"Particles Matter": Achieving Healthy, Energy Efficient, Smart spaces

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Invisible Particles affect your Health

Particulate Matter is the term used for particles in the air we breathe most of which are invisible due to their size and thanks to recent research fueled by Covid, Wildfires and Climate Change we know that these particles are a major health threat[1]. For Covid and most viruses, airborne transmission is how folks get infected. When an infected person coughs, sneezes, yells or even "talks" they expel respiratory droplets (aka "aerosols") of different sizes up to 80 thousand per breath. The heavier particles (5-10 microns in size) drop to surfaces before travelling 2 meters (ie. 6 feet). The smaller, lightweight particles (<1.0 micron) are invisible and simply float away on their own or attach themselves to other particles remaining airborne for up to 18 hours in plume-like clouds which move around the interior airspace, following the path of air currents in a room or building.

The scientific, infectious disease communities' interest in potentially toxic "floating and lingering" particles, is *not* limited to COVID. In the report State of the Air 2022 from the American Lung Association, about 137 million Americans continue to live with unhealthy levels of air pollution in homes and workplaces in part because of climate-change-driven wildfires. In Sept. 2021, the World Health Organization cut in half (to 5 micrograms per cubic meter of air) its annual recommended limit for PM2.5 (particles <2.5 microns). The EPA and others are expected to follow. Clinical studies show Indoor Air Quality is a bigger health threat due to outdoor infiltration and additional sources created by human activities such as cooking, smoking, vaping, cleaning, etc. As a result, Healthy Indoor Air has been added to Energy Efficiency as 'must haves' for building owners and operators as people return to Offices, Schools, Public spaces. At Piera we often get asked, "What is the benefit of measuring individual particles vs the EPA metric of particle mass (weight) PM 2.5?" PM 2.5 was adopted by the EPA 50 years ago to monitor outdoor pollution from vehicles and industrial sources. The EPA's AQI scale based on PM2.5 is useful in telling us air is good, poor, bad, dangerous but not why. Data on the size and distribution of particles delivers insight into the sources, their impact and removal strategies for the pollutants. "It is more energy efficient to eliminate sources of pollution than to increase outdoor air supply rates".[2] In short, **Particles Matter…**

Determining how Particles affect air quality in a building

ASHRAE, the leading organization developing standards and making recommendations for the "Built Environment" published a May 2022 article in the ASHRAE journal. Titled, "Airborne Disease Transmission Risk and Energy Impact of HVAC Mitigation Strategies", it provides guidance on how to optimize a 'typical' building to reduce airborne transmission of viruses in an energy-efficient manner (Figure 1). It discusses the need to achieve a 'balance' point between particle generation and removal since particles are the carrier for the virus with sub-micron (<1.0 micron) particles the deadliest as they remain suspended in the air for hours. In summary, the lower the particle count, the less likely transmission will occur, and the additional health benefits are substantial. ASHRAE recommends a variety of mitigation strategies to remove particles, however since every building is different, the guidelines are simply a starting point. Key findings include:

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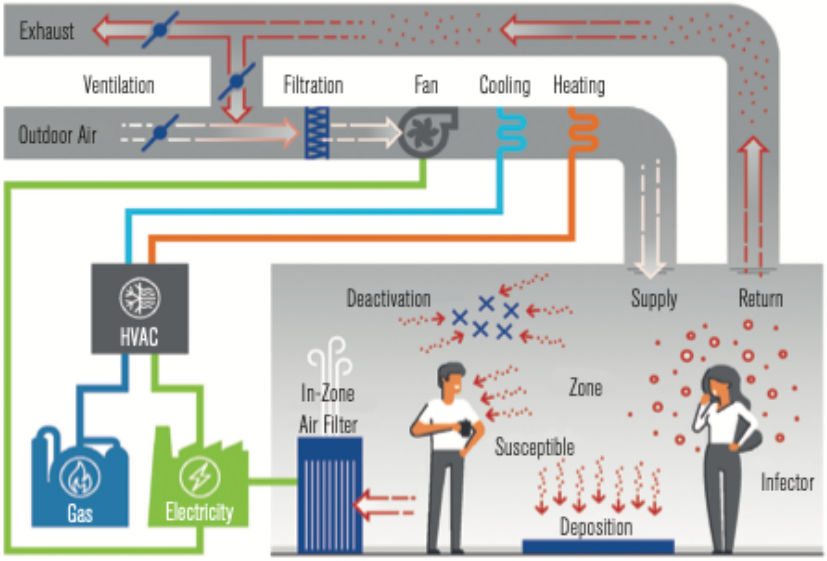
[1] Additional articles on health impact:
https://www.statnews.com/2021/07/20/circumventing-covid-19-with-better-ventilation-and-air-quality/
https://www.cnn.com/2021/02/09/world/climate-fossil-fuels-pollution-intl-scn/index.html
https://pubmed.ncbi.nlm.nih.gov/26502459/
https://www.who.int/health-topics/air-pollution#tab=tab_

[2] Wyon DP. The effects of indoor air quality on performance and productivity. Indoor Air. 2004;14 Suppl 7:92-101. doi: 10.1111/j.1600-0668.2004.00278.x. PMID: 15330777.

- A new metric, Equivalent Outdoor Air (EOA) delivery as a basis for infection-risk and energy-consumption analysis instead of Air Changes per Hour (ACH) which is a widely used metric.
- Increased outdoor air ventilation is effective for reducing infection risk, but it can be costly or infeasible depending on climate and equipment configuration.
- Improved filtration is often the most cost-effective source of EOA (install MERV-13 filters in existing systems)
- When operational flexibility of the HVAC system is limited, high risk zones may need supplementary in-zone filtration (air purifiers or other stand-alone disinfection devices (UV-cleaning and other 'active' methods).
- For buildings and spaces with different HVAC configurations the observations may or may not hold but quantitative analysis can be performed to inform the course of action.

FIGURE 1 Diagram of infectious particle dynamics and HVAC energy consumption in typical buildings. Infectious particles are shown in red, while particle removal sources are shown in blue. Energy consumption for relevant equipment is routed to the appropriate utility.



The last point is key: the air in every building is different and it changes continuously based on occupancy, use, pollutants, HVAC systems and devices that 'clean' the air. What's needed is a way to make the invisible visible. To make spaces safer before there is a problem. You want to actively scan and map how airborne particles travel, pool and clear, this requires real-time air monitoring.

Metrics like ACH and EOA are static measures that don't account for changes in air quality in real-time. They also assume that the air is well mixed when it's not and is affected by occupancy. ASHRAE, the EPA and CDC use models as a guideline for reducing transmission risk of viruses (Recommended ACH of at least 6). ACH is also useful for comparing different air purifiers (higher is better) and selecting the right unit for a room. The data can then be used to approximate how long it will take to 'clean' the air. However, ACH does not include energy consumption whereas EOA determines the volumetric flow of outdoor air that would provide an equivalent removal rate of infectious particles. The authors state, "If particle size distributions are known, it is straightforward to determine the EOA provided by each of the removal mechanisms." Particle Size Distributions require Air Monitors that report particle count and size in real-time not PM.

If you know the EOA of various mitigation approaches and their power consumption you can begin to improve energy efficiency across multiple 'climate zones'. ASHRAE's Building Readiness Guide (May 17, 2022) provides details on EOA including the size of the particles likely to carry Covid. This table suggests you should plan for particles of size 1.0 um or less.

Based on this information, we are suggesting a starting point for anticipated distribution of virus to be per the table:

Filter Ranges (Particle Size)	Anticipated Distribution of Virus
E1 (0.3 um to 1 um)	30%
E2 (1um to 3 um)	30%
E3 (3 um to 10 um)	40%

NOTE: The most conservative approach for the distribution would be for the E1 range to 100% of the particles.

Why not just use CO2 as a proxy for Ventilation Rates?

CO2 levels are easily misinterpreted and may generate confusion. It can be difficult to collect accurate data in poorly mixed spaces, especially when occupancy is low, or the interior air volume is large. Low CO2 levels measured in such spaces may not reflect conditions throughout the space. Another potential way a CO2 reading could be misinterpreted is if there are HEPA filters (in the HVAC or in purifiers) in a room being monitored. HEPAs, which work to remove harmful particles from the air, including ones containing COVID and other viruses, do not impact CO2 levels. So, a high CO2 reading may not be as noteworthy in a room with an air filtration system.

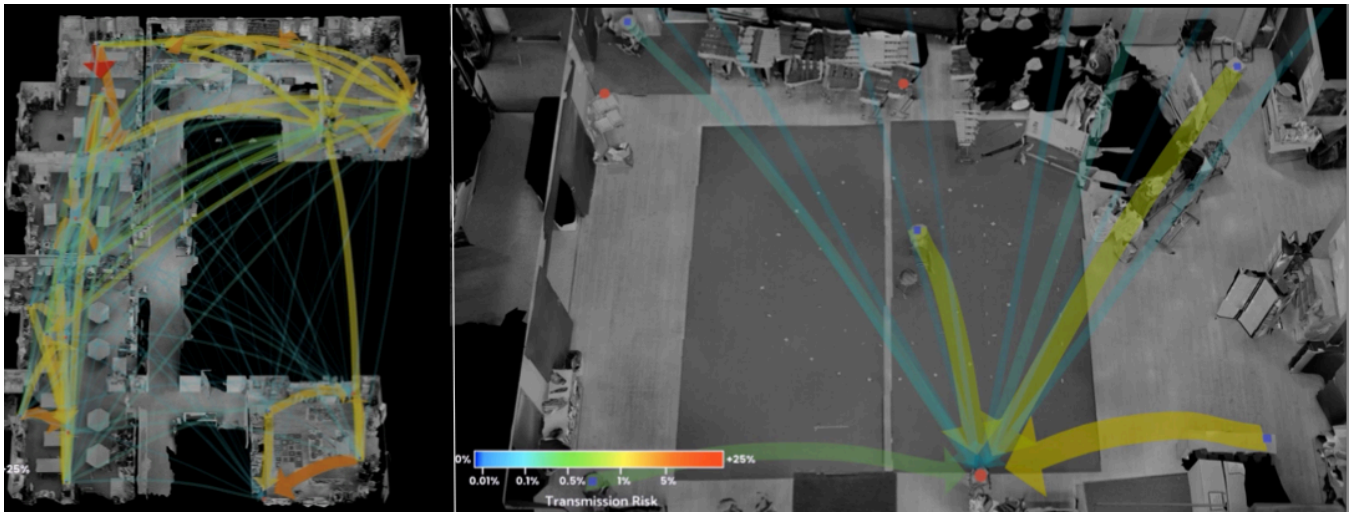
The best approach is to create a 'living' model of the airflow in the building while it's in use. To actively scan and map how airborne particles travel, pool and clear. Once the model is known, a metric called Effective Air Changes per Hour (eACH) can be used to manage the buildings health and energy efficiency. eACH delivers the benefits of EOA and ACH but with the building dynamics included.

If CO2 is available in addition to PM, CO2 data can be used to identify Particle sources especially carbon-based sources more accurately.

Poppy Health and Piera Systems are partnering to deliver such a solution. Using Poppy's Biosafety Intelligence System and data from Piera's particle monitors, Poppy delivers the data you need to create healthier buildings, increase occupant confidence, and reduce energy costs.

Creating healthy, energy-efficient, 'smart' indoor spaces.

Piera's state of the art particle monitoring provides details of the sizes and individual concentrations of particles in an indoor space and is a breakthrough in measuring the smallest particles. Piera uses a custom particle processor developed originally for x-ray devices to 'count and 'size particles while they are in motion. Poppy Diffusers release breath-like particles (1.0 micron in size) called Tracers. Poppy Sensors collect Tracers and real pathogens as they move through the physical site in aerosol particles. Poppy integrates Piera's particle data for real-time air monitoring. Deployed throughout a building, Poppy Diffusers and Sensors under software control generate particles and measure them to calculate eACH for each room, identify transmission pathways, pathogen and pollution hotspots and clearance rates delivering a compelling ROI for a healthy, energy-efficient building. Piera's technology also delivers Air Quality Metrics (AQI), alerts to pollution hot-spots and classifies likely sources of pollution. The Poppy system analyzes the movement over time to produce fine-grained data about how indoor air transports particles and bioaerosols. Cartridges contain pathogens for high accuracy detection of viruses such as Covid-19 and others.



Once the initial model of the building is determined it can manage the building. As the building air changes due to occupancy, use, temperature, humidity, outdoor and indoor pollution, real-time continuous monitoring of particle data ensures clean air by knowing the exact density of the problematic sub-micron (and larger) sized particles that must be diluted and/or filtered. Simply put, the higher the number of particles, the more air filtering and fresh air intake is required to dilute and cleanse /filter the particles. In addition, the ability to classify pollutant sources (vape, smoke, cooking, aerosols) can be used to eliminate sources.

HVAC systems were designed for energy efficient comfort control, primarily relating to temperature and humidity levels. These systems are not designed for air purification and are insufficient. Upgrading to MERV 13 filters (If the system can handle the pressure drop) only captures a small portion of the sub-micron sized (dangerous) respiratory droplets that are floating in the air and may contain viruses. Even other floating particles potentially become “transport vehicles” for these lightweight infections droplets to “hitch a ride”. So, increasing air flow (Purging) WITHOUT addressing the enhanced filtering of the air content, may simply be facilitating the movement of these floating aerosols between all spaces in the building which share a common air supply. You may be spreading the virus, DESPITE your well-meaning “HVAC system upgrade” intentions.

In summary, the 3 ‘pillars’ of Healthy, Energy Efficient spaces are Monitor, Inform and Mitigate in a continuous real-time loop. Piera Systems and Poppy deliver this and can integrate the data with your existing Building Management Systems and a wide range of air cleaning products. To learn more, go to www.pierasystems.com/poppy