

ULTRAFINE PARTICULATE MATTER: PUBLIC HEALTH ISSUES AND RELATED RESEARCH

January 31, 2003

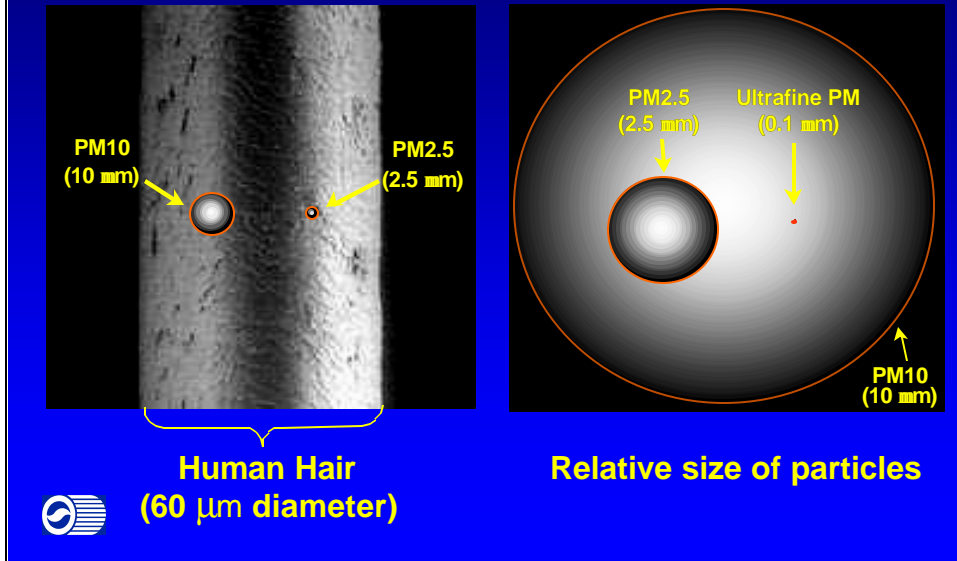
Air Resources Board



California Environmental Protection Agency

Today's presentation focuses on public health issues and research activities related to ultrafine particulate matter. This presentation expands upon last month's health update that summarized a study indicating exposure to ultrafine PM may cause a higher risk of cardiac ischemia, a serious health effect.

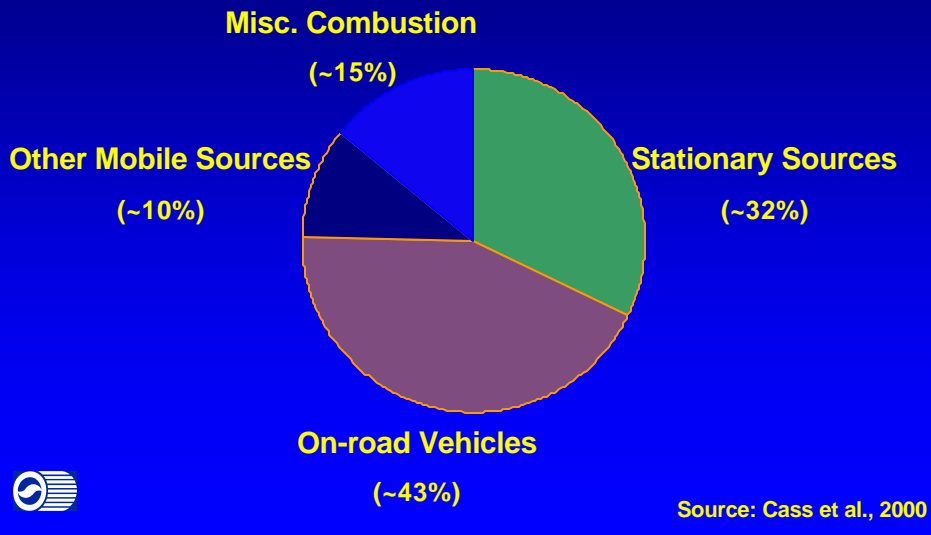
Comparison of PM₁₀, PM_{2.5}, and Ultrafine PM



What, **exactly**, is ultrafine particulate matter? These very small particles are a sub-fraction of the **currently** regulated PM₁₀ and PM_{2.5} size fractions. Technically speaking, they are defined as particles with an aerodynamic diameter of 0.1 microns and smaller. The left panel of this slide compares PM₁₀ and PM_{2.5} **relative** to a human hair which is typically 60 microns in diameter. In this schematic, the particles are idealized as individual spheres, but under real conditions are likely more irregular in shape. However, it does illustrate how different these particles are in size. For example, PM₁₀ and PM_{2.5} particles have diameters that are six and 24 times smaller, respectively, than that of a human hair. In the right panel, PM_{2.5} and ultrafine PM are compared to the much larger PM₁₀ particle, illustrating the fact that ultrafine PM is 25 times smaller than PM_{2.5} and one hundred times smaller than PM₁₀. We're talking about **very small** particles relative to PM₁₀ and even PM_{2.5}.

The right panel also illustrates an important physical characteristic of small particles—a **given mass** of ultrafine PM contains thousands to tens-of-thousands **greater number of particles**, with a **correspondingly larger surface area**, than an equivalent mass of larger particles. This implies that a given mass of ultrafine particles will impact a larger surface area of lung tissue than will an equal mass of larger particles, thus **increasing** exposure.

Combustion is the Major Source of Ultrafine PM



The major source of ultrafine particulate matter is combustion. This pie chart shows the contributions of major combustion sources to total estimated ultrafine PM emissions, based on the 1996 emissions inventory for the South Coast Air Basin. The largest sources of ultrafine particle mass are on-road motor vehicles, stationary source fuel combustion, non-highway mobile sources (for example diesel off-road vehicles), and miscellaneous processes like char-broiling, petroleum refining, and waste burning.

Exposure Information is Limited

- Only existing ultrafine PM network is in southern California
- Freshly emitted ultrafine PM concentrations do not correlate well with PM10 or PM2.5 mass concentrations
- Freshly emitted ultrafine PM concentrations decrease rapidly with distance from source¹



¹ Sioutas et al, 2002

From an exposure perspective the amount of ambient monitoring information for ultrafine particulate matter is limited. In fact, the only comprehensive ambient monitoring network currently in operation in the world was constructed and is currently maintained by ARB. It is located in Southern California. Interestingly, data from this monitoring network show freshly emitted ultrafine PM concentrations do not correlate well with PM10 or PM2.5 mass concentrations. As a result, assessing exposure to these small particles requires dedicated monitors.

Other research has shown that the concentration of freshly emitted ultrafine PM decreases rapidly with distance from its source. A study on two Los Angeles freeways confirmed this, as measurements of ultrafine PM levels decreased to urban background levels at about 300 meters from the freeway source. These findings suggest that near-source exposures may play an important role in ultrafine PM exposure.

Intriguing Health-Related Findings

- Ultrafine PM exposure associated with mortality¹
 - effects strongest for respiratory disease followed by cardiovascular disease
- Individuals with airway obstruction receive greater dose of ultrafine PM than healthy individuals²
- Ultrafine particles pass rapidly into the circulatory system³
- Ultrafine PM is more potent than fine or coarse PM towards inducing cellular damage⁴



¹ Wichman et al, 2000; ²Brown et al., 2002; ³Nemmar et al., 2001; ⁴Li et al., 2002

Exposure to ultrafine PM may lead to adverse health effects. Several recent studies have produced intriguing health-related findings that are worth summarizing for you today. A daily mortality study in Erfurt, Germany, was the first epidemiology study that examined and found significant associations between exposure to ultrafine PM and mortality from respiratory and cardiovascular disease.

Human exposure studies have shown that individuals with moderate to severe airway obstruction receive a greater dose of ultrafine PM than do healthy individuals. In addition, that ultrafine particles pass rapidly into the human circulatory system, implying a clearance mechanism exists for ultrafine PM in the lungs, however, at the same time increasing the number of particles in the blood and thus increasing exposure to other organs. These results suggest that certain sensitive sub-populations, like individuals with chronic obstructive pulmonary disease, may be at greater risk than healthy individuals when exposed to ultrafine PM due to an increased dose in the lungs which leads to an increased dose in the circulatory system.

Finally, a toxicology study published last month indicates that ultrafine PM is more potent than fine or coarse PM toward inducing cellular damage—a possible indicator of the biological mechanism of how ultrafine PM exposure can affect human health.

It should be noted that relatively few reports have been published on the health effects of ultrafine PM. The first epidemiology study was published only a few years ago, which is in contrast to the hundreds of epidemiology studies on PM₁₀ and PM_{2.5} published over the last two decades.

ARB-Sponsored Ultrafine PM Research

- **Emissions**
 - CNG/Diesel
 - Heavy duty/light duty gas vehicle roadside measurements
- **Exposure**
 - Particle Center exposure facility
 - 12-station ultrafine monitoring network
 - In-home and in-vehicle measurements
 - Upcoming mobile monitoring study
- **Health**
 - Mechanisms of PM toxicity
 - Children's Health Study
 - FACES
 - Upcoming proposal for Southern CA epidemiology study



In an effort to help fill this void, ARB is sponsoring research to investigate issues related to the complexity of these particles. For example, we are sponsoring research to investigate emissions, including studying the characteristics of ultrafine particles emitted from compressed natural gas engines compared to those from diesel engines, including the impact of control technologies. Furthermore, and as you will hear in detail during the next agenda item, we are proposing to fund a study on dynamometer and roadside measurements of particulate emissions from heavy and light duty gas vehicles, which will provide valuable information for fine-tuning emission profiles for ultrafine PM.

Exposure-related ultrafine PM measurements are being conducted under contracts supporting the Particle Center exposure facility in Southern CA, the 12-station ultrafine monitoring network, in-vehicle and in-home measurement studies, and an upcoming mobile monitoring study.

Health-related research on ultrafine PM is being performed under contracts supporting studies on elucidating the mechanisms of PM toxicity. More importantly, the ARB is supporting studies to evaluate health impacts from exposure to ultrafine PM as part of the Children's Health Study and the Fresno Asthmatic Children's Environment Study. Finally, staff is working with the University of California to develop a proposal for an epidemiology study focusing on the potential health effects to elderly individuals exposed to ultrafine PM. We expect to bring this proposal before the Board in March.

CONCLUSIONS

- **Ultrafine PM research is in its infancy**
- **Exposure and health-related research is increasing, providing intriguing health-related findings**
- **More focused studies needed in this area of research**
- **Future health studies can utilize ARB's unique ultrafine PM monitoring network**



This area of research is truly in its infancy, especially in comparison to research with other particle size fractions like PM₁₀ and PM_{2.5}. However, exposure and health-related research is gaining momentum, and results from studies to date have provided us with important health related findings that are intriguing from a public health perspective. Therefore, it is imperative to continue on the path of supporting existing research as well as developing more focused studies. In particular, health-related studies that utilize ARB's unique ultrafine PM monitoring network should provide us with needed information on exposure and potential adverse health effects related to these very small particles.

