ASHRAE Addendum *ad* to
ANSI/ASHRAE Standard 62-2001

ASHRAE STANDARD

Ventilation for Acceptable Indoor Air Quality

Approved by the ASHRAE Standards Committee January 25, 2003, and by the ASHRAE Board of Directors January 30, 2003.

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ISSN 1041-2336

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(This foreword is not part of this addendum but is provided for information only.)

FOREWORD

This addendum updates material in Appendix B of the current standard, which contains a number of air-quality guidelines and regulations issued by bodies other than ASHRAE. This appendix has, for many years, been the only compendium of such information and is very helpful to users of the IAQ Procedure in the standard and to those using the standard in IAQ evaluations. It should be very clear to the reader that ASHRAE is not proposing any contaminant concentration standard or guideline values.

In addition to updating this material (originally prepared in 1986), this addendum describes the source of the values and the context in which they were developed. The addendum also deletes Appendix A (Conversion Factors) and places the relevant material at the end of this appendix.

ADDENDUM 62ad

Delete current Appendix A, Conversion Factors.

Replace the current Appendix B with the following material. Assuming no further changes to the standard's appendices, re-letter this appendix as Appendix A and re-letter the following appendices accordingly.

APPENDIX B
SUMMARY OF SELECTED AIR QUALITY GUIDELINES

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and does not have ANSI approval.)

If particular contaminants are of concern or if the Indoor Air Quality Procedure is to be used, acceptable indoor concentrations and exposures are needed for the particular contaminants. When using this procedure, these concentration and exposure values need to be documented and justified by reference to a cognizant authority as defined in the standard. Such guidelines or other limiting values can also be useful for diagnostic purposes. At present, no single organization develops acceptable concentrations or exposures for all indoor air contaminants, nor are values available for all contaminants of potential concern. A number of organizations offer guideline values for selected indoor air contaminants. These values have been developed primarily for ambient air, occupational settings, and, in some cases, for residential settings. They should be applied with an understanding of their basis and applicability to the indoor environment of concern. If an acceptable concentration or exposure has not been published for a contaminant of concern, a value may be derived through review of the toxicological and epidemiological evidence using appropriate consultation. However, the evidence with respect to health effects is likely to be insufficient for many contaminants. At present, there is no quantitative definition of acceptable indoor air quality that can necessarily be met by measuring one or more contaminants.

Table B-1 presents selected standards and guidelines used in Canada, Germany, Europe, and the United States for acceptable concentrations of substances in ambient air, indoor air, and industrial workplace environments. These values are issued by cognizant authorities and have not been developed or endorsed by ASHRAE. The table is presented only as background information when using the Indoor Air Quality Procedure. Specialized expertise should be sought before selecting a value for use in estimating outdoor airflow rates using the Indoor Air Quality Procedure or for building design or diagnostics purposes. Meeting one, some, or all of the listed values does not ensure that acceptable indoor air quality (as defined in this standard) will be achieved.

Table B-2 lists concentration values of interest for selected contaminants as general guidance for building design, diagnostics, and ventilation system design using the Indoor Air Quality Procedure. The values in the table are based on cognizant authorities and studies reported in peer-reviewed scientific publications; ASHRAE does not recommend their adoption as regulatory values, standards, or guidelines. The table is presented as further background when using the Indoor Air Quality Procedure. Consultation should be sought before selecting a particular value for use in calculating ventilation using the Indoor Air Quality Procedure. Meeting one, some, or all of the listed values does not ensure that acceptable indoor air quality will be achieved.

Selection of a specific target concentration and exposure is best made by a team with wide experience in toxicology, industrial hygiene, and exposure assessment. As they review the specific concentrations listed in Tables B-1 and B-2, or others taken from other sources, designers should be mindful of the following:

- Standards and guidelines are developed for different purposes and should be interpreted with reference to the setting and purpose for which they were developed compared to that to which they are being applied.
- Not all standards and guideline values recognize the presence of susceptible groups or address typical populations found in occupancies listed in this standard.
- Most standards and guidelines do not consider interactions between and among various contaminants of concern.
- The assumptions and conditions set forth by the standard or guideline may not be met in the space or for the occupants being considered (such as 8-hour day, 40-hour work week).

When many chemicals are present in the air, as they almost always are in indoor air, then some way of addressing potential interaction of these chemicals is warranted. For additive effects and exceptions, the reader is referred to ACGIH for guidance on the subject (Reference B-1, Appendix B).

Guideline Values for Industrial Environments

ACGIH threshold limit values, or TLVs®, have been applied to industrial workplace air contaminants (see Reference B-1; Reference B-2 is the German counterpart). The ACGIH TLVs® represent maximum acceptable 8-hour, time-weighted average (TWA), 15-minute short-term exposure limit (STEL) and instantaneous (ceiling) case limits. It is a source of concentration limits for many chemical substances and physical agents for industrial use. In light of the constantly changing state of knowledge, the document is updated annually. It cautions the user, "The values listed in this book are intended for use in the practice of industrial hygiene as guidelines or recommendations to assist in the control of potential health hazards and for no other use."

Caution must be used in directly extending the ACGIH TLVs® or other workplace guidelines to spaces covered by this standard and to population groups other than workers. Industrial health practice attempts to limit worker exposure to injurious substances at levels that do not interfere with the industrial work process and do not risk the workers' health and safety. There is not an intention to eliminate all effects, such as unpleasant smells or mild irritation. Further, the health criteria are not uniformly derived for all contaminants. Irritation, narcosis, and nuisance or other forms of stress are not uniformly considered as the basis for the concentration limits. This is because different organizations use different end points and different contaminants have more or less information available on diverse end points of interest. The target population is also different from the occupants found in the spaces covered by this standard. Healthy industrial workers tend to change jobs or occupations if an exposure is intolerable. In contrast, workers in commercial environments such as offices do not expect to have elevated concentrations of potentially harmful substances, nor are monitoring programs in place, as may be the case with industrial contaminants. In addition, the general population may have less choice about where they spend most of their time and includes those who may be more sensitive, such as children, asthmatics, allergic individuals, and the elderly.

Guidelines for Substances in Outdoor Air

Guidelines have been developed for outdoor air for a number of chemicals and metals, as shown in many of the references. These values, including some for metals, may be appropriate for some indoor environments, but they should be applied only after appropriate consultation. These guidelines also supply guidance concerning the quality of outside air if there is suspicion that outdoor air may be contaminated with specific substances or if there is a known source of contamination nearby (B-3).

Regulation of Occupational Exposure to Airborne Contaminants

Regulations of occupational exposure to workplace hazards are based on the results of accumulated experience with worker health and toxicological research and carefully evaluated by groups of experts. Effects are examined in relation to exposure to the injurious substance. Exposure is defined as the mathematical product of the concentration of the contaminant and the time during which a person is subject to this concentration. Since concentration may vary with time, exposure is typically calculated across the appropriate averaging time, expressed as a TWA concentration, STEL, or ceiling limit. Regulations of the U.S. Occupational Safety and Health Administration (OSHA) are TWAs in most cases. Industrial exposures are regulated on the basis of a 40-hour workweek with 8- to 10-hour days. During the remainder of the time, exposure is anticipated to be substantially lower for the contaminant of concern. Application of industrial exposure limits would not necessarily be appropriate for other indoor settings, occupancies, and exposure scenarios. However, lacking exposure limits for a specific nonindustrial target population, substantial downward adjustments to occupational limits have sometimes been used.

Substances Lacking Guidelines and Standards

For indoor contaminants for which an acceptable concentration and exposure value has not been established by a cognizant authority, one approach has been to assume that some fraction of TLV® is applicable and would not lead to adverse effects or complaints in nonindustrial populations. This approach should not be followed without assessing its suitability for the contaminant of concern. In any event, if appropriate standards or guidelines do not exist, expertise must be sought or research needs conducted to determine contaminant concentrations and exposures that are acceptable.

Subjective Evaluation

Scientists have discovered a number of ways that airborne chemicals can cause irritation of mucosal tissue such as that found in the human nose and the upper airways. These irritation responses can occur after the "irritant receptor" is exposed to nonreactive compounds, to reactive compounds with a different pattern of dose-response relationships, and through allergic and other immunologic effects for which dose-response relationships have not been well defined. The theoretical models of these irritation mechanisms have not yet found their way into standard-setting processes. One reason for this may be the recognition of susceptible populations, i.e., individuals with atopy ("allergies") report irritation at lower levels of exposures than individuals without allergies. A complicating factor is that more susceptible populations, such as the elderly and the young, may differ from healthy adults in their response to irritating and odorous substances.

Indoor air often contains complex mixtures of contaminants of concern such as environmental tobacco smoke (References B-30 and B-31), infectious and allergenic biological aerosols (B-32), and human bioeffluent emissions from food preparation. Precise quantitative treatment of these contaminants can be difficult or impossible in most cases. Chemical composition alone may not always be adequate to reliably predict the reaction of building occupants to most common mixtures of substances found in indoor air. To some degree, adequacy of control may rest upon subjective evaluation. Panels of observers have been used to perform subjective evaluation of indoor air quality in buildings.

Many contaminants have odors or are irritants that may be detected by human occupants or visitors to a space. Generally the air can be considered acceptably free of annoying contaminants if 80% of a panel deems the air not to be objectionable under representative conditions of use and occupancy when a group of untrained panelists is exposed to known concentrations of contaminants under controlled conditions.

When performing a subjective evaluation, an observer should enter the space in the manner of a normal visitor and should render a judgment of acceptability within 15 seconds. Each observer should make the evaluation independently of other observers and without influence from a panel leader. Users of subjective evaluation methods are cautioned that they only test odor and sensory responses. Some harmful contaminants will not be detected by such tests. Carbon monoxide and radon are two examples of odorless contaminants that pose significant health risks. To evaluate the acceptability of adapted persons (occupants), an observer should spend at least six minutes in the space before rendering a judgment of acceptability (B-29).

TABLE B-1
Comparison of Regulations and Guidelines Pertinent to Indoor Environments

The substances listed in this table are common air contaminants in industrial and non-industrial environments. The values summarized in this table are from various sources with diverse procedures and criteria for establishing the values. Some are for industrial environments (OSHA, MAK, NIOSH, ACGIH), some are for outdoor environments (NAAQS), and others are general (WHO) or indoor residential environment-related (Canadian) values. The following explanations are intended to assist the reader by providing a brief description of the criteria each agency used in adopting its guideline values.

- NAAQS: Outdoor air standards developed by the U.S. EPA under the Clean Air Act. By law, the values listed in these regulations must be reviewed every five years. These concentrations are selected to protect not only the general population but also the most sensitive individuals.
- OSHA: Enforceable maximum exposures for industrial environments developed by OSHA (U.S. Department of Labor) through a formal rule-making process. Once an exposure limit has been set, levels can be changed only through reopening the rule-making process. These permissible exposure limits (PELs) are not selected to protect the most sensitive individuals.
- MAK: Recommended maximum exposures for industrial environments developed by the Deutsche Forschungs Gemeinschaft, a German institution similar to the U.S. National Institutes of Health and NIOSH. Levels are set on a regular basis, with annual reviews and periodic republication of criteria levels. These levels are enforceable in Germany and are not selected to protect the most sensitive individuals.
- Canadian: Recommended maximum exposures for residences developed in 1987 and reaffirmed in 1995 by a committee of provincial members convened by the federal government to establish consensus guideline-type levels. A revised version is being considered. These are not intended to be enforced.
- WHO/Europe: Environmental (nonindustrial) guidelines developed in 1987 and updated in 1999 by the WHO Office for Europe (Denmark). Intended for application both to indoor and outdoor exposure.
- NIOSH: Recommended maximum exposure guidelines for industrial environments are developed by NIOSH (Centers for Disease Control) and published in a series of criteria documents. NIOSH criteria documents contain both a review of the literature and a recommended exposure limit (REL) guideline. These are not enforceable, are not reviewed regularly, and are not selected to protect the most sensitive individuals. In some cases, they are set at levels above those deemed protective of health because commonly available industrial hygiene practice does not reliably detect the substances at lower levels. (Note that methods used in nonindustrial settings are often more sensitive than NIOSH methods for industrial hygiene measurements.)
- ACGIH: Recommended maximum exposures for industrial environments developed by ACGIH's Threshold Limit Values (TLVs®) Committee. The committee reviews the scientific literature and recommends exposure guidelines. The assumptions are for usual industrial working conditions, 40-hour weeks, and single exposures. Surveillance practices for both exposures and biological responses are often in place in the work environments where these levels are used. These levels are not selected to protect the most sensitive individuals. About half of the TLVs® are intended to protect against irritation. Published studies have shown that many of the TLVs® intended to protect against irritation actually represent levels where some or all of the study subjects did report irritation (References B-33 and B-34).

The table is not inclusive of all contaminants in indoor air, and achieving the listed indoor concentrations for all of the listed substances does not ensure odor acceptability, avoidance of sensory irritation, or all adverse health effects for all occupants. In addition to indoor contaminant levels, the acceptability of indoor air also involves thermal conditions, indoor moisture levels as they impact microbial growth, and other indoor environmental factors. ASHRAE is not selecting or recommending default concentrations.

Users of this table should recognize that unlisted noxious contaminants can also cause unacceptable indoor air quality with regard to comfort (sensory irritation), odors, and health. When such contaminants are known or might reasonably be expected to be present, selection of an acceptable concentration and exposure may require reference to other guidelines or a review and evaluation of relevant toxicological and epidemiological literature.

TABLE B-1 Comparison of Regulations and Guidelines Pertinent to Indoor Environments[a]

(The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

	Enforceable and/or Regulatory Levels			Non-enforced Guidelines and Reference Levels			
	NAAQS/EPA (Ref. B-4)	OSHA (Ref. B-5)	MAK (Ref. B-2)	Canadian (Ref. B-8)	WHO/Europe (Ref. B-11)	NIOSH (Ref. B-13)	ACGIH (Ref. B-1)
Carbon dioxide		5,000 ppm	5,000 ppm 10,000 ppm [1 hr]	3,500 ppm [L]		5,000 ppm 30,000 ppm [15 min]	5,000 ppm 30,000 ppm [15 min]
Carbon monoxide [c]	9 ppm [g] 35 ppm [1 hr] [g]	50 ppm	30 ppm 60 ppm [30 min]	11 ppm [8 hr] 25 ppm [1 hr]	90 ppm [15 min] 50 ppm [30 min] 25 ppm [1 hr] 10 ppm [8 hr]	35 ppm 200 ppm [C]	25 ppm
Formaldehyde[h]		0.75 ppm 2 ppm [15 min]	0.3 ppm 1 ppm[i]	0.1 ppm [L] 0.05 ppm [L] [b]	0.1 mg/m^3 (0.081 ppm) [30 min][p]	0.016 ppm 0.1 ppm [15 min]	0.3 ppm [C]
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 h]	0.05 mg/m^3
Nitrogen dioxide	0.05 ppm [1 yr]	5 ppm [C]	5 ppm 10 ppm [5 min]	0.05 ppm 0.25 ppm [1 hr]	0.1 ppm[1 hr] 0.004 ppm [1 yr]	1 ppm [15 min]	3 ppm 5 ppm [15 min]
Ozone	0.12 ppm [1 hr][g] 0.08 ppm	0.1 ppm	j	0.12 ppm [1 hr]	0.064 ppm (120 µg/m^3) [8 hr]	0.1 ppm [C]	0.05 ppm[k] 0.08 ppm[l] 0.1 ppm[m] 0.2 ppm[n]
Particles[e] <2.5 µm MMAD[d]	15 µg/m^3[1 yr][o] 65 µg/m^3 [24 hr][o]	5 mg/m^3	1.5 mg/m^3 for <4 µm	0.1 mg/m^3 [1 hr] 0.040 mg/m^3 [L]			3 mg/m^3
Particles[e]<10 µm MMAD[d]	50 µg/m^3[1 yr][o] 150 µg/m^3 [24 hr][o]		4 mg/m^3				10 mg/m^3
Radon	See Table B-2[f]				2.7 pCi/L [1yr]		
Sulfur dioxide	0.03 ppm [1 yr] 0.14 ppm [24 hr] [g]	5 ppm	0.5 ppm 1 ppm [i]	0.38 ppm [5 min] 0.019 ppm	0.048 ppm [24 h] 0.012 ppm [1 yr]	2 ppm 5 ppm [15 min]	2 ppm 5 ppm [15 min]
Total Particles[e]		15mg/m^3					

Notes for Table B-1

[a] Numbers in brackets [ ] refer to either a ceiling or to averaging times of less than or greater than eight hours (min = minutes; hr = hours; y = year; C = ceiling, L = long-term). Where no time is specified, the averaging time is eight hours.

[b] Target level is 0.05 ppm because of its potential carcinogenic effects. Total aldehydes limited to 1 ppm. Although the epidemiological studies conducted to date provide little convincing evidence that formaldehyde is carcinogenic in human populations, because of this potential, indoor levels should be reduced as much as possible.

[c] As one example regarding the use of values in this table, readers should consider the applicability of carbon monoxide concentrations. The concentrations considered acceptable for nonindustrial, as opposed to industrial, exposure are substantially lower. These lower concentrations (in other words, the ambient air quality standards, which are required to consider populations at highest risk) are set to protect the most sensitive subpopulation, individuals with pre-existing heart conditions.

[d] MMAD = mass median aerodynamic diameter in microns (micrometers). Less than 3.0 μm is considered respirable; less than 10 μm is considered inhalable.

[e] 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.

[f] See Table B-2 for the U.S. EPA guideline.

[g] Not to be exceeded more than once per year.

[h] 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)

[i] Never to be exceeded.

[j] Carcinogen, no maximum values established.

[k] TLV® for heavy work.

[l] TLV® for moderate work.

[m] TLV® for light work.

[n] TLV® for any work = two hours.

[o] 62FR38652 - 38760, July 16, 1997.

[p] Epidemiological studies suggest a causal relationship between exposure to formaldehyde and nasopharyngeal cancer, although the conclusion is tempered by the small numbers of observed and expected cases. There are also epidemiological observations of an association between relatively high occupational exposures to formaldehyde and sinonasal cancer.

TABLE B-2
Concentrations of Interest for Selected Contaminants

The substances listed in this table are common air contaminants of concern in nonindustrial environments. The target concentrations that have been set or proposed by various national or international organizations concerned with health and comfort effects of outdoor and indoor air are listed for reference only. The table is not inclusive of all contaminants in indoor air, and achieving the target indoor concentrations for all of the listed substances does not ensure freedom from sensory irritation or from all adverse health effects for all occupants. In addition to indoor contaminant levels, the acceptability of indoor air also involves thermal conditions, indoor moisture levels as they impact microbial growth, and other indoor environmental factors. ASHRAE is not selecting or recommending default concentrations.

Health or comfort effects and exposure periods that are the basis for the guideline levels are listed in the “comments” column. For design, the goal should be to meet the guideline levels continuously during occupancy because people spend the great majority of their time indoors.

Users of this table should recognize that unlisted noxious contaminants can also cause unacceptable indoor air quality with regard to comfort (sensory irritation), odors, and health. When such contaminants are known or might reasonably be expected to be present, selection of an acceptable concentration and exposure may require reference to other guidelines or a review and evaluation of relevant toxicological and epidemiological literature. (Table B-2 summarizes some of this literature.)

TABLE B-2 Concentration of Interest for Selected Contaminants

(**Note**: References numbers that are followed by [c] and [m] list the concentrations of interest [c] and measurement methods [m]).
(**Note**: The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

CONTAMINANT	SOURCES	CONCENTRATIONS OF INTEREST	COMMENTS	REFERENCES
CARBON MONOXIDE (CO)	Leaking vented combustion appliances Unvented combustion appliances Parking garages Outdoor air	9 ppm (8-hr)	Based on effects on persons with coronary artery disease, average exposure for 8 hours. Sustained indoor concentrations exceeding outdoor concentrations may merit further investigation. Many carbon monoxide measuring instruments have limited accuracy at low levels. Sources—burning of gasoline, natural gas, coal, oil, etc. Health Effects—reduces ability of blood to bring oxygen to body cells and tissues; cells and tissues need oxygen to work. Carbon monoxide may be particularly hazardous to people who have heart or circulatory problems and people who have damaged lungs or breathing passages.	B-4 [c] B-9 [m]
FORMALDEHYDE (HCHO)	Pressed-wood products Furniture and furnishings	0.1 mg/m^3 (0.081 ppm)	Based on irritation of sensitive people, 30-minute exposure (WHO).	B-11 [c] B-9, 26 [m]
		0.05 ppm	Established to avoid irritation in allergic and asthmatic individuals (residential) and as a value that is reasonable to achieve in light of formaldehyde's potential carcinogenicity (California Air Resources Board).	B-16
		76 ppb (1-hr) 27 ppb (8-hr)	Based on the current acute 1-hour Reference Exposure Level (REL) of 76 ppb (94 μg/m^3), an exposure level of 27 ppb (33 μg/m^3) is derived for an 8-hour exposure period (Cal-EPA, OEHHA).	B-36
			Health Effects—Acute and chronic inhalation exposure to formaldehyde in humans can result in eye, nose, and throat irritation, respiratory symptoms, and sensitization. Limited human studies have reported an association between formaldehyde exposure and lung and nasopharyngeal cancer. Animal inhalation studies have reported an increased incidence of nasal squamous cell cancer. EPA has classified formaldehyde as a Group B1, probable human carcinogen of medium carcinogenic hazard. The value reported here has been proposed in the hazard ranking of hazardous air pollutants in EPA's proposed rulemaking (Section 112(g) of the Clean Air Act, April 1994).	B-19, 20, 36
LEAD (Pb)	Paint dust Outdoor air	1.5 μg/μ^3	Based on adverse effects on neuropsychological functioning of children, average exposure for 3 months (WHO: 0.5-1 μg/m^3 for 1 year). Sources—leaded gasoline (being phased out), paint (houses, cars), smelters (metal refineries), manufacture of lead storage batteries. Health Effects—brain and other nervous system damage; children are at special risk. Some lead-containing chemicals cause cancer in animals. Lead causes digestive and other health problems. Environmental Effects—Lead can harm wildlife.	B-4 [c] B-4 [m] B-18

TABLE B-2 Concentration of Interest for Selected Contaminants (Continued)

(**Note**: References numbers that are followed by [c] and [m] list the concentrations of interest [c] and measurement methods [m]).

(**Note**: The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

NITROGEN DIOXIDE (NO_2)	Leaking vented combustion appliances Unvented combustion appliances Outdoor air	100 µg/m³	Based on providing protection against adverse respiratory effects, average exposure for 1 year. Sources—burning of gasoline, natural gas, coal, oil, etc. Cars are an important source of NO_2 outdoors and cooking and water- and space-heating devices are important sources indoors. Health Effects—lung damage, illnesses of breathing passages and lungs (respiratory system). Environmental Effects—Nitrogen dioxide is a component of acid rain (acid aerosols), which can damage trees and lakes. Acid aerosols can reduce visibility. Property Damage—Acid aerosols can eat away stone used on buildings, statues, monuments, etc.	B-4 [c] B-9 [m] B-18
ODORS	Occupants VOC sources (including fungal sources such as mold) Outdoor air	Predicted (or measured) acceptability to 80% or more of occupants or visitors	CO_2 concentration can be used as a surrogate for occupant odors (odorous bioeffluents). See Appendix C for a discussion of indoor CO_2 levels and ventilation rates. For sources other than people, source control is recommended.	B-12, 24, 29, 30 [c] B-9 (CO_2), B-15 (odor) [m]
OZONE (O_3)	Electrostatic appliances Office machines Ozone generators Outdoor air	100 µg/µ³ (50 ppb)	Based on 25% increase in symptom exacerbations among adults or asthmatics (normal activity), 8-hr exposure (WHO); continuous exposure (FDA). Ozone present at levels below the concentration of interest may contribute to the degradation of indoor air quality directly and by reacting with other contaminants in the indoor space. Ground-level ozone is the principal component of smog. Sources—outdoors, from chemical reaction of pollutants, VOCs, and NO_x; indoors, from photocopiers, laser printers, ozone generators, electrostatic precipitators, and some other air cleaners. Health Effects—breathing problems, reduced lung function, asthma, irritated eyes, stuffy nose, reduced resistance to colds and other infections. May speed up aging of lung tissue. Environmental Effects—Outdoors, ozone can damage plants and trees; smog can cause reduced visibility. Property Damage—Indoors and outdoors, ozone damages natural and synthetic rubbers, plastics, fabrics, etc.	B-6, 11 [c] B-6 [m] B-18
PARTICLES ($PM_{2.5}$)	Combustion products, cooking, candles, incense, resuspension, and outdoor air	15 µg/m³		B-4

TABLE B-2 Concentration of Interest for Selected Contaminants (Continued)

(**Note**: References numbers that are followed by [c] and [m] list the concentrations of interest [c] and measurement methods [m]).

(**Note**: The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

PARTICLES (PM_{10})	Dust Smoke Deteriorating materials Outdoor air	50 μg/m^3	Based on protecting against respiratory morbidity in the general population and avoiding exacerbation of asthma, average exposure for 1 year, no carcinogens. Indoor concentrations are normally lower; guideline level may lead to unacceptable deposition of "dust." Sources—burning of wood, diesel, and other fuels; industrial plants; agriculture (plowing, burning off fields); unpaved roads. Health Effects—nose and throat irritation, lung damage, bronchitis, early death. Environmental Effects—Particulates are the main source of haze that reduces visibility. Property Damage—Ashes, soot, smoke, and dust can dirty and discolor structures and other property, including clothes and furniture.	B-4 [c] B-4 [m] B-18
RADON (Rn)	Soil gas	4 pCi/liter[a]	Based on lung cancer, average exposure for 1 year.	B-7 [c,m] B-10 [m]
SULFUR DIOXIDE (SO_2)	Unvented space heaters (kerosene) Outdoor air	80 μg/m^3	Based on protecting against respiratory morbidity in the general population and avoiding exacerbation of asthma, average exposure for 1 year (WHO: 50 μg/m^3 if with PM). Source—burning of coal and oil, especially high-sulfur coal from the eastern United States; industrial processes (paper, metals). Health Effects—breathing problems; may cause permanent damage to lungs. Environmental Effects—SO_2 is a component of acid rain (acid aerosols), which can damage trees and lakes. Acid aerosols can also reduce visibility. Property Damage—Acid aerosols can eat away stone used in buildings, statues, monuments, etc.	B-4 [c] B-4 [m] B-18
TOTAL VOLATILE ORGANIC COMPOUNDS (TVOCs)	New building materials and furnishings Consumable products Maintenance materials Outdoor air	Precise guidance on TVOC concentrations cannot be given.	A variety of definitions of TVOC have been employed in the past. Reference B-27 contains a specific definition that reflects recent thinking on the subject. There is insufficient evidence that TVOC measurements can be used to predict health or comfort effects. In addition, odor and irritation responses to organic compounds are highly variable. Furthermore, no single method currently in use measures all organic compounds that may be of interest. Therefore, some investigators have reported the total of all measured VOCs as the SumVOC in order to make explicit that the reported value does not represent the total of all VOCs present. Some of the references included here use this method for presenting VOC measurement results. Setting target concentrations for TVOCs is not recommended. Setting target concentrations for specific VOCs of concern is preferred.	B-9 [m] B-14, 26-28, 35, 38

TABLE B-2 Concentration of Interest for Selected Contaminants (Continued)

(**Note**: References numbers that are followed by [c] and [m] list the concentrations of interest [c] and measurement methods [m]).

(**Note**: The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

Volatile Organic Compounds (VOCs)	New building materials and furnishings Consumable products Maintenance materials Outdoor air	Must be determined for each individual compound	Individual volatile organic compounds may be contaminants of concern in the application of the Indoor Air Quality Procedure. Concentrations of concern range from less than 1 part per billion (ppb) for some very toxic compounds or for compounds having very low odor thresholds up to concentrations several orders of magnitude higher. Not all compounds can be identified, and toxicological data are incomplete for many compounds.	B-22-26, 28 [c] B-9, 10, 21 [m] B-15, 37, 39, 40

Notes for Table B-2

[a] The U.S. EPA has promulgated a guideline value of 4 pCi/L indoor concentration. This is not a regulatory value but an action level where mitigation is recommended if the value is exceeded in long-term tests.

CONVERSION FACTORS [B-17]

Parts per million and mass per unit volume

Measurements of indoor airborne concentrations of substances are generally converted to standard conditions of 77°F (25°C) and 29.92 in. Hg (101.325 kPa) pressure. Vapors or gases are often expressed in parts per million (ppm) by volume or in mass per unit volume.

Concentrations in ppm by volume can be converted to mass per unit volume values as follows:

- ppm × molecular weight/24,450 = mg/L
- ppm × molecular weight/0.02445 = µg/m^3
- ppm × molecular weight/24.45 = mg/m^3
- ppm × molecular weight × 28.3/24,450 = mg/ft^3

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POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the standards and guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive technical committee structure, continue to generate up-to-date standards and guidelines where appropriate and adopt, recommend, and promote those new and revised standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating standards and guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.