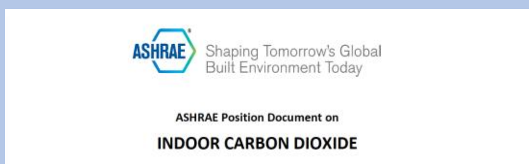
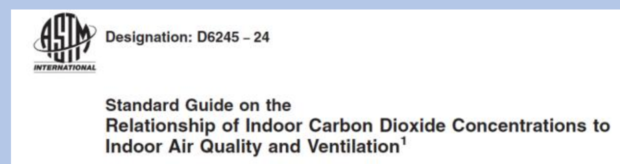
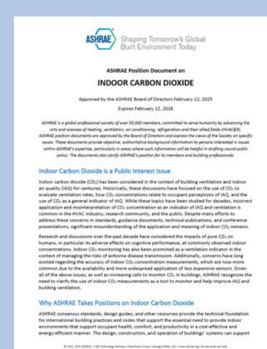
Background on the Application of Indoor CO_2: ASHRAE Position Document (2025) and ASTM Standard D6245 (2024)





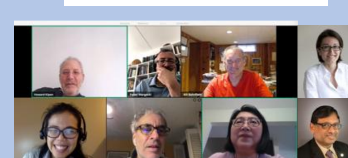
Andrew Persily
National Institute of Standards and Technology
Gaithersburg, Maryland USA

ASHRAE's Position Document on Indoor Carbon Dioxide



First approved February 2022
Revised February 2025

Position Document Committee:
Andrew Persily (Chair), William P. Bahnfleth, Howard Kipen, Josephine Lau, Corinne Mandin, Chandra Sekhar, Pawel Wargocki, Lan Chi Nguyen Weekes



First meeting: 26 March 2020

Motivations

CO_2 part of ventilation and IAQ discussions for centuries
Commonly misinterpreted by industry, researchers, public

Recent trends

- Research on impacts of CO_2 on human performance.
- Standards and regulations for indoor CO_2 in non-industrial workplaces.
- Concerns about accuracy of indoor CO_2 concentration measurements.
- More widespread application of less expensive sensors.
- Indoor CO_2 monitoring promoted as indicator for managing risks of airborne disease transmission.

Outline

Indoor Carbon Dioxide is a Public Interest Issue
Why ASHRAE Takes Positions on Indoor Carbon Dioxide

POSITIONS (abbreviated)

Indoor CO_2 concentrations are not comprehensive indicators of IAQ, but can be useful.

Differences between indoor and outdoor CO_2 concentrations can be used to evaluate ventilation using established tracer gas methods, but assumptions and inputs.

Evidence for CO_2 impacts on health, well-being, learning, sleep, and performance is inconsistent and doesn't justify changes to ventilation and IAQ standards & guidelines.

Use of CO_2 to assess risks of airborne disease transmission must account for space ventilation and occupants, and recognize differences between CO_2 and aerosols.

Sensor accuracy, location and calibration are critical.

Air cleaning technologies that remove only CO_2 will not necessarily improve IAQ

Research recommendations (also abbreviated)

Indoor CO_2 exposure as a modifier of human responses to other environmental factors such as thermal comfort.

IAQ metrics that cover range of indoor contaminants and sources.

Health, comfort, productivity, learning, and sleep impacts of indoor CO_2 at concentrations typical of non-industrial indoor environments.

Physiological impacts of exposure to CO_2 at typical indoor concentrations.

Significance of indoor CO_2 concentration as an indicator of the risks of airborne infectious disease transmission

CO_2 sensor performance and locations for different applications.

Occupant-generated CO_2 as a tracer gas to estimate ventilation rates.

Strategies for DCV using CO_2 and other indicators of occupancy.

Surveys of indoor CO_2, ventilation rates and occupancy in different building types.

Recommended activities

Development of guidance and standards on indoor CO_2 concentration measurement and sensor selection.

Development of educational programs, conference sessions and workshops, and guidance documents to help practitioners and researchers understand the application of indoor CO_2.

Guidance on HVAC equipment and controls employing CO_2 monitoring.

Guidance on the use of CO_2 as a tracer gas for measuring building ventilation rates and outdoor air distribution.

Appendix

Detailed discussion to supports positions and recommendations in the document.

- The history of the role of indoor CO_2 concentrations in the context of building ventilation and IAQ
- Health and cognitive impacts of exposure to CO_2
- Existing standards and regulations for indoor CO_2 concentrations
- CO_2 as an indicator of IAQ and ventilation
- Use of CO_2 as a tracer gas for estimating ventilation rates
- Increases in outdoor CO_2 concentrations
- Air cleaning directed at CO_2 removal alone
- CO_2 as an indicator of the risk of airborne disease transmission

Conclusion

ASHRAE position document clarifies relationship of indoor CO_2 to ventilation and IAQ for practitioners, researchers and policymakers.

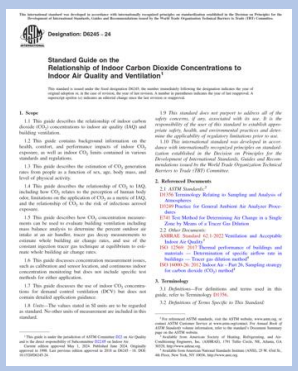
Additional research and new guidance will advance application of indoor CO_2 to improve IAQ.

https://www.ashrae.org/file%20library/about/position%20documents/pd_indoorcarbondioxide_2025.pdf

Search on “ASHRAE indoor carbon dioxide”

ASTM Standard D6245-2024

Standard Guide on the Relationship of Indoor Carbon Dioxide Concentrations to Indoor Air Quality and Ventilation



Designation: D6245 - 24

Standard Guide on the Relationship of Indoor Carbon Dioxide Concentrations to Indoor Air Quality and Ventilation[1]

First published in 1998 as a provisional standard
Latest version published in 2024
Partial revision in progress

ASTM Standard D6245-2024

Scope

Background on health, comfort, and performance impacts of CO_2 exposure, as well as indoor CO_2 limits in standards and regulations.

Estimation of CO_2 generation rates from people as a function of sex, age, body mass, and level of physical activity (Section 6).

Relationship of CO_2 to IAQ, including how CO_2 relates to the perception of human body odor, limitations on CO_2 as a metric of IAQ, and the relationship of CO_2 to the risk of infectious aerosol exposure (Section 7).

How CO_2 concentrations can be used to evaluate building ventilation and the use of indoor CO_2 concentrations for demand control ventilation (DCV) but not a detailed application guide (Section 8).

Concentration measurement issues, such as calibration and sensor location, and continuous indoor concentration monitoring but does not include specific test methods for either application (Sections 9 and 10).

ASTM Standard D6245-2024

Section 6: CO_2 Generation Rates

(Persily and de Jonge, Indoor Air, 2017)

Equation to estimate rate of CO_2 generation of an individual Based on concepts in the fields of human metabolism and exercise physiology

Inputs Individual sex, age and body mass; level of physical activity (met rate)

Standard contains input data from literature

Tables of CO_2 generation rates by sex and age

Alternative to equation in ASHRAE Fundamentals
No explanation of technical basis; old metabolic rate data; sex and age only considered indirectly

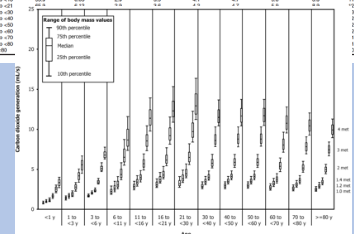
TABLE 2 Metabolic Rates (*M* in Met) for Various Physical Activities (15)

Activity	M (Met)
Calisthenics – light effort	2.8
Calisthenics – moderate effort	3.8
Calisthenics – vigorous effort	8.0
Child care	
Cleaning, sweeping – moderate effort	3.8
Custodial work – light	2.3
Dancing – aerobic, general	7.3
Dancing – general	7.8
Health club exercise classes – general	5.0
Kitchen activity – moderate effort	3.3
Lying or sitting quietly	
Sitting reading, writing, typing	1.3
Sitting at sporting event as spectator	1.5
Sitting tasks, light effort (for example, office work)	1.5
Sitting quietly in religious service	1.3
Sleeping	0.95
Standing quietly	1.3
Standing tasks, light effort (for example, store clerk, filing)	3.0
Walking, less than 2 mph, level surface, very slow	2.0
Walking, 2.8 mph to 3.2 mph, level surface, moderate pace	3.5

TABLE 4 Carbon Dioxide Generation Rates as a Function of Occupant Sex, Age, and Met Level (Based on Body Mass Data in (18))

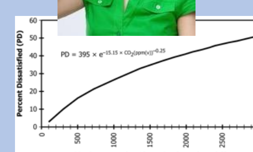
NOTE 1—These CO_2 generation rates are based on an air temperature of 273 K and an air pressure of 101 kPa.

Age (y)	Mean Mass (kg)	BMR (MJ/day)	CO_2 Generation Rate (L/s) Level of Physical Activity (met)						
			1.0	1.2	1.4	1.6	2.0	3.0	4.0
Males									
<1	8.0	1.86	0.9	1.1	1.3	1.4	1.8	2.7	3.6
1 to <3	12.8	3.05	1.5	1.8	2.1	2.4	3.0	4.4	5.9
3 to <6	18.8	3.90	1.9	2.3	2.6	3.0	3.8	5.7	7.5
6 to <11	31.9	5.14	2.5	3.0	3.5	4.0	5.0	7.5	10
11 to <16	57.6	7.02	3.4	4.1	4.8	5.4	6.8	10	13.6
16 to <21	77.3	7.77	3.7	4.5	5.3	6.0	7.5	11	15
21 to <30	84.9	8.24	3.9	4.8	5.6	6.4	8.0	12	16
30 to <40	87.0	7.83	3.7	4.6	5.3	6.1	7.6	11	15
40 to <50	90.5	8.00	3.8	4.6	5.4	6.2	7.7	12	16
50 to <60	89.5	7.95	3.8	4.6	5.4	6.2	7.7	12	15
60 to <70	89.5	6.84	3.3	4.0	4.6	5.3	6.6	9.9	13
70 to <80	83.9	6.57	3.1	3.8	4.5	5.1	6.4	9.5	13
≥80	76.1	6.19	3.0	3.6	4.2	4.8	6.0	9.0	12
Females									
<1	7.7	1.75	0.8	1.0	1.2	1.4	1.7	2.5	3.4
1 to <3	12.3	2.88	1.4	1.7	2.0	2.2	2.8	4.2	5.6
3 to <6	18.3	3.59	1.7	2.1	2.4	2.8	3.5	5.2	7.0
6 to <11	31.7	4.73	2.3	2.7	3.2	3.7	4.6	6.9	9.2
11 to <16	55.9	6.03	2.9	3.5	4.1	4.7	5.8	8.8	11
16 to <21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21 to <30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30 to <40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40 to <50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50 to <60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60 to <70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70 to <80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
≥80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



ASTM Standard D6245-2024

Section 7: CO_2 and Indoor Air Quality



Relation of CO_2 to perception of human body odor

Multiple studies showing CO_2 concentrations of about 700 ppm(v) above ambient corresponds to 80 % perceived odor acceptability by unadapted visitor

Limitations of CO_2 as a metric of IAQ

Many other important pollutants independent of occupants, e.g., outdoor air, building materials, cleaning products.

Relationship of CO_2 to risk of infectious aerosol exposure

Indicator of ventilation or risk?

ASTM Standard D6245-2024

Section 8: Ventilation

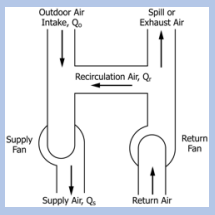
Percent outdoor air at air handler based on CO_2 concentrations in outdoor, return and supply airstreams

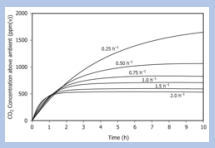
Tracer gas measurements of air change rates using occupant generated CO_2 as a tracer (ASTM E741 and ISO 12569)

- Key assumptions, including single zone
- Constant injection, CO_2 concentration at steady-state

Indicator of ventilation adequacy relative to target ventilation rate, depends on space and occupants (Persily 2022)

Short discussion of using CO_2 for demand control ventilation (DCV), but does not contain detailed application guidance





13

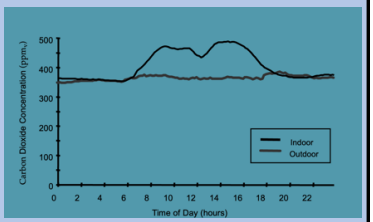
ASTM Standard D6245-2024

Section 9: CO_2 Concentration Measurement

Short discussions of the following:

- Sources of measurement error
- Calibration
- Warm-up
- Interferents
- Outdoor concentration measurement
- Indoor concentration, including sensor location

Courtesy of David Meyer
Shenandoah University



Section 10: Continuous Monitoring of CO_2 Concentrations

Timing and duration; Occupancy; Data archiving and display

14

Conclusion

ASTM D6245 is a guide not a test method or practice, but hopefully it contains useful information for practitioners

And hopefully it can reduce misapplication and misinterpretation of indoor CO_2 concentrations

Still need formal methods of test for measurement and analysis

Reading List

ASHRAE. 2025. *Position Document on Indoor Carbon Dioxide*..

ASTM. 2024. D6245 Standard Guide on the Relationship of Indoor CO_2 Concentrations to Indoor Air Quality & Ventilation.

ASTM. 2011. E741 Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution.

ISO. 2017. 12569: Thermal performance of buildings and materials — Determination of specific airflow rate in buildings — Tracer gas dilution method, International Standards Organization.

Kappelt, Russel, Kwiatkowski, Afshari. and Johnson. 2021. Correlation of Respiratory Aerosols and Metabolic Carbon Dioxide, *Sustainabilty*, Online 5 November 2021.

Lu, et al. 2022. The nexus of the indoor CO_2 concentration and ventilation demands underlying CO2-based demand-controlled ventilation in commercial buildings: A critical review. Building and Environment **218**.

Peng and Jimenez. 2021. Exhaled CO_2 as a COVID-19 Infection Risk Proxy for Different Indoor Environments and Activities, *Environmental Science & Technology Letters*, **8**, 392-397.

Persily, 1997. Evaluating Building Ventilation with Indoor Carbon Dioxide. ASHRAE Transactions, 103(2).

Persily and de Jonge. 2017. Carbon Dioxide Generation Rates of Building Occupants, *Indoor Air*, **27**, 868-879.

Persily, 2021. Don't Blame Standard 62.1 for 1000 ppm CO2, ASHRAE Journal, 63(2).

Persily, 2022. Development and Application of an Indoor Carbon Dioxide Metric. *Indoor Air*. DOI: 10.1111/INA.13059

Persily and Polidoro. 2022. *Indoor Carbon Dioxide Metric Analysis Tool*. NIST Technical Note 2213, National Institute of Standards and Technology.

QICO2 tool: https://pages.nist.gov/CONTAM-apps/webapps/CO2Tool/#/