

Tracking IAQ Problems to Their Source

Ultrafine particle concentrations have been linked to otherwise unexplained IAQ problems.

by Patricia B. Keady and Laurie Mainquist

You've done everything right. Temperature and humidity fall squarely within ASHRAE guidelines. Ventilation is on target. Dust is under control. You can't find evidence of volatile organic compounds, and you've even eliminated mold as the culprit. You did everything right, yet you're still getting complaints about indoor air quality.

Today's sophisticated IAQ instrumentation and advanced building construction should be eliminating these situations, but it's not happening. Building engineers and industrial hygienists alike continue to face tough IAQ problems in office buildings, schools, hospitals, and anywhere else people gather indoors. What are we missing?

Thinking small

One answer is ultrafine particles (UFPs), those less than 0.1 micrometer (mm) in diameter. Often the byproducts of combustion, ultrafine particles are found everywhere. They can enter buildings along with the outside air or result from various processes within the building itself.

Some UFP sources are obvious: building and vehicle exhaust, environmental tobacco smoke, and certain manufacturing operations. Other sources are more easily overlooked. Unexpected levels of UFPs can be traced to unlikely sources such as cleaning solvents, boiler gasket leaks



or malfunctioning photocopiers. Figure 1 provides examples of typical indoor particles and their size ranges. Even though UFPs are everywhere, their small diameter precludes detection with conventional methods. These UFPs easily represent the greatest number of particles in a sam-

ple of air, yet aerosol photometers and filter sampling methods commonly used to measure particle mass concentration miss them completely. Optical particle counters (OPCs) measure number concentration, but even they are insensitive to particles below about 0.3- μm diameter and miss all of the UFPs. Figure 1 illustrates this limitation.

Imagine a particle concentration of 10 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$). That mass concentration might accommodate 19 particles of 1.0- μm diameter, or it might hold over 2,400,000 UFPs of 0.02- μm diameter. Table 1 shows the relationship of particle size, number and surface area for a given mass concentration.

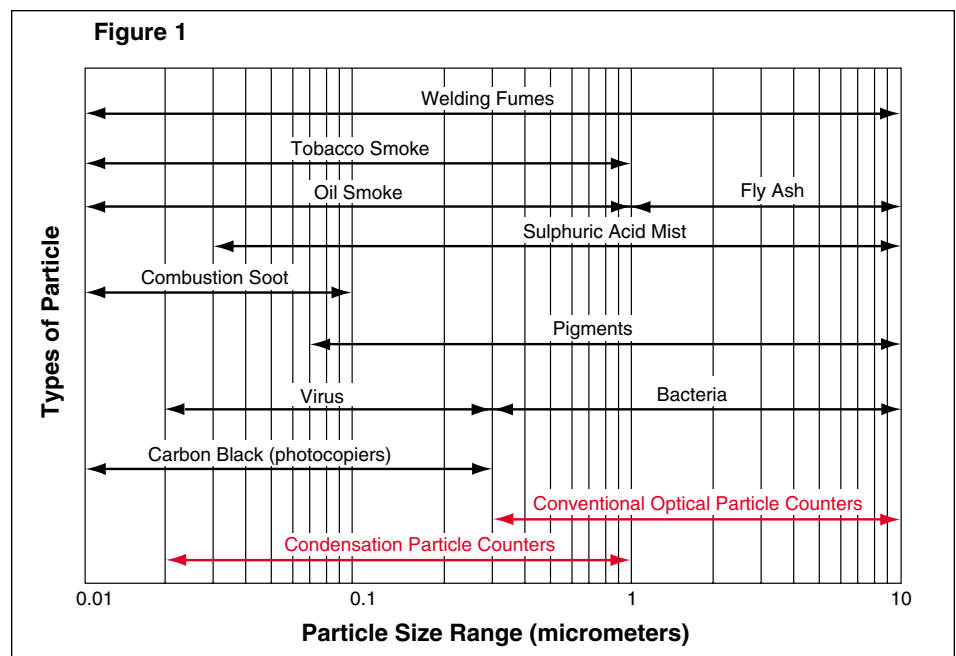


Table 1: Number and surface area of particles of unit density of different sizes at a mass concentration of 10 $\mu\text{g}/\text{m}^3$

Particle Diameter (μm)	Particle Number (per cm^3)	Particle Surface Area ($\mu\text{m}^2/\text{cm}^3$)
0.02	2,400,000	3,016
0.1	19,100	600
0.5	153	120
1.0	19	60
2.5	1.2	24

Source: Oberdörster 1995

Since ultrafine particles weigh almost nothing, they stay airborne for a long time and easily move from one area of a building to another based on small pressure differentials between spaces. In this way, the particles can be transported through unexpected pathways, such as cracks in walls and floors.

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The small size and sheer number of ultrafine particles logically prompt concerns about their effect on human health. Researchers are vigorously studying the actual link between UFPs and health outcomes.

"We can inhale these particles, and when we do, they stay deep in the lungs. They also can affect the eyes and the nose, causing irritation," says Dr. John D. Spengler, Professor of Environmental Health at the Harvard University School of Public Health.

New approach means new mindset

Detecting UFPs and eliminating or controlling their sources requires a new approach to IAQ management. The process involves more than systematic measurements with conventional equipment. Instead, an investi-

gator typically confirms higher-than-expected levels in the complaint area and then uses a deductive process to track the UFPs to the pollutant source. Once the source is identified, the cause of the complaint can be controlled or eliminated.

Using this approach also means looking beyond the practice of

measuring and evaluating particle levels against fixed standards. Indoor air practitioners logically rely on health-based standards (PELs or TLVs) for known chemical and particulate contaminants. However, there are no specific standards for UFPs.

Instead, all UFP measurements are compared against background levels outdoors and in "complaint-free" areas within the building. This comparison of UFP levels against background levels is a

logical extension of ASHRAE Standard 62-1999, which refers to EPA's National Ambient Air Quality Standards (NAAQS) and calls for indoor air that is cleaner than outdoor air.

The departure from fixed standards and the need for location-specific baselines makes sense once one considers the parameter being measured. UFPs are typically measured with a condensation particle counter (CPC), a highly sensitive instrument that counts particles within a specific size range, for example, from 0.02 to 1.0 μm . We don't learn the constituent make-up

of the sample and, in fact, the make-up will be unique for every setting. The relative levels within a single environment are what are important. Specifically, higher UFP levels often point to IAQ problems.

Our understanding of these particles in the indoor environment is still incomplete. Are the particles themselves the cause of the complaint or are they actually surrogates for the real cause? Current research hasn't yet provided the answer, but for the time being, identifying the root cause of the complaint is certainly a good start.

Tracking UFPs to the source

Using UFP levels to eliminate IAQ complaints calls for an investigation methodology that first examines the big picture within the building, then focuses on the complaint area and finally tracks increasing UFP levels to the pollutant source.

The first step in evaluating a building's IAQ is measuring outdoor particle levels with a commercially available ultrafine particle counter and calculating an average value for outside air entering the building. Using this average value and the relative air handling system filter effectiveness, one can readily calculate the expected UFP levels within the building. For example, outside air containing 10,000 particles/ cm^3 and passing through 80 percent efficient filters provides an indoor goal of 2,000 to 3,000 particles/ cm^3 within the building.

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Once inside the building, interviews with occupants and facility personnel usually provide the back-

ground information for a survey of the building. UFP levels over 2,000 to 3,000 particles/cm³ in the complaint area suggest the presence of one or more pollutant sources. Additional measurements within the complaint area and in complaint-free areas provide a clearer picture of the situation and can point to pollutant pathways. For example, UFP levels higher in supply air than in the room might indicate a pollutant source related to the HVAC system itself.

With this deductive process of investigating and eliminating pollutant sources and pathways, the cause of an IAQ complaint is often revealed within a few minutes. Once identified, a remedy as simple as a temporary seal often provides an immediate reduction in UFPs to levels near the calculated goal. In some cases, two or three iterations of this process may be required to identify secondary sources previously masked by the primary one.

"Understanding ultrafine particles and how they move within buildings is the key to solving these tough IAQ problems," says Richard Fogarty, President of New Trend Environmental Services Ltd. Fogarty pioneered the use of ultrafine particle counters for IAQ surveys and has conducted over 2,000 successful investigations.

Case studies

Fogarty believes the ubiquity of UFPs in the indoor environment makes particle-counting technology an essential tool for just about everyone responsible for IAQ. He points to his experiences in a variety of settings.

Called to a clothing store, Fogarty was asked to investigate the cause of a health-related incident. A clerk had been rushed to a hospital when she experienced a bleeding nose and severe respiratory difficulties while restocking dresses onto a rack. Fogarty tracked UFPs to an adjacent, vacant office space where batteries for snow removal equipment were

being charged. The pressure differential between the vacant space and the clothing store was drawing high levels of UFPs into the store through a small hole behind the rack where the clerk was working. Discontinuing the charging operations and sealing the hole significantly reduced UFPs to expected levels. The clerk returned to the store and was able to work without further incident.

At a public school, personnel asked him to investigate the administration area. UFP levels within the room were three times those in the supply air. He quickly found that the particles were originating from floor joints around the support beams to the floor below. Further investigation revealed a welding shop in this space. Sealing the floor joints reduced UFPs to expected levels, and the complaints ended.

In an office building, Fogarty found UFPs as much as 20 times higher than outside air. As he investigated the air handling system, he learned that particles originating in the building's own boiler exhaust were re-entrained through the air intake of the supply air system. Raising the height of the chimney eliminated this reentrainment and the complaints ended.

At another facility, personnel complained about the air quality on a specific floor. A survey showed UFP levels four times higher than in other parts of the building. More measurements led Fogarty to a janitor's closet where particles were leaking from loose storage caps on containers of cleaning solutions. Securely sealing the containers ended the complaints.

With such diverse building activities, each of these settings appears completely unrelated. Yet they have at least one element in common—unexpected levels of ultrafine particles. By understanding how these particles act in the indoor environment and interpreting their relative levels, we can eliminate another common element—IAQ complaints. ■

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