The Future of Residential Ventilation: A Harm-Based IAQ Procedure

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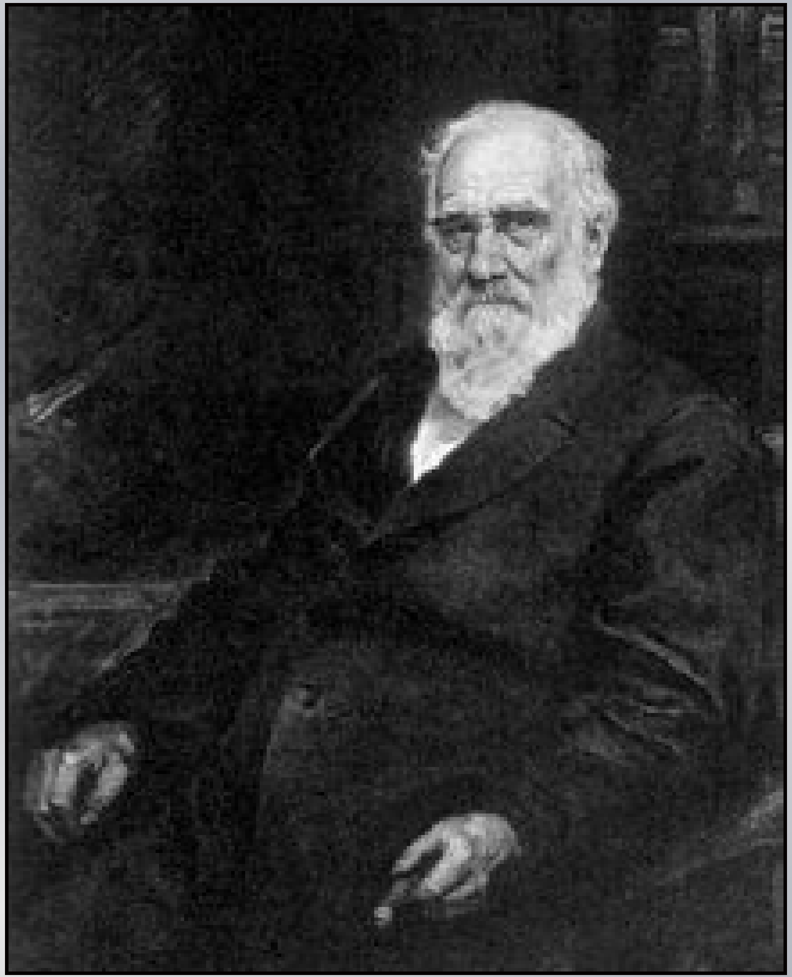
Introduction

Fundamental Purpose of Mechanical Ventilation

Improve the air quality in the dwelling to protect the health of the occupants and the structure.

Ventilation Methods

- Natural or airing
  - Unpredictable and erratic
  - Based primarily on wind during warmer weather
- Infiltration
  - Unpredictable and erratic
  - Based on wind and stack effect during colder weather
- Mechanical, based on ASHRAE 62.2
  - Local for bathrooms and kitchen (source control)
  - Dwelling-unit (dilution). Ventilation rate procedure (VRP)
- IAQ procedure (IAQP) based on harm to occupants



"If there is a pile of manure in a space, try not to remove the odour by ventilation. Remove the pile of manure."

Attributed to Max Von Pettenkofer, circa 1850, pioneer of modern hygiene and environmental science.

Common Contaminant Health Effects

- Short- and long-term effects:
  - Lack of concentration and reduced performance.
  - Headaches.
  - Eye, nose, throat, lung or skin irritation.
  - Injury to internal organ systems (e.g. cardio-vascular, central nervous, immune, gastro-intestinal, kidney, liver, endocrine, or limbic systems).
  - Cancer.
  - Infectious disease, such as COVID-19.

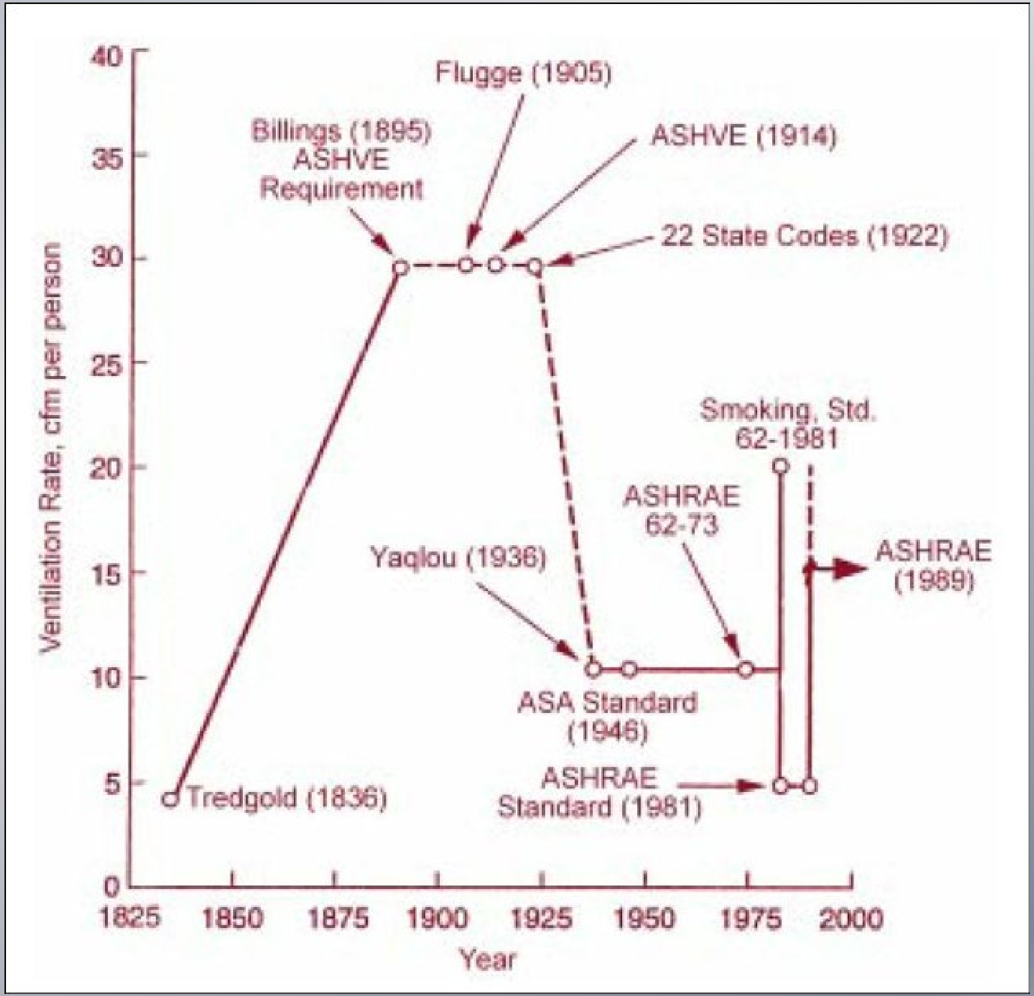
Source: *Introduction to Indoor Air Quality*, EPA

Ventilation

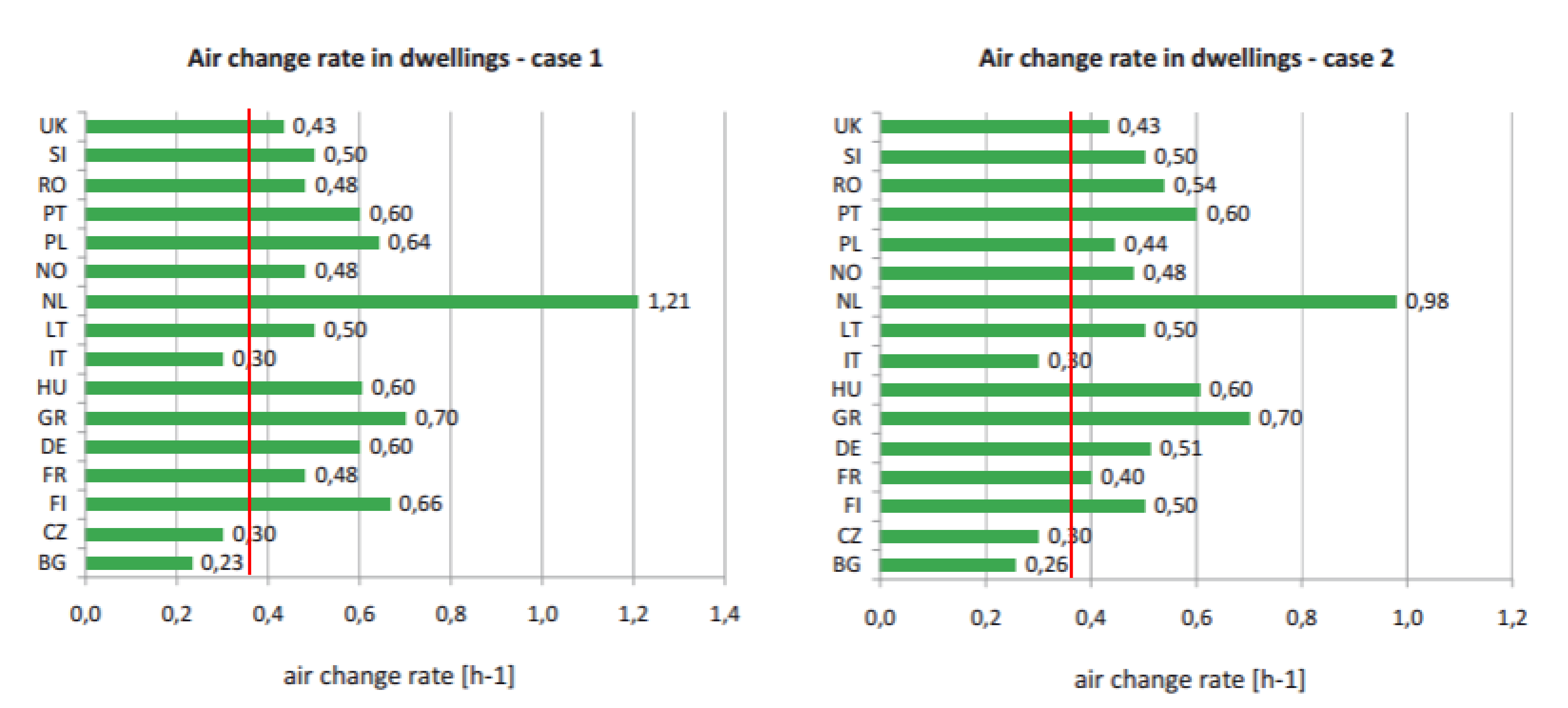
ASHRAE 62.2
Ventilation and Acceptable Indoor Air Quality in Residential Buildings

Selecting Ventilation Rates

Dwelling-unit (whole-dwelling) ventilation is controlled by a single average number based on square footage and number of occupants.



Dwelling-Unit Ventilation Western World



Source: Ventilation Rates and IAQ in National Regulations, Nejc Brelih, 2011.

Ventilation Rate Range

Ventilation rates in world standards differ by up to 4 times.

Source: Metrics of Health Risks from Indoor Air, B. Jones, AIVC, 36, Sept 2017.

Ventilation Rate Alternative

- What if the ventilation rate was controlled by levels of contaminants?

Finding a Normalized Metric for IAQ - 1

- Occupant perception of IAQ
  - Smells are subjective with fading perception
  - Many contaminants have no odor
  - Early ventilation standards were based on perceived air quality
- Exposure Limit Values (ELV)
  - Used in occupational environments to reduce health risks. Using for IAQ is problematic:
    - Difficult to relate ELV and IAQ
    - Normalization of contaminants is difficult

Source: Jones, Benjamin, *"Metrics of Health Risks from Indoor Air"*, Ventilation Information Paper 36, Air Infiltration and Ventilation Centre, 2017.

Finding a Normalized Metric for IAQ - 2

- Disability-Adjusted Life-Year (DALY)
  - Seems to be the best metric available currently.
  - DALY is the sum of the years of life lost to premature mortality and morbidity in a population for a negative health effect, such as contaminants in air. A harm-based value.

Source: Jones, Benjamin, *"Metrics of Health Risks from Indoor Air"*, Ventilation Information Paper 36, Air Infiltration and Ventilation Centre, 2017.

Measuring IAQ Impacts

"Dallying with DALYs"

Source: Jones, Benjamin, "Dallying with DALYs", *ASHRAE Journal*, February 2023, 24 - 27.

DALY, a Normalized Harm Metric
Cost of Adverse Health Effects

Disability Adjusted Life Years (DALYs)

Used by the World Health Organization (WHO)

DALY = YLL + YLD

- YLL = Years lost to premature death
- YLD = Equivalent years lost to disability

DALY

- Cost of adverse health effects
  - If we compare a number of options, the one with the lowest DALY value is the most favorable
  - For a large population sample
    - Years of death averted
    - Years of disability averted (lung disease, blindness, for example)
  - For example, a 5-year illness that reduces the quality of life to 4/5 that of a healthy year is valued at 1 DALY lost

Harm Intensity = DALY/concentration/person/year

Source: Morantes, Giobertti and Jones, Benjamin and Molina, Constanza and Sherman, Max Howard, *Harm from Indoor Air Contaminants*, University of Nottingham, 2023

Cost of Adverse Health Effects

Disability Adjusted Life Years (DALYs)

Source: Wikipedia: http://en.wikipedia.org/wiki/Disability-adjusted_life_year

Line of Life

Disabilities can move a person up in THE LINE.

Pollutants with Greatest DALY Losses "Harm Budget" for ASHRAE 62.2 Advisory Public Review

Top IAQ Contaminants* of Concern (CoC) - 1

- $PM_{2.5}$
- Formaldehyde, HCHO
- Nitrogen Dioxide, NO_2

Source: Logue et al., *A Method to Estimate the Chronic Health Impact of Air Pollutants in U.S. Residences*, Feb 2012, Environmental Health Perspectives, and ASHRAE SSPC 62.2 Addendum c to ASHRAE Standard 62.2-2022 advisory public review (harm-based IAQ procedure for Standard 62.2)

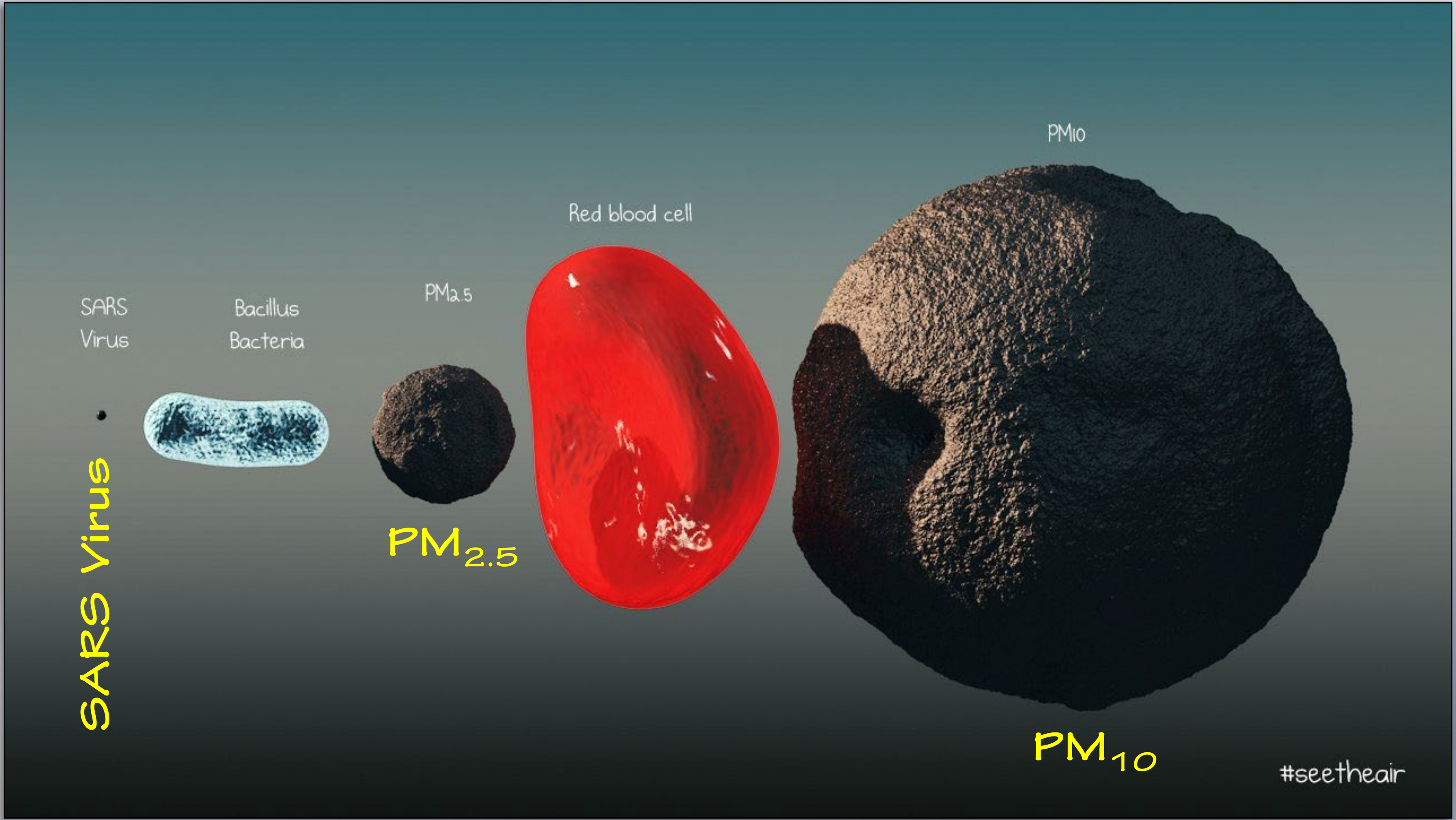
Top IAQ Contaminants* of Concern (CoC) - 2

- $PM_{2.5}$
- $PM_{10-2.5}$
- Formaldehyde, HCHO or CH_2O
- Nitrogen Dioxide, NO_2
- Radon
- Ozone

*It is estimated that these contaminants "account for over 99% of the total median harm caused by airborne contaminants in dwellings."

Source: Morantes, Giobertti and Jones, Benjamin and Molina, Constanza and Sherman, Max Howard, *Harm from Indoor Air Contaminants,* University of Nottingham, 2023.
Note: this work is currently under peer review, so information might change

Particle Sizes



https://smartairfilters.com/

Proposed ASHRAE 62.2 IAQP

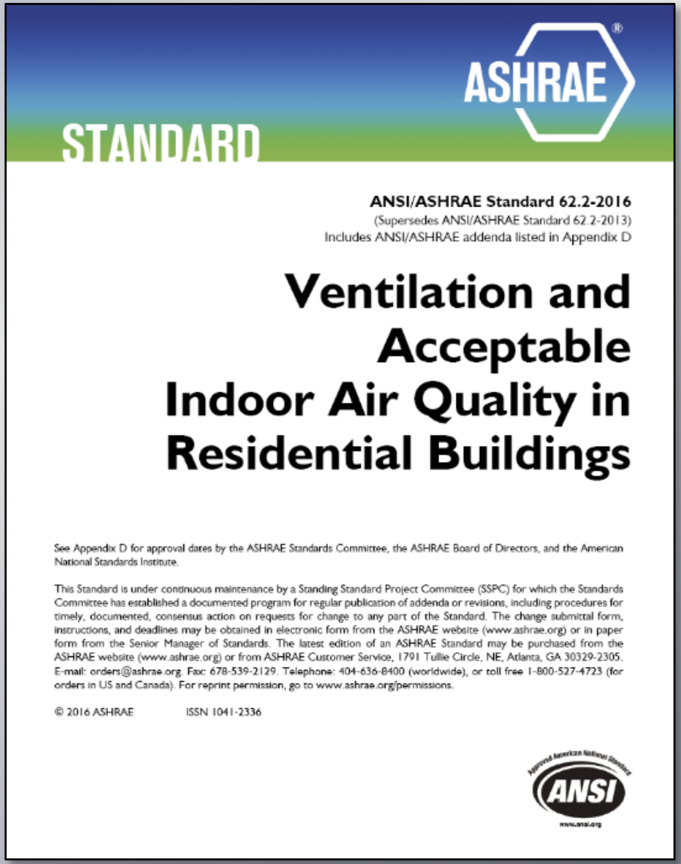
Source: ASHRAE SSPC 62.2 Addendum c to ASHRAE Standard 62.2-2022 advisory public review (harm-based IAQ procedure for Standard 62.2)

Moving into the Future with an Indoor Air Quality Procedure (IAQP)

ASHRAE 62.2-2016 is part of the Maine code package.

Proposed changes discussed here are to ASHRAE 62.2-2022.

ASHRAE 62.1 currently has and IAQP



STANDARD

ASHRAE

ANSI/ASHRAE Standard 62.2-2016
(Supersedes ANSI/ASHRAE Standard 62.2-2013)
Includes ANSI/ASHRAE addenda listed in Appendix D

Ventilation and Acceptable Indoor Air Quality in Residential Buildings

See Appendix D 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 Senior Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. 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.

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ANSI

This IAQ standard applies to single-family and multifamily residential buildings, including multifamily, manufactured, and modular houses.

www.ashrae.org

ASHRAE 62.2 Requirements

- Local exhaust ventilation
  - Kitchen - 100 CFM.
  - Bathroom - 50 CFM.
    - Defined as any room containing a bathtub, shower, spa, or similar source of moisture.

Local ventilation comes into play with bioeffluent control of the IAQP

ASHRAE 62.2 Requirements

- Dwelling-unit ventilation:
  - General dilution ventilation in addition to “local ventilation”.

$$Q_{tot} = 0.03A_{floor} + 7.5(N_{bedrooms} + 1)$$

[building] [people]

Proposed ASHRAE 62.2 IAQP - 1

Introduction

- Indoor Air Quality Procedure = IAQP
- Dwelling-Unit Ventilation (Section 4 of 62.2) = Ventilation-Rate Procedure (VRP)
- The IAQP is an alternative compliance method to Section 4, the VRP
  - "With low contaminant levels, for example, the IAQP would allow the dwelling to be operated at lower ventilation rates than the VRP."

Source: ASHRAE SSPC 62.2 Addendum c to ASHRAE Standard 62.2-2022 advisory public review (harm-based IAQ procedure for Standard 62.2)

Proposed ASHRAE 62.2 IAQP - 2

- Two major sections to IAQP:
  - Bioeffluent Control
    - The "people part" or odor part of the issue
  - Contaminant Control
    - Uses normalized harm metric, DALY, on the contaminants of concern (CoC)

Source: ASHRAE SSPC 62.2 Addendum c to ASHRAE Standard 62.2-2022 advisory public review (harm-based IAQ procedure for Standard 62.2)

Proposed ASHRAE 62.2 IAQP - 3

- Bioeffluent Control
  - Provide by using "people part" of ASHRAE 62.2, Section 4, that is, 7.5 cfm per person, or
    - Local and acute odors are presumed controlled by Section 5, local ventilation (bathrooms and kitchens), of ASHRAE 62.2
    - Ventilation rate reduction for filtration is not allowed for this base ventilation.
  - CO_2-based system that adjusts for actual occupancy and does not allow CO_2 levels higher than 1600 ppm

Source: ASHRAE SSPC 62.2 Addendum c to ASHRAE Standard 62.2-2022 advisory public review (harm-based IAQ procedure for Standard 62.2)

Proposed ASHRAE 62.2 IAQP - 4

- Contaminant Control
  - Uses normalized harm metric, DALY, on the contaminants of concern (CoC)
    - PM2.5
    - Formaldehyde
    - Nitrogen Dioxide
  - May base on real-time measurements, or
  - On deemed values based on design or commissioning
  - Must show compliance with harm budget, rather than contaminant thresholds
  - The harm budget coefficients are intended to provide equivalence (on average) between VRP and IAQP

Source: ASHRAE SSPC 62.2 Addendum c to ASHRAE Standard 62.2-2022 advisory public review (harm-based IAQ procedure for Standard 62.2)

Proposed ASHRAE 62.2 IAQP - 5

- **Contaminant Control Equation:**

$$CR = W_{PM2.5}C_{PM2.5} + W_{HCHO}C_{HCHO} + W_{NO2}C_{NO2}$$

where
CR is the contaminant rating [-], must be 100 or less
$C_{PM2.5}$ is the concentration of PM2.5 [μg/m^3]
C_{HCHO} is the concentration of Formaldehyde [μg/m^3]
C_{NO2} is the concentration of Nitrogen Dioxide [μg/m^3]
$W_{PM2.5}$ is the PM2.5 weighting: 8.8 [m^3/μg]
W_{HCHO} is the Formaldehyde weighting: 1.1 [m^3/μg]
W_{NO2} is the Nitrogen Dioxide weighting: 1.1 [m^3/μg]

Source: ASHRAE SSPC 62.2 Addendum c to ASHRAE Standard 62.2-2022 advisory public review (harm-based IAQ procedure for Standard 62.2)

Proposed ASHRAE 62.2 IAQP - 6

- Contaminant concentration determination
  - Real-time measurement for Contaminant Rating (CR)
  - Alternative methods
    - PM2.5
      - 12 μg/m³ divided by Particle Reduction Factor (see section 7.6 of Advisory Public Review document, p 4)
    - Formaldehyde
      - Default values or commissioning study
    - Nitrogen Dioxide
      - Default values defined by conditions

Source: ASHRAE SSPC 62.2 Addendum c to ASHRAE Standard 62.2-2022 advisory public review (harm-based IAQ procedure for Standard 62.2)

Control System Technologies

Sendal + AirThings

Zehnder CO2 Sensor

Overture + Creston

HAVEN: Particles, chemicals. humidity

Questions & Concerns

- Does limiting the run-time of the ventilation system improve health – or just save energy?
- Can the presence of the contaminants of concern be predicted during the design phase?
- Will harm-based control reduce lost productivity and justify the added cost?
  - Will it convert mechanical ventilation from a cost (added energy use) to an asset (reduction of lost productivity)?

www.freepik.com/.htm

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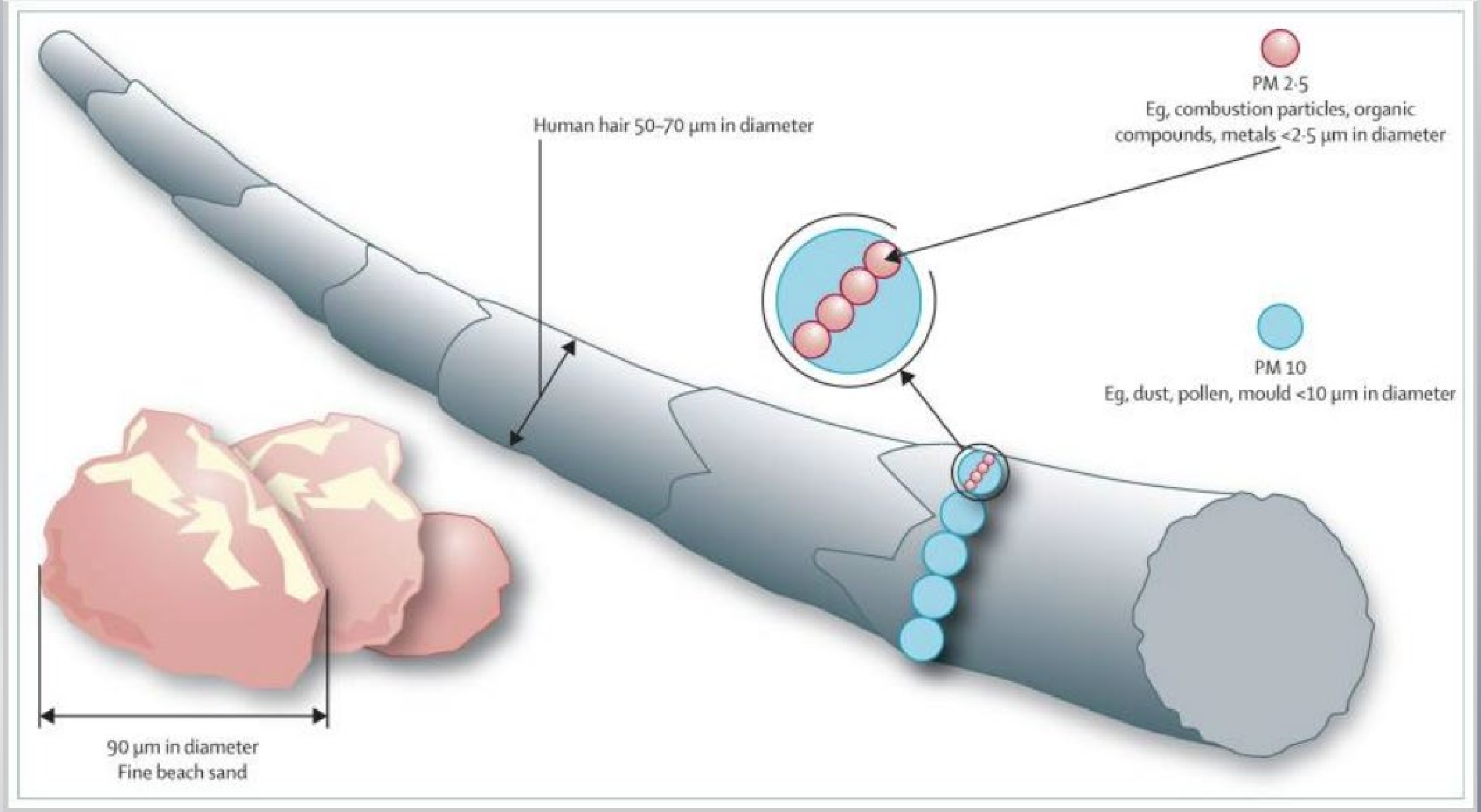
$PM_{2.5}$

- What is it?
  - Particulate Matter (PM) with a diameter of 2.5 micrometers or less.
  - Small enough to invade the smallest airways of the lungs.
  - Generally the source is from activities that burn fossil fuels, such as traffic and cooking.

How Small is 2.5 Microns?



$PM_{2.5}$

- Sources:
  - Cars/trucks are biggest source.
  - Burning fossil fuels.
  - Oven cleaning with high temperatures.
  - Cooking on gas range-top.
  - Candles emitting soot.
  - Grilling.
  - Sweeping.
  - Kerosene lamps.
  - Burning solid fuels.

$PM_{2.5}$

- Health effects:
  - Coughing, wheezing, shortness of breath.
  - Chronic and acute bronchitis.
  - Aggravated asthma.
  - Lung damage.
  - Premature death for those with existing heart disease.
  - Premature death for those existing lung disease.
  - Lost work days.

$PM_{2.5}$

- Lowering risk:
  - Avoid $PM_{2.5}$.
  - Clean up auto emissions.
  - Fewer vehicles on road.
  - Generate less electricity.
  - Be aware of particle pollution.
  - Filter air with HEPA filters.
  - Ventilate while cooking and baking.

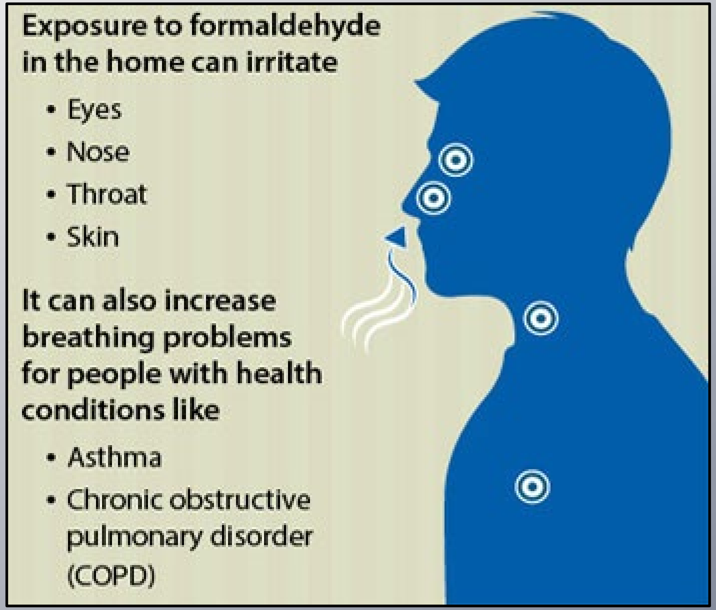
Formaldehyde

- What is it:
  - Colorless, flammable gas at room temperature.
  - Has strong odor at higher concentrations.

- Sources:
  - Composite wood products (plywood, particleboard).
  - Building materials and insulation.
  - Household products (paper, glue, fabrics, paints, etc.)
  - Fertilizers and pesticides.
  - By-product of combustion.
  - Cigarette smoke.

Formaldehyde

- Health effects:
  - Irritation of skin, eyes, nose, and throat.
  - Skin rashes.
  - Shortness of breath.
  - Exacerbation of asthma.
  - High levels can cause cancer.



Source: U.S. CDC

Formaldehyde

- Lowering risk:
  - Source control: keep it out!
  - Wash permanent press clothing before wearing.
  - Ventilate home.
  - No smoking in home.
  - Keep temperature and humidity as low as possible.

NO_2 (Nitrogen Dioxide)

- What is it:
  - Reddish-brown gas.
- Sources:
  - Combustion, both indoors and outdoors.
  - Responsible for reddish color of mushroom clouds from nuclear blasts.
  - Cigarette smoke.

NO_2 (Nitrogen Dioxide)

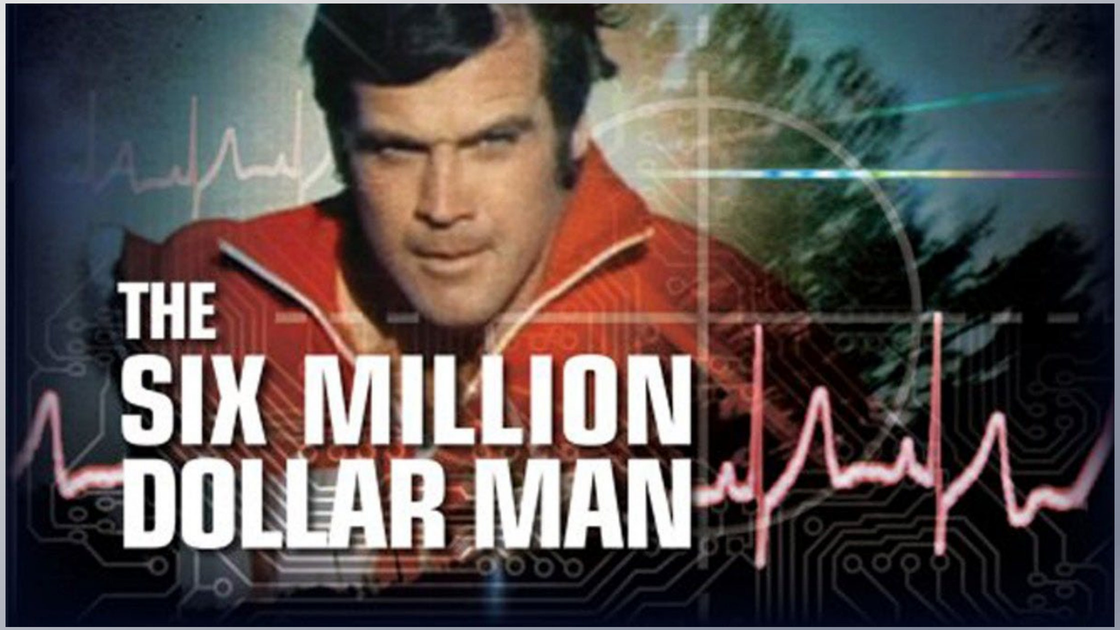
- Health effects:
  - Airway inflammation in healthy lungs.
  - Exacerbates symptoms of asthma.
  - Study show NO_2 can retard the development of children's lungs.

NO_2 (Nitrogen Dioxide)

- Lowering risk:
  - When using gas-fired gas range, use vented range hood.
  - Keep gas ranges in good repair.
  - Replace gas-fired range with electric.
  - No exposure to cigarette smoke.
  - Children are most vulnerable.
  - No unvented combustion indoors.

We have the technology!

Gentlemen, we can rebuild him. We have the technology. We have the capability to make the world's first bionic man. Steve Austin will be that man.



One word you associate with mechanical ventilation.