-Ethoxyethanol [EGEE]	110-80-5	18	740	0.07	n.p.			
212	2-Ethoxyethyl acetate [EGEEA]	111-15-9	27	540	0.3	n.p.			
213	Ethyl acetate	141-78-6	1442	1400					
214	Ethyl acrylate	140-88-5	20	100					
215	Ethylamine	75-04-7	9	18					
216	Ethyl amyl ketone	541-85-5	131	130					
217	Ethyl benzene	100-41-4	434	435	2	22 [1 yr]	3.8	1.447	
218	Ethyl bromide	74-96-4	22	890					
219	Ethyl tert-butyl ether [ETBE]	637-92-3	21						
220	Ethyl butyl ketone	106-35-4	234	230					
221	Ethyl chloride	75-00-3	264	2600	30				
222	Ethyl cyanoacrylate	7085-85-0	1						
223	Ethylene	74-85-1	223441						
224	Ethylene chlorohydrin	107-07-3	(C)3	16					
225	Ethylenediamine	107-15-3	25	25					
226	Ethylene dibromide	106-93-4	A3		0.0008				

Table 6 (continued)

#	Substances	CAS #	ACGIH [1] mg/m^3	OSHA [2] mg/m^3	OEHHA[3] mg/m^3	WHO [4] mg/m^3	Japan [5] mg/m^3	HK [6] mg/m^3	Germany [7] mg/m^3
227	Ethylene dichloride	107-06-2	41		0.4				
228	Ethylene glycol - Aerosol	107-21-1	(C)100		0.4				
229	Ethylene glycol dinitrate [EGDN]	628-96-6	0.3	(C)1					
230	Ethylene oxide	75-21-8	2	2	0.03				
231	Ethylenimine	151-56-4	0.9	Carcinogen					
232	Ethyl ether	60-29-7	1213	1200					
233	Ethyl formate	109-94-4	303	300					
234	2-Ethylhexanoic acid	149-57-5	5						
235	Ethylidene norbornene	16219-75-3	(C)25						
236	Ethyl mercaptan	75-08-1	1	(C)25					
237	N-Ethylmorpholine	100-74-3	24	94					
238	Ethyl silicate	78-10-4	85	850					
239	Fenamiphos	22224-92-6	0.1						
240	Fensulfothion	115-90-2	0.1						
241	Fenthion	55-38-9	0.2						
242	Ferbam	14484-64-1	10						
243	Fenobucarb	3766-81-2					0.033		
244	Fonofos	944-22-9	0.1						
245	Formaldehyde	50-00-0	(C)0.4	0.9	0.003	0.1 [30 min]	0.1		
246	Formamide	75-12-7	18						
247	Formic acid	64-18-6	9	9					
248	Fuel oil No.2 - Vapor & aerosol	68476-30-2	100						
249	Fuel oil No.4 - Vapor & aerosol	68476-31-3	100						
250	Furfural	98-01-1	8	20					
251	Furfuryl alcohol	98-00-0	40	200					
252	Gasoline - Bulk handling	86290-81-5	300 ppm						
253	Glutaraldehyde	111-30-8	(C)0.2		0.00008				
254	Glycidol	556-52-5	6	150					
255	Glyoxal	107-22-2	0.1						
256	Halothane	151-67-7	404						
257	Heptachlor	76-44-8	0.05	0.5					
258	Heptachlor epoxide	7024-57-3	0.05						
259	Heptane - All isomers		1640						
260	n-Heptane		1640	2000					
261	Hexachlorobenzene [HCB]	118-74-1	0.002						
262	Hexachlorobutadiene	87-68-3	0.2						
263	Hexachlorocyclopentadiene	77-47-4	0.1						
264	Hexachloroethane	67-72-1	10	10					
265	Hexachloronaphthalene	1335-87-1	0.2	0.2					
266	Hexafluoroacetone	684-16-2	0.7						
267	Hexahydrophthalic anhydride	85-42-7	(C)0.005						
268	Hexahydrophthalic anhydride - cis-isomer	13149-00-3	(C)0.005						
269	Hexahydrophthalic anhydride - trans-isomer	14166-21-3	(C)0.005						
270	1,6-Hexamethylene diisocyanate [HDI]	822-06-0	0.03						

Table 6 (continued)

#	Substances	CAS #	ACGIH [1]	OSHA [2]	OEHHA [3]	WHO [4]	Japan [5]	HK [6]	Germany [7]
			mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3
271	Hexamethyl phosphoramide	680-31-9	A3						
272	n-Hexane	110-54-3	176	1800	7				
273	Hexane, other isomers excluding n-hexane		500 ppm						
274	1,6-Hexanediamine		2						
275	1-Hexene	592-41-6	172						
276	sec-Hexyl acetate	108-84-9	295	300					
277	Hexylene glycol	107-41-5	(C)121						
279	Hydrogenated terphenyls - Nonirradiated	61788-32-7	5						
278	Hydrogen cyanide (as CN)	74-90-8	(C)5	11	0.009				
280	Hydroquinone	123-31-9	2	2					
281	2-Hydroxypropyl acrylate	999-61-1	3						
282	Indene	95-13-6	48						
283	Isoamyl alcohol	123-51-3	361	360					
284	Isobutane	75-28-5	2378						
285	Isobutyl acetate	110-19-0	713	700					
286	Isobutyl alcohol	78-83-1	152	300					
287	Isobutyl nitrite	542-56-3	(C)4						
288	Isooctane	540-84-1	1402						
289	Isooctyl alcohol	26952-21-6	266						
290	Isopentane	78-78-4	1772						
291	Isopentyl acetate	123-92-2	266	525					
292	Isophorone	78-59-1	(C)28	140	2				
293	Isophorone diisocyanate	4098-71-9	0.05						
294	2-lsopropoxyethanol	109-59-1	107						
295	Isopropyl acetate	108-21-4	418	950					
296	Isopropylamine	75-31-0	12	12					
297	N-Isopropylaniline	768-52-5	11						
298	Isopropyl ether	108-20-3	1045	2100					
299	Isopropyl glycidyl ether [IGE]	4016-14-2	238	240					
300	Jet fuels		200						
301	Kerosene		200						
302	Kerosene - Hydrodesulferized	64742-81-0	200						
303	Ketene	463-51-4	0.9	0.9					
304	Lindane	58-89-9	0.5	0.5					
305	Liquified petroleum gas [L.P.G .]	68476-85-7	1743	1800					
306	Malathion	121-75-5	1	15					
307	Maleic anhydride	108-31-6	0.4	1	0.0007				
308	Manganese cyclopentadienyl tricarbonyl (as Mn)	12079-65-1	0.1						
309	Mesityl oxide	141-79-7	60	100					
310	Methacrylic acid	79-41-4	70						
311	Methane	74-82-8	656						
312	Methanol	67-56-1	262	260	4				
313	Methomyl	16752-77-5	3						
314	Methoxychlor	72-43-5	10	15					
315	2-Methoxyethanol	109-86-4	16	80	0.06	n.p.			
316	2-Methoxyethyl acetate	110-49-6	24	120	0.09				

Table 6 (continued)

#	Substances	CAS #	ACGIH [1] mg/m^3	OSHA [2] mg/m^3	OEHHA[3] mg/m^3	WHO [4] mg/m^3	Japan [5] mg/m^3	HK [6] mg/m^3	Germany [7] mg/m^3
317	(2-methoxymethylethoxy)propanal [DPGME]	34590-94-8	606	600					
318	4-Methoxyphenol	150-76-5	5						
319	1-Methoxy-2-propanol [PGME]	107-98-2	369		7				
320	Methyl acetatE	79-20-9	639	610					
321	Methyl acetylene	74-99-7	1640	1650					
322	Methyl acetylene-propadiene mixture [MAPP]	59355-75-8	1640						
323	Methyl acrylate	96-33-3	7	35					
324	Methylacrylonitrile	126-98-7	3						
325	Methylal	109-87-5	3114	3100					
326	Methylamine	74-89-5	6	12					
327	Methyl n-amyl ketone	110-43-0	234	465					
328	N-Methyl aniline	100-61-8	2	9					
329	Methyl bromide	74-83-9	4	(C)80	0.005				
330	Methyl tert-butyl ether [MTBE]	1634-04-4	180		8				
331	2-Methylbutyl acetate	624-41-9	266						
332	Methyl n-butyl ketone	591-78-6	20	410					
333	Methyl chloride	74-87-3	103	207					
334	Methyl chloroform	71-55-6	1911	1900	1				
335	Methyl 2-cyanoacrylate	137-05-3	0.9						
336	Methylcyclohexane	108-87-2	1607	2000					
337	Methylcyclohexanol	25639-42-3	234	470					
338	o-Methylcyclohexanone	583-60-8	230	460					
339	2-Methylcyclopentadienyl manganese tricarbonyl	12108-13-3	0.2						
340	Methyl demeton	8022-00-2	0.5						
341	Methylene bisphenyl isocyanate [MDI]	101-68-8	0.05	(C)0.2	0.0007				
342	4,4'-Methylene bis(2-chloroaniline) [MBOCA]	101-14-4	0.1						
343	Methylene bis(4-cyclohexylisocyanate)	5124-30-1	0.05						
344	4,4'-Methylene dianiline	101-77-9	0.8		0.02				
345	Methyl ethyl ketone [MEK]	78-93-3	590	590					
346	Methyl ethyl ketone peroxide [MEKP]	1338-23-4	(C)0.6						
347	Methyl formate	107-31-3	246	250					
348	Methyl hydrazine	60-34-4	0.02	(C)0.35					
349	Methyl iodide	74-88-4	12	28					
350	Methyl isoamyl ketone	110-12-3	234	475					
351	Methyl isobutyl carbinol	108-11-2	105	100					
352	Methyl isobutyl ketone	108-10-1	205	410					
353	Methyl isocyanate	624-83-9	0.05	0.05	0.001				
354	Methyl isopropyl ketone	563-80-4	705						
355	Methyl mercaptan	74-93-1	1.0	(C)20					
356	Methyl mercury (as Hg)	22967-92-6	0.01						
357	Methyl methacrylate	80-62-6	205	410		0.2 [1 yr]			

Table 6 (continued)

#	Substances	CAS #	ACGIH [1] mg/m^3	OSHA [2] mg/m^3	OEHHA[3] mg/m^3	WHO [4] mg/m^3	Japan [5] mg/m^3	HK [6] mg/m^3	Germany [7] mg/m^3
358	Methyl parathion	298-00-0	0.2						
359	2-Methyl pentane	107-83-5	1763						
360	3-Methyl pentane	96-14-0	1763						
361	Methyl propyl ketone	107-87-9	705	700					
362	Methyl silicate	681-84-5	6						
363	alpha-Methyl styrene	98-83-9	242	(C)480					
364	Methyl vinyl ketone	78-94-4	(C)0.6						
365	Metribuzin	21087-64-9	5						
366	Mevinphos	7786-34-7	0.01	0.1					
367	Monocrotophos	6923-22-4	0.05						
368	Morpholine	110-91-8	71	70					
369	Naled	300-76-5	0.1	3					
370	Naphthalene	91-20-3	52	50	0.009				0.02 / 0.002
371	alpha-Naphthylamine	134-32-7		Carcinogen					
372	beta-Naphthylamine	91-59-8	A1	Carcinogen					
373	Natural gas	8006-14-2	1000 ppm						
374	Natural rubber latex	9006-04-6	0.001						
375	Nicotine	54-11-5	0.5	0.5					
376	p-Nitroaniline	100-01-6	3	6					
377	Nitrobenzene	98-95-3	5	5					
378	p-Nitrochlorobenzene	100-00-5	0.6	1					
379	4-Nitrodiphenyl	92-93-3	A2	Carcinogen					
380	Nitroethane	79-24-3	307	307					
381	Nitroglycerin [NG]	55-63-0	0.5	(C)2					
382	Nitromethane	75-52-5	50	250					
383	1-Nitropropane	108-03-2	91	90					
384	2-Nitropropane	79-46-9	36	90					
385	N-Nitrosodimethylamine	62-75-9	A3	Carcinogen					
386	Nitrotoluene - o-isomer	88-72-2	11	30					
387	Nitrotoluene - m-isomer	99-08-1	11	30					
388	Nitrotoluene - p-isomer	99-99-0	11	30					
389	Nonanal	124-19-6					0.041 (interim due to data gap)		
390	Nonane - All isomers	111-84-2	1050						
391	Octachloronaphthalene	2234-13-1	0.1	0.1					
392	n-Octane	111-65-9	1402	2350					
393	Oxalic acid	144-62-7	1	1					
394	p,p'-Oxybis(benzenesulfonyl hydrazide)	80-51-3	0.1						
395	Paraquat	4685-14-7	0.1						
396	Paraquat	4685-14-7	0.5						
397	Parathion	56-38-2	0.05	0.1					
398	Pentachloronaphthalene	1321-64-8	0.5	0.5					
399	Pentachloronitrobenzene	82-68-8	0.5						
400	Pentachlorophenol	87-86-5	0.5	0.5					0.001 / 0.0001
401	Pentane - All isomers		1772						
402	n-Pentane		1772	2950					
403	tert-Pentane [Neopentane]	463-82-1	1772						
404	Pentyl acetate - All isomers		266						

Table 6 (continued)

#	Substances	CAS #	ACGIH [1] mg/m^3	OSHA [2] mg/m^3	OEHHA[3] mg/m^3	WHO [4] mg/m^3	Japan [5] mg/m^3	HK [6] mg/m^3	Germany [7] mg/m^3
405	1-Pentyl acetate		266	525					
406	2-Pentyl acetate	626-38-0	266	650					
407	3-Pentyl acetate	620-11-1	266						
408	tert-Pentyl acetate	625-16-1	266						
409	Perchloromethyl mercaptan	594-42-3	0.8	0.8					
410	Perfluorobutyl ethylene [PFBE]	19430-93-4	1007						
411	Perfluoroisobutylene	382-21-8	(C)0.08						
412	Phenol	108-95-2	19	19	0.2				
413	Phenothiazine	92-84-2	5						
414	o-Phenylenediamine	95-54-5	0.1						
415	m-Phenylenediamine	108-45-2	0.1						
416	p-Phenylenediamine	106-50-3	0.1	0.1					
417	Phenyl ether - Vapor	101-84-8	7	7					
418	Phenyl ether-biphenyl mixture, vapor			7					
419	Phenyl glycidyl ether [PGE]		0.6	60					
420	Phenylhydrazine	100-63-0	0.4	22					
421	Phenyl mercaptan	108-98-5	0.5						
422	N-Phenyl-beta-naphthylamine	135-88-6	A4						
423	Phenyl phosphine	638-21-1	(C)0.2						
424	Phorate	298-02-2	0.05						
425	Phthalic anhydride	85-44-9	6	12	0.02				
426	m-Phthalodinitrile	626-17-5	5						
427	Picric acid	88-89-1	0.1	0.1					
428	Pindone	83-26-1	0.1	0.1					
429	alpha-Pinene	80-56-8	112						2 / 0.2 (terpenes) **
430	beta-Pinene	127-91-3	112						
431	Piperazine dihydrochloride	142-64-3	5						
432	Propane	74-98-6	1804	1800					
433	Propane suItone	1120-71-4	A3						
434	n-Propanol	71-23-8	492	500					
435	2-Propanol	67-63-0	492	980	7	n.p.			
436	Propargyl alcohol	107-19-7	2						
437	beta-Propiolactone	57-57-8	1	Carcinogen					
438	Propionaldehyde	123-38-6	48						
439	Propionic acid	79-09-4	30						
440	Propoxur	114-26-1	0.5						
441	n-Propyl acetate	109-60-4	836	840					
442	Propylene	115-07-1	335800		3				
443	Propylene dichloride	78-87-5	347	350					
444	Propylene glycol dinitrate	6423-43-4	0.3						
445	Propylene imine	75-55-8	5	5					
446	Propylene oxide	75-56-9	5	240	0.03				
447	n-Propyl nitrate	627-13-4	108	110					
448	Pyrethrum	8003-34-7	5	5					
449	Pyridine	110-86-1	3	15					
450	Quinone	106-51-4	0.4	0.4					
451	Resorcinol	108-46-3	45						

Table 6 (continued)

#	Substances	CAS #	ACGIH [1] mg/m^3	OSHA [2] mg/m^3	OEHHA[3] mg/m^3	WHO [4] mg/m^3	Japan [5] mg/m^3	HK [6] mg/m^3	Germany [7] mg/m^3
452	Ronnel [Fenchlorphos]	299-84-3	10	15					
453	Rosin core solder thermal decomposition products (colophony)	8050-09-7	sensitization						
454	Rotenone (commercial)	83-79-4	5	5					
455	Rubber solvent (Naphtha)	8030-30-6	1588	400					
456	Sesone	136-78-7	10						
457	Sodium fluoroacetate	62-74-8	0.05	0.05					
458	Stoddard solvent	8052-41-3	573	2900					
459	Strychnine	57-24-9	0.2	0.2					
460	Styrene - monomer	100-42-5	85	426	0.9	0.26 [1 wk]	0.22		0.3 / 0.03
461	Subtilisins [Proteolytic enzymes]	1395-21-7	(C)0.00006						
462	Sulfometuron methyl	74222-97-2	5						
463	Sulfotepp [TEDP]	3689-24-5	3						
464	Sulprofos	35400-43-2	1						
465	2,4,5- T [2,4,5-Trichlorophenoxyacetic acid]	93-76-5	10						
466	Temephos	3383-96-8	10						
467	Terbufos	1307-79-9	0.01						
468	Terephthalic acid	100-21-0	10						
469	o-Terphenyl	84-15-1	(C)5						
470	m-Terphenyl	92-06-8	(C)5						
471	p-Terphenyl	92-94-4	(C)5						
472	Terphenyl- Mixed isomers	26140-60-3	(C)5	(C)9					
473	1,1,1,2-Tetrachloro-2,2-difluoroethane [FC-112a]	76-11-9	4171	4170					
474	1,1,2,2-Tetrachloro-1,2-difluoroethane [FC-112]	76-12-0	4171	4170					
475	1,1,2,2-Tetrachloroethane	79-34-5	7	35					
476	Tetrachloroethylene [Perchlorophthalene]	127-18-4	170	679	0.035	0.25 [24 hr]		0.25	
477	Tetrachloronaphthalene	1335-88-2	2	2					
478	Tetradecane	629-59-4					0.33		
479	Tetraethyllead (as Pb)	78-00-2	0.1	0.08					
480	Tetraethyl pyrophosphate [TEPP]	107-49-3	0.05	0.05					
481	Tetrafluoroethylene	116-14-3	8						
482	Tetrahydrofuran	109-99-9	590	590					
483	Tetramethyllead (as Pb)	75-74-1	0.2	0.08					
484	Tetramethyl succinonitrile	3333-52-6	3	3					
485	Tetranitromethane	509-14-8	0.04	8					
486	Tetryl	479-45-8	2	2					
487	Thimerosal	54-64-8	0.1						
488	4,4'- Thiobis(6-tert-butyl-m-cresol)	96-69-5	10						
489	Thioglycolic acid	68-11-1	4						
490	Thiram	137-26-8	1	5					
491	Tin - Organic compounds (as Sn)	7440-31-5	0.1	0.1					
492	o-Tolidine	119-93-7	A3						
493	Toluene	108-88-3	189	754	0.3	0.26 [1 wk]	0.26	1.092	3 / 0.3

Table 6 (continued)

#	Substances	CAS #	ACGIH [1] mg/m^3	OSHA [2] mg/m^3	OEHHA[3] mg/m^3	WHO [4] mg/m^3	Japan [5] mg/m^3	HK [6] mg/m^3	Germany [7] mg/m^3
494	Toluene-2,4-diisocyanate [2,-4-TDI]	584-84-9	0.04	(C)0.14	0.00007				
495	Toluene-2,6-diisocyanate [2,6-TDI]	91-08-7	0.2						
496	Toluene diisocyanate - Mixed isomers	26471-62-5	0.04						
497	o-Toluidine	95-53-4	9	22					
498	m-Toluidine	108-44-1	9						
499	p-Toluidine	106-49-0	9						
500	Tributyl phosphate	126-73-8	2	5					
501	Trichloroacetic acid	76-03-9	7						
502	1,2,4-Trichlorobenzene	120-82-1	(C)37						
503	1,1 ,2-Trichloroethane	79-00-5	55	45					
504	Trichloroethylene	79-01-6	269	538	0.6	n.v		0.77	
505	Trichlorofluoromethane [FC-11]	75-69-4	(C)5600	5600					
506	Trichloronaphthalene	1321-65-9	5	5					
507	1,2,3-Trichloropropane	96-18-4	60	300					
508	1,1 ,2-Trichloro-1 ,2,2-trifluoroethane [FC-113]	76-13-1	7669	7600					
509	Trichlorphon	52-68-6	1						
510	Triethanolamine	102-71-6	5						
511	Triethylamine	121-44-8	4	100	0.2				
512	Trifluorobromomethane [F-13B1]	75-63-8	6094	6100					
513	1,3,5- Triglycidyl-s-triazinetrione	2451-62-9	0.05						
514	Trimellitic anhydride	552-30-7	(C)0.04						
515	Trimethylamine	75-50-3	33						
516	1,2,3- Trimethyl benzene	526-73-8	123						
517	1,2,4- Trimethyl benzene	95-63-6	123						
518	1,3,5- Trimethyl benzene [Mesitylene]	108-67-8	123						
519	Trimethyl benzene - Mixed isomers	25551-13-7	123						
520	Trimethyl phosphite	121-45-9	10						
521	2,4,6- Trinitrotoluene [TNT]	118-96-7	0.1	2					
522	Triorthocresyl phosphate	78-30-8	0.1	0.1					
523	Triphenyl amine	603-34-9	5						
524	Triphenyl phosphate	115-86-6	3	3					
525	Tris(2-chloroethyl)phosphate	115-96-8							0.05 / 0.005
526	Turpentine	8006-64-2	111	560					
527	n-Valeraldehyde	110-62-3	176						
528	Varnish makers' & Printers'	8032-32-4	1400						
529	Vinyl acetate	108-05-4	35		0.2				
530	Vinyl bromide	593-60-2	2						
531	Vinyl chloride	75-01-4	3	3					
532	4-Vinyl cyclohexene	100-40-3	0.4						
533	Vinyl cyclohexene dioxide	106-87-6	0.6						
534	Vinyl fluoride	75-02-5	2						
535	Vinylidene chloride	75-35-4	20		0.07				

Table 6 (continued)

#	Substances	CAS #	ACGIH [1] mg/m^3	OSHA [2] mg/m^3	OEHHA[3] mg/m^3	WHO [4] mg/m^3	Japan [5] mg/m^3	HK [6] mg/m^3	Germany [7] mg/m^3
536	Vinylidene fluoride	75-38-7	1310						
537	N-Vinyl-2-pyrrolidone	88-12-0	0.2						
538	Vinyl toluene [Methyl styrene] - Mixed isomers	25013-15-4	242	480					
539	Warfarin	81-81-2	0.1	0.1					
540	o-Xylene	95-47-6	434						
541	m-Xylene	108-38-3	434						
542	p-Xylene	106-42-3	434						
543	Xylene - Mixed isomers	1330-20-7	434	435	0.7	4.8 [24 hr]	0.87	1.447	
544	m-Xylene alpha,alpha'-diamin	1477-55-0	(C)0.1						
545	Xylidine - Mixed isomers	1300-73-8	2	25					
546	TVOC						0.4	0.6	0.2 - 0.3 ***

[1] **ACGIH TLV** (ACGIH, 2004)
- TLV: threshold limit value set by American Conference of Governmental Industrial Hygienists
  The time-weighted average conc. of a substance to which most workers can be exposed without adverse effects.
- A1 (confirmed human carcinogen), A2 (suspected human carcinogen), A3 (confirmed animal carcinogen w/ unknown relevance to humans) & A4 (not classifiable as a human carcinogen)
- Ref: ACGIH (2004) "TLVs and BEIs with other worldwide occupational exposure values 2004 CD-ROM"

[2] **OSHA PEL** (OSHA, 2004 a & 2004 b)
- PEL: permissible exposure level set by the Occupational Safety and Health Administration (OSHA), US Department of Labor to protect workers against the health effects of exposure to hazardous substances over a normal 8-h workday or a 40-h workweek.
- PELs are regulatory limits on the amount or conc. of a substance in the air & are based on an 8-hour time weighted average (TWA) exposure.
- (C) denotes a ceiling limit.
- Ref: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992
  http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9993

[3] **CREL** (OEHHA, 2005)
- Non-caner chronic reference exposure level, Office of Env. Health Hazard Assessment (OEHHA), California EPA.
- CRELs are available at http://www.oehha.org/air/chronic_rels/AllChrels.html.
- CREL of a chemical is the airborne concentration that would pose no significant health risk to the general public.

[4] **WHO Guidelines for Air Quality** (WHO, 1999)
- Guidelines for air pollutants with non-carcinogenic and carcinogenic health endpoints.
- Ref: http://www.who.int/environmental_information/Air/Guidelines/Chapter3.htm#3.2
- n.p.: not provided, n.v.: no value is given for chemicals with cancer health endpoints, Number in brackets [ ] is averaging time.

[5] **Japan - MHLW IAQ Guidelines** (MHLW, 2004)
- IAQ Guidelines by Ministry of Health, Labour and Welfare of Japan
- The values are mainly based on long-term exposure except for formaldehyde.
- Ref: http://www.nihs.go.jp/mhlw/ocs/sickhouse/rep-eng4.pdf

[6] **Hong Kong - IAQ Guidelines** (Hong Kong, 2003)
- Guidelines for Good Class IAQ set by the Government of the Hong Kong Special Administrative Region
- Ref: http://www.iaq.gov.hk/cert/doc/CertGuide-eng.pdf

[7] **Germany - IAQ Guidelines** (Umwelt Bundes Amt, 2005)
- IAQ Guidelines set by an ad hoc working group of members of the Federal Environmental Agency's Indoor Air Hygiene Commission (IRK) & the Working Group of the Health Ministries of the Länder (AOLG) of Germany.
- Ref: http://www.umweltbundesamt.de/uba-info-daten/daten/irk.htm & http://www.umweltbundesamt.de/uba-info-daten-e/daten-e/irk.htm#4

* Guide value II / Guide value I [averaging time]

** The value is for the sum of several terpenes.

*** These values of TVOC are for the maximum long-term average.

Note:
- Some of the values were converted from ppm to mg/m^3 at 25 ^{o}C and 1 atm.

5. Labelling Schemes for Low-VOC Emitting Products

In the past 25-30 years, a wide variety of organisations have developed criteria for specific building materials and products, in order to help consumers choose those that emit lower levels of VOCs. The total number of labelling systems has become quite large, with individual systems adopted by many different countries. This section of the report presents twelve of the most well known, and most-widely used of these labelling schemes. They are briefly described below. The criteria used by these labelling schemes for representative indoor materials are summarised in Table 7 (the top portion of the table lists specific emission requirements for the individual materials tagged in the bottom half of the table).

5.1 Description of Labelling Systems

Brief descriptions of the labelling systems featured in Table 7 are provided below. For detailed information, web links for each of these systems are provided in the References.

5.1.1 **Environmental Choice Eco-Logo** (Canada)

The Canadian Environmental Choice Label Program was one of the original labelling systems, preceded only by Germany's Blue Angel program. It was developed in 1988 by Environment Canada, and is administered by TerraChoice Environmental Services (www.terrachoice.ca). The labelling program is much broader than just emissions testing and includes many environmental management requirements. Examples follow:

- Adhesives: no use in manufacture of aromatic or halogenated solvents, formaldehyde, borax, Hg, PB, Cd, Cr; detailed instructions for safe (health) application and disposal; VOC content < 5% by weight.
- Office Furniture and Panel Systems: Guideline ECP-66 is based on and uses the same limits as the State of Washington specification (VOC and formaldehyde emission rates such that resulting indoor concentrations will not exceed 0.5 mg/m^3).

5.1.2 **Green Label** (USA)

Industry-designed and administered. Developed in 1992 by the Carpet and Rug Institute (the national trade association of carpet and rug industry) in consultation with US EPA. The program specifies maximum emission rates for 4-PC, formaldehyde, styrene and TVOC following small emission chamber trials conducted by a single commercial lab.

5.1.3 **Green Label Plus** (USA)

This is a revised version of the Green Label program developed to satisfy California's CHPS Criteria. Green Label Plus Testing and Product Requirements: Initial test - The carpet meets the environmental emissions criteria as outlined in Section 01350 (modeled concentration after 14 d test (10d condition + 96h chamber) not to exceed 1/2 of the current OEHHA CREL value found at www.oehha.ca.gov/air/chronic_rels/AllChrels.html). Exception: Formaldehyde - based on the ALARA principle, modeled concentration not to exceed 1/2 of 33ug/m3 (23ppb). Every carpet receiving Green Label Plus certification has been tested for emission levels for all chemicals as required by Section 01350, plus six additional chemicals for a total of 13 chemicals:

Acetaldehyde, Benzene, Caprolactam, 2-Ethylhexanoic Acid, Formaldehyde, 1-Methyl-2-Pyrrolidinone, Naphthalene, Nonanal, Octanal, 4-Phenylcyclohexene, Styrene, Toluene, and Vinyl Acetate. Quarterly testing - the carpet meets the established emissions criteria for TVOC. Annual testing - the carpet meets the TVOC emissions criteria, plus stringent emissions criteria for the thirteen individual chemicals.

5.1.4 **Green Seal** (USA)

Developed by independent non-profit organization of the same name. Based on ISO 14020 and ISO 14024, and US EPA, and global ecolabelling network. Guiding principles and procedures are from Type I Environmental labelling (ISO 14024). Example criteria:

- Paints – should not contain any of the following ingedients – methylene chloride, 1,1,1-trichloroethane, benzene, toluene (methylbenzene), ethylbenzene, vinyl chloride, naphthalene, 1,2-dichlorobenzene, di (2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, di-n-octyl phthalate, diethyl phthalate, dimethyl phthalate, isophorone, antimony, cadmium, hexavalent chromium, lead, mercury, formaldehyde, methyl ethyl ketone, methyl isobutyl ketone, acrolein, acrylonitrile.

5.1.5 **Green Guard** (USA)

Developed from AQSpec List, which was first initiated in 1996. Product-by-product specifications for emissions of formaldehyde, VOC, respirable particles, ozone, and other pollutants (include any California Proposition 65, US NTP or IARC carcinogens and reproductive toxins) using small environmental chambers. Tested to see if they meet "acceptable IAQ pollutant guidelines and standards" within a 5-day period of unpackaging. Examples:

- Construction materials, furnishings and office furniture must meet the low pollutant requirements of the State of Washington's IAQ program, OSHA's formaldehyde rule, US EPA's office furniture specifications, US EPA's national ambient air quality standards, and 1/10 of all regulated chemical exposure limits established by OSHA.
- Office equipment and certain processes: products must also meet Germany's Blue Angel Program for styrene, particulates, and ozone (where the above organizations conflict, the less stringent level is used by Greenguard). "Office furniture" includes – desks, free standing case goods, tables, vertical and lateral files, storage cabinets, bookcases, metal case goods, moveable walls, acoustical panels

5.1.6 **Environmentally Preferable Product** (USA)

Managed by Scientific Certification Systems (SCS). EPP Certification is based upon a full Lifecycle Impact Assessment (LCIA). To achieve certification, part of the evaluation protocol requires that calculated model building concentrations (school classroom and office space) for chemicals emitted by the product must conform to the following:

- Formaldehyde – Less than or equal to16.5 ug/m^3; and
- All other organic chemicals – Less than or equal to ½ the established Chronic Reference Level as listed in the latest edition of the Cal/EPA OEHHA list of chemicals with noncancer chronic Reference Exposure Levels (RELs). The current version of this list is accessible at http://www.oehha.ca.gov/air/chronic_rels/AllChrels.html

5.1.7 **Blue Angel** (Germany)

The first environmental label, created in 1977, now used by about 710 companies for ~3,800 products in ~80 product categories. The label is the property of the Federal Ministry of the Environment, Nature Protection and Nuclear Safety. It is sponsored and administered by the Federal Environmental Agency and the quality assurance and product labelling institute RAL Deutsches Institut für Gütesicherung und Kennzeichnung e.V. All technical demands placed on products and services for the award of the Environmental Label are decided by an independent Environmental Label jury. Emission data assessed after 28 days of chamber testing.

5.1.8 **EMICODE** (Germany)

A group of German manufacturers of flooring installation products founded the "Gemeinschaft Emissionskontrollierter Verlegewerkstoffe e.V." (GEV), or translated "Association for the Control of Emissions in Products for Flooring Installation ". The EMICODE ® system is based on defined analytical test chamber procedures and strict classification criteria. These criteria have been defined by the Technical Council of the GEV with the professional support of the environmental institute Miljö-Chemie, the Carpet Research Institute (TFI) and the Association for Environmentally-Friendly Carpets (GuT).

5.1.9 **GuT** (Germany)

The Association of Environmentally-Friendly Carpets was established in 1990. The original criteria includes prohibitions for certain substances (including pentachlorophenol, formaldehyde, vinylchloride, vinylacetate, benzene, certain pesticides, azo dyes, etc). Based on 24 hour chamber emission testing and odour testing (in compliance with the Swiss standard SNV 195651). A new evaluation scheme, instituted in Jan.2004, is based on the ECA-18-system and is compatible with other systems such as the procedure suggested by AgBB (Ausschuss zur gesundheitlichen Bewertung von Bauprodukten = Committee for Health-related Evaluation of Building Products) for the evaluation of building products used for large indoor areas. Emissions testing is now conducted after 72 hours, and uses the LCI (Lowest Concentration of Interest) table published by AgBB (http://www.umweltdaten.de/daten-e/agbb.pdf). Prohibits carcinogens vs. EU list Classes 1 and 2.

5.1.10 **Finnish M-1, M-2** (Finland)

The first version of the emission classification was developed by the Finnish Society of Indoor Air Quality and Climate (FiSIAQ) in 1995 as part of Classification of Indoor Climate, Construction, and Finishing Materials. The first emission classifications were granted in 1996. In May 2000 the system changed its name into emission classification of building materials. Classifications are granted by the Building Information Foundation (RTS), a private foundation with representatives from 43 Finnish building organisations, and Finland's leading information service for the building and construction sector. Carcinogens are identified vs. IARC.

5.1.11 **Indoor Climate Label** (Denmark and Norway)

The scheme was developed by the Danish Society of Indoor Climate in 1995 on the initiative of The Danish Ministry of Housing. Normative bodies for the system are the Danish Society of Indoor Climate and the Norwegian Forum of Indoor Climate Labelling. Chemical and sensory odour emission testing in cells or conventional chambers for 28 days is required. Results are converted to indoor air concentrations in a standard room. All products are declared with an "indoor-relevant time-value", which is based on of the time it takes the most slowly emitting individual substances to fall below their odour and irritation thresholds. Threshold values for odour and irritation used are those given in VOCBASE (Jensen and Wolkoff, 1996). Assessment protocols for the following product-areas have been developed: 1) Wall and ceiling systems, 2) Carpets, 3) Interior doors and folding partitions, 4) Windows and exterior doors, 5) Resilient floors, wood-based floors and laminated floors, 6) Oils for wood-based floors and 7) Kitchen, bath and wardrobe cabinets, 8) Interior building paint, and 9) Furniture.

5.1.12 **Nordic Swan** (Scandinavia)

The Nordic Swan labelling system was developed in 1989 by the Nordic Council of Ministers and administered by the Nordic Ecolabelling Board. It is a voluntary program intended to enable consumers to select products that are the least harmful to the environment. Lifecycle assessment criteria are developed on a product-by-product basis. Chemical emissions impacting indoor air are assessed based on 28-day chamber tests. Examples of emissions criteria include:

- Plywood: Formaldehyde emission: ≤ 0.125 mg/m^2 at 28 days
- Adhesives: TVOC: ≤ 0.2 mg/m^{2}h (as toluene equivalent)

Table 7. Labelling Schemes for Low-VOC Emitting Materials

	Label Name:	Environmental Choice EcoLogo			Green Label				Green Label Plus		Green Seal			GreenGuard						
	Agency	TerraChoice Environmental Services			Carpet and Rug Institute				Carpet and Rug Institute		Green Seal (non-profit org.)			GreenGuard Environmental Institute (GEI) / Air Quality Sciences (AQS)						
	Countries:	Canada			USA				USA		USA			USA						
	Year Initiated:	1988			1992				2004		1989			~1996						
	Products/Prod.Categories	~3000/120									~300/31									
		Unit	CrpTile	CrpAdh	Unit	Carp	Cush	Adh	Unit	Value	Unit	Values		Unit	Material Specific Values					
Contaminants Evaluated	2-Ethyl-1-Hexanol							3.00												
	4-Phenyl Cyclohexene				mg/m^2h	0.05	0.05				mg/m^2hr	0.05		mg/m^3	0.0065				0.007	0.00325	
	Aldehydes, Total													ppm	0.1	0.1	0.1		0.1	0.05	0.1
	Ammonia																				
	Benzene								mg/m^3	0.03				mg/m^3				0.0002			
	ButylatedHydroxyToluene				mg/m^2h		0.30														
	Formaldehyde	mg/m^2h	0.02	0.02	mg/m^2h	0.05	0.05	0.05	mg/m^3	0.0165	mg/m^2hr	0.05		ppm	0.05	0.05	0.05	0.04	0.05	0.025	0.05
	Ozone													mg/m^3				0.08			
	Particles, Respirable													mg/m^3			0.05				
	Particles, Total Dust													mg/m^3				0.15			
	Styrene				mg/m^2h	0.40			mg/m^3	0.45	mg/m^2hr	0.4		mg/m^3	0.07			0.04			0.07
	VOCs, Individual													x TLV	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	VOCs, Total (TVOC)	mg/m^2h	0.25	0.05	mg/m^2h	0.50	1.00	10.00			mg/m^2hr	0.5		mg/m^3	0.5	0.5	0.5	0.4	0.5	0.25	0.5
	VOCs, (BP 50-250°C)																				
	VOCs, (BP > 250°C)																				
	VOCs, Total (-Water)										g/L	50	150								
	SVOCs (C 16-22)																				
	Odours																				
	CMT Substances **																				
Protocol applies to these Material / Furnishings	Adhesives														xxx						
	Appliances															xxx					
	Carpet		xxx			xxx				xxx											
	Carpet adhesive			xxx				xxx													
	Carpet cushion						xxx														
	Ceiling																xxx				
	Consumer products																xxx				
	Flooring														xxx						
	General Construction														xxx						
	Insulation																xxx				
	Office Equipment																	xxx			
	Office Furniture *																			xxx	
	Office Workstation																		xxx		
	Paint																				xxx
	Paint - Flat											xxx									
	Paint - Non-Flat												xxx								
	Particleboard																				
	Sealants																				
	Textiles														xxx						
	Wall Covering														xxx						
	Wood Products																				

Table 7 (continued): Labelling Schemes for Low-VOC Emitting Materials

	Label Name:	Environmentally Preferable Product			Blue Angel		EMICODE			GuT		Finnish M-1, M-2			Indoor Climate Label		Nordic Swan		
	Agency	Scientific Certification Systems (SCS)			Fed'l Environ'l Agency/RAL		GEV			Assoc.Envly-Friend.Carp.		Bldg Informn Foundn (RTS)			DSIC, NFICL (see below)				
	Countries:	USA			Germany		Germany			Germany		Finland			Denmark, Norway		Scandinavia		
	Year Initiated:				1977		1990					1996			1995		1989		
	Products/Prod.Categories				~3800/80										~100 Manuf./9		~660/59		
		Unit	Values		Unit	Value	Unit	EC1	EC2	Unit	Value	Unit	M-1	M-2	Unit	Value	Unit	Adh	Value
Contaminants Evaluated	2-Ethyl-1-Hexanol																		
	4-Phenyl Cyclohexene																		
	Aldehydes, Total																		
	Ammonia									Individual VOCs vs. published LCI values, or 0.10 mg/m³ if no LCI exists		mg/m²hr	0.03	0.06					
	Benzene																		
	ButylatedHydroxyToluene																		
	Formaldehyde											mg/m²hr	0.05	0.125					
	Ozone																		
	Particles, Respirable																		
	Particles, Total Dust																		
	Styrene						mg/m³	500	1500										
	VOCs, Individual	x CREL	< 0.5	< 0.5						mg/m³	0.10								
	VOCs, Total (TVOC)	mg/m²hr	0.5	10.0						mg/m³	0.30	mg/m²hr	0.20	0.50			mg/m²hr	0.20	
	VOCs, (BP 50-250°C)				mg/m³	0.30													
	VOCs, (BP > 250°C)				mg/m³	0.10													
	VOCs, Total (-Water)																		
	SVOCs (C 16-22)									mg/m³	0.03								
	Odours									see note									
	CMT Substances **				mg/m³	<1						mg/m²hr	0.005	0.005					
Protocol applies to these Material / Furnishings	Adhesives			xxx				xxx	xxx									xxx	
	Appliances																		
	Carpet										xxx								
	Carpet adhesive																		
	Carpet cushion																		
	Ceiling																		
	Consumer products																		
	Flooring		xxx																
	General Construction																		
	Insulation																		
	Office Equipment																		
	Office Furniture *																		
	Office Workstation																		
	Paint																		
	Paint - Flat																		
	Paint - Non-Flat																		
	Particleboard																		
	Sealants			xxx															
	Textiles																		
	Wall Covering																		
	Wood Products					xxx													

6. Conclusions

This report has shown that there is a wide range of IAQ standards and guidelines. This observation is more pronounced with guidelines relating to indoor air pollutants in both types of substances and levels of each substance. An order of magnitude of difference is not unusual even among the standard and guideline values for industrial settings (OSHA, MAK, NIOSH, and ACGIH in Table 5), which have a longer history of establishment. The difference becomes greater when values for non-industrial settings are considered. For example, the guideline level of nitrogen dioxide ranges between 1 and 10 ppm for occupational exposures, while the range broadens to 0.004 and 10 ppm by including non-occupational exposures. A similar observation can be made for organic compounds in Table 6. A wide variety of substances and guide values exist for guidelines intended for non-occupational exposures (OEHHA, WHO, Japan, Hong Kong, and Germany) compared to those for occupational exposures (OSHA and ACGIH).

The labelling schemes for low-VOC emitting products in Table 7 have shown more variety in terms of materials/products, chemical substances (criteria), levels of criteria, and testing methods. This may imply that there is not much consensus in deriving the schemes. The necessity of more standardized testing methods and criteria becomes obvious to maximize the effectiveness of the labelling schemes.

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Links for Product Labelling Systems:

- **Environmental Choice Eco-Logo** (http://www.environmentalchoice.ca)
- **Green Label** (http://www.carpet-rug.com/index.cfm)
- **Green Label Plus** (http://www.carpet-rug.com/index)
- **Green Seal** (www.greenseal.org)

- **Green Guard** (http://www.greenguard.org)
- **Scientific Certification Systems (SCS) Environmentally Preferable Product (USA)** (http://www.scscertified.com/epp/)
- **Blue Angel** (www.blauer-engel.de/englisch/)
- **GEV EMICODE** (http://www.emicode.com/)
- **GuT** (http://193.201.162.104/)
- **Finnish M-1, M-2** (http://www.rts.fi/english.htm)
- **Indoor Climate Label** (www.dsic.org)
- **Nordic Swan** (http://www.svanen.nu/Eng/default.asp)