Navigating Ventilation in Schools

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Navigating Mature and Emerging Technologies in Your Schools for COVID and Beyond

EPA IAQ for Schools Webinar
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NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

Outline

Very quick overview of IAQ and Ventilation

Ventilation basics

Buildings, ventilation systems & ventilation rates vary; these variations matter
Performance often doesn't match design intent
Standards & regulations exist, but ... adoption, compliance, enforcement

How to navigate ventilation

Assess ventilation performance
Consider options to improve but understand what you got first
CO_2 monitoring: What it does and doesn't mean

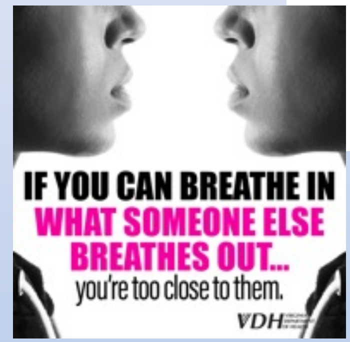
Bottom line messages

Navigating ventilation important for infection control; also for "everyday" IAQ
CO_2 is a tool but not the answer to every question
Understand your building; what you can do depends on what you got
Don't neglect the neglected buildings

Indoor Air Quality and Ventilation

IAQ control principles
Source control: elimination, substitution, local removal
Ventilation – with clean air, outdoor or recirculated
Air cleaning/filtration

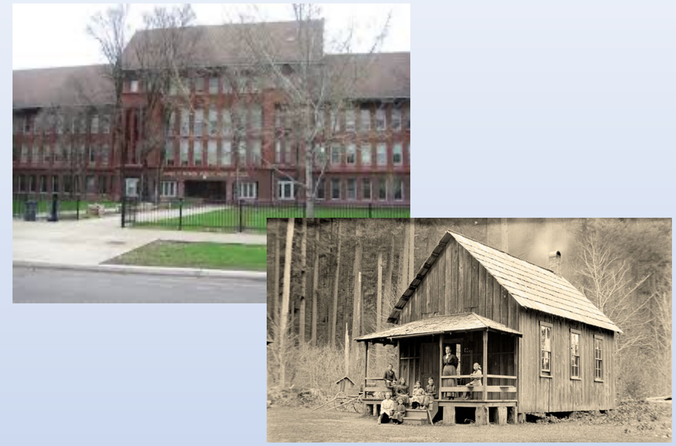
Indoor vs outdoor sources
Indoor: Materials, activities, people
Outdoor: Regional, local, site



Ventilation
A mature technology, but can do better
Emerging technologies exist, but 1st operate as intended

Application to COVID-19 and Beyond
Manage the sources, i.e., the people
Ventilation is important – what does that mean?
Clean/filter/disinfect – listen to next speakers and other sound guidance

Ventilation basics - with schools in mind



Buildings

Age; Size; Condition; Resources; TLC

Ventilation strategies

Mechanical ventilation Central, rooftop, …

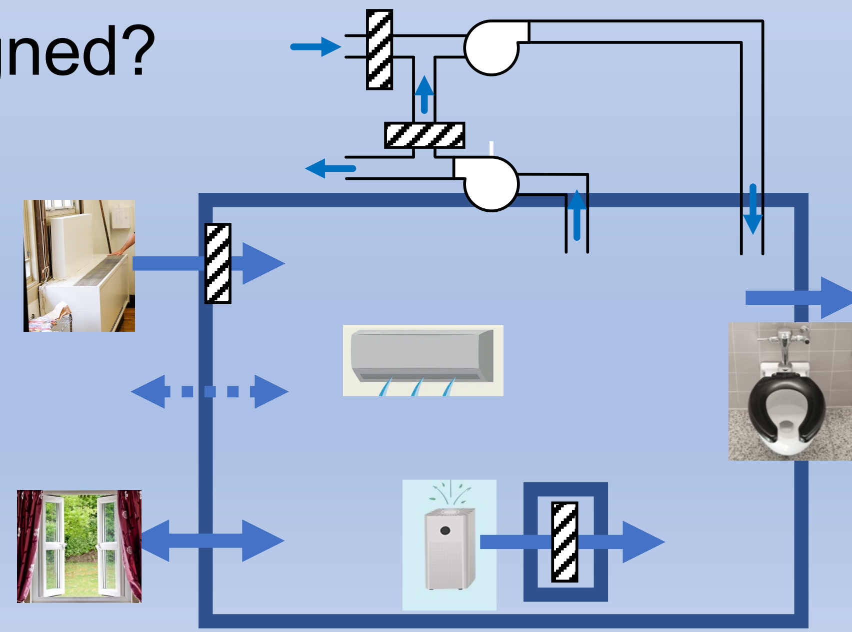
Infiltration Unintentional and uncontrolled

Natural ventilation Windows or designed?

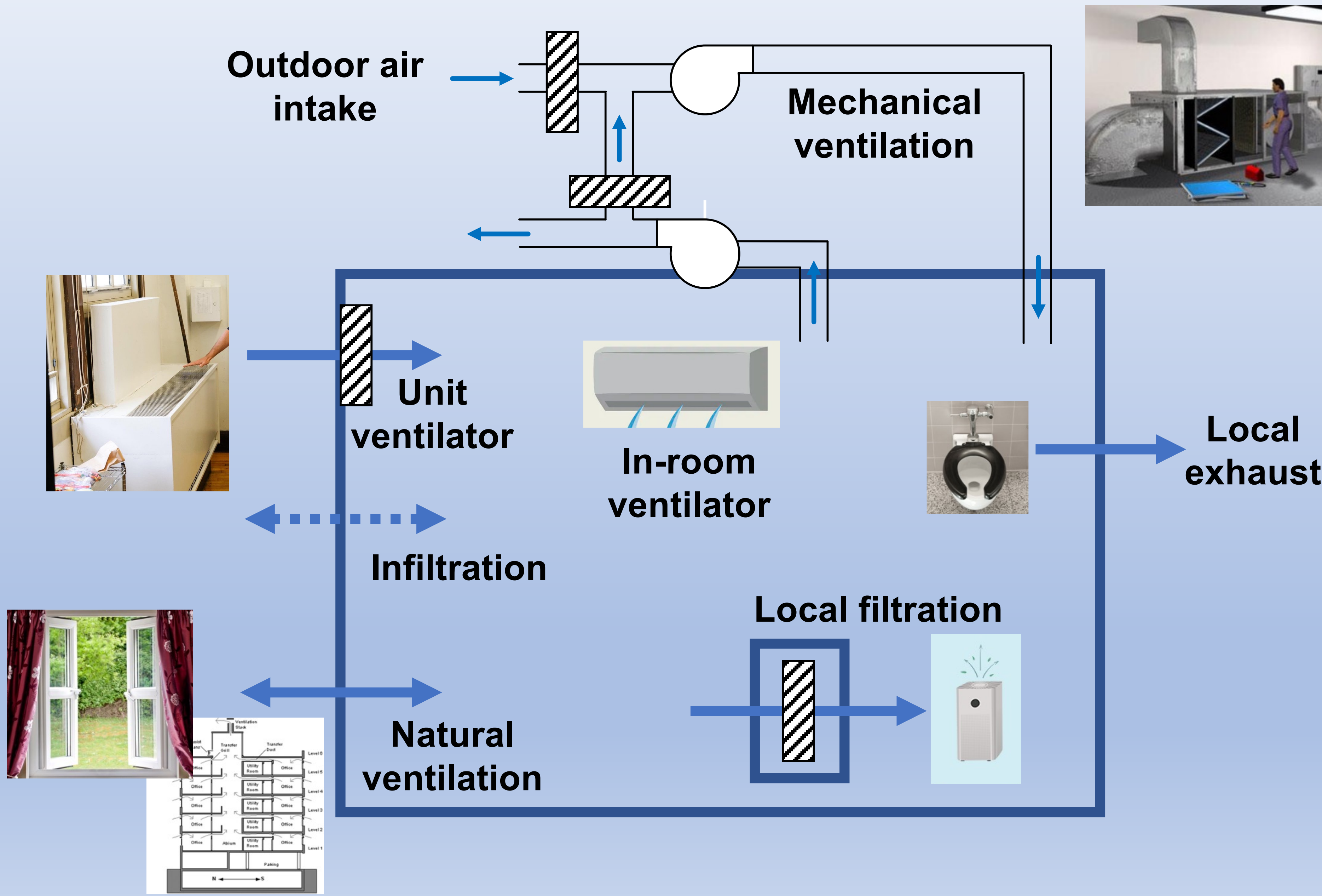
Local filtration Portable air cleaners

Local exhaust Toilets & kitchens

In-room ventilator Outdoor air?



Ventilation strategies



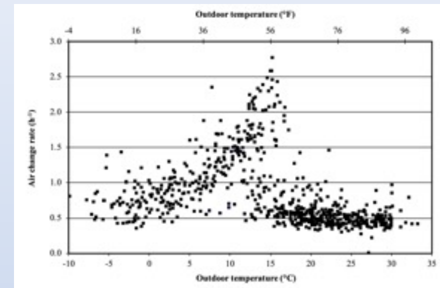
More ventilation basics

Ventilation rates vary

Weather; system controls; system condition

Easily over a range of 5 to 1;

1 measurement doesn't tell you much



Performance often doesn't match design

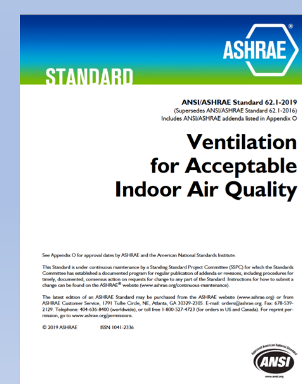
O&M critical but resources not always there

Ventilation rates required by standards

ASHRAE Standard 62.1 applies to educational spaces

Issues of adoption, enforcement, existing buildings

Compliance – actual rates often below standards



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STANDARD

ANSI/ASHRAE Standard 62.1-2019
(Supersedes ANSI/ASHRAE Standard 62.1-2016)
Includes ANSI/ASHRAE addenda listed in Appendix O

Ventilation for Acceptable Indoor Air Quality

See Appendix O for approval dates by ASHRAE and the American National Standards Institute.

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Measured ventilation rates in schools

	Median OA ventilation rate (L/s per person)
Mendell et al. 2013, Indoor Air, 23.	
Permanent	5.2
Portable	3.1
Natural ventilation	6.0
Mechanical – no AC	7.6
Mechanical with AC	2.8
Haverinen-Shaughnessy et al. 2011, Indoor Air, 21.	3.6
ASHRAE Standard 62.1	**6.7 to 7.4 (depends on grade level)**

Navigating Ventilation: What's been recommended

Inspect systems; verify operation per design & standards

MORE: outdoor air, filtration, open windows, humidity
Change standards for more air, more filtration, …

Monitor indoor CO_2
Concentrations below X ppm_v indicate good ventilation/low risk

Improve air distribution for air delivery & aerosol removal

MISC: Longer ventilation operation (e.g., 24/7), Flushing before/after occupancy; Disable demand control ventilation

Ventilation recommendations

Increase outdoor air ventilation rates

System capacity
Outdoor air quality
Moisture management
Assuming good HVAC control

More efficient filtration

System capacity
Maintenance

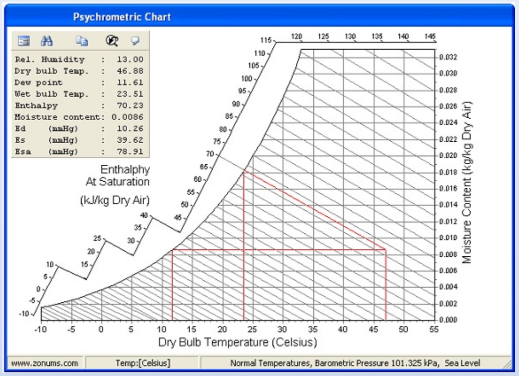
More ventilation recommendations

Change relative humidity

Do we know the right number?

System capacity

Condensation potential/microbial growth

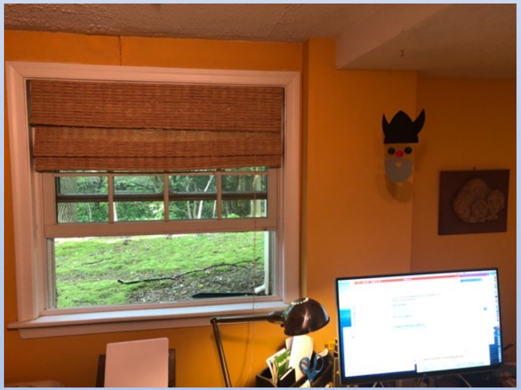


Open windows

Outdoor air quality

Moisture, noise, security

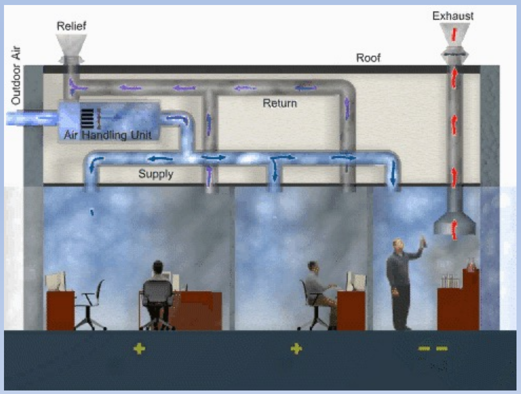
Direction, magnitude, distribution?



Change air distribution

System configuration

Options may be limited

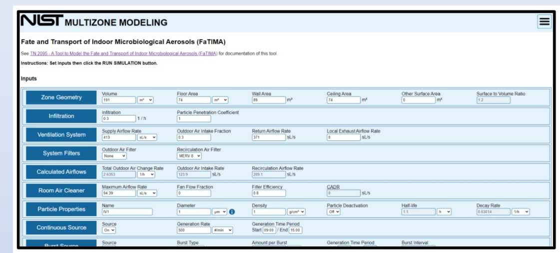


Simulation Study in Educational Spaces

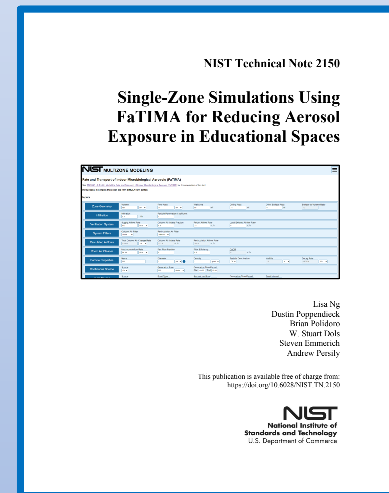
Ng, et al. 2021. Single-Zone Simulations Using FaTIMA for Reducing Aerosol Exposure in Educational Spaces. NIST Technical Note 2150-upd. https://doi.org/10.6028/NIST.TN.2150-upd

Employed NIST FaTIMA online tool

https://www.nist.gov/services-resources/software/fatima



To evaluate relative exposure reduction from HVAC and non-HVAC controls


NIST Technical Note 2150

Single-Zone Simulations Using FaTIMA for Reducing Aerosol Exposure in Educational Spaces

Lisa Ng
Dustin Poppendieck
Brian Polidoro
W. Stuart Dols
Steven Emmerich
Andrew Persily

This publication is available free of charge from: https://doi.org/10.6028/NIST.TN.2150

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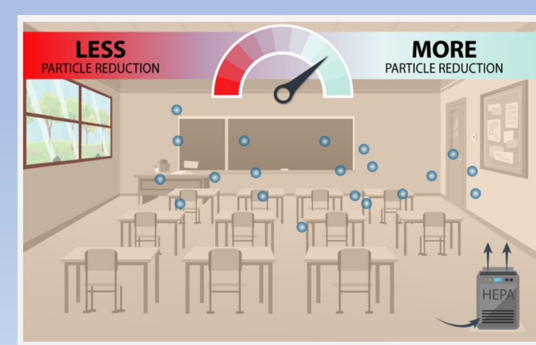
Impact depends on HVAC system type

And how controls are implemented

- Fit of face coverings
- Portable air cleaner setting
- Filter fit and maintenance

Results used in CDC Interactive School Ventilation Tool

https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/interactive-ventilation-tool.html



Ventilation assessment: To understand system & options before making changes

Persily. 2021. *Evaluating Ventilation Performance*, *Handbook of Indoor Air Quality*.
https://www.nist.gov/publications/evaluating-ventilation-performance

System Design

- Documentation exist? Is it current? What standard used?
- Outdoor air intake rate; Recirculation; Local mixing boxes; Filter efficiency; Heat/enthalpy recovery; Operating schedule; Controls

Actual performance

- System status: on/off, mode of operation, …
- System airflows: Supply, outdoor air, exhaust
- Whole building outdoor air change rates
- Pressure differences, air distribution/ventilation effectiveness

Other important factors

- Condition of system components
- Operations & Maintenance programs

CO_2 monitoring can be useful

Understand technical basis

Measure and interpret with care

History of confusion and misinterpretation

More measurement & less expensive sensors

Guidance not always clear

Reasons to monitor CO_2

Verify design or protective ventilation rate

Indicator of transmission risk

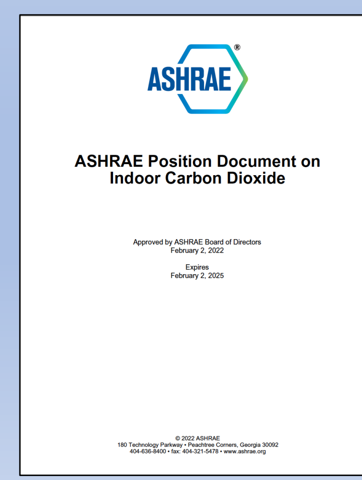
Prioritize spaces/systems for inspection/repair

Critical to understanding concentration data

Building & system, occupancy schedule, sensor location & accuracy, outdoor concentration

ASHRAE Position Document on Indoor CO_2

Courtesy of David Meyer, Shenandoah University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ASHRAE Position Document on Indoor Carbon Dioxide

Approved by ASHRAE Board of Directors
February 2, 2022

Expires
February 2, 2025

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CO_2 as a metric of adequate ventilation

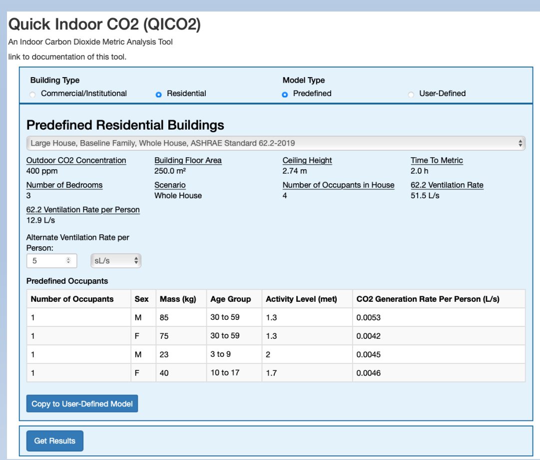
A single value for all spaces doesn't make sense

Must consider timing of occupancy & measurement, occupants, target ventilation rate, …

Space-specific CO_2 ventilation metric

QICO2: On-Line Calculator

(Search on: NIST CO2 tool)



Quick Indoor CO2 (QICO2)

An Indoor Carbon Dioxide Metric Analysis Tool

link to documentation of this tool.

Building Type: Commercial/Institutional · Residential

Model Type: Predefined · User-Defined

Predefined Residential Buildings

Large House, Baseline Family, Whole House, ASHRAE Standard 62.2-2019

Outdoor CO2 Concentration: 400 ppm
Building Floor Area: 250.0 m²
Ceiling Height: 2.74 m
Time To Metric: 2.0 h
Number of Bedrooms: 3
Scenario: Whole House
Number of Occupants in House: 4
62.2 Ventilation Rate: 51.5 L/s
62.2 Ventilation Rate per Person: 12.9 L/s

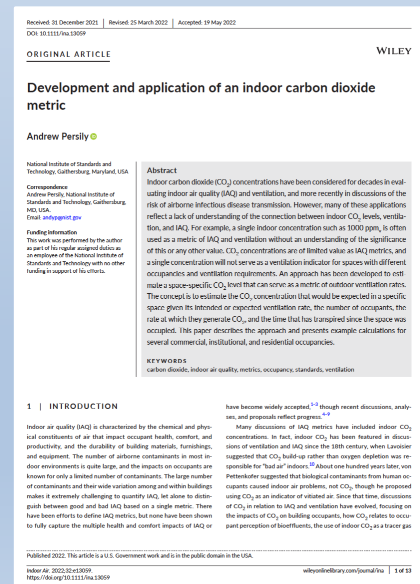
Alternate Ventilation Rate per Person: 5 sL/s

Predefined Occupants

Number of Occupants	Sex	Mass (kg)	Age Group	Activity Level (met)	CO2 Generation Rate Per Person (L/s)
1	M	85	30 to 59	1.3	0.0053
1	F	75	30 to 59	1.3	0.0042
1	M	23	3 to 9	2	0.0045
1	F	40	10 to 17	1.7	0.0046

Copy to User-Defined Model

Get Results



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ORIGINAL ARTICLE

WILEY

Development and application of an indoor carbon dioxide metric

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Abstract
Indoor carbon dioxide (CO_2) concentrations have been considered for decades in evaluating indoor air quality (IAQ) and ventilation, and more recently in discussions of the risk of airborne infectious disease transmission. However, many of these applications reflect a lack of understanding of the connection between indoor CO_2 levels, ventilation, and IAQ. For example, a single indoor concentration such as 1000 ppm_v is often used as a metric of IAQ and ventilation without an understanding of the significance of this or any other value. CO_2 concentrations are of limited value as IAQ metrics, and a single concentration will not serve as a ventilation indicator for spaces with different occupancies and ventilation requirements. An approach has been developed to estimate a space-specific CO_2 level that can serve as a metric of outdoor ventilation rates. The concept is to estimate the CO_2 concentration that would be expected in a specific space given its intended or expected ventilation rate, the number of occupants, the rate at which they generate CO_2, and the time that has transpired since the space was occupied. This paper describes the approach and presents example calculations for several commercial, institutional, and residential occupancies.

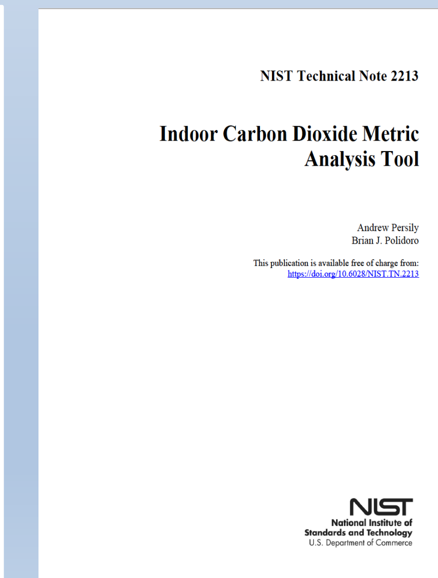
KEYWORDS
carbon dioxide, indoor air quality, metrics, occupancy, standards, ventilation

1 | INTRODUCTION

Indoor air quality (IAQ) is characterized by the chemical and physical constituents of air that impact occupant health, comfort, and productivity, and the durability of building materials, furnishings, and equipment. The number of airborne contaminants in most indoor environments is quite large, and the impacts on occupants are known for only a limited number of contaminants. The large number of contaminants and their wide variation among and within buildings makes it extremely challenging to quantify IAQ, let alone to distinguish between good and bad IAQ based on a single metric. There have been efforts to define IAQ metrics, but none have been shown to fully capture the multiple health and comfort impacts of IAQ or have become widely accepted,[1-3] though recent discussions, analyses, and proposals reflect progress.[4-9]

Many discussions of IAQ metrics have included indoor CO_2 concentrations. In fact, indoor CO_2 has been featured in discussions of ventilation and IAQ since the 18th century, when Lavoisier suggested that CO_2 build-up rather than oxygen depletion was responsible for "bad air" indoors.[10] About one hundred years later, von Pettenkofer suggested that biological contaminants from human occupants caused indoor air problems, not CO_2, though he proposed using CO_2 as an indicator of vitiated air. Since that time, discussions of CO_2 in relation to IAQ and ventilation have evolved, focusing on the impacts of CO_2 on building occupants, how CO_2 relates to occupant perception of bioeffluents, the use of indoor CO_2 as a tracer gas

Indoor Air. 2022;32:e13059.
https://doi.org/10.1111/ina.13059
wileyonlinelibrary.com/journal/ina | 1 of 13



NIST Technical Note 2213

Indoor Carbon Dioxide Metric Analysis Tool

Andrew Persily
Brian J. Polidoro

This publication is available free of charge from:
https://doi.org/10.6028/NIST.TN.2213

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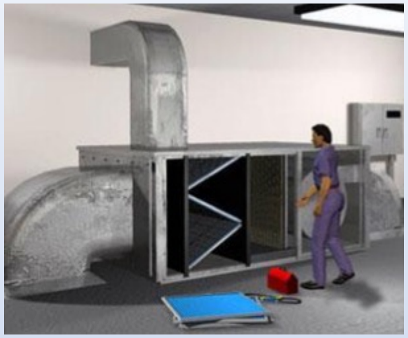
Emerging Technology

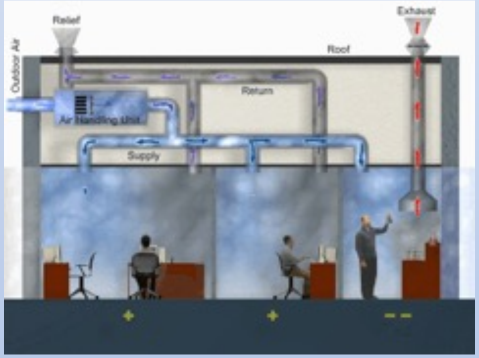


Do the right things

Make sure systems operating per design

Understand before making changes

We know how to do this!



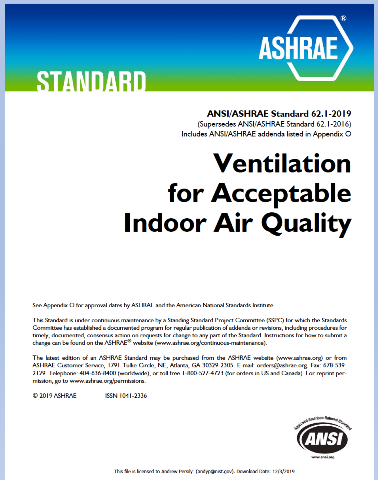
New stuff?

Localized or personal ventilation

Sensors

Ventilation control approaches

Revise ventilation/IAQ standards to
address operation, existing buildings
and airborne infection more directly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Wrap-up

Navigating ventilation is nontrivial, but it's not rocket science

Each building/system is unique and dynamic

We have the knowledge and the tools

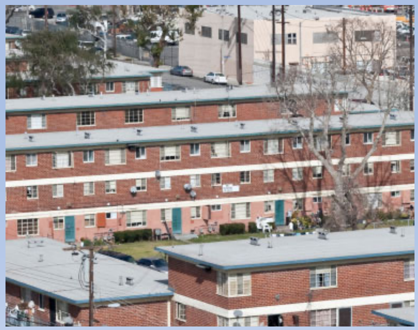
CO_2 is a tool; not everything is a nail

Measure and interpret with thought and care

Want innovation?

Operate and maintain systems as intended

Then get fancy with sensors, air distribution, …



Don't neglect the neglected buildings

Existing; Older; Without budgets and plaques

Persily and Siegel. 2022. Improving Ventilation Performance in Response to the Pandemic. *The Bridge* 52(3).
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https://www.youtube.com/watch?v=88XCmW8yIhs

Persily and Ng. 2020. Ventilation Impacts on Indoor Aerosol Transport and Current HVAC Recommendations for Re-Opening Buildings. Federal Interagency Committee on IAQ.
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