IAQ

Indoor Air Quality from A to Z

PARTICLES PLUS®

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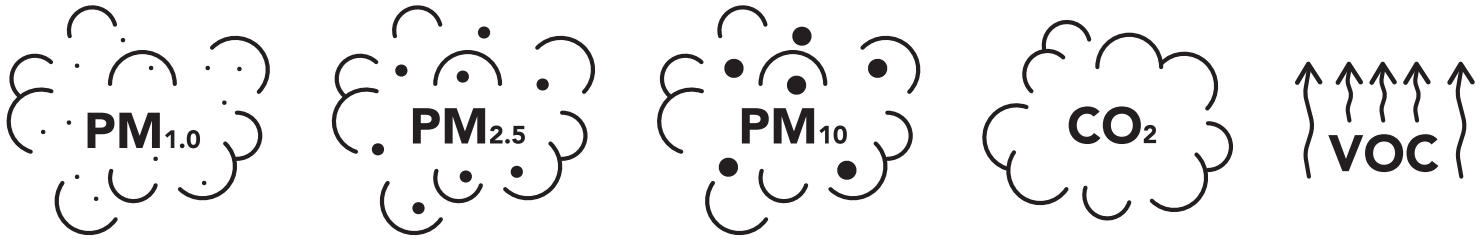
What is Indoor Air & Environmental Quality?

Indoor Air Quality **(IAQ)** is the air quality within buildings. IAQ is known to affect the health, comfort, and well-being of building occupants.
IAQ is all about what we breathe.

Some of the major contributors to poor IAQ are:

PM_{10} (thoracic fraction ≤10 µm)
$PM_{2.5}$ (respirable fraction ≤2.5 µm)
PM_{1} (super fine particles ≤1.0 µm)
CO_2 (carbon dioxide above ~1000 ppm)
TVOC (array of chemicals)



What is Indoor Air & Environmental Quality?

Indoor Environmental Quality **(IEQ)** encompasses the conditions inside buildings. It is known to affect the health of occupants, but it can also affect the building structure.
IEQ is all about what we breathe, hear, see, and feel.

IAQ + Thermal Comfort + Lighting (Lux) + Acoustics (dB)

ºC/ºF + RH%

Why Indoor AQ Matters?

We spend up to 87%[NHAPS] of our time indoors.

A rule of thumb is to take your age and multiply it by 0.87.

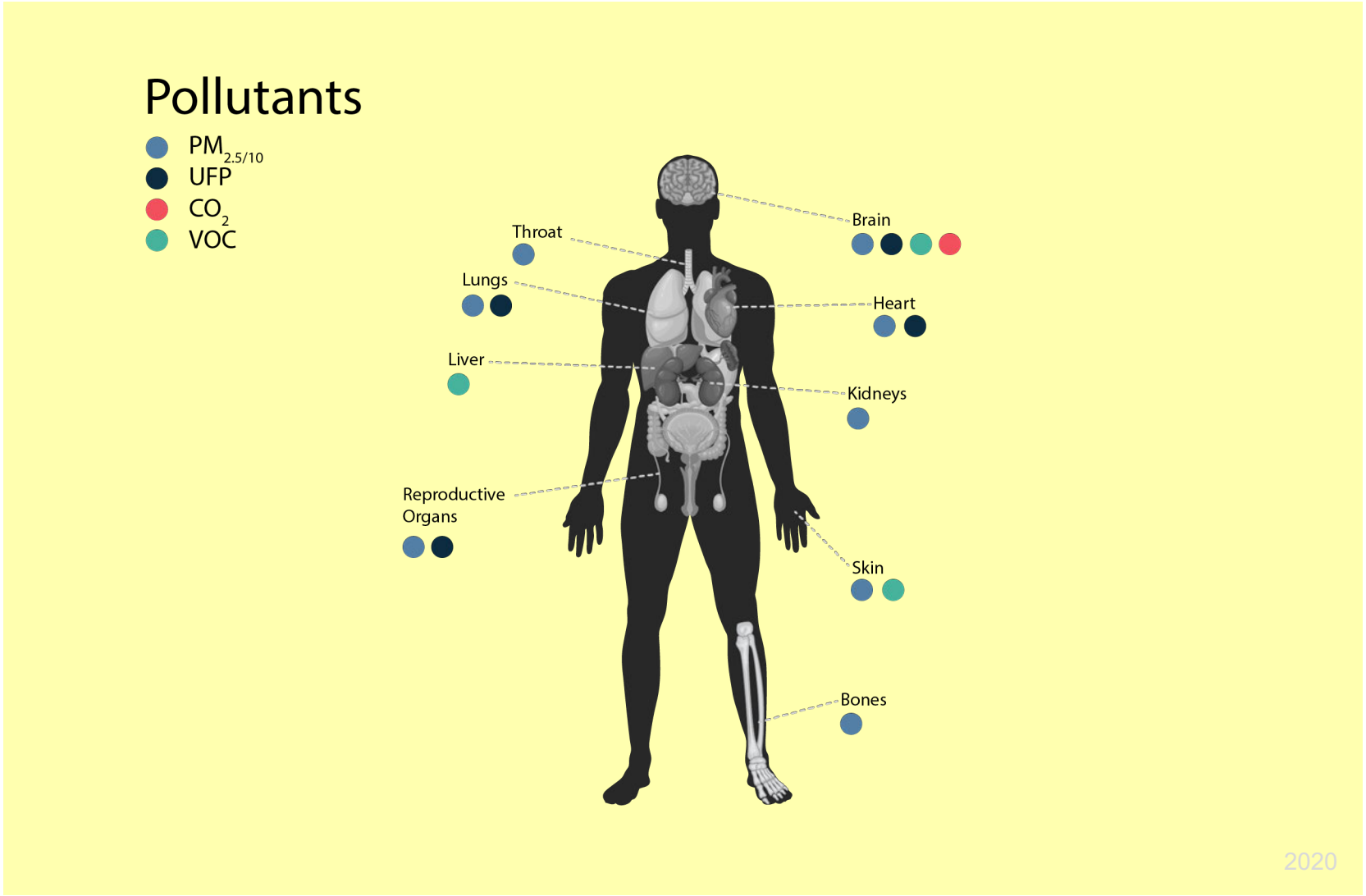
In some cases, exposure to indoor air pollution ($PM_{2.5}$) can lead to acute and chronic respiratory illnesses, including asthma, lung cancer, pneumonia, systemic hypertension, and chronic obstructive pulmonary disease (COPD).

Effective measurement of IAQ reduces the health risks associated with poor indoor air, creating a safer, more harmonious environment for people to thrive.

Benefits

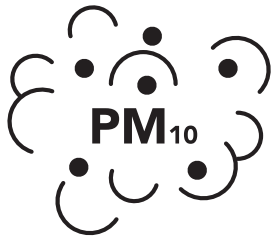
- Save on energy costs
- Prevent building deterioration
- Reduce environmental impact
- Boost wellness (employers report higher retention levels, increased productivity, and a reduction in absenteeism)

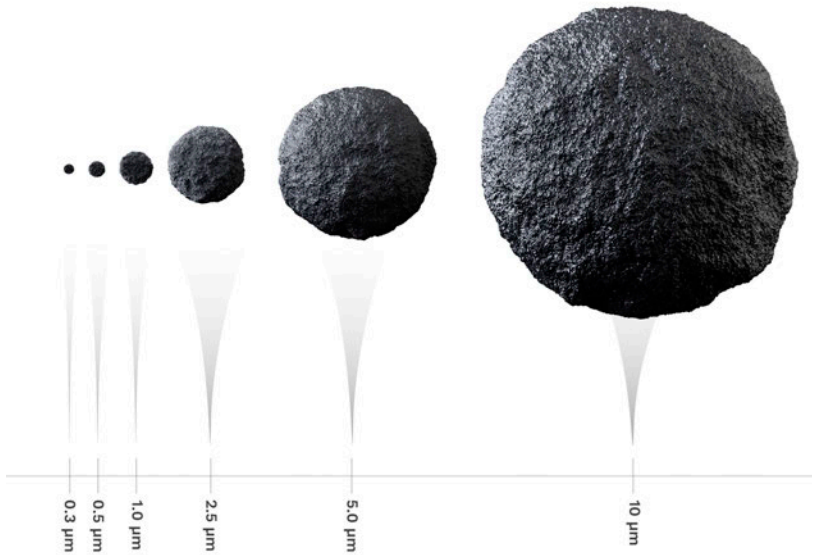
Indoor Air Pollutants

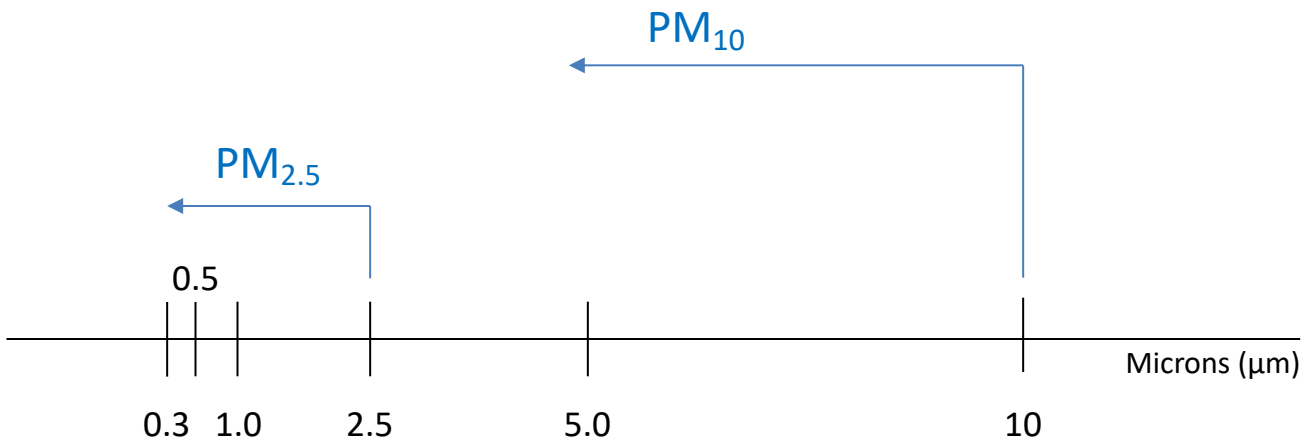


Indoor Air Pollutants: Particulate Matter

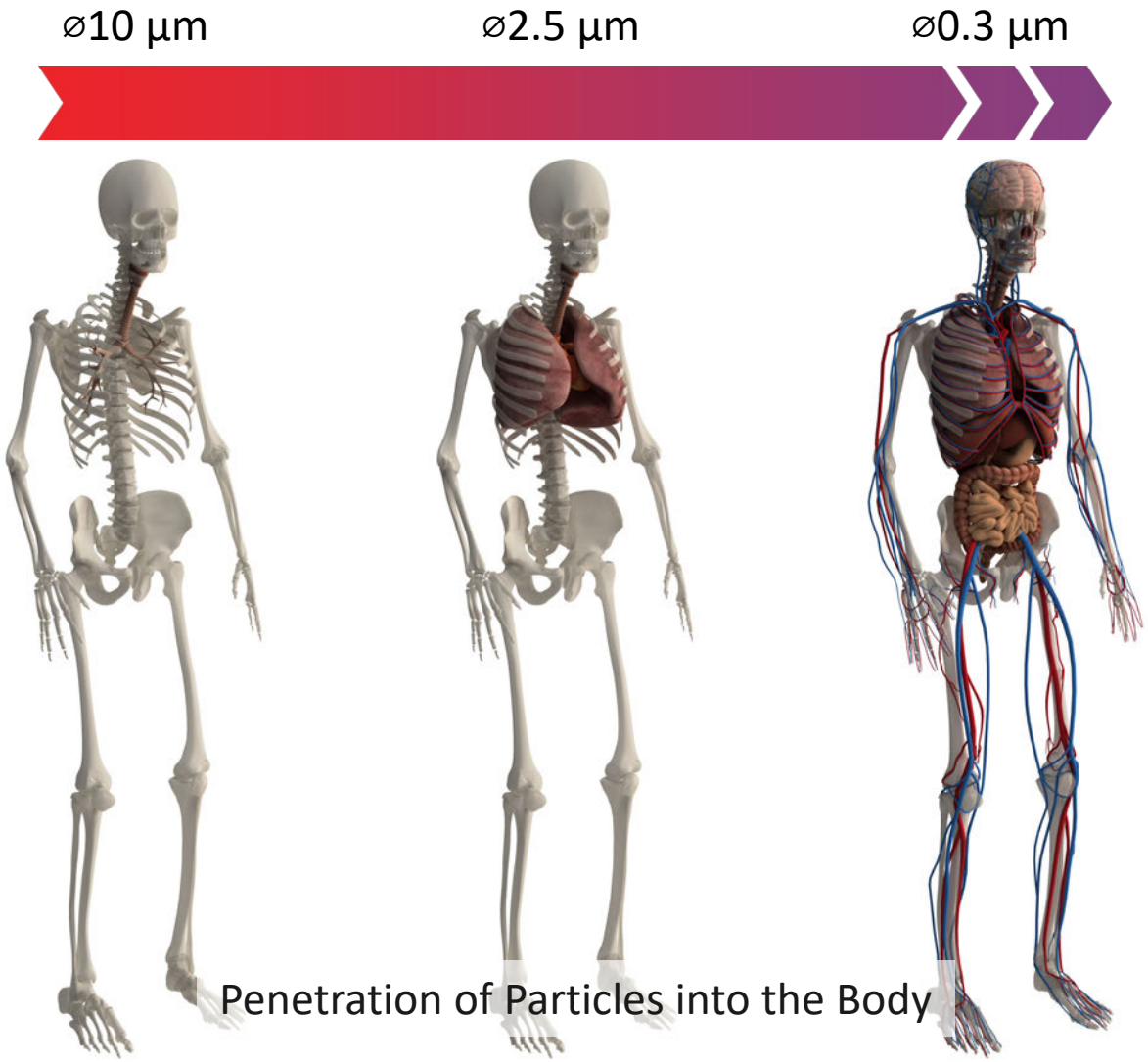
Particulate matter (PM) is a mixture of solid particles and/or liquid droplets found in the breathable air. Particulates can also be described by size as in, fine, ultra-fine or nanoparticles. *Common terms such as dust, dirt, soot, aerosols, black carbon, or smoke may be used to describe particulate matter.*







Indoor Air Pollutants: Particulate Matter



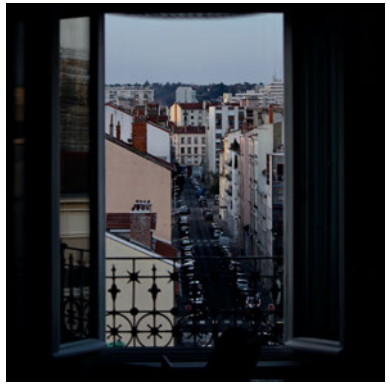
Penetration of Particles into the Body

Indoor Air Pollutants: Particulate Matter



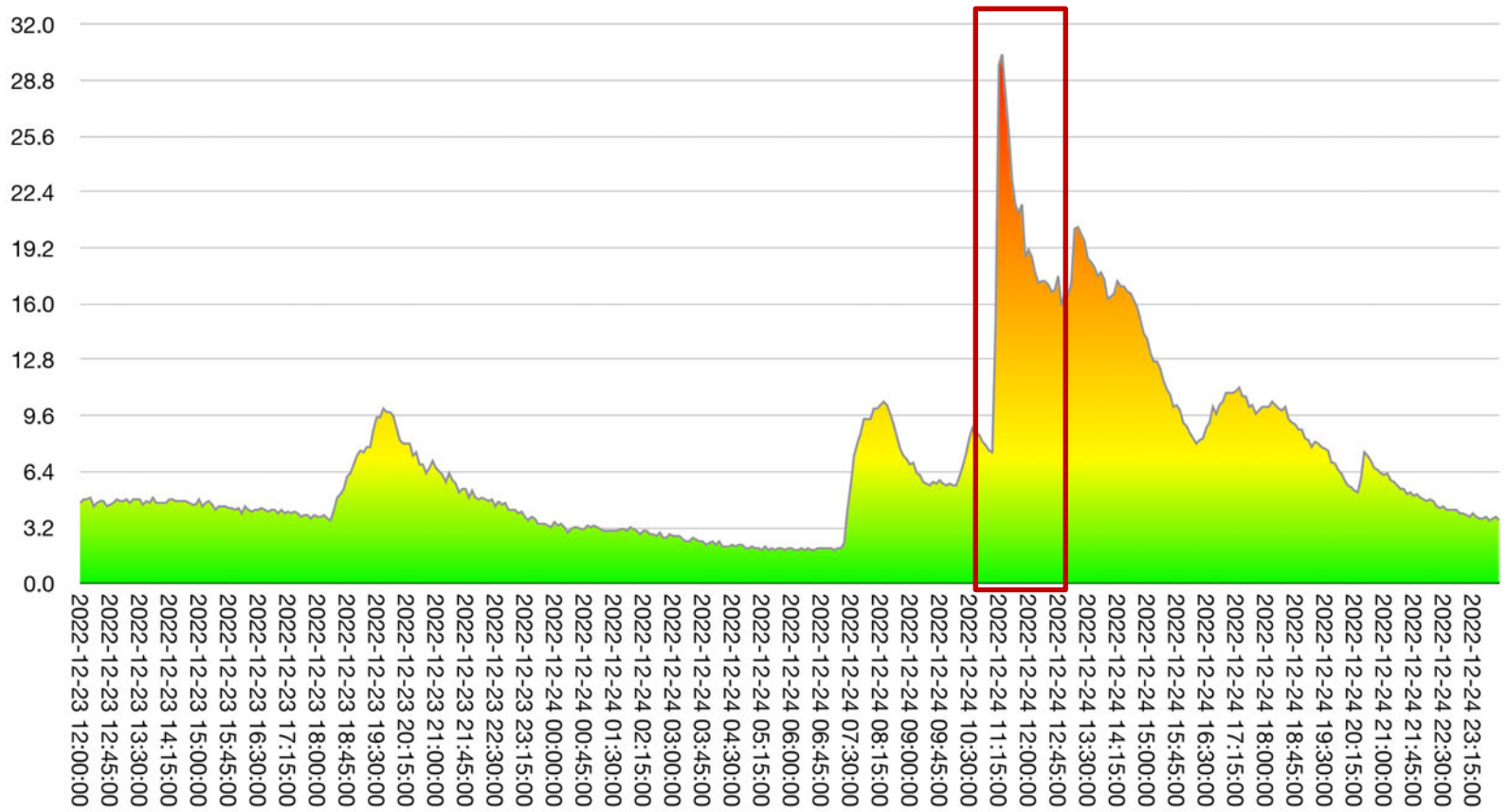






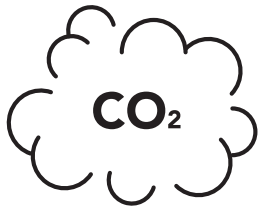

Fine particulate matter is produced from all types of combustion. Indoors, cooking is a major source of particulate matter especially when gas or wood/coal cookstoves are used, but even if you cook on an electric stove, a great amount of particles is released into the breathable air. Other sources are vacuuming without proper filtration or sweeping. Candles, diffusers, humidifiers, burning of incense, burning sage, etc. Finally, pets and humans release some particles of biological origins.

Indoor Air Pollutants: Particulate Matter



$PM_{2.5}$ concentration during cooking pasta with a tomato sauce.

Indoor Air Pollutants: Carbon Dioxide



Carbon Dioxide (CO_2) is formed as a metabolite of cell respiration. Indoors, CO_2 levels dependent on human occupation and air renewal in the building and it is used as an indicator of the level of air confinement.

<u>CO_2 levels depends on the following factors:</u>

- Number of occupants in the indoor environment
- Activity of the occupants (exercise, seated, etc.)
- Duration spent by the occupants in the indoor environment
- Combustion processes in the indoor environment
- Air exchanges by mechanical or natural means

CO_2 can decrease our cognitive ability: Researchers found that for every 500 ppm increase of CO_2 results in a drop in response times by 2.4%. A different study concludes that levels of CO_2 at 1400 ppm, may cut our basic decision-making ability by 25%, and complex strategic thinking by around 50%.

10.1111/ina.12706
10.1088/1748-9326/ac1bd8
10.1289/ehp.1510037
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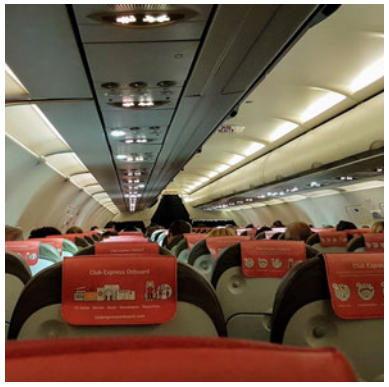
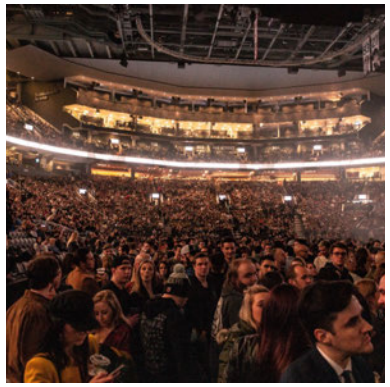
Indoor Air Pollutants: Carbon Dioxide

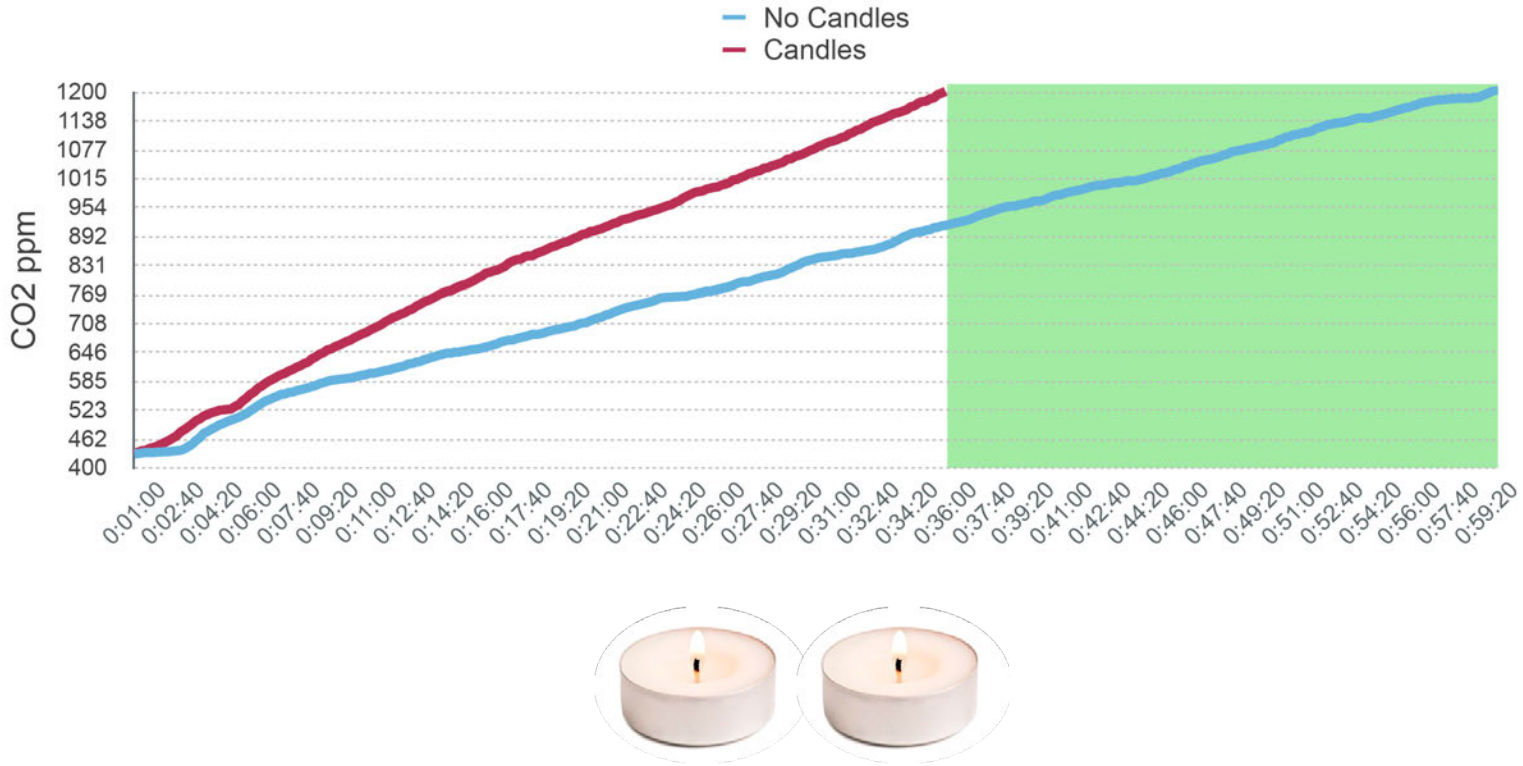






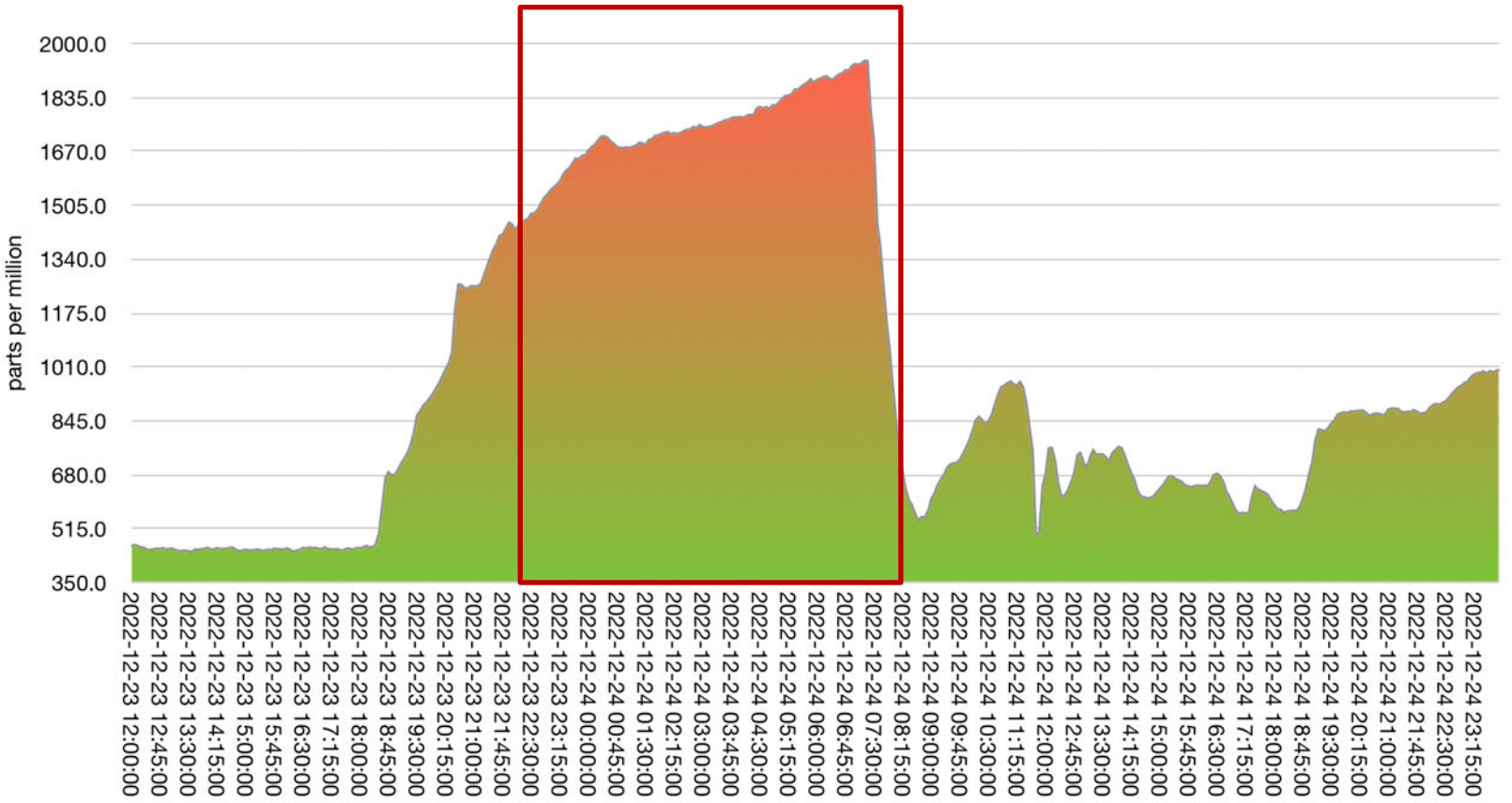

The correlation between CO_2 and productivity has been studied a lot for over 50 years by many academics. Interesting facts, the design standard for CO_2 levels in most buildings is 1000 ppm but the recommended concentration is below 700 ppm. In one of the studies, Harvard researchers have found significant negative impact at 930 ppm.

Indoor Air Pollutants: Carbon Dioxide



CO_2 levels with and without 2 small candles and 1 occupant

Indoor Air Pollutants: Carbon Dioxide



CO_2 levels during sleep inside a 60m²/645ft² apartment occupied by two adults

Indoor Air Pollutants: Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are organic chemicals that evaporate at ordinary room temperature. This evaporation is also called **off-gassing** which is the process of releasing chemicals from the objects into the air. Temperature plays an important role as higher temperatures accelerate the off-gassing of the chemicals.

Studies have shown that the level of VOCs indoors is generally **two to five times higher** than the level of VOCs outdoor. Ventilation rates play a very important role.

Some of the symptoms associated with short-term exposure to the following VOCs are:

Trichloroethylene (C2HCl3)
Dizziness, headaches, nausea, and vomiting
Formaldehyde (CH2O)
Irritation to nose, mouth, and throat
Benzene (C6H6)
Irritation to eyes, drowsiness, dizziness, and headaches
Xylene (C8H10)
Irritation to mouth and throat, headaches, dizziness, heart problems, and damage on liver, and kidney
Ammonia (NH3)
Irritation to eyes, coughing, sore throat, and sterility

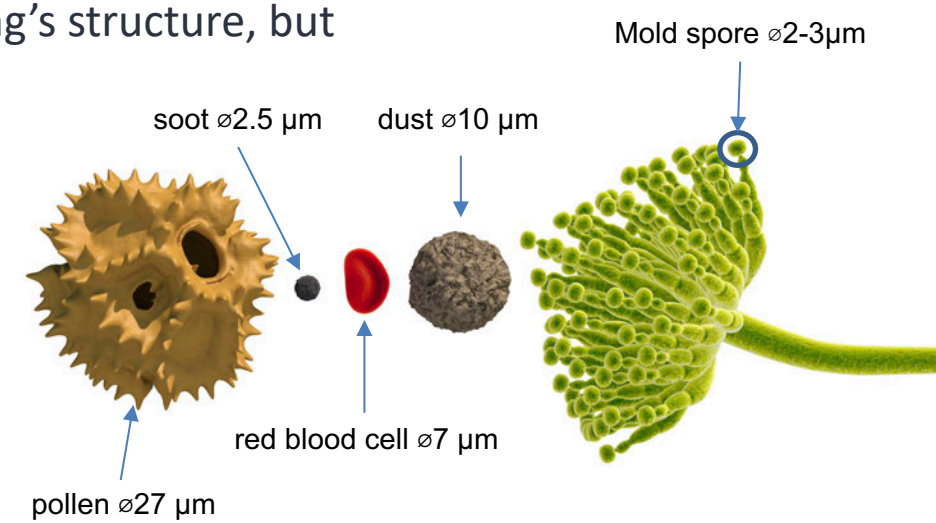
Indoor Air Pollutants: Volatile Organic Compounds

VOCs are numerous, varied, and ubiquitous. They include both human-made and naturally occurring chemical compounds. Most scents or odors are VOCs.

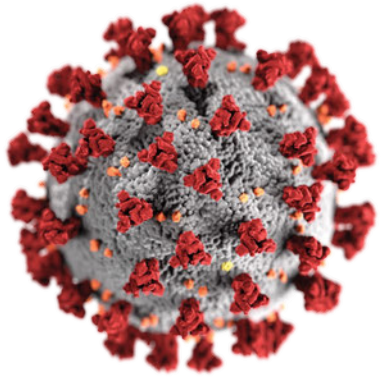
IEQ: Mold

Mold spores are viable airborne particles between 2 and 40 microns (µm) in diameter. The majority of mold spores are so small (e.g. Aspergillus fumigatus 2.0 – 3.0 µm in diameter) they easily float through the air and can be transported everywhere through the HVAC systems indoors. The number of mold spores suspended in indoor air depends on the time of the day and environmental conditions like temperature and humidity.

Mold can be a problem indoors. Once mold spores land on a wet or humid spot, they start to grow. As mold grows it breaks down whatever it is growing on and it can cause damage to furnishings, wood floor, drywall, building's structure, but most importantly mold has acute health effects.



IEQ: COVID-19



CO_2: Even though CO_2 levels are not a direct measure of possible exposure to SARS-CoV-2 virus, measuring levels using an Indoor AQ Monitor can help us identify poorly ventilated spaces. Recommended levels below 700 ppm.

Temp/RH: Low relative humidity increases the infection risk as aerosols become lighter and thus stay in the air for longer. Low indoor air temperature affects the survival rates of the virus thus when temperature is below 25ºC/77ºF there is an increased risk. Recommended RH between 40-60%.

PM: It is clear that airborne transmission is a major pathway for the spread of COVID- 19 and in order to reduce aerosol concentrations, we need to measure the particles in indoor air too. Recommended $PM_{2.5}$ values below 5µg/m^3.

RESET® Viral Index

$$[\text{Airborne Infection Potential}] = \frac{[\text{Virus Survivability}] \cdot [\text{PM2.5 Impact}]}{[\text{Immune System Health}]} \cdot [\text{Dosage}]$$

Temperature

RH

PM

CO_2

RH

Green Buildings

According to World Green Building Councils a green building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life.

Most importantly, in the last few years (maybe COVID-19 has pushed them towards that direction) they focus heavily on a good indoor environmental air quality. Temperature, humidity, particulate matter, chemicals (VOCs) and carbon dioxide are some of the major indoor environmental parameters that are monitored and responsible for controlling HVAC systems automatically in order to ensure that occupants are safe, productive, and healthy.

Indoor AQ Standards $PM_{2.5}$ limits

WHO	< 5 µg/m³ 1-year (2021 AQGs)	< 15 µg/m³ 24-hour
USA EPA	< 12 µg/m³ 1-year	< 35 µg/m³ 24-hour
RESET	< 12 µg/m³ (high-performance)	< 35 µg/m³ (acceptable)
Fitwel	< 12 µg/m³	
LEED	< 15 µg/m³	
EU	< 25 µg/m³ 1-year	
UK	< 10 µg/m³ 1-year	

Indoor AQ Standards CO_2 limits

USA	< 1100 ppm (ASHRAE 62.1)
EU	800-1000 ppm (UNE-EN 13779)
WHO	1000-1500 ppm
France	1000-1500 ppm
RESET	600 ppm (high-performance) or 1000 ppm (acceptable)
LEED	< 1000 ppm
Fitwel	< 1000 ppm

Indoor AQ Standards TVOC limits

USA EPA	< 123 µg/m³ (only Formaldehyde)
Netherlands	< 200 µg/m³
WHO	< 250 µg/m³
Germany	< 300 µg/m³
RESET	< 400 µg/m³
LEED	< 500 µg/m³
Fitwel	< 500 µg/m³

Monitor Indoor Air Quality

Indoor Air Quality Monitors can help us benchmark and stay on top of the requirements occupants have in green buildings. They can report the levels of common pollutants and other conditions inside indoor spaces in real-time.

Common hardware configuration:

- Particle Counter (0.3 to 10µm, 6 Channels, particle number & mass)
- CO_2 Sensor (NDIR: 0 to 5000 ppm)
- TVOC Sensor (PID: 0 to 50 ppm, minimum detection level 5 ppb)
- Temperature (32 to 122ºF or 0 to 50ºC)
- Humidity (15 to 90%)

Instruments that are calibrated according to industry standards and are NIST traceable offer data confidence and reliability.

Why Monitor Indoor and Outdoor Air Quality?

It is an essential step in order to have a holistic approach to IAQ that surrounds us in both environments.

Indoor air quality depends on many factors like building material, furniture, and indoor activities (cooking in a home or printing documents in an office, the perfumes people wear, etc). All of these factors will determine indoor air quality from the inside but indoor air quality is subject to outdoor conditions too. Vehicle traffic, wood-burning, industrial activities in the area, and wildfires are some of the sources that will affect IAQ as buildings need to breathe or ventilate as we have learnt.

By monitoring both worlds we or the automated systems can make better decisions when it comes to ventilation and energy consumption.

IAQ Monitoring and Commercial BMS/BAS

Particles Plus Monitors support Modbus which is the preferred protocol in Building Management or Automation Systems (**BMS** or **BAS**) to automate control and monitoring of various building systems such as the heating, ventilation, air conditioning and refrigeration systems (HVAC-R).

Case Study 1: BAS can minimize ventilation rates when occupancy and CO_2 levels are low to save on energy and boost ventilation rates during high-occupancy periods to ensure high productivity levels and performance.

Case Study 2: During pollution events, like wildfires or high vehicle traffic, outdoor and indoor particulate matter data can help automate air filtration and ventilation to optimize indoor air quality. This technique also prolongs filters life expectancy reducing maintenance costs.

Conclusion

- According to World Green Building Council, they estimate the reduced absenteeism through sick days to be worth ~$35/$m^2$. Again the World Green Building Council estimates that if employees' productivity improves by even a 5% because of better IAQ, that alone would be worth ~$400/$m^2$.

- On average, cognitive scores were 61% higher in the buildings that IEQ was a priority than conventional buildings.

- Proper ventilation and filtration help to eliminate contaminants like PM, CO_2 and VOCs but also the mitigation of the spread of airborne viruses.

- Indoor & outdoor air monitoring systems are crucial in order to benchmark building conditions and help occupants thrive indoors.

Q&A

The questions which aren’t answered during the webinar will be answered via email.

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Thank you!