National Academies Indoor Chemistry Matters Workshop 3:
Reaching Communities for Action
April 10, 2024

Standards, Guidelines, & Regulations Matter
Where We Are & What We Need

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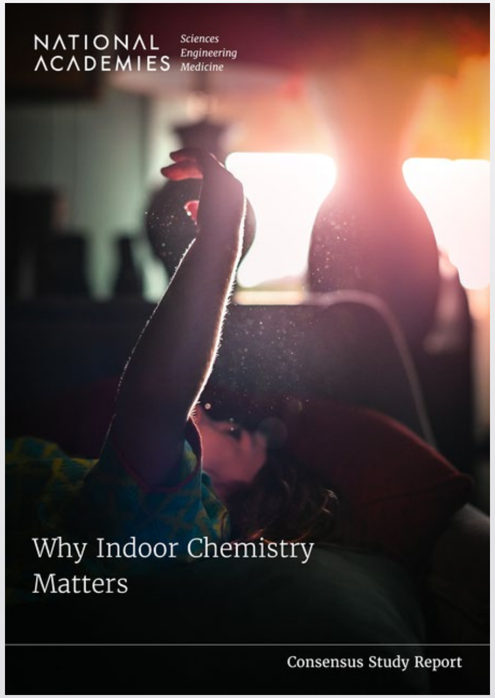
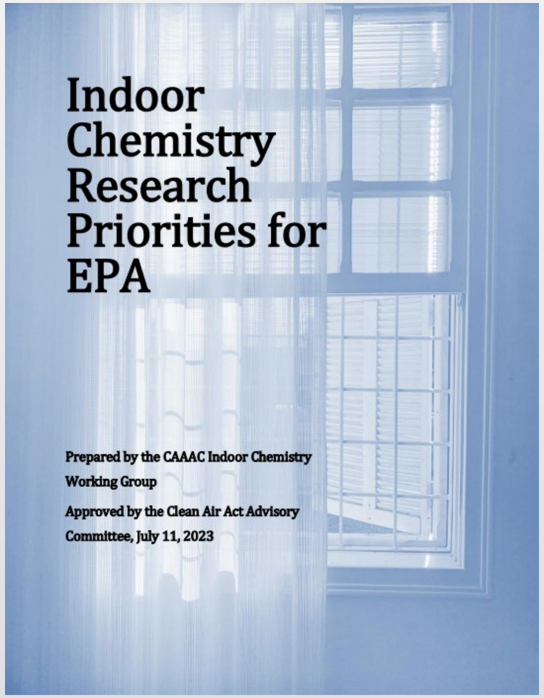
My Involvement with Indoor Chemistry

- Mechanical engineer with industry and academic experience
- Teach indoor air quality to future design engineers and building scientists
- Research indoor air quality control technologies, some with significant associated chemistry
- Apply IAQ standards as a practitioner
- Influence IAQ/IEQ goals and activities in volunteer organizations
- Advocate for better IAQ through research, standards, regulations

My Role in the "Why Indoor Chemistry Matters" Consensus Study Report

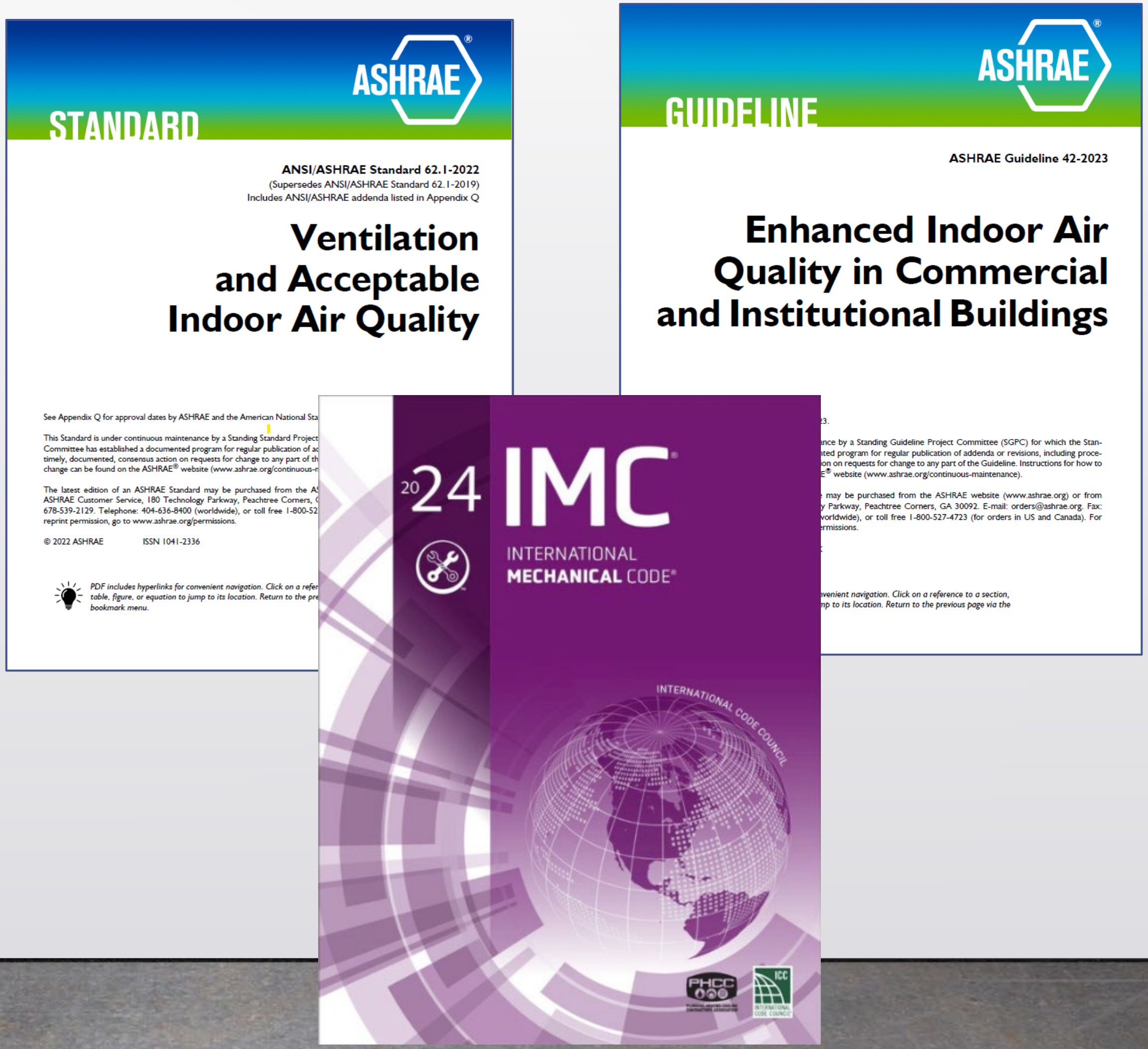
- Member, Committee on Emerging Science on Indoor Chemistry
  - Chapter 5 – Management of Chemicals in Indoor Environments
  - Chapter 6 – Indoor Chemistry and Exposure
- Clean Air Act Advisory Committee (CAAAC)
  - Chair – Indoor Chemistry Working Group
  - "short term research (1-3 years) that could inform public health guidance and building practices for improving Indoor Air Quality (IAQ) in homes, schools, and commercial and office buildings."



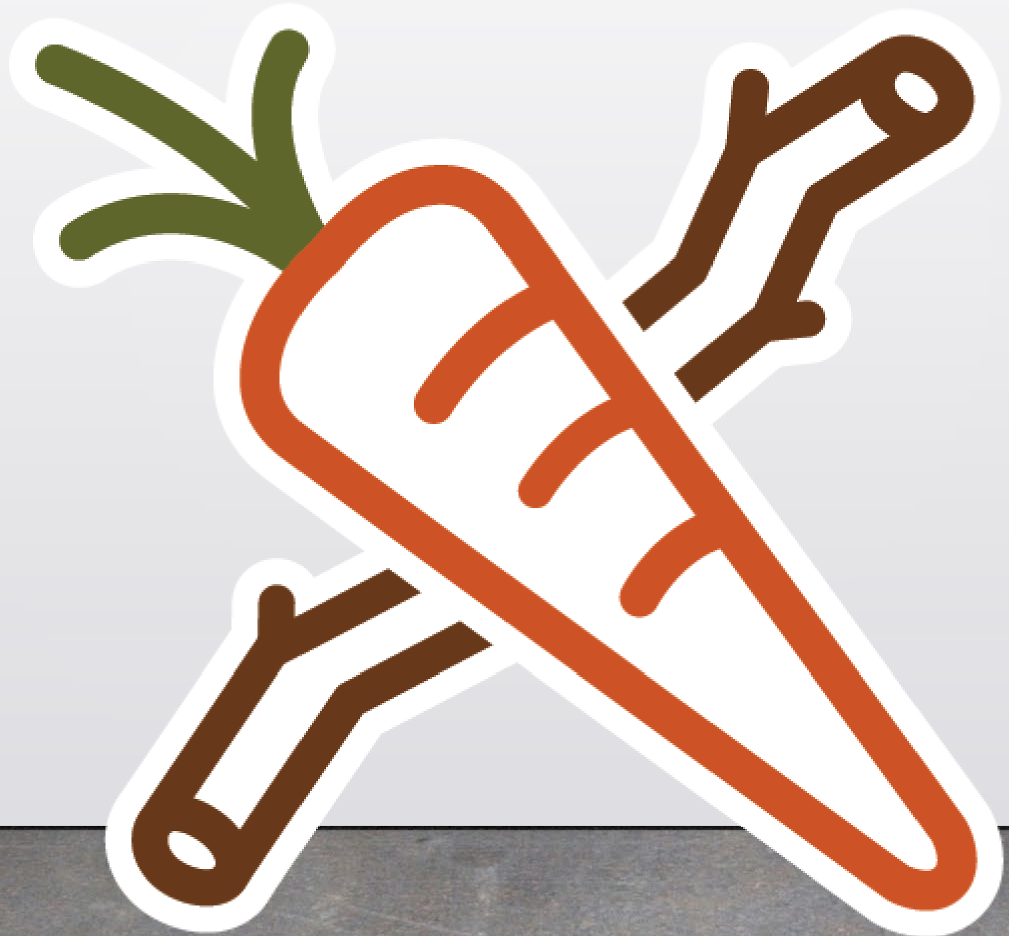


Standards, Guidelines and Regulations

- Guidelines
  - Define good practice
  - Voluntary
  - Includes "standards" that are not code-intended
- Standards
  - Set minimum requirements
  - Written to be enforceable
  - Not mandatory unless adopted by an authority
- Regulations
  - Rules set by authorities
  - Force and effect of law



Voluntary best practices or mandated minimum requirements? We need both!



Role of Indoor Environment Standards

- Requirements for
  - Materials and equipment
  - System design and construction
  - Operation and maintenance
  - Documentation
- Functions
  - Define minimum acceptable criteria
  - Protect the public and professionals
  - Establish stable environment for manufactuers

Importance of Standards, Guidelines & Regulations

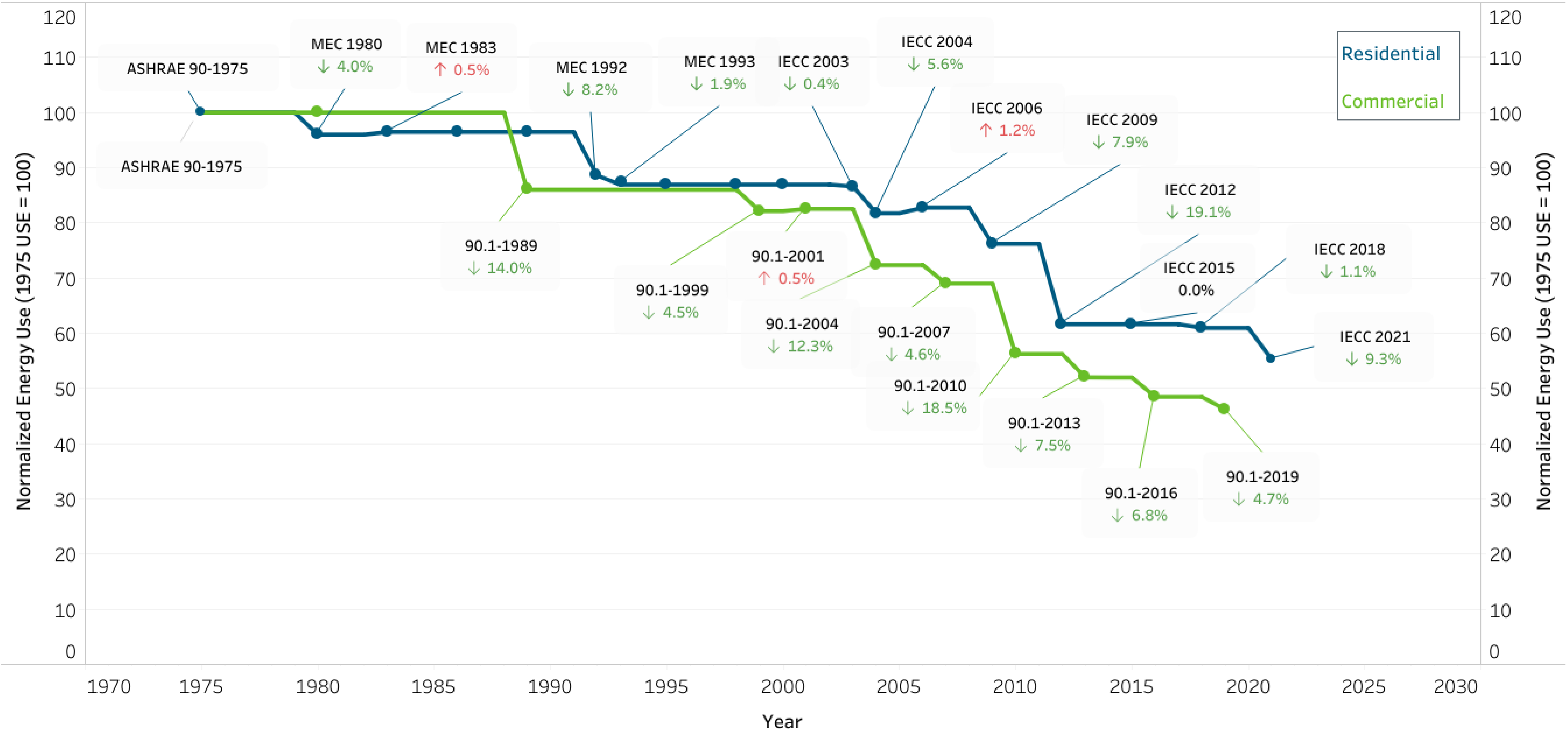
- Regulation is essential to compliance
- Regulations depend on standards
- Standards protect parties involved in the covered activity
- Guidelines, especially rating systems can exert pull on standards

Standards/regulation are a powerful force for change

U.S. DEPARTMENT OF ENERGY

Estimated Improvement in Residential & Commercial Energy Codes (1975 - 2021)

Pacific Northwest NATIONAL LABORATORY



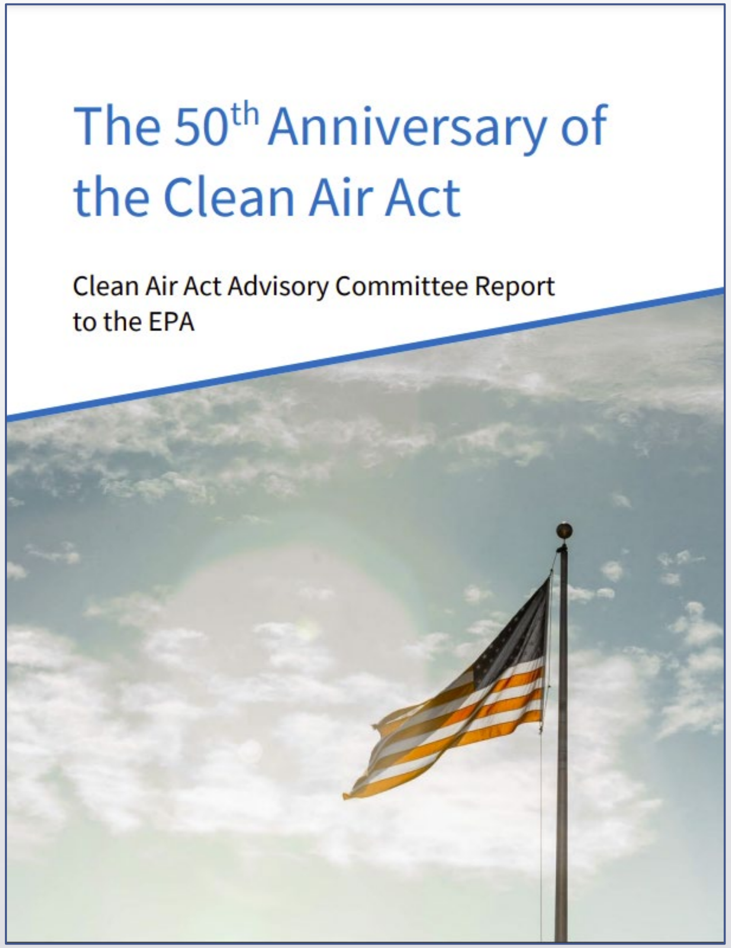
https://www.energycodes.gov/infographics

The indoor air quality revolution – delayed half a century

"Fifty years after adoption and successful implementation of air quality standards for the ambient environment, an important air quality challenge remains: the majority of human exposure to airborne pollutants occurs in the indoor environment…

…The EPA has estimated that the CAA's benefits have outweighed its costs by a factor of thirty to one…

…This report recommends that the EPA build on the success of the CAA by developing a strategy exploring the viability of the federal government establishing national *indoor* air quality guidelines and/or standards…"



www.epa.gov/clean-air-act-overview/evolution-clean-air-act

www.epa.gov/caaac/final-caa-50th-anniversary-workgroup-report-findings-and-recommendations-us-epa

INSIGHTS

POLICY FORUM

PUBLIC HEALTH

Mandating indoor air quality for public buildings

If some countries lead by example, standards may increasingly become normalized

By **Lidia Morawska, Joseph Allen, William Bahnfleth, Belinda Bennett, Philomena M. Bluyssen, Atze Boerstra, Giorgio Buonanno, Junji Cao, Stephanie J. Dancer, Andres Floto, Francesco Franchimon, Trish Greenhalgh, Charles Haworth, Jaap Hogeling, Christina Isaxon, Jose L. Jimenez, Amanda Kennedy, Prashant Kumar, Jarek Kurnitski, Yuguo Li, Marcel Loomans, Guy Marks, Linsey C. Marr, Livio Mazzarella, Arsen Krikor Melikov, Shelly L. Miller, Donald K. Milton, Jason Monty, Peter V. Nielsen, Catherine Noakes, Jordan Peccia, Kimberly A. Prather, Xavier Querol, Tunga Salthammer, Chandra Sekhar, Olli Seppänen, Shin-ichi Tanabe, Julian W. Tang, Raymond Tellier, Kwok Wai Tham, Pawel Wargocki, Aneta Wierzbicka, Maosheng Yao**

People living in urban and industrial- ... in the derivation procedure; the complex po- ... is different and is used differently, and we

science.org/doi/10.1126/science.adl0677

Prescriptive and Performance Standards

- Prescriptive standard
  - Specific requirements that, if met, are deemed to comply
  - Examples
    - Minimum outdoor air requirements
    - Equipment ozone emission limits

- Performance standard
  - Compliance is based on achieving a desired outcome
  - Examples
    - Control limits on air contaminants
    - Specified level of perceived air quality

Prescriptive approaches tend to be favored by users

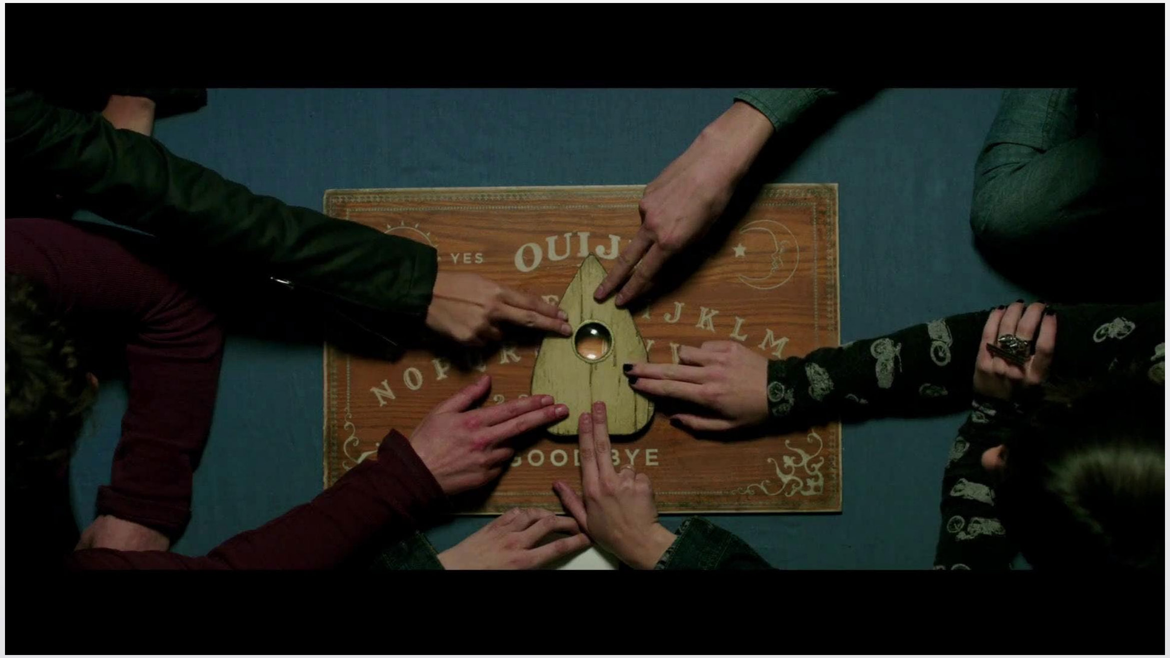
Performance path may require more expertise and bring increased liability

Consensus is Critical to Standards Impact

- US standards related to indoor air quality are considered credible if they have American National Standards Institute (ANSI) certification
- Key aspects of consensus standards process
  - Balanced committee
  - Open meetings
  - Public review and comment – with mandatory response
  - Anyone has standing to propose changes

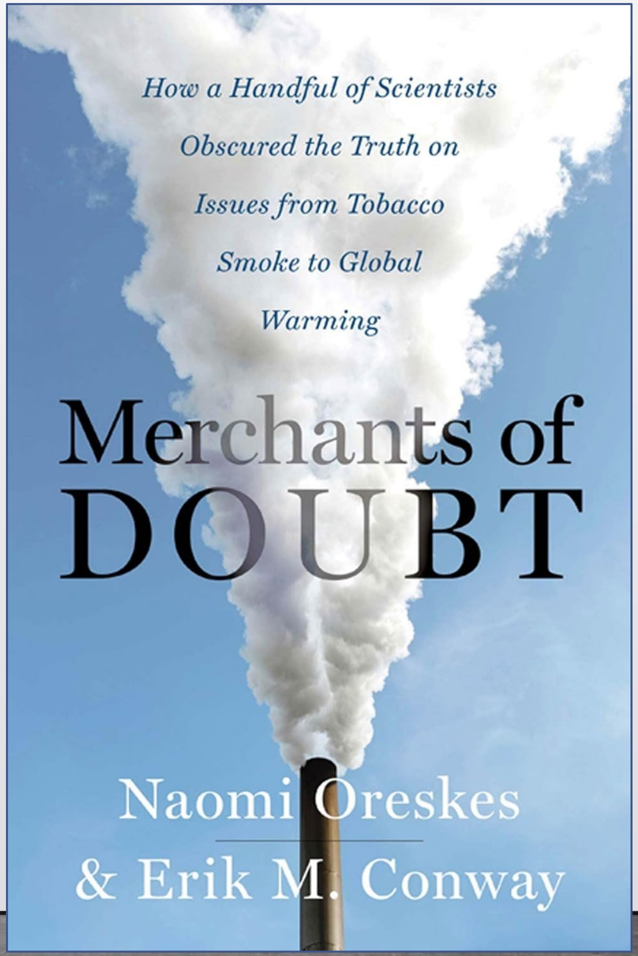
Consensus has Limitations

- Normal development time measured in years
- Requires compromise – standard becomes what can be agreed to by most
- Not a great tool for activism – change can be slow



Connection of Science to Standards, Regulations, and Guidelines

- Standards should be science-based, but may be written with or without clear science exists if they are needed
- "Scientific consensus" is a major factor in development and acceptance of standards
- Claim of unclear evidence can be a tactic to prevent action
- Science does not automatically adopt move into standards and regulations



What is in IAQ Standards Today Related to Indoor Chemistry? ASHRAE Standard 62.1-2022

- Definition of acceptable indoor air quality: air in which there are no known contaminants at harmful concentrations, as determined by cognizant authorities, and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction.
- Prescriptive compliance path – minimum outdoor air flow based on space type, floor area, number of occupants (Ventilation Rate Procedure)
- Performance compliance path – control specific contaminants to required levels – *permits use of alternatives to outdoor air* (Indoor Air Quality Procedure)

ASHRAE Standard 62.1 – Outdoor Air

- Smoking excluded, smoking areas must be isolated
- Special requirements if outdoor air exceeds national standards for PM2.5, PM10, ozone

ASHRAE Standard 62.1 – Ventilation Rate Procedure

Table 6-1 Minimum Ventilation Rates in Breathing Zone *(Continued)*

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Default Values: Occupant Density	Air Class	OS (6.2.6.1.4)
	cfm/person	L/s·person	cfm/ft²	L/s·m²	#/1000 ft² or #/100 m²		
Occupiable storage rooms for dry materials	5	2.5	0.06	0.3	2	1	
Office space	5	2.5	0.06	0.3	5	1	✓
Reception areas	5	2.5	0.06	0.3	30	1	✓
Telephone/data entry	5	2.5	0.06	0.3	60	1	✓
Public Assembly Spaces							
Auditorium seating area	5	2.5	0.06	0.3	150	1	✓
Courtrooms	5	2.5	0.06	0.3	70	1	✓
Legislative chambers	5	2.5	0.06	0.3	50	1	✓
Libraries	5	2.5	0.12	0.6	10	1	
Lobbies	5	2.5	0.06	0.3	150	1	✓
Museums (children's)	7.5	3.8	0.12	0.6	40	1	
Museums/galleries	7.5	3.8	0.06	0.3	40	1	✓
Places of religious worship	5	2.5	0.06	0.3	120	1	✓
Residential							

ASHRAE Standard 62.1 – IAQ Procedure

Table 6-5 Design Compounds, PM2.5, and Their Design Limits

Compound or PM2.5	Cognizant Authority	Design Limit
Acetaldehyde	Cal EPA CREL (June 2016)	140 µg/m^3
Acetone	AgBB LCI	1,200 µg/m^3
Benzene	Cal EPA CREL (June 2016)	3 µg/m^3
Dichloromethane	Cal EPA CREL (June 2016)	400 µg/m^3
Formaldehyde	Cal EPA 8-hour CREL (2004)	33 µg/m^3
Naphthalene	Cal EPA CREL (June 2016)	9 µg/m^3
Phenol	AgBB LCI	10 µg/m^3
Tetrachloroethylene	Cal EPA CREL (June 2016)	35 µg/m^3
Toluene	Cal EPA CREL (June 2016)	300 µg/m^3
1,1,1-trichloroethane	Cal EPA CREL (June 2016)	
Xylene, total	AgBB LCI	
Carbon monoxide	U.S. EPA NAAQS	
PM2.5	U.S. EPA NAAQS (annual mean)	
Ozone	U.S. EPA NAAQS	
Ammonia	Cal EPA CREL (June 2016)	

Table 6-6 Mixtures of Compounds

Upper Respiratory Tract Irritation	Eye Irritation	Central Nervous System
Acetaldehyde	Acetaldehyde	Acetone
Acetone	Acetone	Dichloromethane
Xylene, total	Formaldehyde	Xylene, total
Ozone	Xylene,total	1,1,1-trichloroethane
	Ozone	Toluene

Source: ACGIH (2017) (See Informative Appendix P, "Informative References").

What to Regulate?

- For *harm*, Disability Adjusted Life Years (DALY) may be a good metric
- DALY do not comprehensively address wellness
- Combine toxicity and epidemiology data with prevalence
- Of 45 contaminants evaluated, 6 cause 99% of harm in residential applications

Environmental Science & Technology
pubs.acs.org/est
Article

Harm from Residential Indoor Air Contaminants

Giobertti Morantes, Benjamin Jones,* Constanza Molina, and Max H. Sherman

Cite This: *Environ. Sci. Technol.* 2024, 58, 242–257

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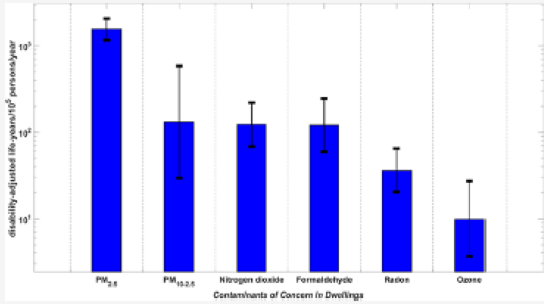
ABSTRACT: This study presents a health-centered approach to quantify and compare the chronic harm caused by indoor air contaminants using disability-adjusted life-year (DALY). The aim is to understand the chronic harm caused by airborne contaminants in dwellings and identify the most harmful. Epidemiological and toxicological evidence of population morbidity and mortality is used to determine harm intensities, a metric of chronic harm per unit of contaminant concentration. Uncertainty is evaluated in the concentrations of 45 indoor air contaminants commonly found in dwellings. Chronic harm is estimated from the harm intensities and the concentrations. The most harmful contaminants in dwellings are $PM_{2.5}$, $PM_{10-2.5}$, NO_2, formaldehyde, radon, and O_3, accounting for over 99% of total median harm of 2200 DALYs/10^5 person/year. The chronic harm caused by all airborne contaminants in dwellings accounts for 7% of the total global burden from all diseases.



KEYWORDS: *DALY, dwelling, harm intensity, harm budget, ranking, acceptable indoor air quality*

https://doi.org/10.1021/acs.est.3c07374
Environ. Sci. Technol. 2024, 58, 242–257

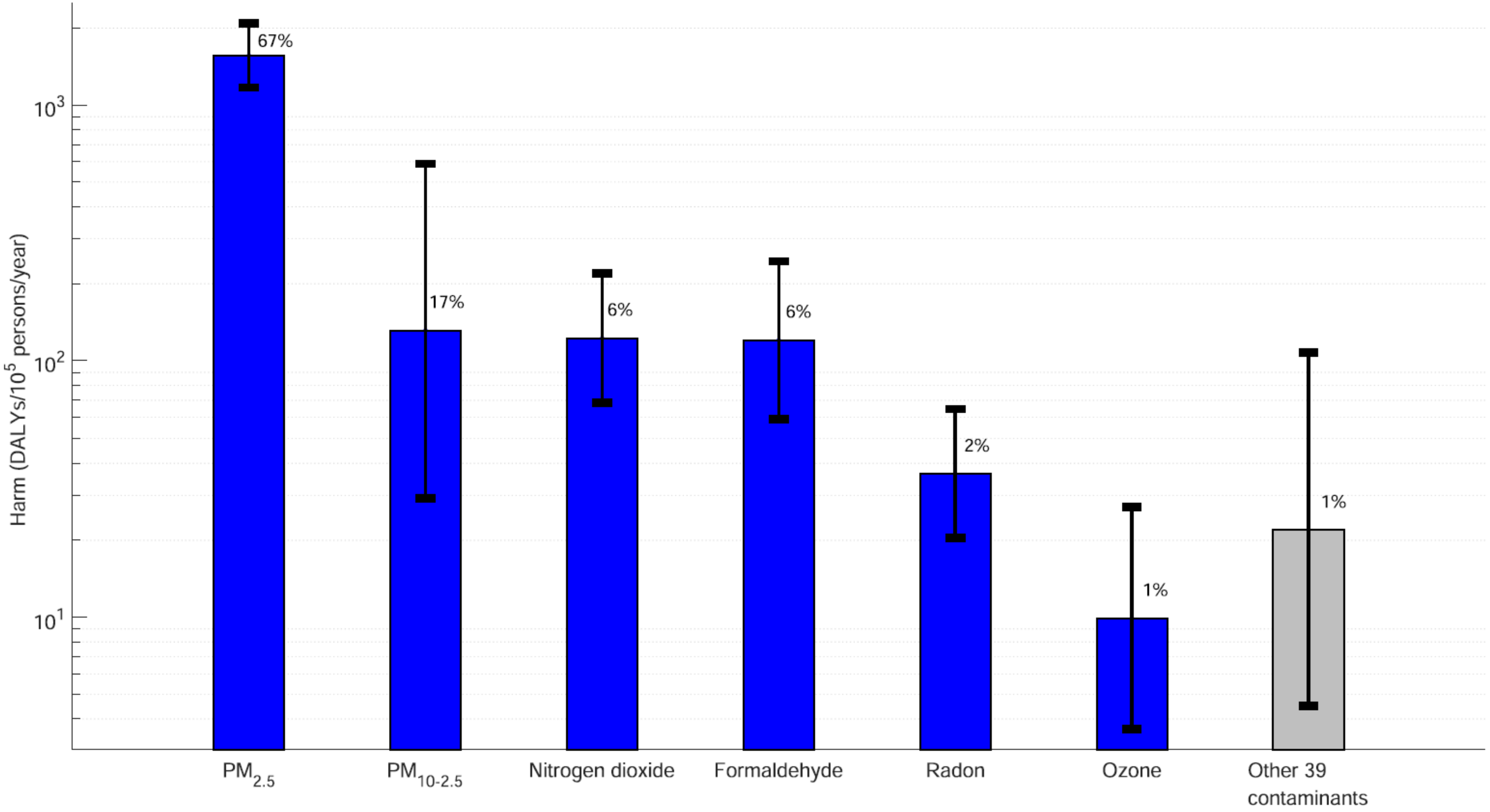


Figure 2. Harm caused by CoCs. Median (bar) and GSD (error bar). Percentage contribution for total harm.

ASHRAE Standard 62.1 – Air Cleaners

- Ozone generating devices (primary or byproduct) must comply with UL 2998, 0.5 ppb ozone emission limit
- UV devices must not emit 185 nm UVC (mercury vapor lamp)
- Particulate filters
  - ASHRAE 52.2 or ISO 16890
- Gas phase filters
  - ASHRAE Standard 145.2 or ISO 10120-2 or
  - Other approved methods

Air Cleaner Byproduct Generation

- With the exception of ozone, limited concern, attention in standards to other byproducts
- Focus on use of anti-microbial air cleaners during Covid has made it an issue
- ASHRAE Standard 241 *Control of Infectious Aerosols* has testing requirements for PM, ozone, and formaldehyde

Air Cleaner Byproducts – UVC Photolysis

- Germicidal UV source contribute to photochemistry
- Direct effects
- Effects of excess ozone created
- Recent work raises concerns, but outdoor air also has adverse effects

Environmental Science & Technology LETTERS
pubs.acs.org/journal/estlcu
Letter

Model Evaluation of Secondary Chemistry due to Disinfection of Indoor Air with Germicidal Ultraviolet Lamps

Zhe Peng,* Shelly L. Miller, and Jose L. Jimenez*

Cite This: *Environ. Sci. Technol. Lett.* 2023, 10, 6−13 Read Online

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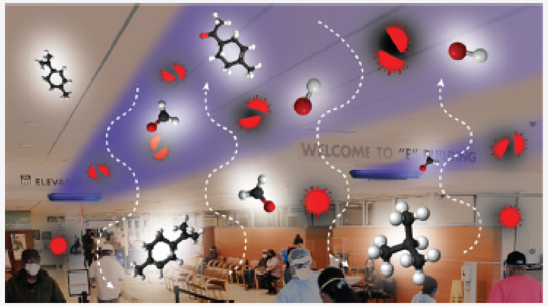
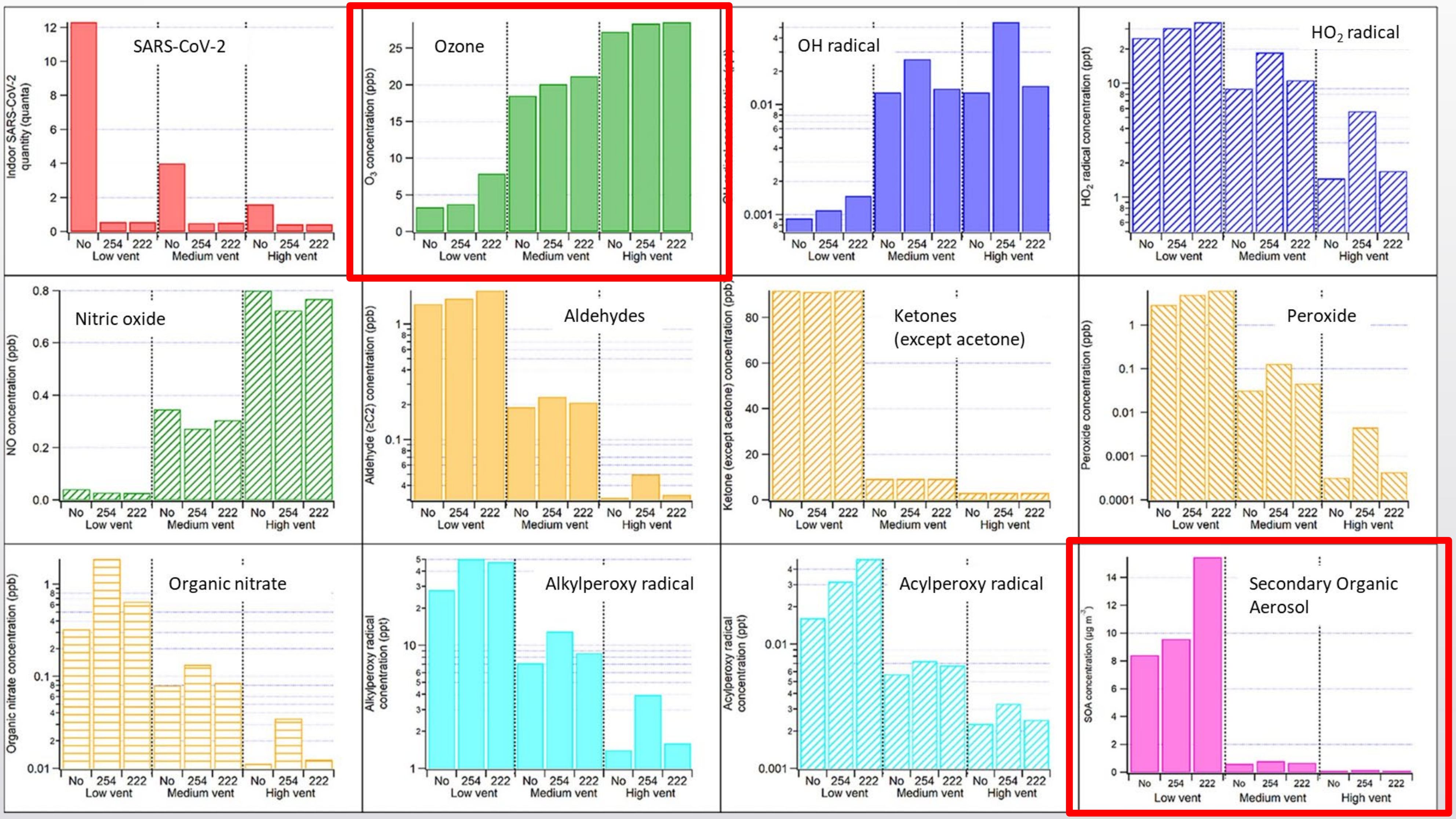
ABSTRACT: Air disinfection using germicidal ultraviolet light (GUV) has received increasing attention during the COVID-19 pandemic. GUV uses UVC lamps to inactivate microorganisms, but it also initiates photochemistry in air. However, GUV's indoor-air-quality impact has not been investigated in detail. Here, we model the chemistry initiated by GUV at 254 ("GUV254") or 222 nm ("GUV222") in a typical indoor setting for different ventilation levels. Our analysis shows that GUV254, usually installed in the upper room, can significantly photolyze O_3, generating OH radicals that oxidize indoor volatile organic compounds (VOCs) into more oxidized VOCs. Secondary organic aerosol (SOA) is also formed as a VOC-oxidation product. GUV254-induced SOA formation is of the order of 0.1–1 $\mu g/m^3$ for the cases studied here. GUV222 (described by some as harmless to humans and thus applicable for the whole room) with the same effective virus-removal rate makes



https://doi.org/10.1021/acs.estlett.2c00599Environ.Sci. Technol.Lett.2023,10, 6−13

Ventilation rates
-low 0.3 ACH
-medium 3 ACH
-high 9 ACH



Peng, et al. 2023. doi.org/10.1021/acs.estlett.2c00599

What's left to do

- Assess recent work on indoor chemistry to determine what effects justify remediation
- Resolve testing issues of air cleaners for effectiveness and safety
- Make performance standards the norm
- Move beyond outdoor air + filter approach to equivalent clean air approach as in ASHRAE Standard 241-2023
- Better quantitative metrics for that consider net benefits, wellbeing
- Regulations for O&M in public buildings
- Address equity issues

Thank You!

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