

Current Issues in Ultrafine Particle Research: The ARB's Health and Exposure Research Program

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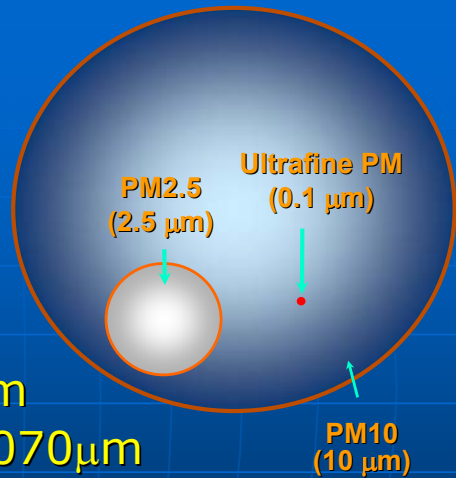
Air Resources Board
California Environmental Protection Agency

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Thank you Ms. Witherspoon; good morning Dr. Sawyer and members of the Board. Today's health update will discuss ultrafine particles; what is currently known about their effects and how ARB's research program is working to better understand the impacts on California.

Relative particle size

- Ultrafine Particles: less than $0.1\mu\text{m}$
- Viruses: $0.002 - 0.070\mu\text{m}$
- Bacteria: $3 - 50\mu\text{m}$
- Red Blood Cell: $7.5\mu\text{m}$
- Human Hair: $60\mu\text{m}$



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What, exactly is ultrafine particulate matter? These very small particles are a sub-fraction of the currently regulated PM₁₀ and PM_{2.5} size particulate matter. Ultrafine particles, on their own are not regulated.

Most commonly, ultrafine particles are defined as having an aerodynamic diameter of 0.1 micrometers and smaller, although this definition is not universally used. Ultrafine particles are about the same size as viruses and considerably smaller than bacteria or red blood cells. This slide provides a graphic comparison of the size of ultrafine particles with PM₁₀ and PM_{2.5} particles. A human hair is approximately 60 micrometers in diameter, which on the scale of the particles shown, would be considerably wider than the entire slide.

Since these particles are extremely small they contribute very little to the conventional particle mass measurements. More commonly, they are measured as the number of particles per cubic centimeter.

Why are we concerned about ultrafine particles?

Contain little mass, but:

- Possess a large surface area and high numbers
- Have a high deposition rate in the lung
- Can enter the circulatory system and move from the lungs to other organs
- Contain toxic components
- May initiate harmful oxidant injury

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So, why are we concerned about ultrafine particles?

Although ultrafine particles contribute only a small amount to total PM mass they have a large surface area and often very high number concentrations. They behave much like a gas and may enter all parts of the lung where they tend to deposit in the deep lung. Once deposited in the lung they may penetrate through lung tissue into the blood stream. They have been shown to deposit in critical organs such as the heart and brain. They have also been shown to contain many toxic components such as metals, carbon, and organic compounds which may initiate or play a role in many types of harmful tissue-level oxidant processes that damage the heart, lung, and other organs.

To better understand the impacts of ultrafine particles on California health and welfare, the ARB has made this area a focus of our research the past several years.

Health Effects

Recent Findings

- Ultrafine PM has been associated with premature death, cardiovascular disease, and respiratory illness
 - Detroit and Erfurt, Germany
 - Animal and cellular studies

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Our ultimate concerns are the health impacts of ultrafine particles. Previous research findings, both in ARB funded studies and in other studies, indicate that they are important in respiratory health. They also appear to play a role in systemic inflammation and cardiovascular health, including heart rate variability, atherosclerosis, and changes in the concentrations of numerous blood markers of cardiovascular health. They also appear to be able to cross the blood/brain barrier to lodge in brain tissues and may cause additional, as yet unidentified, effects.

Studies in Detroit, Erfurt, Germany, and other cities are suggestive of an increase in premature mortality due to ultrafine PM exposure. USEPA and ARB funded animal chamber studies and cell culture studies have shown that ultrafine particles can be rapidly carried throughout the body and will penetrate cells to induce oxidative stress and mitochondrial damage.

Health Effects Research Issues

- How much of the health effects associated with PM_{2.5} are actually caused by ultrafine PM?
 - Cardiovascular effects in the elderly (UC Irvine)
 - Cardiovascular effects from on-road exposures (UCLA)
 - Role in atherosclerosis (UC Irvine)
- USEPA PM Centers at UCLA, Rochester, and Harvard focus on ultrafine particle research

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Some of the effects seen in PM_{2.5} studies may be from the ultrafine fraction of the total fine PM since PM_{2.5} includes the ultrafine particulate. However, studies that examine both PM_{2.5} and ultrafine indicate that there are often different effects from the two fractions. This may be due to the particle sources or different properties that are typically associated with the fine vs. the ultrafine fractions. To evaluate this issue further, the ARB currently has three studies investigating ultrafine particle health effects.

Professor Delfino at UC Irvine will determine the health effect of air pollution on elderly persons living in the Southern California air basin.

An in-vehicle study conducted by Professor Hinds at UCLA will investigate cardiovascular health effects in healthy adults over 60 years old during exposures on the 405 and 710 freeways.

Professor Kleinman at UC Irvine will examine the effects of fine and ultrafine PM exposures on markers of vascular cell inflammation and the role of PM on the development of atherosclerosis in older normal and atherosclerotic prone mice.

The USEPA has established five particle research centers around the nation; three of which have ultrafine particles as a focus of their research program. UC Davis was also recently named one of the particle centers and will concentrate on studies in the San Joaquin Valley.

Exposure Recent Findings



- Exposure to ultrafine particles varies by location and time
 - Local sources can have a major impact
 - Ultrafine particle levels fall off rapidly near roadways
 - Much of your exposure occurs during daily commute

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The ARB has been investigating ultrafine exposure for several years. Completed ARB ultrafine particle exposure research has produced a number of new findings indicating a strong variation of particle concentrations and exposures between locations and over time on both daily and seasonal scales. From 2001 through 2004 the ARB operated one of the first ultrafine particle monitoring networks in the 12 communities participating in the Children's Health Study in Southern California. An important finding was the degree of variation of ultrafine particle concentrations at different locations. ARB supported research on the distance from freeways showed that the concentration of ultrafine particles fell off quite rapidly within the first several hundred meters from a freeway due to diffusion and combining into larger particles. This finding helped support the passage of a School Siting Bill authored by Senator Escutia.

Roadside, and especially in-vehicle studies have shown that the concentrations of ultrafine particles related to freeway driving may be quite high. We've estimated that over 50% of a person's daily exposure to ultrafine particles can occur during a commute on a freeway.

Exposure Research Issues

- What are community levels of ultrafine particles?
 - Ultrafine particles at LAX (UCLA)
 - Harbor Communities Monitoring Project
 - Community level monitoring (USC)
 - Mobile monitoring of spatial gradients (UCLA)

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Current ARB studies are expanding on these exposure findings. UCLA is monitoring ultrafine particles, black carbon, and PM_{2.5} in communities around LAX.

The ARB is coordinating multiple research efforts in the Harbor Communities Monitoring Project in the Wilmington/West Long Beach/San Pedro area to investigate the variations in number concentrations at a fine spatial and temporal scale and determine if freeway sound walls and tree lines have an important impact. Professor Siotas will lead the ultrafine particle portion of this project.

In a study, by Professor Winer at UCLA, an electric vehicle has been developed into a mobile monitoring platform to collect highly time- and spatially-resolved pollutant data near sources such as freeways, arterial roads, rail yards, refineries, and ports.

This study will start this fall and continue for one year.

Indoor Exposure Recent Findings



- Indoor sources can be important to ultrafine particle exposures
 - Indoor combustion sources contribute to ultrafine particle exposures
 - Indoor Air Chemistry: Ultrafine particles and formaldehyde are produced by terpene – ozone reactions

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Since most persons spend a substantial fraction of their time indoors, indoor air quality is also important in determining a person's pollutant exposure.

Indoor combustion sources such as cooking, woodburning, and candles can contribute to ultrafine exposure.

A recently completed study at UC Berkeley reported on the production of ultrafine particles and formaldehyde from indoor ozone-terpene reactions during the use of common cleaning products. Terpenes such as limonene and pinene are added to cleaning products as the solvent for their cleaning properties and as fragrance components.

Indoor Exposure Research Issues

- How much of the indoor exposure is due to indoor sources and how much to infiltration of outdoor particles?
 - Measurement of ultrafine particulate matter in classrooms and homes (UC Berkeley)
 - Emissions from office machines (UC Berkeley)

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Currently, we are researching how ultrafine particles get into the indoor environment. Indoor exposures can be divided into two sources: processes that occur in the indoor environment, and those that occur outdoors and infiltrate into the indoor environment.

Professor Nazaroff at UC Berkeley will measure ultrafine particles and related pollutants inside California classrooms and residences. The study will provide information on the infiltration of outdoor ultrafine particles to indoor environments. The investigators will also assess the indoor source contributions.

In a study by Professor McKone, the emissions from office machines such as computers, laser printers, and inkjet printers are being measured in controlled chambers.

Emissions and Controls

Recent Findings

- Sources:
 - Combustion, condensation, photochemistry, indoor sources

- Findings: The internal combustion engine is a prominent source of ultrafine particles
 - Gasoline/CNG/Diesel/Jet engines/etc.

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Sources of ultrafine particles are primarily combustion processes, which in most places in California means that mobile source internal combustion processes predominate; stationary combustion processes can also be significant sources. In addition, ultrafine particles can be formed through condensation of semi-volatile gases, secondary particle formation in photochemical processes, and in certain indoor sources and reactions.

Emissions and Controls

Research Issues

- **Characterization and quantification of mobile source emissions are still needed**
 - Toxicity of emissions from heavy-duty and light-duty vehicles (USC)
 - Evaluation of the European Particle Measurement Program (PMP) protocol (UC Riverside)
 - Source apportionment (UC Davis)

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With the evolution of engine designs, fuels, and aftertreatment control technologies; the emissions of ultrafine particles will change. The characterization and quantification of mobile source emissions remain an area of interest.

In the near term, ARB researchers, in collaboration with USC, UCLA, the South Coast AQMD, the National Renewable Energy Laboratory (NREL), and others are getting ready to investigate the physicochemical and toxicological characteristics of mobile source emissions at the ARB heavy-duty emissions laboratory in Los Angeles. Investigators will focus on both heavy- and light-duty vehicles for the various fuel and technology types expected on the road.

The ARB is also collaborating with key international players in the area of ultrafine particle emission measurements and new certification standards. The European particle measurement protocol (PMP) project has opened up a valuable opportunity for coordinated and focused scientific exchange on sampling methodologies for emissions of ultrafine particles.

An additional study is being performed by investigators at UC Davis and the University of Colorado to apportion sources of fine and ultrafine particles collected during two field studies. To support the source apportionment ultrafine particles from gasoline and heavy duty diesel vehicles were collected and analyzed and measurements were made of particle size and composition in the roadside environment.

Conclusion

- Ultrafine particles are a concern
- ARB is active in research into all aspects of ultrafine particles
- We will continue our research effort in the future

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In conclusion, the health impacts of ultrafine particles are still largely unknown, but the evidence being published in the scientific literature increasingly indicates that they can be a significant source of risk to respiratory and cardiovascular health. The ARB research program is investigating the health impacts and the sources and properties of these particles. Our studies will help the board to evaluate the risks associated with ultrafine particles and develop policies consistent with these risks.

Thank you for your attention. I will be happy to answer any questions that you may have.