



BAY AREA  
AIR QUALITY  
MANAGEMENT  
DISTRICT

## ADVISORY COUNCIL MEETING

WEDNESDAY  
NOVEMBER 9, 2011  
9:00 A.M.

7<sup>TH</sup> FLOOR BOARD ROOM  
939 ELLIS STREET  
SAN FRANCISCO, CA 94109

### AGENDA

#### CALL TO ORDER

Opening Comments  
Roll Call

Ken Blonski, Chairperson  
Clerk of the Board

#### PUBLIC COMMENT PERIOD

*Public Comment on Non-Agenda Items, Pursuant to Government Code Section 54954.3. The public has the opportunity to speak on any agenda item. All agendas for Advisory Council meetings are posted at the District, 939 Ellis Street, San Francisco, at least 72 hours before a meeting. At the beginning of the meeting, an opportunity is also provided for the public to speak on any subject within the Council's purview. Speakers are limited to three minutes each.*

#### CONSENT CALENDAR

1. Approval of Minutes of the October 12, 2011 Advisory Council meeting.

#### DISCUSSION

2. Discussion of draft report on the Advisory Council's October 12, 2011 meeting.

*The Advisory Council will discuss the draft report on the October 12, 2011 meeting on Ultrafine Particles: Characterization of Mobile Source Emissions and Related Health Effects with Air District staff and finalize the recommendations.*

3. Discussion, Recommendation and Selection of Slate of Officers for 2012

*The Advisory Council will discuss, recommend and select a Slate of Officers for 2012.*

## **OTHER BUSINESS**

### 4. Chairperson's Report

Ken Blonski, Chair

### 5. Council Member Comments/Other Business

*Council Members may make a brief announcement, provide a reference to staff about factual information, or ask questions about subsequent meetings.*

### 6. Time and Place of Next Meeting

*At 9:00 a.m., Wednesday, January 11, 2012, at 939 Ellis Street, San Francisco, CA 94109.*

### 7. Adjournment

**CONTACT EXECUTIVE OFFICE - 939 ELLIS STREET SF, CA 94109**

**(415) 749-5130**  
**FAX: (415) 928-8560**  
**BAAQMD homepage:**  
**[www.baaqmd.gov](http://www.baaqmd.gov)**

- To submit written comments on an agenda item in advance of the meeting.
- To request, in advance of the meeting, to be placed on the list to testify on an agenda item.
- To request special accommodations for those persons with disabilities notification to the Clerk's Office should be given in a timely manner, so that arrangements can be made accordingly.
- Any writing relating to an open session item on this Agenda that is distributed to all, or a majority of all, members of the body to which this Agenda relates shall be made available at the District's offices at 939 Ellis Street, San Francisco, CA 94109, at the time such writing is made available to all, or a majority of all, members of that body. Such writing(s) may also be posted on the District's website ([www.baaqmd.gov](http://www.baaqmd.gov)) at that time.

**BAY AREA AIR QUALITY MANAGEMENT DISTRICT**  
**939 ELLIS STREET, SAN FRANCISCO, CALIFORNIA 94109**  
**(415) 771-6000**

**EXECUTIVE OFFICE:**  
**MONTHLY CALENDAR OF DISTRICT MEETINGS**

**NOVEMBER 2011**

<u>TYPE OF MEETING</u>	<u>DAY</u>	<u>DATE</u>	<u>TIME</u>	<u>ROOM</u>
<b>Board of Directors Mobile Source Committee</b> <i>(At the Call of the Chair)</i> - CANCELLED	Tuesday	8	9:30 a.m.	4 <sup>th</sup> Floor Conf. Room
<b>Advisory Council Meeting</b> <i>(Meets 2<sup>nd</sup> Wednesday each Month)</i>	Wednesday	9	9:00 a.m.	Board Room
<b>Board of Directors Personnel Committee</b> <i>(At the Call of the Chair)</i>	Monday	14	9:30 a.m.	4 <sup>th</sup> Floor Conf. Room
<b>Board of Directors Regular Meeting</b> <i>(Meets 1<sup>st</sup> &amp; 3<sup>rd</sup> Wednesday of each Month)</i>	Wednesday	16	9:45 a.m.	Board Room
<b>Board of Directors Mobile Source Committee</b> <i>(Meets 4<sup>th</sup> Thursday each Month)</i> - CANCELLED	Thursday	24	9:30 a.m.	4 <sup>th</sup> Floor Conf. Room
<b>Board of Directors Mobile Source Committee</b> <i>(Meets 4<sup>th</sup> Thursday each Month)</i>	Monday	28	9:30 a.m.	4 <sup>th</sup> Floor Conf. Room
<b>Board of Directors Stationary Source Committee</b> <i>(At the Call of the Chair)</i> - CANCELLED	Monday	28	Immediately Following Mobile Source Cme.	4 <sup>th</sup> Floor Conf. Room

**DECEMBER 2011**

<u>TYPE OF MEETING</u>	<u>DAY</u>	<u>DATE</u>	<u>TIME</u>	<u>ROOM</u>
<b>Board of Directors Regular Meeting</b> <i>(Meets 1<sup>st</sup> &amp; 3<sup>rd</sup> Wednesday of each Month)</i>	Wednesday	7	9:45 a.m.	Board Room
<b>Board of Directors Budget &amp; Finance Committee</b> <i>(At the Call of the Chair)</i>	Wednesday	14	9:30 a.m.	4 <sup>th</sup> Floor Conf. Room
<b>Board of Directors Executive Committee</b> <i>(At the Call of the Chair)</i>	Monday	19	9:30 a.m.	4 <sup>th</sup> Floor Conf. Room
<b>Board of Directors Regular Meeting</b> <i>(Meets 1<sup>st</sup> &amp; 3<sup>rd</sup> Wednesday of each Month)</i>	Wednesday	21	9:45 a.m.	Board Room
<b>Board of Directors Mobile Source Committee</b> <i>(Meets 4<sup>th</sup> Thursday each Month)</i> - CANCELLED	Thursday	22	9:30 a.m.	Board Room

## JANUARY 2012

<u>TYPE OF MEETING</u>	<u>DAY</u>	<u>DATE</u>	<u>TIME</u>	<u>ROOM</u>
<b>Board of Directors Regular Meeting</b> <i>(Meets 1<sup>st</sup> &amp; 3<sup>rd</sup> Wednesday of each Month)</i>	Wednesday	4	9:45 a.m.	Board Room
<b>Board of Directors Stationary Source Committee</b> <i>(At the Call of the Chair)</i>	Monday	9	9:30 a.m.	4 <sup>th</sup> Floor Conf. Room
<b>Advisory Council Meeting</b> <i>(Meets 2<sup>nd</sup> Wednesday each Month)</i>	Wednesday	11	9:00 a.m.	Board Room
<b>Special Board of Directors Regular Meeting / Retreat</b> <i>(Meets 1<sup>st</sup> &amp; 3<sup>rd</sup> Wednesday of each Month)</i>	Wednesday	18	9:45 a.m.	San Pablo, CA
<b>Board of Directors Mobile Source Committee</b> <i>(Meets 4<sup>th</sup> Thursday each Month)</i>	Thursday	26	9:30 a.m.	4 <sup>th</sup> Floor Conf. Room
HL – 11/2/11 (2:00 p.m.)				P/Library/Forms/Calendar/Calendar/Moncal

BAY AREA AIR QUALITY MANAGEMENT DISTRICT  
Memorandum

To: Chairperson Blonski and Members  
of the Advisory Council

From: Jack P. Broadbent  
Executive Officer/APCO

Date: November 3, 2011

Re: Advisory Council's Draft Meeting Minutes of October 12, 2011

RECOMMENDED ACTION:

Approve attached draft minutes of the Regular Advisory Council's meeting of October 12, 2011.

DISCUSSION

Attached for your review and approval are the draft minutes of the October 12, 2011 Advisory Council meeting.

Respectfully submitted,

Jack P. Broadbent  
Executive Officer/APCO

Prepared by: Vanessa Johnson  
Reviewed by: Jennifer C. Cooper

Bay Area Air Quality Management District  
939 Ellis Street  
San Francisco, CA 94109  
(415) 749-5000

## **DRAFT MINUTES**

Advisory Council Regular Meeting  
Wednesday, October 12, 2011  
9:00 a.m.

### **CALL TO ORDER**

**Opening Comment:** Chairperson Blonski called the meeting to order at 9:05 a.m.

### **ROLL CALL**

**Present:** Chairperson Ken Blonski, M.S., Vice Chairperson Stan Hayes, Secretary Robert Bornstein and Council Members Sam Altshuler, Ph.D., Benjamin Bolles, Jeffrey Bramlett, Harold Brazil, Jonathan Cherry, John Holtzclaw, Ph.D., Gary Lucks JD, CPEA, REA, Liza Lutzker, Jane Martin, Ph.D., Kendall Oku, and Jonathan Ruel were in attendance.

**Absent:** Council Members Jenny Bard, Louise Bedsworth, PhD., Alexandra Desautels, Kraig Kurucz, and Dorothy Vura-Weis, M.D., M.P.H. were absent.

**Public Comment Period:** There were no public comments.

### **CONSENT CALENDAR**

#### **1. Approval of Minutes of the September 14, 2011 Advisory Council Meeting:**

**Council Action:** Mr. Holtzclaw made a motion to approve the minutes of September 14, 2011, and Mr. Hayes seconded the motion; carried unanimously without objection.

**PRESENTATION: ULTRAFINE PARTICLES****2. Ultrafine Particles: Characterization of Mobile Source Emissions and Related Health Effects****A. Internal combustion engine generated particles: formation, measurement, trends, and knowledge gaps.**

Alberto Ayala, PhD, MSE  
Chief, Monitoring and Laboratory Division  
Air Resources Board  
California Environmental Protection Agency

Jean Roggenkamp, Deputy APCO, introduced and gave a brief background of Alberto Ayala, PhD, MSE, Chief, Monitoring and Laboratory Division Air Resources Board, California Environmental Protection Agency.

Dr. Ayala began his presentation on Internal Combustion Engine Generated Particles: formation, measurement, trends, and knowledge gaps and its historical perspective. He said the knowledge gaps highlighted include particles generated from internal combustion emissions.

Dr. Ayala explained that 1950s Ken Whitby and Bruce Cantrell both of the University of Minnesota, discovered the tri-modal distribution of the aerosol in ambient air. Dr. Ayala stated that a lot is known about ambient aerosols including the source, specifically the motor vehicle source, and what causes these particles, how they are measured and what can be done about reducing them..

Source attributions include:

- Surface coating – 0.2%,
- On-Road vehicles – 43.1%,
- Other mobile sources – 10.4%,
- Waste burning – 1.3%,
- Other industrial processes – 7.2%,
- Miscellaneous processes – 5.2%,
- Petroleum industry – 0.5%; and
- Stationary fuel use – 32.2%

In addition, Dr. Ayala stated that motor vehicle contribution to ambient mass concentration is 17%. He also said the problem is not as it once seemed and that precursors in ambient air lead to secondary formation. On a clear day when air quality appears to be at its best, there are secondary formation of aerosols, which are small particles and are not easy to detect.

The tools being developed to better understand the formation and dispersion of these particles are coming along.

Dr. Ayala said from a health standpoint that the latest and best assessment in terms of ultrafine particles versus fractions of the particulate matter is the integrated science assessment that the U.S. Environmental Protection Agency (EPA) just released. The California Air Resources Board (CARB) needed and was able to utilize in its own diesel assessment program. Before any action can be taken, one need is to find out the concern from a health perspective.

Dr. Ayala continued stating when the study was initially conducted it was everyone's theory that this was a diesel only problem, but after 10-15 years of research it was understood that this was the case. Anytime there is internal combustion, there is the potential to form particles. Complete combustion of gas is particle free, but anytime fossil fuel is burned in an engine there will be a need for lubricating oils, some incomplete combustion and a need for after-treatment controls.

He also stated when it comes to motor vehicle emissions the historical marker comes from a study that Susan Bagley and John Johnson of Michigan Technological University (MTU) conducted in 1996. The key issue they came across was that newer diesel engine technology for reduced the total mass emissions but it increased the number of the various small particles, and the end result was an increase in the very small particles resulting in an increase in the total number of particles.

Dr. Ayala stated the Children's Health Study is the first time CARB tried to look at the issue of seasonality and the spatial distribution of ultrafine particles and ambient air. Dr. Ayala stated there are short term acute impacts which everyone is aware of, but the question is what happens long term. The need is for better tools to assess exposure.

He said if we are interested in reducing emissions, we should also concern ourselves not only with the engines and fuel, but lubricating oil, activity and other factors that will come into play. In addition, there is an issue of proximity to the sources. If you are planning to get close to the roadway you are bound to see higher emissions. In addition, ultrafine particles are not emitted by themselves, but they are usually in a mixture of emissions and this matters from a health standpoint.

Dr. Ayala said CARB is in the process of rulemaking for the next set of car standards, and is working closely with the Federal Government in specifically looking at the light duty fleet. The light duty fleet is primarily gasoline powered. An effort is being placed on understanding gasoline particulate matter (PM) emission from conventional technology and from a chemistry perspective. If you look at the carbon fraction most of the emissions from conventional gasoline engines are organic in nature with minimal soot. Particles are not a diesel only problem. A recent study shows a chase experiment which consists of a mobile lab that follows a vehicle of interest. While conducting this test, it was determined that under acceleration a car can emit lots of small particles. If you review the particles smaller than 300 nanometers, the excess emissions



from the gasoline fleet under acceleration have particle concentrations just as high as what you see in diesel fleet.

Dr. Ayala stated he is working to determine how much lube oil can contribute to PM, and this work is being conducted at Southwest Research. Looking ahead, gasoline technology, because of the emphasis on the reduction of greenhouse gases, is going to evolve into gasoline direct injection Gasoline Direct Injection (GDI). This means that diesel is very efficient so a gasoline engine should run like a diesel engine. However, benefit of better CO<sub>2</sub> emissions comes from upward pressure on PM emissions. There is an emphasis in the United States and Europe to focus on understanding the impacts and tweaks that can be made to the engine and whether there is there after treatment that can be considered.

He said he feels car makers will be able to deploy this with minimal or no cost. The selling point about GDI is better fuel economy like diesel, but the emissions resemble a diesel because there is more soot and black carbon than organic carbons. The key question is how diesel-like features can be reduced. Dr. Ayala shows a comparison of particle mass / particle number (PM/PN) and stated the low emission choices are the current technology which is the port fuel injection (PFI) gasoline engines. He said if you put a diesel particle filter (DPF) on a GDI then those emissions would be eliminated. Mr. Bornstein requested Dr. Ayala explain the acronyms. Dr. Ayala stated compressed natural gas (CNG), gasoline direct injection (GDI) and diesel particle filter (DPF) diesel.

Dr. Ayala stated biodiesel has different blends and feed stocks, and depending on the blend and the feed stock there will be different PM emissions. For example, an engine without control versus an engine with control is consistent with what has been seen in the past, which is that the control technology is reducing emissions, and that blends with higher proportions of the biodiesel is going to reduce PM emissions.

The alternative fuel CNG is the most current compliant technology because it is advanced, has better combustion, has after treatment and has very low emissions that are very hard to measure. There are many factors that influence emissions, which include:

- Ambient conditions,
- Engine design,
- Driver,
- Lubricating oil,
- Other factors,
- Maintenance,
- After treatment,
- Activity, and

- Fuel

Diesel PM consists of:

- Heterogeneous mixture of fuel injected into hot compressed air
- Fuel rich/oxygen deficient regions
- High temperature/pressure breaks down fuel before combustion
- Pyrolysis (high temperature cracking reaction) leads to formation of soot
- Condensation of unburned and partially burned species
- Agglomeration
- Visible smoke

Diesel PM is comprised of sixty percent of diesel PM is carbon, five percent is ash, ten percent is sulfate and water, twenty percent is lube oil soluble organic fraction (SOF) and five percent is fuel SOF. Dr. Ayala stated if you want to reduce emissions, you would include an after treatment and the after treatment technology has become more advanced. Moving from diesel oxidation catalyst to the partial filters to the most current, the diesel particle filters, is complete elimination of soot.

Dr. Ayala mentioned that diesel particles are not perfect spheres and are not just carbon, but that there are many things associated with them and embedded in all of this are precursors that can actually lead to aerosol particles. He said you do not need a lot of sulfur in the fuel to obtain formation of small particles, as this does not count for much of the mass.

He continued stating a filter can be effective at controlling particles of all sizes and that number of particles coming from a DPF equipped diesel can be very low under certain conditions. If a filter is added particles of all sizes are eliminated. In addition to PM control, there is a need for nitrogen oxides (NO<sub>x</sub>) control and the industry has chosen the technology solution known as Selective Catalytic Reduction (SCR).

Dr. Ayala stated there are now tools which allow one to follow the particle size distribution, as well as the total concentration in real time as it is emitted from the vehicle. Dr. Ayala said with a vehicle running at 50 miles per hour, it shows a lot of catalytic action, high exhaust temperature, sufficient precursors in the exhaust which leads to formation of small particles, some less than 20 nanometers. Dr. Ayala stated these are volatile particles, which explains the sharp gradient seen in ambient air. In addition, the size distribution is different for the technology that has the high concentration, but when heated, the concentrations are lower.

Dr. Ayala mentioned that the Conception Model for Particle Formation is whether or not sulfur is in the form of SO<sub>2</sub> or the particle form. Dr. Ayala provided an example of a basic model depicting when nucleation occurs in the heavy duty diesel engine (HDDE) with after treatment. The important factors are catalyst, catalyst storage, and SO<sub>2</sub> to SO<sub>3</sub> conversion.

He mentioned the biggest challenge with engines is cold start emissions, as this exceeds by far the total emissions that you generate while driving. Dr. Ayala emphasized that cold start emissions are something to be concerned about.

Dr. Ayala said people ask what can be done in the lab to conduct a measurement that is a representative of what the health concern would be. Dr. Ayala stated that the emissions from different technologies are run through different assays. These are cellular assays that health experts stated were good ideas to look at when assessing emissions.

Dr. Ayala concluded his presentation and thanked the Council for the opportunity. Chair Blonski thanked Dr. Ayala for the comprehensive overview.

- B. Semi-volatile components of fine and ultrafine particles: Do they exacerbate airway allergies, promote development of cardiovascular disease and induce inflammation in the brain?  
Michael T. Kleinman, PhD  
Professor  
Division of Occupational and Environmental Health  
University of California, Irvine

Jean Roggenkamp, Deputy APCO, introduced and gave a brief background of Michael Kleinman, PhD, Professor, Division of Occupational and Environmental Health, University of California, Irvine.

Dr. Michael Kleinman said he could talk about a complex set of studies involving large numbers of people as this is team collaboration.

Dr. Kleinman stated that epidemiological studies link air pollution to cardiovascular disease. The studies show the following:

- An increase in air pollutants leads to increased mortality and hospital admissions because of cardiovascular diseases (Analitis A. et al. 2006, Zanobetti et al. 2003, Dominici et al. 2006, Peel et al. 2007)

- Exposure to elevated levels of particulate matter (PM) in ambient air leads to an increased heart rate (HR) and a decreased heart rate variability (HRV) in elderly patients (Dubowsky Adar S. et al. 2007, Luttmann-Gibson et al. 2006)
- Individuals in the >65 year-old age bracket are more susceptible to air pollution-associated heart-related morbidity and mortality

Dr. Kleinman cited relevant health components associated with urban air, some of which include:

- Emissions from power plants, motor vehicles, dust.
- Pollutants gases:
  - Ozone and NO<sub>2</sub> are major problems in California.
  - SO<sub>2</sub> and organic vapors are also important.
- Particles or Particulate Matter (PM):
  - Particles are associated with increased heart-related deaths during air pollution episodes.
  - Toxicology studies show that PM<sub>2.5</sub> accelerates the development of atherosclerosis.
  - The strongest associations with human heart-related illness and death are with PM.

He stated that human studies are very important and epidemiological studies are currently the gold standard for setting regulatory limits, but in order to develop relationships direct measurements need to be conducted. Although human clinical studies can be conducted, where you can control exposures and look at short term effects, when you attempt to look at the mechanisms and its long term effects, animal models are used.

Dr. Kleinman stated he has used animal models for various kinds of human diseases or human states. Dr. Kleinman said he has conducted studies with aged rats, in particular geriatric rats that are close to the end of their normal life expectancy and studies with animals with hypertension.

He mentioned these studies are conducted in the ambient air. The animals are placed in sealed chambers, the chambers are loaded on a cart with an air purification system and the cart is rolled into a van, which is driven to various locations. Studies have been conducted next to freeways and at various distances from freeways, as well as various locations in Southern California. He also stated studies were conducted in Mexico City.

Dr. Kleinman stated they installed a device similar to the installation of a pacemaker. This radio device was hooked to an electrocardiograph miniaturized to about the size of a thumbnail, and with a magnet attached to the device, it could be turned on or off and it could broadcast the

cardiograph 24 hours a day. The measurement included EKG's and blood pressure. This test can be conducted during or after exposures, and this allows for a comprehensive study.

He stated the same endpoints could be measured as in humans which include:

- Biochemistry
  - Blood Samples
    - Acute phase proteins
    - Cytokines
  - Expired Breath
- Cardiac Physiology
  - Heart Rate and Heart Rate Variability (HRV)
  - Blood Pressure
    - Systolic
    - Diastolic
    - Mean
  - Developed Pressure
  - Contractility
- Molecular Biology
  - Gene/protein expression from lung, heart, brain
  - In-situ hybridization for effects localization

Dr. Kleinman stated these systems can be deployed almost anywhere and in various circumstances. Examples of these locations are:

- Wildfires in Southern California
  - Rats exposed before, during and after the fires.
    - spontaneously hypertensive (SHR)
    - pithed normotensive (WKY)
  - Cardiac Physiology Monitored During Exposures.
- Allergy Studies Near a Freeway

He said the blood pressure was measured in two types of rats, one type who had high blood pressure and the other type with normal pressure. The study shows that as the blood pressure dropped, the heart rate also dropped, which meant there was a substantial decrease in cardiac output, which is not good from a health standpoint.

Dr. Kleinman said he used a model called the Langendorff System, where beating heart is suspended, kept alive and perfused with media. The cardiac output is measured as well as the amount of pressure it develops and the heart rhythms. Then somewhere between 1 and 10

micrograms of ultrafine particles is injected into the perfusate. As a result, there was a dramatic effect of the heart.

Another model was also used with asthma as an endpoint that can be developed two weeks after exposure, as opposed to a couple of months of exposure with the cardiac model. This study looked to see if particles increased the tendency of the animals to become allergic to an antigen.

He also noted that some results are difficult to explain. For example, near roadway exposures with (~50 m) induced airway allergies in mice but effects were not significant at greater distances (~150 m). An aerosol mass spectrometer (AMS) to analyze ambient and quasi-ultrafine concentrated ambient particles (CAPs) and a thermal denuder to strip semi-volatile components from CAPs. An AMS is a device that determines particles down to nanometer sizes and then conducts chemical analysis on the individual particles and sorts the data to a functional particle size. CAPs are run through a thermal denuder to remove the organics. The denuder heats the particles, then the particles come out and the animals are exposed to the naked particle. The naked particle contains carbon and metallic components without almost any loss, but what is lost is about 50% or more of the actual mass therefore leaving most of the ultrafine mass as organic. Dr. Kleinman provided a summary of what happens when you denude quasi-ultrafine CAPs:

- Particle number and mass are reduced.
- Refractory constituents, such as heavy metals and elemental carbon, were only marginally affected by heating.
- Labile species such as total and water soluble organic carbon and PAHs showed progressive loss in concentration with increase in thermal denuder (TD) temperature.

What happened to the animals and their heart rate variability (HRV)? The air exposed animals over an eight week period had no change in HRV, but there was a small change to the animals that were exposed to the denuded particles. Yet, when looking at the un-denuded particles which the organics attached to them, there is a very dramatic drop in HRV and this is a chronic effect accumulated over the course of an eight week period, and is not just a transient affect. Dr. Kleinman briefly mentioned the effect of aortic plaque, stating plaque is expected in the animals based on their cholesterol level and they will get some plaque, but the ones exposed to the un-denuded particles had a huge amount of plaque.

He provided a summary of the environmental effects on the brain which include:

- Degenerative brain disease incidences are increasing and may be irreversible.
- There is increasing evidence of environmental interactions in the rising disease rates.
- Mechanisms are elusive, at best.

Some of the key cells that make dopamine in the brain were dead so there is an association between PM exposure and brain damage. Dr. Kleinman stated there were numerous questions when asked relative to brain damage. The following are some of the questions:

- Does inhalation represent a “privileged” route of entry for pollutants that affect the brain?
- Is uptake to the brain from the respiratory tract greater than by other routes?
- Can inhaled PM or PM components bypass normal mechanisms that control uptake of toxic chemicals in the brain?
- Can pollutants access the brain directly by transport along the olfactory nerve?
- Do cytokines and other mediators released from the respiratory tract after PM deposition make the blood brain barrier more permeable to toxic pollutants?
- Do free radicals generated in the brain by the action of PM or PM components mediate damage to neurons?

Dr. Kleinman stated that ultrafine particles deposit in the upper respiratory tract very efficiently, in fact they deposit in both the upper and lower respiratory tract. Once deposited, they can move through the mucus layer by diffusion and get into the ends of cells and migrate and get into the brain.

He also stated inhalation of fine and ultrafine particles injures or kills cells in the brain that make dopamine from tyrosine hydroxylase in the region called the substantia nigra. This may be due to glial fibrillary acidic protein (GFAP). In addition, Mr. Kleinman said both fine and ultrafine particles can cause inflammatory responses in the brain, which can be identified by measuring increased levels of the cytokines TNF-alpha in the brains of CAPs exposed mice.

Dr. Kleinman stated when conducting studies you want to see that there is some dependence on dose. He conducted a study of diluted concentrations of ambient particles and identified two very prominent markers of an inflammation different than TNF-alpha. The high concentration of CAP 15, which had about four times as much concentration in terms of mass as CAP 4, had the greatest affect, but there is an affect at the lower CAP 4 concentration.

Dr. Kleinman presented a slide entitled What Do We Know and it showed the following:

- Inhaled ultrafine particles can travel from the nose to the brain by traveling along the olfactory nerve.
- This “backdoor” pathway bypasses the blood brain barrier which is the brain’s defensive shield that blocks unwanted chemicals from reaching sensitive brain cells.

He also asked, “Where Do We Stand?”:

- Inhaled fine and ultrafine particles can damage brain cells in the part of the brain that we know is also injured in degenerative nerve diseases such as Parkinson’s.
- In addition to damaging cells that make dopamine, inhaled ultrafine and fine particles induce biochemical pathways of inflammation in the brain and those changes can be seen weeks after the exposures were completed.

“What does it all mean?”:

- The linkage of PM-induced injury in the central nervous system may also be related to impaired control of heart and lung function (i.e. HRV is controlled by the balance of sympathetic and parasympathetic nerve pathways).
- The transfer of inhaled fine and ultrafine particles into the brain raises serious concerns, for example:
  - for individuals exposed in regions with high concentrations of these particles, i.e. near heavily trafficked roads,
  - near pollutant sources and in some workplaces during the manufacture or application of numerous industrial and commercial products that contain nanomaterials.

Conclusions:

- The nuclei and accumulation mode particle compositions are different.
  - Accumulation mode contains more oxygenated organics
  - Quasi-ultrafine CAPs are composed of less oxygenated compounds including PAHs.
- Toxicity and free radical generating capacity of CAPs is greatly reduced by thermal denuding of the particles.
- CAPs exposure increases inflammatory responses in the brain and is associated with damage to dopamine producing cells in the brain.
- The effects of denuded CAPs on HRV and arterial plaque formation are significantly reduced suggesting that organic components can affect cardiac function and disease pathology due to toxic effects of the organics (e.g. PAHs or oxygenated hydrocarbons) or by free radicals released by organic constituents.

He also stated that motor vehicle exhaust and motor vehicle emissions are critical both in terms of air pollution levels and effects on health. Dr. Kleinman thanked the Council.

**Council Action:** None.



**PANEL DISCUSSION****3. Ultrafine Particles: Characterization of Mobile Source Emissions and Related Health Effects**

Eric Stevenson noted that questions were sent to the speakers for answers or at least to shed light on certain issues. Those questions include:

- a. Are ambient air quality and/or emission standards for ultrafine particles necessary?
- b. If so, at what level and form:
  - i) level
  - ii) measurement units (mass, particle count, surface area)
  - iii) averaging time (one hour, 24 hours, annual, other)
- c. What would be the best way to measure ultrafine particles for ambient air quality and/or emission standards?
- d. What are the implications of ultrafine particulate for the Air District's regulatory and legislative agendas, and programs?

Dr. Kleinman said one of the implications of ultrafine particulate is that fine particulates contain the ultrafine particles stick together, attracting to larger particles, and they accumulate and grow.

He provided an illustration of putting ultrafine particles in a box, and particles would disappear and larger particles would grow. Chemically, some of this is conserved so what are the things that disappear, are there labile compounds that are lost from the particles that might carry some of the biological effects. He continued that is not just the particles, but you have to look at the particle vapor as a mix.

Dr. Kleinman mentioned that it would be difficult to develop a standard that just looks at particle number, as the number by itself does not correlate with biological responses. Dr. Kleinman suggested looking for some of the hot chemicals that are associated with the particles or least some of a marker for those hot chemicals. He said one of the other things that come out of the freeway curve where it showed a decrease in concentration, underneath the particle curve there was a carbon monoxide curve, which tells you something that carbon monoxide does not oxidize very rapidly which is being reduced by dilution. Therefore, the loss of particle number over time is particle dilution but there is also something else happening in terms of the dynamics of where organics are on the particle and whether they jump from little particles to big particles.

Dr. Ayala said the more we think about particles and learn about them and we know what makes them and how to measure them and that the complexities of the issue are interesting and raise

questions, but the things that one would do to control particles are the same things that one would do to control other type of pollutions. Dr. Ayala said if you are concerned about internal combustion engine generated particles, then you have to get rid of internal combustion. He said that is why ARB has a transportation vision that calls for transition away from conventional technology to something that is cleaner, i.e. hybridization, electrification of the motor fleet and then eventually fuel cell hydrogen fuel vehicles and new technology forthcoming.

Dr. Ayala spoke about near road exposure to particles and said if you get close to a heavily trafficked road, you will be exposed to particles, but you are also going to be exposed to higher CO and higher hydrocarbons. If you had a choice between a clean and a dirty car, you would not need to know the particle concentrations and the emissions to make the determination. It would be wise to get away from the dirtier car. He said the more we learn about particles, the more we understand that we are not really talking about anything distinctly different from the central mission which is getting rid of the emissions to the extent that we can.

Dr. Ayala asked why is there such an emphasis in particle number versus surface, versus biological activity, versus a long list of different metrics that is more representative than mass. Dr. Ayala said the answer is simple we can count particles rather easily that is why you see in the literature that 90% of what is published is particle number. He also stated it is relatively simple and easy to grow the particles and to use a particle counter to count them but we should step back and let the medical community and the public health community tell us the real concern as we become smarter at looking at the PM emission profile.

He also mentioned the particle number regulation currently in Europe. He stated there is a misconception because the regulation in Europe that limits particle number from cars is very specifically focused on solid particles. Dr. Ayala said it is those non-solid particles, and in some cases, it is the non-solid organic particles that are going to be of concern.

Mr. Lucks thanked the presenters and asked what can the Air District do from a policy standpoint to address ultrafine particles and from a regulatory standpoint that is mobile source driven. Dr. Kleinman said you can consider roadways as long skinny stationary sources, and there is not enough information on ultrafine components of large stationary sources. The most that has come out of the research from the health side is that there is a very strong relationship between biological response and the metallic components. Those components include nickel and vanadium which are associated with fuel oil, combustion and some other things associated with coal combustion which we don't have much of. He said when organics are stripped off the ultrafine particles the results is not benign, so there is some effect on heart rate variability. He also said for stationary sources looking at specific components of the emissions, may be better than some particle number approach which may not be well defined unless you are close to the source.

Dr. Ayala said there is not a lot of data but counterparts are active in pursuing more information. He mentioned in particular South Coast Air Quality Management District made a significant effort to try and understand specifically particles and stationary sources, and were involved in advisory activities. Dr. Ayala also said to reduce emissions as much as possible. Dr. Ayala said if you are focusing solely on ultrafine particles, you would not do anything differently. He said they are taking that approach and trying to do as much as possible with motor vehicles, but for motor vehicles new vehicles are very clean, but the concern is after 100,000 miles, what happens after lack of maintenance and when things go wrong.

Mr. Altshuler asked Dr. Ayala if the white smoke emitters were also lube oil burners. Dr. Ayala said the National Renewable Energy Lab funded an extensive project, specifically looking at the question of diesel and gasoline emissions. He said the selling point is when you have a smoking vehicle and things appear to be worse than a conventional diesel. The study also looked at high emitters and whether an identified high PM emitter (vehicle) is a high oil fine particle emitter, and what can be done about it. The answer to the first one is no, you can have a high emitter that is high PM that does not necessarily have a high number of various small particles and the opposite is also true. One can have a high emitter that is high in hydrocarbons that is not a PM emitter.

Dr. Ayala also said they took a couple of vehicles and ran them through the smog check test, and also completed the certification test in their labs and then sent the vehicles out to be repaired. When the vehicles were returned if you get high emissions of PM from a vehicle, it is likely because you are either burning oil or blew the rings or you are running rich. Therefore, the fuel metering needs adjustment or repair, but what was found, the bottom line, was that the repair for these vehicles was more expensive than the value of the vehicles. In that particular strategy the best thing was to get rid of the vehicles and modernize the fleet.

Mr. Altshuler asked if cold starts contributed to more emissions when looking at hybrids. Dr. Ayala stated he did not have any results on hybrids. Dr. Ayala said cold starts are due to transient emissions similar to up and down inclines, acceleration and deceleration and the change from 50 miles per hour and stopping. A hybrid mitigates this issue, as the engine is not powering the vehicle you are only essentially charging the battery.

Mr. Hayes asked if the ultrafine particle problem, by controlling fine particles will be addressed or is this something that we will have to address in a different way. Dr. Kleinman said the problem is that the ultrafine particles here may differ from place to place. As there is a continuous manufacturer of ultrafine particles in the air just from gas to particle conversion relative to hydrocarbons from motor vehicles, other sources, natural sources and photochemical reactions. He said if there is photochemistry and you have organic vapor, you will find ultrafine particles and eventually they will grow into fine particles. There is a question as to whether the secondary organic particles are as toxic as the particles from primary emissions. He said there is not much data available.

Mr. Hayes also asked if ultrafines are an on roadway issue. Dr. Kleinman said no, you will have ultrafines from a number of sources, but the toxicity of the ultrafines near the roadway maybe different than the toxicity ultrafines in a different location. Dr. Kleinman stated a simplistic approach should not be taken regarding ultrafines.

Dr. Ayala said nothing that we have learned in the last two decades with respect to ultrafine particles suggest a strategy that is focused on PM<sub>2.5</sub> is the wrong strategy.

Dr. Kleinman also added that when you look back at the history of particulate regulation, we started with a TSP standard because that what was measured. This was measured because the existing samplers were originally Electrolux vacuum cleaners that were set out and deployed by the U.S. Atomic Energy Commission to measure radioactive fallout from nuclear weapons tests. He also stated when EPA was created it essentially took that existing technology and started collecting 8x10 filters. He also said there are a lot of large particles that you do not even inhaled in the TSP, so they established a PM<sub>10</sub> standard because PM<sub>10</sub> was theoretically the cut point where you are able to inhale those things. Based on fluid dynamics of particles and breathing under normal conditions, when you are breathing in, 10 micron particles can make that transition and be sucked into your nose. In addition, he said it is not true but it is the theory that they used to develop a PM<sub>10</sub> sampler and collect lots of PM<sub>10</sub> samples.

Dr. Kleinman said when the Six Cities Study was conducted, there were some particle size analyses and found that small particles correlated better with the biological effects that they were looking at, and John Bockman at EPA suggested measuring PM<sub>2.5</sub>. He said EPA stimulated a regulation based on little measurement data, but this allowed them to deploy PM<sub>2.5</sub> samplers across the country when they were not there in the past. Dr. Kleinman said California had some data but, one of the big problems with understanding the ultrafine measurements is that we do not have that many data points on a regular basis, where we can begin to draw a conclusion about what the correlations are to health effects.

He said he is not saying that PM<sub>2.5</sub> is the wrong way to go, you definitely have to control PM<sub>2.5</sub>, but for ultrafine particles knowing they are source related we should think more in terms of not building schools next to the freeways and encourage individuals not to jog or exercise along busy roads and there are a lot of common sense things that can be done to protect health beyond putting a cork in the bottom of a car. He also said he agrees that if we can move to hybrids and maybe to zero emission vehicles, that would be make a big improvement and mass transit would make a big improvement, but he is not sure you can develop an overall policy on emission reduction other than getting rid of those sources.

Dr. Holtzclaw said we don't have control as an Air District over anything other than stationary sources, but we do have control over the use of mobile sources. He also said we have promoted smart growth and complete streets. In addition he asked how the presenters would evaluate the programs in terms of improving or reducing the amount of toxicity from particulates. Dr.

Kleinman suggested reducing the use of the roads to some extent, will reduce emissions, and on a total emission basis this helps. The toxicity issue gets complicated because the particles coming out of a car during idling are different than particles coming out of a car when it is moving steadily. He also suggested having traffic control to improve traffic flow to reduce the amount of idling time might be helpful.

Dr. Ayala said if you are thinking in terms of simple accounting of emissions, people are trying to come up with inventories where you take a simple mass emission factor, and make it more sophisticated and add size fractionation of that emission. He suggested limiting emissions to the extent that we can and if need be, to focus on ultrafine particles, but also limiting emissions of every other type of pollution. Dr. Ayala said yes, we need to continue to understand it better and there are many years of excellent research and future research that is going to make us smarter and more educated in terms of the nuisances of what do get if you have a combination of vehicle fuel activity, etc. It all comes back to reducing PM pollution, reducing dependence on fossil fuel combustion to the extent that we can. He also said education is the key and that agencies should get the word out, but he is not sure that ultrafine particles are any different than any other issue that we should be concerned about, including climate change and greenhouse gas emissions.

Dr. Ayala mentioned the State is leading the charge in this area, but we have to balance both and it comes down to better planning, promote walking instead of driving and riding your bicycle rather than driving your car or taking the bus.

Mr. Brazil asked Dr. Ayala if vehicle acceleration tests were conducted on freeways. Dr. Ayala said the test was conducted on a freeway. Dr. Ayala said the tests were conducted on freeway on ramps and that the magnitude of the acceleration is proportional to the production of the particles.

Dr. Martin asked Dr. Kleinman if in his research, if he looked at the reversal of health effects once the chronic exposure to pollution was stopped, from a mitigation perspective. Dr. Kleinman said that was done only a few times because usually the animals are killed after the exposure and its biological affect and with certain things they look to determine what happens physiologically after exposures, so there is some recovery but for things long term the best examples are studies of smoking cessation in humans, where you can see recovery of lung function to some extent but not entirely. But if someone quit smoking then 30 years later their risk of dying of a heart attack is the same as nonsmokers. So there is repair and regeneration. One of the most interesting studies with regard to that is out of the UCS Children's Health Study, where they showed children growing up in more polluted communities in California had diminished lung function when they reached adulthood. He also said if they left before they were fully grown, their lungs recovered back to what the norm would be. So that while there is regeneration happening in growth, there is a possibility to improve things. Once lungs are fully

formed, those stem cells stop being active and repair become less likely, the same as with your heart.

Ms. Lutzker said she appreciated Dr. Ayala's simplified policy approach but asked about diesel control approach and noticed there is only one that does not increase ultrafines to baseline and wondered if this would be considered more of a nuisance policy approach which is not always the most affective policy approach. We want to control PM overall and pollutants overall, but with the need to take in consideration each pollutant that we want to control in relative sizes when looking at different control options.

Dr. Ayala said DPF number 3 is an active technology, where the control technology involved a school that require you to plug it in, to clean it up, and to regenerate the catalyst. Typically, this control technology is useful for captive fleets, for example buses, vehicles that leave and comes back to the same point. He agreed that this particular technology has a bare filter and has no oxygenation catalyst, no reliance on NO<sub>2</sub> for regeneration or any external fuel injection to burn off the trapped soot. He said if you are only looking at particles you are correct, this does not form very small particles, but the technology that gave the highest metric in terms of the toxicity acids was DPF number 3 and the reason is that there is no oxidation in this particular device, no control of PAHs.

Mr. Lucks asked Mr. Kendall and Mr. Stevenson if there was value in to reinventing the wheel and exploring some collaboration with South Coast Air Quality Management District (SCAQMD) both on science and policy, recognizing they have different demographics and other factors as they are a multi-county agency. He also asked if they would recommend bringing speakers from (SCAQMD) who could share with Council where they are, where they came from and where they are going.

Mr. Stevenson responds saying one of the speakers they hope to have next year is Dr. Phillip Fine, who is from SCAQMD and is performing a number of these studies. Mr. Stevenson said the Air District conducts more PM speciation in the Bay Area. In the South Coast their focus is on near roadway exposures, as their concentrations are much higher and they are able to locate those stations in a way that gets them much higher and better defined composition.

Dr. Bornstein said Dr. Ayala demonstrated the need for saturation monitoring, so is there movement to develop remote sensing technology. We have lidar systems that look upward and give us boundary layer structure, can we have horizontal looking instruments, can we have downward looking lidar systems mounted on roofs so that one measurement device is measuring over a large area and that takes the place of saturated monitoring.

Mr. Stevenson said he is trying to coordinate efforts with various technologies that are available, not quite as accurate or robust as we would like them to be but it is the balancing act of getting large amounts of data versus not getting any data.

Dr. Bornstein asked what kind of regulation would the Air District need and Dr. Kleinman mentioned the nature of technology and impacts in the evolution of standards on particles, but we should consider the evolution in measuring gases in the same manner. As initially there were dirty emissions coming out of tailpipes and we said clean them up. Now this is more sophisticated and we started controlling individual pollutants because we realized individual pollutants and gases are a problem.

Dr. Ayala said saturation monitoring is not the answer, and the future is bright. He said NASA is currently refining the satellite signals so that we can look at the signal and get an idea in terms of PM pollution. He said although that is further down the line, but efforts that are currently being done and promoting these efforts will generate better tools for everyone to understand this issue. He also said the one concept that has been talked about specifically for particles are that we need to think in terms of the ultrafine particle potential from a system. Not just the engine, but engine, fuel and oil along with the application of that particular vehicle as this points to the fact that what we are probably concerned about the precursors. The things in the emissions that are components of this thing we call PM that eventually generate OC fractions that cause the health impacts communities are finding are of concern.

Mr. Altshuler asked if CO is falling off the same as PM, is it 1 for 1 or is PM really falling off more than CO. Dr. Ayala said this is a good marker for vehicle emissions and does follow the trajectory of those things that vehicles emit. He said when you look at black carbon and PM, you are looking at the regional contributions and those are about the same.

After a lengthy discussion Chairperson Blonski thanked the speakers for coming.

Mr. Kendall thanked the speakers for coming and that the Council asked if it better, worse or the same in terms of looking at control technology. In addition, he said CRC holds its meeting in San Diego each year and what was shared regarding CO, NO<sub>x</sub> and VOC is ten percent of fleet emits fifty percent of emissions. He asked is this true for particles that maybe ten percent of fleet is responsible for fifty percent of particles. Dr. Ayala said he does not think so, and wishes it were simple, and makes the argument that vehicle operation is a strong determinant.

Chairperson Blonski thanked both Mr. Kendall and Mr. Stevenson for providing the speakers, and each session continues to get better and better with more understanding.

#### **4. Council Member Comments / Other Business**

Chairperson Blonski stated that November 16, 2011 is the presentation to the Board of Directors.

Mr. Hayes said November 16, 2011 the Air & Waste Management Association (AWMA) will hold its Climate Conference in San Francisco, California to be held at Fisherman's Wharf. He also mentioned that Mr. Broadbent will chair a keynote panel.

Chair Blonski thanked everyone for their time.

5. **Next meeting:** The next meeting of the Advisory Council will be held on Wednesday, November 9, 2011 at 9:00 a.m. at 939 Ellis Streets, San Francisco, CA 94109
6. **Adjournment:** Chair Blonski adjourned the meeting at 12:10 p.m.

Vanessa Johnson  
Executive Secretary II



BAY AREA AIR QUALITY MANAGEMENT DISTRICT  
Memorandum

To: Chairperson Ken Blonski and Members  
of the Advisory Council

From: Jack P. Broadbent  
Executive Officer

Date: November 1, 2011

Re: Discussion of Draft Report of the Advisory Council's October 12, 2011  
Meeting on Ultrafine Particles: Characterization of Mobile Source Emissions  
and Related Health Effects

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The attached draft report of the October 12, 2011 Advisory Council Meeting on Ultrafine Particles: Characterization of Mobile Source Emissions and Related Health Effects was prepared by Advisory Council members Stan Hayes, Sam Altshuler, Jane Martin and Robert Bornstein.

The draft report will be discussed by the Advisory Council at its November 9, 2011 meeting.

Respectfully submitted,

Jack P. Broadbent  
Executive Officer/APCO

Prepared by: Gary Kendall  
Reviewed by: Jean Roggenkamp

**DRAFT REPORT ON THE OCTOBER 12, 2011 ADVISORY COUNCIL MEETING ON ULTRAFINE PARTICLES: CHARACTERIZATION OF MOBILE SOURCE EMISSIONS AND RELATED HEALTH EFFECTS FOR DISCUSSION BY THE ADVISORY COUNCIL AT THE NOVEMBER 9, 2011 MEETING**

**SUMMARY**

The following presentations were made at the October 12, 2011 Advisory Council meeting on Ultrafine Particles: Characterization of Mobile Source Emissions and Related Health Effects:

1. ***Internal combustion engine generated particles: formation, measurement, trends, and knowledge gaps*** by Dr. Alberto Ayala, Ph.D. MSE. Dr. Ayala is the Chief of the Monitoring and Laboratory Division at the California Environmental Protection Agency, Air Resources Board, and previously served as the Manager of Climate Change Mitigation and Emissions Research in the Research Division of the Air Resources Board. He holds an M.S. in Engineering and a Ph.D. in Mechanical and Aeronautical Engineering from the University of California at Davis. Dr. Ayala's research group is the chief unit in charge of emissions research and ultrafine particle characterization at the Air Resources Board. His group has on-going collaborations with international agencies and is leading the ARB's studies of emission measurement protocols, control technology and exposure. He has published more than 25 articles in peer-reviewed journals, a number of them focused on PM and ultrafine particle emissions from internal combustion engines and made presentations at more than 25 conferences, many of them focused on ultrafine particles.
2. ***Semi-volatile components of fine and ultrafine particles: Do they exacerbate airway allergies, promote development of cardiovascular disease and induce inflammation in the brain?*** by Dr. Michael T. Kleinman, Ph.D. Dr. Kleinman is a Professor of Occupational and Environmental Medicine in the Department of Medicine at the University of California, Irvine (UCI). He holds a M.S. in Chemistry (Biochemistry) from the Polytechnic Institute of Brooklyn and a Ph.D. in Environmental Health Sciences from New York University. He has published more than 100 articles in peer-reviewed journals dealing with environmental contaminants and their effects on cardiopulmonary and immunological systems, and has directed more than 50 controlled exposure studies of human volunteers and laboratory animals to ozone, PM and other pollutants. Dr. Kleinman's current research focuses on neurological and cardiopulmonary effects of inhaled particles on humans and laboratory animals. His recent studies have demonstrated that inhalation of combustion-generated particles can promote airway allergies and accelerate the development of cardiovascular disease and that these effects may be associated with organic and elemental carbon components of the ultrafine fraction of the ambient aerosol. He has also served on EPA CASAC panels for PM and chairs the Air Quality Advisory Committee for California.

## DISCUSSION MEETING

At the November 9, 2011 meeting, the Advisory Council discussed the presentations and materials received at the October 12, 2011 meeting and the draft report on that meeting.

### KEY POINTS

#### Dr. Alberto Ayala

- We need to be careful about generalizing UFP.
- Not all UFP particles are created equal. The number, size, chemical composition, and physical state of UFP are dynamic, that is, they change with time and location, even by the mode by which a UFP emission source is operated (e.g., vehicles in cruising or acceleration mode). All of these variations may affect UFP toxicity.
- There are many different sources of UFP, including stationary, mobile, industrial, occupational, and atmospheric conversion (secondary formation via photochemical processes).
- 85% of ambient PM<sub>2.5</sub> mass results from fuel combustion. On-road vehicles are the largest contributors to UFP.
- UFP is not just a “diesel only” problem. All internal combustion engines and fuels produce UFP, including engines fueled by gasoline, diesel, natural gas, hydrogen, ethanol, and biofuels. Lube oil use from internal combustion engines also contributes to UFP.
- The concentration of PM from roadway emissions drops off sharply with distance from the roadway.
- UFP monitors are commercially available and could be deployed.
- One frequently measured indicator of UFP is particle number, that is, the number of particles in a cubic centimeter of air. The lowest UFP particle numbers are from CNG-fueled and conventional gasoline engines. The highest UFP particle numbers are from diesel engines, although the particles formed are measurably lower in toxicity (nitrates and sulfates).
- The contributions of lube oil and metals to UFP are of growing interest. Sulfur in lube oil becomes more of an issue as fuel sulfur drops.
- Diesel engine technology is evolving. The diesel particulate filter (DPF) is a PM “game-changing” technology that not only achieves dramatic reductions in PM mass emissions from a non-controlled baseline engine, but also reduces UFP particle numbers to those similar to CNG and conventional gasoline engines.

- Gasoline engine technology is also evolving. Gasoline direct injection (GDI) is effective in reducing carbon dioxide for climate protection purposes, but in earlier-vintage engines caused higher PM mass and UFP particle counts than conventional gasoline engines. Newer GDI engines, however, have reduced PM mass and UFP significantly.
- Transition away from traditional internal combustion engines to hybridization, fuel cells, and electric vehicles will reduce UFP emissions.

Dr. Michael Kleinman

- An increase in air pollutants can lead to increased mortality and hospital admissions because of cardiovascular diseases.
- Exposure to elevated particulate matter (PM) in ambient air can lead to increased heart rate and decreased heart rate variability in elderly patients. Individuals 65 years and older are more susceptible to air pollution-associated heart-related morbidity and mortality.
- PM can accelerate atherosclerosis (hardening of the arteries) and can cause premature mortality due to cardiac causes.
- Dr. Kleinman described results of a series of experiments in which he found that the semi-volatile components of PM<sub>2.5</sub> and UFP can exacerbate airway allergies, promote development of cardiovascular disease, and induce inflammation in the brain. These experiments include the following:
  1. Rats were exposed before, during and after wildfires in Southern California, and their cardiac physiology during UFP exposures measured. Results showed that a significant drop in blood pressure occurred in UFP-exposed rats during the fire.
  2. Rats were injected with UFP directly into the venous return to the heart, and heart contractile function and coronary flow were measured. Results showed that UFP can directly alter heart physiology and cardiac contractile function, which is closely correlated to changes in coronary flow.
  3. Mice were exposed to UFP in ambient air downwind of a freeway in Southern California. Measurements of allergy response biomarkers were made at about 50 meters, 150 meters, and 250 meters downwind of the freeway. Results showed that ambient UFP exposures near the freeway (~50 meters) induced airway allergies in mice, but responses at greater distances (~150 meters and ~250 meters) were not statistically significant. The association with allergy biomarkers was strongest for elemental carbon (EC) and organic carbon constituents (OC), but was not explained by difference in particle number, metals, or particle mass concentrations.

4. Mice were exposed to quasi-UFP (< 180 nm) concentrated ambient particles (CAPs). Mice were exposed to CAPs in which a thermal denuder was used to strip semi-volatile components by heating and un-denuded CAPs. Results showed that heart rate variability decreased progressively over an 8-week period in mice exposed to un-denuded CAPs, but mice exposed to air or denuded CAPs were not significantly affected. Results were similar for biomarkers of aortic plaque (associated with atherosclerosis, or hardening of the arteries).
- These results suggest that
    - UFP can directly alter heart physiology and cardiac function.
    - Increases in heart rate variability and aortic plaque buildup with UFP exposure are more attributable to the semi-volatile organics coated on the UFP core than to the UFP core particles themselves.
    - Stripping the organic carbon (semi-volatiles) from CAPs leaves denuded CAPs that include heavy metals and elemental carbon, that have reduced particle size and mass, and that are not as harmful to health as the larger, un-denuded particles.
    - Very-near roadway exposures to UFP (~50 meters) can induce airway allergies, but these effects drop to below statistical significance at greater distances (~150 and ~250 meters) due to dilution and particle conversion.
  - UFP can deposit in both upper and lower respiratory tracts.
  - Inhaled UFP can penetrate directly into the brain by traveling along the olfactory nerve, bypassing the blood-brain barrier, which is the defensive shield that blocks unwanted chemicals from reaching sensitive brain cells.
  - There is growing evidence that PM exposure increases production of inflammatory mediators and can damage or kill brain cells. PM exposure can affect cells that are essential for the production and metabolism of the neurotransmitter dopamine, thus damaging cells in the part of the brain that is injured in degenerative nerve diseases such as Parkinson's.
  - In addition to damaging cells that make dopamine and diminishing its production, inhaled PM<sub>2.5</sub> and UFP can induce inflammation in the brain that persists for weeks after exposure.
  - Oxidative stress is a very important mechanism for UFP health effects, but there may also be other mechanisms.
  - UFP effects are not just about inflammation, but also may be related to cancer.

## Joint Panel Discussion

- UFP is contained within, and thus is a part, of PM<sub>2.5</sub>, but UFP size and chemical composition is dynamic and changes with time and location.
- Historically, UFP has been characterized by particle number, primarily because it was easy to measure. However, by itself, particle number does not correlate well with biological response.
- Thus, it would be difficult to set a UFP air quality standard based just on particle number. We need a better metric of UFP, one that correlates more closely with biological response.
- There is a very strong association between PM health effects and metals.
- We need to look at PM and air pollutant gases more holistically, taken together as a mixture and not just separately.
- The same things that we are doing to address PM<sub>2.5</sub> are those things that we would do for UFP.
- Nothing that we have learned about UFP suggests that a control strategy based on PM<sub>2.5</sub> needs to be fundamentally changed based on UFP. We need to reduce PM emissions with cleaner cars, we need to use vehicles less to reduce miles traveled (VMT), and we need to reduce near-road exposures.

## EMERGING ISSUES FROM THE ADVISORY COUNCIL

1. The interrelationships between PM<sub>2.5</sub> and UFP and their implications for public health, control technology design, and control measure selection need to be further investigated and supporting research done.
2. Measurements of UFP that correlate better with public health than particle number are needed. Better tools are needed to assess UFP exposure, particularly on and near heavily-traveled roadways.
3. More research is needed to build on the growing evidence that both PM<sub>2.5</sub> and UFP cross the blood-brain barrier through the olfactory nerve; that they permeate, linger, and diffuse through sections of the brain; that they trigger inflammatory responses that are dose dependent; and that those inflammatory responses trigger oxidative stresses that may activate cells involved in cancer.
4. As PM emissions from diesel engines have been significantly reduced, emissions of PM from gasoline engines become more important. PM emissions from gasoline engines are a result of different driving cycles (high acceleration, cold starts) and lube oil control (engine design, age and wear of engine).

5. Nothing we have learned about UFP suggests that the current control of PM 2.5 is going in the wrong direction. We need to stay the course, including removal of older and gross polluting vehicles and replacement of traditional gasoline engine with hybrids, fuel cells, and cleaner fuels (hydrogen, natural gas, bio fuels).
6. Semi-volatile hydrocarbons (unburned or partially burned fuel and lube oil) are associated with the most measureable health impacts. UFP nitrates, sulfates, and metals are not as toxic. While the Europeans are focused on total number of UFP, ARB is keeping the focus on the semi-volatile UFP.
7. The role of metal and metal oxide UFP in producing adverse biological responses from UFP exposure needs to be better understood.
8. The contribution of burned lube oil in engine exhaust to UFP and in producing adverse biological responses from UFP exposure needs to be further investigated.

#### ADVISORY COUNCIL RECOMMENDATIONS

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

1. While no UFP air quality standard has been proposed or is on the immediate regulatory horizon, we recommend that the District continue to regard UFP as very likely to have important public health significance.
2. We commend the District for its proactive stance on UFP and endorse its efforts to integrate UFP considerations into PM2.5 planning. We recommend that the District continue to be proactive on UFP.
3. We recommend that the District move ahead as planned with its efforts to reduce PM levels in the Bay Area, and in doing so, we further recommend that the District also:
  - a. Maintain a focus on PM2.5 and UFP emissions from fuel-burning vehicles, with particular attention to PM emissions resulting from unburned and partially burned fuel and lube oil.
  - b. Continue to investigate and evaluate implications of UFP for the structuring and design of PM reduction strategies for the Bay Area.
  - c. Continue to investigate and evaluate measures to reduce personal exposure to PM2.5 and UFP, as well as to reduce their emissions.
  - d. Be prepared to make "mid-course corrections" to PM reduction efforts in the Bay Area, if necessary based on on-going UFP research developments.

4. We recommend that, within its mission and resources, the District continue to point out the importance of, and to lend its support to, further UFP-related research to
  - a. Identify better metrics for assessing UFP health impacts. Continue to monitor ongoing research on UFP health effects, chemical composition, and emission control technology.
  - b. Better understand UFP public health significance.
  - c. Better characterize UFP sources, ambient air quality levels, and chemical composition.
5. We recommend that the District continue its efforts to characterize UFP sources and ambient air levels in the Bay Area.
  - a. We recommend that the District consider development of a UFP emission inventory.
  - b. We recommend that the District consider conducting UFP monitoring to characterize ambient UFP levels and speciation at selected key locations (e.g., near heavily traveled roadways), possibly integrating those efforts with upcoming near-roadway NO<sub>2</sub> monitoring to be done pursuant to the 1-hour NO<sub>2</sub> national AAQS.
  - c. We recommend that the District monitor improvements in UFP control technology and its integration with PM<sub>2.5</sub> reduction efforts, especially as regards vehicle engine exhaust.



## **GLOSSARY**

AAQS	Ambient Air quality Standard
CAP	Concentrated ambient particles
CNG	Compressed natural gas
EC	Elemental carbon (black carbon)
GDI	Gasoline direct injection
NO <sub>2</sub>	Nitrogen dioxide
OC	Organic carbon, can be semi-volatile
Oxidative Stress	A biological indicator of health effects on biological cells
PM 2.5	Fine sized PM less than 2.5 microns in diameter
PM	Particulate matter (of all sizes)
UFP	Ultrafine PM, less than 0.1 microns in diameter