ULTRAFINE PARTICLES: A NEW IAQ METRIC

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Overview

Today's indoor air quality (IAQ) professional is able to measure many parameters of the indoor air. However, even though the analytical capability may be better than it has ever been, it is still difficult or sometimes impossible to identify the root cause of the IAQ concerns or complaints. This difficulty begs the question, what are we missing? Do we need better sensitivity and resolution in commonly used techniques? Or, do we need an entirely different metric that is not now used?

IAQ experts specializing in each of the IAQ parameters typically measured can identify technology extensions or measurement refinements that would add to our larger understanding of IAQ problems. But there are limited resources available to fund research in these areas. Particle technology is a recent area of attention for IAQ. Other research efforts mainly sponsored by the US Environmental Protection Agency (EPA) have the potential to significantly add to our understanding of the dynamics between health effects and airborne particles, especially ultrafine particles. If the current research is conclusive, ultrafine particles could become a significant indicator of the relative quality of indoor air and the presence of indoor pollutant sources.

Comfort, temperature, and humidity have long been a source of IAQ concerns but these parameters are easily measured, instrumentation is readily available, and guidelines are well documented in ASHRAE Standards. One combination of comfort not commonly evaluated in the US is a draft index. Draft Index is a combination of temperature, humidity and velocity (although velocity is addressed in ASHRAE Standard 55-1995). Adding velocity to the comfort measurement taken in the occupied space adds a component that has a great deal of influence on the perception of warming and cooling.

Ventilation, the outdoor air delivered to an area of interest, and circulation, the total air delivered including fresh air, are defined by American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 62-89 and further clarified by proposed addenda to that standard. Measurements of carbon dioxide (CO_2) are commonly used to determine the ventilation effectiveness of occupied spaces but are commonly misconstrued as an indicator of health hazards. The highest levels of CO_2 commonly found in indoor spaces are not considered a hazard but lead to the perception of spaces seeming "stuffy", so cannot be dismissed.

Toxic substances commonly found and regulated in the industrial workplace are occasionally identified as the source of indoor air complaints. As an operating guideline in the past, practitioners often used 0.1 of the threshold level value (TLV) or permissible exposure level (PEL) for identifying acceptable levels in indoor air spaces. This value may still have been too high for the general population, particularly hypersensitive individuals. Unique environments are sometimes the exception. For example, ice arenas can have unusually high levels of carbon monoxide (CO) and nitrogen oxides (NOX) due to combustion pollutants generated during ice resurfacing.

Toxicologists are still grappling with volatile organic compounds (VOCs). VOCs are often identified as a parameter of interest but many questions exist regarding which compounds, what levels, and in which combinations will present a health risk. The permutations of these combinations quickly become a colossal measurement challenge. Epidemiologists share the challenge with toxicologists because little definitive data exists as to exposures and health effects in the indoor environment.

Bioaerosols are an area of great concern today. A recently published book Bioaerosols Assessment and Control (American Conference of Governmental Industrial Hygienists [ACGIH]) does not offer definitive levels of acceptability for bioaerosols at which the general population should not have adverse health reactions, except that there are indicators for endotoxins and some allergens. The guidelines offered by ACGIH do assist the practitioner in designing a bioaerosol sampling strategy but these strategies can quickly become large, complex, and expensive due to the extensive lab analysis costs and specialized data interpretation. Bioaerosols, like VOCs, need additional research.

Particle measurement and analysis also are done but have limited results. Regulations are in terms of particulate mass per unit volume. Some real time aerosol measurements, typically light scattering photometers, indicate mass measurements in real time to identify indoor problem areas. It is unusual to find indoor measurements approaching the regulated levels unless ventilation is inadequate and cooking or environmental tobacco smoke is present. Laser particle counters are used to measure a number distribution and estimate a mass concentration. This measurement is usually of limited value because the bulk of the numbers are below the sensitivity of the instrument and sampling inefficiencies tend to underestimate the larger particles that will dominate the mass measurement. Laser photometers have been found to be very useful in monitoring during construction projects.

When reviewing the large number of measurements that are possible, the task quickly requires an expert in the field to determine the most beneficial measurement strategy. Even when great efforts are made to scientifically determine the root cause of IAQ complaints, the causal relationship between health effects and an indoor pollutant can be very elusive.

Ultrafine Particles, A New Parameter

An ultrafine particle (UFP) is defined as having a diameter smaller than 0.1 micrometer. Although identified in air pollution research more than 30 years ago, UFPs are receiving more attention in recent years as a parameter with possible health implications. Classic work published by Whitby[1] in 1978 shows the relationship between particulate number, surface area, and volume measurements in the atmosphere. Regulations and commonly held beliefs regarding dosing are in terms of mass per unit volume. His work indicates that when mass measurements are made, they will be completely dominated by those particles greater than 0.1 micrometer. However, if the number or surface area distributions are scrutinized, it is quickly evident by the lack of mass from particles of less than 0.1 micrometer that a typical filter type mass measurement will yield virtually no information about the UFP regime. Keywood[2] recently confirmed the lack of correlation between typical PM10, PM2.5 and UFP in six Australian cities.
A definitive causal link between UFP and health effects has not been determined but is being addressed by several researchers. A critical review by Sverre Vedal[3] of British Columbia in 1997 determined "particles in the ultrafine particle fraction are pathogenic, as demonstrated in experimental studies." He

went on to conclude that it was not clear what portion of particulate mass concentrations were in the ultrafine range when the particulate mass concentrations correlated to adverse health effects. Both particle size and composition were considered in this review.

Work reported by Gunter Oberdorster[4] shows that even inert UFP could have adverse health effects in rats. In his work, rats exposed to inhaled concentrations of $0.7 - 1.0 \times 10^6$ particles/cm^3 resulted in acute hemorrhagic pulmonary inflammation and death after 10-30 minutes of exposure. It is conceivable that these concentration levels can be realized in an urban aerosol. Oberdorster references measurements by Castellani[5] of an urban aerosol that have shown the number concentration of ambient ultrafine particles reach well into the range of 10^5 particles/cm^3. While these are outdoor measurements, it is conceivable that similar concentrations can be seen indoors, especially if there are indoor sources.

In another study addressing ultrafine particles, Peters[6] determined that elevated ultrafine particle number concentrations were more closely associated with decreases in expiratory flow rate than elevated particle mass concentration. Particles from 0.01 –2.5 micrometer were studied during this winter period. Ultrafine particles accounted for 70% of the total particles.

Much of the work associated with UFP is focused on the outdoor environment and the relationship between indoor and outdoor environments is not well established. Research in Australia by Jamriska[7] has begun to address this indoor/outdoor relationship but, thus far, has shown that the ultrafine particles decrease indoors when compared to the outdoors due to the effects of the ventilation system and filtration. However, the measured indoor spaces were not identified as areas having air quality problems.

The link between ultrafine particles and health effects has not been identified but there is enough research to suggest that there may be a causal link. The link may be associated with the number of particles, the surface area distribution, the particle size, the acidity, the chemical properties, the compounds condensed on the surface, or a variety of other parameters. Table 1 demonstrates the influence of these very small particles.

Table 1: NUMBER AND SURFACE AREA OF PARTICLES OF UNIT DENSITY OF DIFFERENT SIZES AT A MASS CONCENTRATION OF 10 micrograms/m^3.[8]

PARTICLE DIAMETER (micrometers)	PARTICLE NUMBER (#/cm^3)	PARTICLE SURFACE AREA (micrometer^2/cm^3)
0.02	2,400,000	3016
0.10	19,100	600
0.50	153	120
1.00	19	60
2.50	1.2	24

In an independent effort, a consulting firm called New Trend Environmental Services located in Halifax, Nova Scotia isn't waiting for additional scientific proof. They are tracing UFP as a method of identifying indoor pollutant sources. The owner, Richard Fogarty, reported on this technique[9] at ASHRAE's Winter '98 meeting. Fogarty simply measures the ultrafine number concentrations in the area of concern and systematically begins eliminating the sources. While simple in concept, it requires significant experience to determine the relevance of the measurements. Fogarty claims solving 90% of IAQ problems with this technique. The best source for further information is their website at http://www.newtrend.ca.

Summary

Some indoor air quality problems continue to go unsolved because the root cause is elusive. A causal link between ultrafine particles and health effects is being researched. If a causal link is substantiated, then the added metric of ultrafine particle concentration may become very important in indoor air quality investigations.

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