**ANSI/ASHRAE Standard 62.1-2013**
**(Supersedes ANSI/ASHRAE Standard 62.1-2010)**
**Includes ANSI/ASHRAE addenda listed in Appendix J**

# Ventilation for Acceptable Indoor Air Quality

See Appendix J for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE Web site (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

 ISSN 1041-2336

Approved American National Standard
ANSI
www.ansi.org

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c. offering constructive criticism for improving the Standard, or
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## CONTENTS

## ANSI/ASHRAE Standard 62.1-2013, Ventilation for Acceptable Indoor Air Quality



**NOTE**

**Approved addenda, errata, or interpretations for this standard can be downloaded free of charge from the ASHRAE Web site at www.ashrae.org/technology.**

$E_v$ ***system ventilation efficiency:*** the efficiency with which the system distributes air from the outdoor air intake to the breathing zone in the ventilation-critical zone, which requires the largest fraction of outdoor air in the primary air stream.

$E_v$ may be determined in accordance with Section 6.2.5.2 or Section A1.

$E_{vz}$ ***zone ventilation efficiency:*** the efficiency with which the system distributes air from the outdoor air intake to the breathing zone in any particular ventilation zone.

$E_z$ ***zone air distribution effectiveness:*** a measure of the effectiveness of supply air distribution to the breathing zone.

$E_z$ is determined in accordance with Section 6.2.2.2.

$F_a$ ***supply air fraction:*** the fraction of supply air to the ventilation zone that includes sources of air from outside the zone.

$F_b$ ***mixed-air fraction:*** the fraction of supply air to the ventilation zone from fully mixed primary air.

$F_c$ ***outdoor air fraction:*** the fraction of outdoor air to the ventilation zone that includes sources of air from outside the zone.

$P_s$ ***system population:*** the simultaneous number of occupants in the area served by the ventilation system.

$P_z$ ***zone population:*** see Section 6.2.2.1.

$R_a$ ***area outdoor air rate:*** see Section 6.2.2.1.

$R_p$ **people outdoor air rate:** see Section 6.2.2.1.

$V_{bz}$ ***breathing zone outdoor airflow:*** see Section 6.2.2.1.

$V_{dz}$ ***zone discharge airflow:*** the expected discharge (supply) airflow to the zone that includes primary airflow and secondary recirculated airflow, cfm (L/s).

$V_{ot}$ ***outdoor air intake flow:*** see Sections 6.2.3, 6.2.4, and 6.2.5.4.

$V_{ou}$ ***uncorrected outdoor air intake:*** see Section 6.2.5.3.

$V_{oz}$ **zone outdoor airflow:** see Section 6.2.2.3.

$V_{ps}$ ***system primary airflow:*** the total primary airflow supplied to all zones served by the system from the air-handling unit at which the outdoor air intake is located.

$V_{pz}$ ***zone primary airflow:*** see Section 6.2.5.1.

$X_s$ ***average outdoor air fraction:*** at the primary air handler, the fraction of outdoor air intake flow in the system primary airflow.

$Z_{pz}$ ***primary outdoor air fraction:*** the outdoor air fraction required in the primary air supplied to the ventilation zone prior to the introduction of any secondary recirculation air.

**(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 may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)**

## INFORMATIVE APPENDIX B SUMMARY OF SELECTED AIR QUALITY GUIDELINES

If particular contaminants are of concern, or if the IAQ 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 IAQ 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 IAQ Procedure. Specialized expertise should be sought before selecting a value for use in estimating outdoor airflow rates using the IAQ Procedure or for building design or diagnostics purposes. Meeting one, some, or all of the listed values does not ensure that acceptable IAQ (as defined in this standard) will be achieved.

Tables B-2 and B-3 list concentration values of interest for selected contaminants as general guidance for building design, diagnostics, and ventilation system design using the IAQ 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 tables are presented as further background when using the IAQ Procedure. Consultation should be sought before selecting a particular value for use in calculating ventilation using the IAQ Procedure. Meeting one, some, or all of the listed values does not ensure that acceptable IAQ 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, B-2, and B-3, 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 an 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 additive effects is warranted. The ACGIH guidance on the subject instructs that when two or more substances acting on the "…same organ system are present, their combined effect, rather than that of either individually, should be given primary consideration." [B-1] Information on affected organs is readily available on the websites of the cited references for ACGIH, OEHHA, and ATSDR. If no contradictory information is available, the effects of the different substances "should be considered as additive." A formula is given wherein the ratios of the concentrations of each substance with the same health-related endpoint to the threshold-limit value for each substance are added. If the sum of all these ratios exceeds unity, then it is considered that the concentration value has been exceeded.

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots + \frac{C_n}{T_n}$$

where

$C_i$ = airborne concentration of the substance

$T_i$ = threshold-limit value of that substance

### B1. GUIDELINE VALUES FOR INDUSTRIAL ENVIRONMENTS

ACGIH threshold limit values, or TLVs®, have been applied to industrial workplace air contaminants.[B-1] (Reference B-2 is the German counterpart.) The ACGIH TLVs® represent maximum the acceptable eight-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 [illegible]rial 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 becomes intolerable. In contrast, workers in commercial environments such as offices often do not expect elevated concentrations of potentially harmful substances in their work environments. Also, monitoring programs are unlikely to be in place, as may be the case with industrial workplaces. 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, the sick, and the elderly.

## B2. 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 provide guidance concerning the quality of outdoor 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]

## B3. 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 exposed 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 contaminants of concern. Application of industrial exposure limits would not necessarily be appropriate for other indoor settings, occupancies, and exposure scenarios. However, for certain contaminants that lack exposure limits for a specific nonindustrial target population, substantial downward adjustments to occupational limits have sometimes been used.

## B4. 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 health effects or complaints in general populations. This approach should not be used without first 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 to be conducted to determine contaminant concentrations and exposures that are acceptable.

## B5. SUBJECTIVE EVALUATION

Indoor air often contains complex mixtures of contaminants of concern, such as environmental tobacco smoke,[B-30,B-31] infectious and allergenic biological aerosols,[B-32] and emissions of chemicals from commercial and consumer products. 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 exposed to most common mixtures of substances found in indoor air. There are many toxicological endpoints used in assessing the effects from exposure to air contaminants.

Irritation of mucosal tissue, such as that found in the human nose, eyes, and the upper airways, is one of the endpoints often used in assessing short-term exposure to air contaminants. 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. Susceptible populations, i.e., individuals with atopy ("allergies") may report irritation at lower levels of exposures than individuals without allergies. Other susceptible populations, such as the elderly and the young, may differ from healthy adults in their response to irritating and odorous substances.

To some degree, adequacy of control may rest upon subjective evaluation. Panels of observers have been used to perform subjective evaluation of IAQ 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 consisting of a group of untrained subjects exposed to

known concentrations of contaminants under representative controlled conditions of use and occupancy deems the air not to be objectionable.

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]

**Guide for Using TABLE B-1**

The substances listed in Table B-1 are common air contaminants in industrial and nonindustrial 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.[B-33, 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 IAQ 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 | | | Nonenforced 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 | | 5000 ppm | 5000 ppm<br>10,000 ppm [1 h] | 3500 ppm [L] | | 5000 ppm<br>30,000 ppm [15 min] | 5000 ppm<br>30,000 ppm [15 min] |
| Carbon monoxide[c] | 9 ppm [g]<br>35 ppm [1 h] [g] | 50 ppm | 30 ppm<br>60 ppm [30 min] | 11 ppm [8 h]<br>25 ppm [1 h] | 90 ppm [15 min]<br>50 ppm [30 min]<br>25 ppm [1 h]<br>10 ppm [8 h] | 35 ppm<br>200 ppm [C] | 25 ppm |
| Formaldehyde[h] | | 0.75 ppm<br>2 ppm [15 min] | 0.3 ppm<br>1 ppm[i] | 0.1 ppm [L]<br>0.05 ppm [L] [b] | 0.1 mg/m$^3$ (0.081 ppm) [30 min][p] | 0.016 ppm<br>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$^3$<br>1 mg/m$^3$ [30 min] | Minimize exposure | 0.5 µg/m$^3$ [1 yr] | 0.050 mg/m$^3$ | 0.05 mg/m$^3$ |
| Nitrogen dioxide | 0.05 ppm [1 yr] | 5 ppm [C] | 5 ppm<br>10 ppm [5 min] | 0.05 ppm<br>0.25 ppm [1 h] | 0.1 ppm[1 h]<br>0.02 ppm [1 yr] | 1 ppm [15 min] | 3 ppm<br>5 ppm [15 min] |
| Ozone | 0.12 ppm [1 h][g]<br>0.08 ppm | 0.1 ppm | j | 0.12 ppm [1 h] | 0.064 ppm<br>(120 µg/m$^3$) [8 h] | 0.1 ppm [C] | 0.05 ppm[k]<br>0.08 ppm[l]<br>0.1 ppm[m]<br>0.2 ppm[n] |
| Particles[e]<br><2.5 µm MMAD[d] | 15 µg/m$^3$[1 yr][o]<br>35 µg/m$^3$ [24 h][o] | 5 mg/m$^3$ | 1.5 mg/m$^3$ for <4 µm | 0.1 mg/m$^3$ [1 h]<br>0.040 mg/m$^3$ [L] | | | 3 mg/m$^3$ [C] |
| Particles[e]<br><10 µm MMAD[d] | 150 µg/m$^3$ [24 h][o] | | 4 mg/m$^3$ | | | | 10 mg/m$^3$ [C] |
| Radon | | | | 800 Bq/m$^3$ [1 yr] | | | |
| Sulfur dioxide | 0.03 ppm [1 yr]<br>0.14 ppm [24 h][g] | 5 ppm | 0.5 ppm<br>1 ppm [i] | 0.38 ppm [5 min]<br>0.019 ppm | 0.048 ppm [24 h]<br>0.012 ppm [1 yr] | 2 ppm<br>5 ppm [15 min] | 2 ppm<br>5 ppm [15 min] |
| Total Particles[e] | | 15 mg/m$^3$ | | | | | |

a. Numbers in brackets [ ] refer to either a ceiling or to averaging times of less than or greater than eight hours (min = minutes; h = 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). In addition, California Air Resources Board Regulation §93120, entitled "Airborne Toxic Control Measure to Reduce Formaldehyde Emissions from Composite Wood Products" has specific chamber-based requirements for composite wood products sold in California. [B-47]
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 heavy, moderate, or light workloads (less than or equal to 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.