REPORT ON THE MAY 9, 2012 ADVISORY COUNCIL MEETING ON ULTRAFINE PARTICLES: EXPOSURE ASSESSMENT

SUMMARY

The following presentations were made at the May 9, 2012 Advisory Council meeting on Ultrafine Particles: Exposure Assessment:

1. Indoor Exposure to Particles from Cooking, Cleaning and Smoking by Lynn M. Hildemann, Ph.D. Dr. Hildemann is an Associate Professor at Stanford University in the Environmental Engineering and Science Program of the Department of Civil and Environmental Engineering Department. Professor Hildemann's research interests include atmospheric chemistry, characterization of source emissions, dispersion modeling, and indoor air pollutants. She is currently studying the sources, chemistry and fate of organic pollutants, with a focus on aerosols. Major areas of research include investigating the sources and size distributions of indoor particulate matter (including allergens), and characterizing the uptake of water by organic aerosols. She has published more than 30 articles on her research.

2. Toward Understanding Ultrafine Particle Exposures in Indoor Environments by William W. Nazaroff, Ph.D. Dr. Nazaroff is a Professor of Engineering in the Department of Civil and Environmental Engineering at the University of California, Berkeley. Professor Nazaroff's research group studies the physics and chemistry of air pollutants in proximity to people, especially in indoor environments, in the domain of exposure science, stressing the development and application of methods to better understand mechanistically the relationship between emission sources and human exposure to pollutants. Professor Nazaroff presently serves as editor-in-chief of Indoor Air, president of the American Association for Aerosol Research (AAAR), president of the Academy of Fellows in the International Society of Indoor Air Quality and Climate (ISIAQ), and member of the California Environmental Protection Agency's Scientific Review Panel on Toxic Air Contaminants. He has published 130+ articles on his research.

KEY POINTS

As was pointed out by the speakers, the studies summarized herein represent small convenience samples. Until confirmation studies are conducted, broad extrapolation is not warranted. Additionally, the studies did not follow occupants in their activities outside of the home or school, so it is not possible to know how in-home or in-school exposures compared to exposure levels in other locations throughout the rest of a typical day (including in transit or outdoors).

Dr. Lynn M. Hildemann

- Dr. Hildemann presented study results on three aspects of indoor air quality that she posed as the greatest exposure risks related to indoor Ultrafine Particles (UFPs; See Glossary for all acronyms): use of scented cleaning products, presence of combustion sources, and proximity of human receptors to sources.

- "Ingredients" for high UFP exposures include: Presence of gaseous pollutants (from combustion or chemical reactions) likely to condense, low ambient $PM_{2.5}$ concentrations (so gases will form UFP rather than condensing onto larger PM), and fresh UFP emissions that have not yet coagulated (i.e., combined to form larger particles).

- Scented cleaning produc**ts**: Products containing citrus-scented limonene or other terpenes (often pine-scented) can chemically react in the presence of moderate ozone levels (from outdoors) to form UFP. If used, these products should be limited to off- peak (morning or evening) ozone periods, and windows should be opened and rooms vacated afterwards.

- Indoor combustion sources include clothes dryers, cigarette smoking, and cooking:

    - Clothes dryers can contribute to indoor UFP levels due to imperfect venting, especially at startup. Elevated UFP levels can persist for a couple hours.
    - In one study of casino air quality, UFP particle number concentrations were more than three times greater in indoor smoking areas than outdoors. UFP concentrations in nonsmoking indoor areas varied greatly, based on the extent to which the location was influenced by outdoor air or drift from adjoining rooms.
    - Cooking various foods on an electric cooktop, UFP number concentrations were detected at levels up to 10 times greater than the ambient indoor air. UFP emissions from some foods were comparable to emissions from cigarette smoking. The warm cooktop itself generated initial UFP levels almost as high as from the food. In the absence of a range hood vented to the outdoors, elevated UFP levels from food persisted for an hour or more.

- UFP exposure levels are generally correlated with proximity to source**,** but micro environmental factors can influence exposure levels:

    - Air circulation patterns in an indoor environment affect dilution levels and can have a greater effect than distance. (For example, a nonsmoker can have nearly the same exposure as a smoker, depending on position and air circulation.) Mechanical ventilation systems generally tend to more effectively promote vertical mixing and dilution of indoor air than simply opening windows.
    - In two exploratory outdoor studies comparing cigarette smoke exposure to motor vehicle emission exposure, subjects on the sidewalk of an arterial

road within 1.5 m of a smoker were exposed to high UFP levels while a cigarette was smoked. Along roadways with fewer heavy-duty trucks, UFP exposure from nearby cigarette smoke was much greater than UFP exposure from traffic. However, traffic-related UFP along roadways with a high proportion of heavy-duty vehicles generated UFP levels of similar magnitude as UFP from cigarette smoke. These results illustrate the potential importance of UFP exposure from both secondhand smoke and roadways.

<u>Dr. William W. Nazaroff</u>

- Dr. Nazaroff presented results of two studies that characterized indoor UFP and co-pollutant levels in a small number of typical East Bay houses and schools.

- Studies involved monitoring and occupant surveys to characterize indoor air quality and also to quantify exposure of occupants**,** based on time and duration of occupancy.

- Study in seven non-smoking houses:
    - A variety of indoor sources contributed to UFP levels, with both gas and electric cooking appliances (stoves and ovens) contributing UFPs in all cases. Other sources (though not contributing in all cases) included gas clothes dryers, gas furnaces, toasters or toaster ovens, irons, and candles.
    - Approximately half the UFPs contained in outdoor air infiltrated into the homes. Over the course of the day and night, these outdoor-origin particles contributed ~30% of the average resident's indoor exposure to UFPs, with the remaining 70% of daily indoor UFP exposure associated with indoor sources. The majority of these indoor sources were associated with peak events that occurred when the residents were home and awake (i.e., cooking or other activities under their control).
    - In some cases particle counts were actually higher upstairs, away from UFP sources, because warm air rises, carrying UFPs with it.

- Study in six classrooms in four schools:

    - Compared to homes, which have more indoor sources of UFP, there was not as strong a correlation of indoor occupancy to high UFP exposure (exceptions: cooking activity in classrooms and custodial activities).
    - During outdoor peak UFP periods, particle counts within classrooms were somewhat lower than outdoors. However, UFP counts in the classroom during occupied periods generally fluctuated along with outdoor UFP counts, because classroom windows tended to be open when the rooms were occupied.
    - When doors were closed and HVAC off, an average of 38% (ranging from 16% to 51%) of the UFPs contained in outdoor air infiltrated into the classroom. When doors/windows were open and/or HVAC on, an average

of 60% (ranging from 51% to 76%) of the UFPs contained in outdoor air infiltrated into the classroom.

- Other air quality issues exist at schools besides PM counts, but this study suggests an opportunity for effective air filtration and ventilation techniques, as well as for greater attention to custodial practices, to help improve air for children and staff at school. A more detailed cost-effectiveness evaluation of air filtration should be performed.

<u>EMERGING ISSUES FROM THE ADVISORY COUNCIL</u>

1. Dr. Hildemann and Dr. Nazaroff agreed that much of a typical person's total UFP exposure occurs indoors, since indoor concentrations of UFP in residential settings can in some cases be significantly higher than outdoors, and the average Californian spends approximately 90% of their time indoors.

2. The apportionment of indoor and outdoor sources of indoor UFPs can be highly variable, depending on factors such as location, building type, building ventilation system, and occupant behavior. A need exists to better understand the relative contribution of indoor and outdoor UFP sources to indoor UFP levels.

3. Similar to UFPs in outdoor environments, indoor UFPs can exhibit high spatial and temporal variability due to micro environmental factors, presenting challenges to the use of traditional measurement techniques.

4. Not all UFPs have equal health impacts. Although the science is still evolving and there is not yet enough data, it has been suggested, for example, that insoluble UFPs may be a greater health concern than highly soluble UFPs.

5. Despite these uncertainties, and although we can not totally eliminate UFP exposure, it is possible to mitigate exposure from both indoor and outdoor sources through a combination of source reduction, managing proximity to sources, and effective ventilation and air filtration to reduce both ambient and episodic UFP levels. Additional information is needed regarding effective mitigation techniques, including ventilation and filtration.

<u>ADVISORY COUNCIL RECOMMENDATIONS</u>

The following Advisory Council recommendations to the Board are based on the above presentations and subsequent discussions among Advisory Council members. The Air District should:

1. Encourage further research on indoor UFP exposures, health effects, and the interaction of indoor and outdoor UFP sources that considers issues, such as:
   a. Better define health impacts and relative risks from different types of UFPs, as well as from different exposure levels (e.g., episodic exposures vs. average exposures).

b. Use of a total exposure methodology (considering duration and peak levels of exposure) can help identify priorities for mitigation and public education, and help integrate research on indoor UFP exposure with research on outdoor UFP exposure. Attention should be given to existing research on occupational exposures (e.g., cleaning products) and cumulative exposure to secondhand smoke, as well as to exposure expected from different types of commute patterns (car, bike, mass transit).

c. Assess variations in UFP concentration and type from seasonal air quality impacts associated with ozone and smoke (e.g., fireplaces, wood stoves, campfires, charcoal grills) and their effect on indoor UFP exposures.

2. Encourage regional partners to determine ventilation and filtration methods most effective at removing UFPs in different building types, while also being energy efficient and cost effective in the range of Bay Area climates.

   a. The Air District should share findings with regional planning and public health departments to provide uniform guidance so that those involved with designing, building, and maintaining buildings are aware of best practices in reducing occupant exposure to UFPs (through ventilation, effective filtration, building siting and landscape design, custodial practices, etc.).
   b. Prioritize adoption of best practices for ventilation and filtration in schools.

3. Integrate information on indoor UFP exposure into existing Public Education and Outreach efforts. Concepts for integration may include awareness about individuals' ability to reduce UFP levels in the home, as well as the potential to reduce or mitigate exposures in schools, workplaces, and outdoors:

   a. Limonene or other terpene cleaning products (e.g., citrus and pine scented products) can react with ozone in the air to form UFPs as well as formaldehyde, and are themselves respiratory irritants. Encourage building owners and employers to switch to unscented and safer cleaning products. Urge those with any degree of respiratory impairment to avoid use of cleaning products and air fresheners with these scenting agents. Educate the public and those with occupational exposures (including domestic workers) about these products and their proper use. Avoid using these products mid-day or other times when ozone levels are high, but be aware that even moderate ozone levels can cause these chemical reactions.

   b. Build on existing awareness about the health effects of cigarette smoke to give advice about good cooking and ventilation practices: Turn on the ventilation hood when the stove or oven are in use. Limit the time that those with asthma, lung, or heart disease spend in kitchen while cooking, and ventilate and vacate kitchen for a while after cooking. Encourage adoption of quieter stove hood fans and avoid use of recirculating fans. Educate the public about high UFP levels from stoves or ovens containing pilot lights or self-cleaning features.

c. Secondhand smoke can contribute significantly to indoor or outdoor UFP concentrations. Living with a smoker can expose one to levels of $PM_{2.5}$ that exceed AAQS.

4. Continue to integrate knowledge of indoor and outdoor UFP exposure and health effects into the Air District's existing PM program.

GLOSSARY

AAQS: Ambient Air Quality Standard

HVAC: Heating, Ventilation, and Air-Conditioning

Micrometer, or micron: One millionth of a meter; used as measure of particle diameter

nm: nanometer: One billionth of a meter; used as measure of particle diameter; generally 1-5 atomic diameters

PM: Particulate matter, typically PM smaller than 10 or 2.5 microns; largest $PM_{2.5}$ is 25 times larger than diameter of largest UFP

UFP: Ultra Fine Particulate, smaller than 100 nm (or 0.1 micron)