Symposium Summary:
Symposium on
Particulate Matter

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Symposium on Particulate Matter

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Symposium on Particulate Matter - Endicott House - August 12 and 13, 2003			
Tuesday, August 12, 2003			
Speaker	Organization	Subject	Moderator
Bob Slott	MIT	Announcements	
Mario Molina	MIT	Introduction	
Jim Vickery	EPA	NARSTO PM Assessment	
John Bachmann	EPA	Regulations affecting PM including visibility	Mario Molina
Tom Curran	EPA	Ambient PM trends and Air Quality Index forecasts	
Judy Chow	DRI	Challenges in PM measurement	
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Phil Hopke	Clarkson U	The EPA National Ambient Air Quality Monitoring Strategy	
Dan Greenbaum	HEI	Health Effects	
Mike Brauer, UBC	U British Columbia	Exposure to particulate matter	Dan Greenbaum
Nancy Brown	LBNL	Field and Modeling Investigations of the Fate of Outdoor PM-2.5 in Residences	
Ron Wyzga	EPRI	Health Effects	
Mark Utell	U Rochester	Pulmonary	
Doug Dockery	Harvard U	Epidemiology	
Ted Russell	GIT	Transport & Modeling	Bob Slott
Axel Friedrich	Umweltbundesamt (UBA)	PM Control Strategies in Europe	

Symposium on Particulate Matter - Endicott House - August 12 and 13, 2003			
Wednesday, August 13, 2003			
Speaker	Organization	Subject	Moderator
Praveen Amar	NESCAUM	Announcements	
John Watson	DRI	Applications of Receptor Methods to Air Pollution Problem Solving	Praveen Amar
Praveen Amar	NESCAUM	Controlling Emissions from Industrial Sources of PM and its Precursors	
Steve Cadle	GM	Nonroad Mobile Source Emissions	Steve Cadle
Dave Kittelson	U Minnesota	Nano Particles	
Matti Maricq	Ford	Mobile Source PM	
John Fairbanks	DOE	Overview of Issues Involving Diesel and Natural Gas Engine Buses	
Doug Lawson	NREL	DOE's Gasoline/Diesel PM Split Study	
Wayne Miller	UC Riverside	Effect of Driving Cycles on HDDV PM	
Tim Johnson	Corning	Aftertreatment PM Control Measures	
Spyros Pandis	CMU	Pittsburgh Supersite	Bob Slott
Panel: If I were King, What would be particulate control policy? What would be particulate research objectives?			
Alan Lloyd	ARB		
Tom Grahame	DOE		
Allen Schaeffer	DTF		
Vickie Patton	ED		
Ken Colburn	NESCAUM		
John Shanahan	U.S. Senate Committee on Environment and Public Works		
Chris Miller	U.S. Senate Committee on Environment and Public Works		

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-Summaries-

Mario Molina, ***Introduction: Atmospheric Particles (A Personal Perspective)***

The first implications derived from the study of the reactions occurring in the stratosphere evolved in the understanding of the ozone depletion phenomena and the role of polar stratospheric clouds. Although there are still important unknowns in the field, more studies have been developed over the years producing an increasing understanding of these phenomena. This is a clear example of how the continuous progress in scientific research can lead to a better understanding of important atmospheric process directly affecting humans. Nowadays, the urban atmosphere represents a challenge but also a good opportunity to understand many of these processes, from the microphysics of particles to the global implications of aerosols. Hydrological cycles and radiative equilibrium are also two clear examples of important processes that have large local and global implications. Complications in the study of urban aerosols arise from several factors, including their size variation, the potential multiple sources involved, the large amount of chemical compounds sitting on a single particle and the transient chemical-physical transformations that they have in connection with meteorological variables. Enormous advances in currently available measurement techniques give us reasons to be optimistic for the upcoming years, but a lot still needs to be done. Field campaigns carried on urban areas, as the one recently performed in Mexico City, will allow us to develop new hypotheses and test many of our current hypotheses, including the global implications of aerosols. As an example, the percentage of days exceeding PM standard has improved in Mexico City in the last few years, but annual PM emissions are still high. Given that about one third of the total PM10 comes from heavy diesel trucks, the research team made a strong recommendation to Mexico about more stringent regulations on diesel engines and trucks. Even reducing 10% of PM can reduce mortality on the order of thousands of people. Because of the large effects of these phenomena, better communication between the scientific community and the regulatory agencies is crucial when economical, social and human health issues are taken into account.

Discussion

Mexico began its particle measurements with total suspended particles, and therefore may have been leaving out certain particles. PM10 and PM2.5 are now continuously monitored on a regular basis as well. As more chemical analysis has been conducted, there have been a lot of organic particles observed. Causes for the significant PM reductions observed in Mexico City include the reformulation of gasoline, lowering of the sulfur content, addition of catalytic converters, the introduction of Inspection and Maintenance programs and other policy strategies. It is still unclear to what extent meteorology has also participated. Current hypothetical ideas about the fate of fresh emitted aerosol from a mobile source can be tested with new data. In a polluted atmosphere, a soot particle or organic particle functions as a nucleus on which other particles are deposited. This results in a mixed particle. It takes about a week for the particle to lose enough organic material to rise up into the atmosphere. Even hydrophobic particles can become hydrophilic over time and become part of the rainfall. As a result, a large fraction of particles is exported. With regards to the extent that ambient particles can act as a sink for ozone, it is likely that in the atmosphere reactivity with ozone is relatively mild compared to reaction with radicals.

Jim Vickery, *Particulate Matter Science for Policy Makers: NARSTO PM Assessment*

NARSTO, a public-private tri-national multi-stakeholder entity, released its PM assessment in April 2003. As a science community, NARSTO wanted to develop scientifically based information that can be used in the decision process by policy makers. NARSTO used to focus exclusively on tropospheric ozone, but now it built its assessment around a three-part framework consisting of: the atmospheric environment and its multiple tropospheric pollutants, human exposure and impacts, and public policy. Their experience indicates that an intimate relationship with policy makers is actually needed in order to have an adequate impact in the proposed policies. Moreover, continuous conversations with leaders of various organizations and qualified people helped the NARSTO researchers to learn about the knowledge needs. The resulting peer-reviewed PM assessment resulted in an executive summary, synthesis, and detailed science chapters. The NARSTO team prepared conceptual models for nine representative areas in North America and the authors summarized their knowledge and recommendations for each region. Taking the Northeast region as an example, many of the atmospheric processes in the Northeast have been extensively studied and that effort has lead to an increased scientific progress. Nevertheless, there are there still important research needs such as the study of organic carbon content and consideration of seasonal differences in pollution episodes. Generally, across North America, PM2.5 levels exceed existing standards. Not surprisingly, the worst areas are the Southeast, Northeast, and California basins given that PM2.5 are tracked to anthropogenic sources. There is a large regional contribution to fine particulates while PM10 tends to have pockets across the regions. Because of the regional and urban contributions to the total aerosol loading, regulatory policies need to deal with urban and rural sources. This can be further analyzed in terms of composition. For example, organic carbon is an important fraction of PM2.5 but it is not very well understood. Sulfur content is very significant on the East Coast, whereas nitrates are more important in the West. The summer-winter differences are substantial, with more PM2.5 in the summer than during the winter. However, nitrate becomes more significant in the winter in urban areas. The complex mixture of chemicals that compose the aerosols can be linked in some instances to the different sources using receptor models and chemical transport models. Although a lot still needs to be understood, these tools may be used now to identify PM management strategies. Their report included a chart rating the current confidence of the chemical transport model simulations for different PM mass and chemical components. Their recommended areas of research included the following: the carbonaceous components of aerosols, long-term monitoring, chemical transport models, improvement of emission inventories and models, synthesis of data among different scientific communities, and more systematic approaches towards the integration of diverse types of knowledge.

Discussion

The sulfur component in PM2.5 is significant and a policy directed to lower sulfur content alone will probably take us below the standard. However, getting below the standard may not be enough. In the NARSTO analysis, they did not say how low is enough and whether strategies will help regions reach attainment all the time. This is mainly because its purpose is not to specify policies. A policy tackling multiple pollutants should not be discharged, and reaching the standard should not be the ultimate goal. The NARSTO "stops at the door," meaning that the study did not analyze actual exposure to people. From the scientific standpoint, NARSTO recommends which pollutants are important but not which ones to regulate. Rather than answering which pollutant should be controlled, it is concerned with which pollutant is more important to a specific region.

John Bachmann, *Regulations Particulate Matter Overview of the current U.S. agenda*

A number of studies have associated not only fine particles but also coarse particles with health impacts, and even some specific chemical compositions in particles have shown some associations. Moreover, multi-pollutant short-term analyses in different cities show varying results. Given the emerging findings about the relationships between PM and health impacts, it is of high importance to produce and sustain a consistent particle matter regulation. Visibility regulations include standards for the large national areas, which are different according to their local background, and the local urban visibility standards. Climate change is not necessarily always global, but regional climate changes have been observed already. The Asia case is an interesting example of this. Currently there is an ongoing review of the NAAQS based on what is best scientifically known for PM, the cost effectiveness of the implementations, and the need to be consistent with regional and long-term strategies. EPA has already a proposed schedule for the PM regulatory framework, including the Regional Haze Program, the Mobile Source Program and the PM2.5 standards. EPA is pursuing three mechanisms to address regional transport: 1) the Clear Skies Act, 2) Transport Rule and 3) Legislation for power plants and a Transport Rule for other sectors. These plans are certainly aggressive in terms of reductions but the earlier significant reductions achieved in NOx, SOx and Hg for power plants will likely maximize the benefits and the expected improvements for 2010 at large. Importantly, the pursued strategy is balanced because it is not attacking sulfur alone but multiple components. On the other hand, if the Clear Skies Approach is not applied, EPA would set budgets but the States would ultimately decide which sources to control. It would also give EPA authority to regulate interstate transport through SIPs. The Transport Rule plan would address SO2 and NOx based on their sources and determines the significant contributions from individual states. This approach also plans to propose an optional cap-and-trade program similar to Acid Rain and NOx SIP call. EPA would develop an emissions budget for each state but the states would have discretion in deciding which sources to control to meet the budget. A model can be used to neglect some states' emissions to determine the extent of the impact of a single state's SOx and NOx contributions on the surrounding region. EPA is going to continue look for opportunities for integration. People may actually consider actively changing the urban area (roads, etc.) structure to impact the climate and subsequently affect air pollution. It is not clear whether studies will suggest lowering all the pollutants at the same time or focus on certain pollutants. There is still the question of whether there will be multi-pollutant legislation or transport rule.

Discussion

EPA will continue to urge states to come into attainment by the deadline. Any adopted policy will not allow states to delay the deadline. If in-use mobile emissions can be monitored, EPA will be interested to see what and how much future vehicles will be emitting. Interestingly, according to the projections, there will be substantial reductions from base reductions in 2010 and 2020. Regarding the question of how quickly we are going to see a Super-site program for coarse particles, the complexity of the coarse particles makes it unclear whether there will be a Super-site program. There is, however, a need to control different types of particulate sources (erosion, dust, biomass, etc.).

Tom Curran, ***Ambient PM Trends and Air Quality Index Forecasts***

Most of this information on air quality trends comes from the EPA's report "Latest Findings on National Air Quality," which is available at www.epa.gov/airtrends. Over the last 10 years, there has been a 13% decrease in PM10 nationally while PM2.5 levels decreased 8% from1999 to 2002. PM2.5 trends cover a shorter period because most data has only been collected since 1998. PM2.5 decreases were larger in the Southeast region mainly because of substantial sulfate decreases. Topics that EPA is currently examining are particle speciation, coarse modes of particles, satellite data linkage and better data delivery both inside and outside EPA. With respect to better data delivery, steps include the use of the National Environmental Information Exchange Network, a joint EPA/State effort incorporating data standards and XML, as well as data warehouse and database design techniques. NASA has shown interest in working with EPA on capturing satellite images of aerosol density and superimposing data from our ground based monitoring sites, with 3-D bars showing the PM levels. Because of the sparseness of spatial and temporal coverage of PM data, this is potentially important for tracking regional impacts of the different sources as well as for use in air quality modeling. The Air Quality Index (AQI) is a color-coded way of communicating air quality information to the public. Given the health effects of the pollutants, the challenge lies in protecting people from exposure between the time an air quality problem is identified and when the area eventually comes into attainment and meets the air quality standards. A recent survey showed that people were aware of ozone action days or code orange/red air quality days and that many people responded to information about air quality hazards by changing their activities. People want information about PM because there is increasing concern with the health effects of particles. EPA has recently made an effort to make the air quality index publicly available year-round. In the past, EPA and the media would usually stop reporting the AQI on September 30, but starting October 1, 2003 EPA will go year-round with PM forecasts and data reporting for 36 cities. We expect PM2.5 to be more difficult to report than ozone because people are less familiar with it. For example, there are differences in seasonality from city to city. In Los Angeles, there were 42 ozone days and 41 PM days but there was no overlap. There are some cities that do overlap, and there are different health-related responses. There needs to be a way to quickly and clearly communicate the message to the public. There is the additional complication of how to deal with the annual average PM2.5 standard. Perhaps we can learn from the way annual rainfall is reported as a shortfall or excess above normal on a year to date basis. However, there is currently not enough data to express "normal" year to date levels of PM2.5.

Discussion

An important question we are trying to investigate with the current forecasting tools is what fraction of the aerosol load is secondarily formed and more work is needed in that area. Presently, EPA is worried about the methodology used for PM2.5 forecasting and the health message given, since the October 1 deadline is rapidly approaching. Because of the spatial sparseness of the PM2.5 network, interpolation is more of a problem than it was for ozone. Perhaps one way to present the PM2.5 data on a map is to just use color coded dots for each city rather than some sort of spatial distribution for each region. There are only 12 non-attainment areas where the 24-hr average is the problem. In those areas, annual PM is also a problem, so it serves as an adequate indicator.

Judy Chow*, Challenges in PM Measurement*

Dr. Chow discussed issues related to monitoring purposes. These included: compliance, forecasting, health effects, and visibility. Sites for monitoring must be located considering zones of influence, community exposure, etc. The scale of the study is an important issue to be considering in PM measurement. These may be collocated, micro scale, middle scale, neighborhood, urban, regional and global scale. As an example she commented the influence in PM10 of sulfate and ammonia in the Mexico City Metropolitan Area (MCMA) air shed and emphasized the variations of chemicals in PM and the diurnal variations in concentrations. Different levels of monitoring strategies can be used. Decisions depend on the number of samples and resolution of data you want to collect. She described the characteristics of PM samplers and the different configurations you can use, as well as the filters and filter holders that can be used. The results of sampling depend on averaging times and sensitivities of the equipment. She discussed the possibilities of volatilization of nitrate in samples taken in the MCMA. In the case of Fresno, CA, possible diurnal and seasonal variations of PM chemical composition exist. Several techniques may be used to avoid losses by volatilization when denuded filters are used. As an example, Dr. Chow commented on the differences in chemical composition between PM2.5 and PM10 in the MCMA. Techniques to measure mass, as well as methods to measure ions, carbon (OC, EC, and carbonate), elements (non-destructive and destructive methods), and organics (measurement species and functional groups, nomenclature standardization, etc.) were discussed. She discussed variations in thermal analysis methods and described the use of pyrolysis to better quantify OC and EC. Dr. Chow finished her presentation talking about different equipment to measure PM and summarizing PM measurement challenges and the different information you can obtain to characterize PM.

Discussion

Dr. Chow answered questions related to techniques for measuring metals. These include XRF (X-ray fluorescence), PIXE (proton induced x-ray emission), INAA (instrumental neutron activation analysis), and ICP-MS (inductively coupled plasma-mass spectroscopy). She also commented that filter measurements of particulate nitrate seem to report higher values than continuous measurements of nitrate by flash volatilization, but this needs to be studied further.

Chuck Kolb, *Real-time and Near Real-time Fine Particle Composition Instrumentation*

Dr. Kolb´s presentation was based on the issue that better understanding of gas phase concentrations in the atmosphere and spatial and time resolution may be gained obtaining data at real time. He talked about PMFINE characteristics, and innovative real time instrumentation, including the ARI aerosol mass spectrometer (AMS). Several characteristics are usually measured in PM. These include size (diameter, surface area, mass), shape, number, and chemical composition. These characteristics are important to establish relationships between concentration, exposure and deaths and in the influence of PM concentration in air on the radiation balance on Earth. For this, we need to know what controls the mass loadings, chemical compositions, microphysical properties and optical properties. He described new, real-time or near real-time techniques to measure chemical species in PM. Measurements include nitrite, nitrate, sulfate, chloride, organics, ammonia, soot, and metals. Dr. Kolb emphasized the time of response that you may obtain using these techniques and identified recent publications inter-comparing methods for near real time monitoring. He described the aerosol mass spectrometer used to measure non-refractory chemical compositions as a function of aerodynamic diameters of fine PM. The chemical species adsorbed in PM are desorbed and analyzed in the MS. As an example, results obtained in an urban site and in a remote site were presented and discussed. The results show that organics and nitrates seem to dominate the composition of PM in the urban area while sulfate dominates in the rural area. Dr. Kolb discussed the correlation between mass concentration measures using a TEOM and the AMS for New York City fine PM. Good correlation exist for sulfate concentration measured with four different techniques in New York, while total secondary aerosol species correlated well with other photochemically produced pollutants like ozone and formaldehyde. Size resolved measurements also show that urban sites seem to have bimodal distributions of PM while remote sites show a mono-modal distribution. He concluded discussing the results obtained chasing diesel exhaust vehicles in the MCMA, emphasizing changes in mass concentration with changes in CO concentrations, EC, OC and TC measurements form diesels.

Discussion

Dr. Kolb answered questions about water estimation with AMS, the real possibility of taking data in real time and how the data can be reconciled. He answered that water retention depends, for example, on nitrate content. It is very hard to estimate the amount of water since it is very volatile, but estimates can be improved. Data can be taken in real time, the problem is to validate, analyze and correlate the data, this is not simple but progress on software designed to automate these processes for AMS data is good. About reconciled data, he noted that the instruments record data, the problem is to decide which data should be included in a study's analysis tasks. Part of the answer is in the next presentation.

Phil Hopke, *The EPA National Ambient Air Quality Monitoring Strategy*

The presentation of Prof. Hopke addressed the issue of data measurement and management. Monitoring networks have been developed for a variety of purposes including detection of non attainment areas, ozone precursor species, toxic pollutant, etc. and they have been operating independent of each other. OAQPS and STAPPA/ALAPCO have addressed the problem of developing a strategy for a unified national network. The main objective is to develop a national core network where minimum monitoring needs will be defined. The design of the network must consider the need to know what are the concentrations, health effects, environmental effects, and other effects of air pollutants, as well as what can be done and how to track progress. The information must be consistent for different pollutants and users, for urban and rural areas, and must be flexible in the use of data and technologies for data management. He commented that near real-time public information should be provided with exposure emphasis. Other objectives include effects of air pollutants in ecosystems, their global effects, use of data for diagnosis and for model calibration, etc. At this time the focus is population based or on hot spots and the expectation is that the new design will provide more reliable and extensive information across a broader spatial extent. New approaches will be required to accomplish these goals. It is expected to have reasonable coverage for health exposure assessment, a better understanding of air pollutants transport, rural coverage for spatial analysis, etc. Prof. Hopke presented and commented the planned network for the US and discussed the proposal to deploy the monitoring sites. The proposal includes three levels: (1) 3 to 10 comprehensive sites, (2) 70 to 100 multi-pollutant sites and (3) a large number of limited number of pollutant monitoring sites. These sites could encompass both PM criteria pollutants, PAMS species, HAPs, as required by a combination of national and local needs. Prof. Hopke discussed the cost implications to accomplish the program and next steps that will follow. He concluded that the vision is to have a more integrated, multidimensional network with data that can be used for public information and for research activities. This will help to take better policy decisions.

Discussion

Prof. Hopke answered questions related to monitoring equipment for semivolatiles adsorbed in PM, the transport of air pollutants to select monitoring sites, and efforts to interact with people working on health effects. He answered that GC/MS has been suggested to monitor semivolatiles in PM but there are not enough resources to be able to make such measurements on a large scale basis. With high PM concentration measurement time resolution, you can obtain better information about atmospheric processes and source/receptor relationships. The question of what to measure remains a problem. The question was raised of using input from toxicology and epidemiology providing input into designing the measurements. However, at this time, there has not been definitive identification of critical species and an iterative process will be required as better understanding of the relationships between exposure and health effects is obtained.

Dan Greenbaum, *Health Effects Institute, Introduction*

The particulate matter air quality standards set in the 1990s in U.S. and Europe were driven by epidemiology. Daily time series studies and longer term cohort studies had found associations between PM exposure and health effects. At that time, EPA expressed the need to know more about PM exposure, so Congress procured $50 million per year for research. Meanwhile, Europe was also investing in multi-country research programs. More research needs to be done to answer questions about the types of exposure, sources, biological mechanisms for effects, and relative toxicity of different PM components.

Michael Brauer, ***University of British Columbia, Personal Exposure to PM***

There are multiple simultaneous modes of exposure. Source proximity, topography, meteorology and differences in individual time-activity patterns result in spatial and temporal contrasts in exposures. For example, within a city, areas closest to the roadside (less than 200 m) have the highest concentrations of traffic-related air pollutants. There can also be considerable temporal variations between seasons and throughout a single day. Over the course of one day, people are exposed to many PM sources, while indoors, outdoors and as they commute. Total personal PM exposure consists of ambient source PM, which includes exposure while outdoors in-vehicles, and indoors to ambient PM that has penetrated from outdoors. People actually spend very little time outdoors, so indoor sources are also very important. Exposure to non-ambient PM includes exposure to indoor sources (cooking, cleaning) and personal sources (smoking, activities). The most highly exposed segment of the population receives most of their PM exposure from environmental tobacco smoke. Ambient sources penetrating indoors make up the largest proportion of the least exposed population's exposure. In-vehicle exposures to PM2.5 may exceed ambient concentrations by an order of magnitude or two. Since people are taking longer commutes, as much as 2 or more hours per day, in-vehicle exposures can be a potentially high contribution to total PM exposure. Since time series epidemiological studies look at day-to-day changes in ambient PM concentrations, there is interest in understanding and quantifying the correlation between personal exposure and ambient concentrations over time. Many studies have demonstrated high correlations over time between personal exposures and ambient PM concentrations, especially for markers of ambient source PM such as sulfate and elemental carbon. Sulfate is an indicator of regional source ambient PM while elemental carbon is an indicator of local source ambient PM. Studies for coarse and ultrafine particles are still needed. Generally, consistency in ambient-personal relationships exists across population subgroups and locations, but there is a lot of variation within subgroups. Apportioning someone's exposure by source produces a better assessment of the priority sources to mitigate. Estimation of infiltration efficiency, the fraction of ambient PM that penetrates indoors, and exposure attenuation, the fraction of ambient PM that contributes to personal exposure, can be performed with a variety of approaches (outdoor tracer methods, the recursive model (using continuous measurements), a mass balance model (measurements of indoor, outdoor concentrations and air exchange rates), and a total exposure model). Studies show a 50-70% contribution of outdoor PM to personal exposure. Infiltration efficiency is strongly correlated with air exchange rate; the higher the air exchange rate, the higher the infiltration. Across population subgroups, no particular subgroup stands out as having a higher fraction of ambient PM as its total personal PM exposure, although residential infiltration efficiency explains much of the variability between individuals. Within a population of subjects with chronic lung disease studied in Vancouver, one can demonstrate that exposures to ambient PM have a significant relationship with health effects. Between-city comparisons in epidemiological studies are supported by a consistent average attenuation factor across locations, varying from 0.4-0.7. Although there is high correlation between ambient PM and personal exposures, there is large variability in exposure attenuation, probably due mainly to differences in indoor ventilation. Identifying the sources of exposure to ambient PM would point to which sources to reduce.

Nancy Brown, *Lawrence Berkeley National Laboratory, Field and Modeling Investigations of the Fate of Outdoor PM-2.5 in Residences*

Individuals spend 85-90% of their time indoors, and yet outdoor measurements are used to assess exposure. A research group at LBNL performed extensive field measurements to understand the transport and fate of outdoor PM in indoor environments. PM can enter indoors through infiltration, exfiltration, coagulation, deposition, formation, resuspension, and phase change. LBNL used a house in California as a laboratory. The research team manipulated the house's pressure, window openings, and indoor-outdoor temperature differences. A key condition was the absence of indoor PM2.5 sources such as cooking, smoking, or cleaning. The research group used a suite of field instruments to detect different particle sizes and types. High exchange rates and lower temperature differentials were associated with comparable outdoor and indoor environments. Low exchange rates and high temperature differentials were associated with substantial differences in outdoor and indoor PM concentrations. Because of the highly time-resolved measurements, the time-derivative of the indoor concentration could be calculated. Although averaged concentrations produce a better curve fit, a time-averaged model predicts indoor/outdoor ratios that vary significantly from individual measurements. Filters are useful to measure long-term exposures, but not for acute exposures (e.g. 10 minutes), where more short-term detail is necessary. In the San Joaquin Valley, ammonium nitrate's contribution to PM is a major concern, so researchers are interested in what happens to ammonium nitrate inside a building. This research has implications for the penetration of outdoor ammonium nitrate indoors. Higher temperatures are associated with higher evaporation rates. It was important to verify that the results came from actual concentrations, not from artifacts of measuring techniques. The dominant process affecting ammonium nitrate is shaped by thermodynamics and kinetics. Chemically and time-resolved data are necessary for elucidating indoor particle transformations and their dynamics. Predictive mechanistic understanding has been achieved for chemical transformations of individual chemical species, physical loss terms for PM, and infiltration rate. The ultimate objective is to extend the model to other types of structures with different ventilation rates.

Discussion:

Further research will have to take into account indoor activities. For example, installing an exhaust fan to disperse smoke from a stove will increase particle penetration from the outside. Pets or diapers are indoor ammonia sources, which should be included in future modeling. Regarding in-vehicle exposure, ;leaving car windows open or turning on the fan will result in high exchange rates, and potentially lead to higher exposure. The exposure depends largely on the speed of surrounding cars and the length of commute. People are usually told to remain indoors in high ambient PM conditions. However, there may be events where the public would be encouraged to open their windows, or to even stay outside, a reversal from the traditional advice. The response depends strongly on meteorology and the infiltration rate in the home. If outdoor concentrations are lower, then people should be encouraged to go outside. The response differs for ozone and PM. Since ozone does not penetrate indoors, people are told to stay inside on high ozone days. A key issue is determining how to communicate directions to the public without confusing them or exposing them to other risks. For example, in poor neighborhoods on very hot days, it is worse for people to stay inside where there is no air conditioning. The scientific community has been demanding better data on the correlation between ambient exposure and personal and indoor exposure. The research just presented demonstrates that the research funds have produced useful data.

Ron Wyzga, ***Electric Power Research Institute, Cardiovascular Endpoints and Air Pollution: Recent Results***

Health concerns related to air pollution tend to focus on respiratory effects rather than cardiovascular effects. The Aerosol Research Inhalation Epidemiology Study (ARIES) study, conducted in metropolitan Atlanta, examined many different cardiovascular endpoints. The team looked at CO, NO2, PM2.5, PM10, coarse PM, ultrafines, and oxygenated hydrocarbons. The different endpoints were daily mortality, emergency visits, arrhythmic events, unscheduled physician visits, and heart rate variability. The ARIES research team started with several initial hypotheses. This study differed from other studies in that it took an a priori model and ran sensitivity studies on that model. Setting a model in advance avoids simply fitting the data to the results. Lags were fixed for the different endpoints, but time periods beyond the fixed lags were also considered. With background levels as a baseline, the investigators compared the increase in deaths for incremental risks above the background levels. Carbon monoxide was the only pollutant giving statistically significant results. In a single-pollutant model, NO2, CO, PM2.5, organic carbon, and elemental carbon had statistically significant higher risks. The relative risk comes from increasing the pollutant concentration by one standard deviation above the background. There was consistency between AIRS and ARIES data. A two-pollutant model, such as that for PM2.5 and CO, needs a lot of statistical power, i.e. a larger sample size, to show which pairs have the strongest effects. All five pollutants were tried in a model, but CO was the only one that stood out with significant cardiovascular effects. The sample sizes were constrained by the date when pollutant measurements began. For unscheduled cardiovascular visits, the default lag structure was zero, one, or two days, but unexpectedly, the lag extended to 3 to 5 days. People probably waited to go to urgent care if they did not already go to emergency care. There are several limits to the modeling approach. Statistical power varies by pollutant data availability. For example, PM2.5 was not measured until 1998. CO is not very spatially homogeneous which means results could be underestimated. Therefore, the model results may not have been as robust. While CO was the best index, it could also be an index for something not measured. Comparing the ARIES results to other studies, there was consistency across studies and similar endpoints. CO should not be ignored. Future research should consider the possibility of higher peak exposures near roadways, and conduct studies in other cities. CAPs studies may not explain what is going on because it only conserves particles, not gases. Other epidemiological studies will be necessary.

Discussion:

Incorporating the day of week into the model accounts for weekday and weekend differences. Nitrogen oxide data was available but it was not one of the eleven pollutants studied. Human and animal studies have the same endpoints, so CAPs studies can be used for comparison. Recently completed studies indicated no effects when CO was added to CAPs. CAPs studies are focused on understanding mechanisms so their endpoints would differ from those in epidemiological studies. There was the question of whether the survival of CO indoors in hot weather explains the strong CO effects. Cardiovascular events occur more often in the winter. One of the surprising sources of CO is controlled burn in the winter. Adjusting time periods would not be enough to put ARIES and CAPs studies on par because PM2.5 data is not available for 1993. One option is to wait a few years, when there are more data points for PM2.5 and compare PM2.5 for the same length of time as other pollutants.

Mark J. Utell, *University of Rochester Medical Center*

A recent series of epidemiologic reports have shown associations between fine particulate matter (PM) levels and increased cardiovascular and pulmonary morbidity and mortality. Elevated PM levels have been linked with cardiac events including serious ventricular arrhythmias and myocardial infarction as well as asthma hospitalizations and alterations in lung function. Given this series of studies, there was a paucity of toxicological and clinical studies looking at possible mechanisms. Firmer conclusions for policy implications appeared to be dependent on finding underlying mechanisms that that could explain why one might anticipate these cardiac or respiratory responses.

Recently, several mechanistic pathways have emerged that may underlie the link between PM exposure and adverse health effects. The portal of entry for PM pollution is the lungs, and PM interactions with respiratory epithelium likely mediate a wide range of effects. Research findings support different pathways by which particles can affect the respiratory tract and cardiovascular system: 1) inflammation - both pulmonary and systemic, with perhaps a key role played by reactive oxygen species; 2) alterations in immune competence; and 3) autonomic nervous system dysfunction. For example, clinical studies of young and elderly subjects exposed to real-world or surrogate particles have shown reductions in heart rate variability, altered cardiac repolarization, and increases in blood fibrinogen levels. Ultrafine particles, by virtue of their extremely small size, may enter pulmonary capillary blood and be rapidly transported to extra-pulmonary tissues such as the liver, heart or even brain via nerves.
A number of recent clinical and toxicological cardiovascular observations provide insights into potential mechanisms. For example, healthy volunteers exposed to CAPs (concentrated ambient particles) and ozone for 1 hour resulted in constriction in the diameter of the brachial artery. This may reflect changes that are also occurring in the coronary arteries. In addition, elderly subjects exposed to CAPs for 2-hours demonstrated a decrease in heart rate variability and heart rate, immediately and 24-hours post-exposure, reflecting changes in autonomic cardiac regulation. Similarly, inhalation of ultrafine carbonaceous particles (CMD = 26 nm) by healthy volunteers at 10 and 25 ug/m3 for 2-hours with intermittent exercise resulted in blunted cardiac repolarization. Most recently, exposure to ultrafine particles was found to cause a significant reduction in the diffusing capacity for carbon monoxide 24-hours after exposure. Coupled with the changes in adhesion molecules suggesting increased stickiness in the pulmonary capillaries, the fall in diffusion capacity presumably reflects vasoconstriction in the pulmonary circulation. Exposure to diesel particles, ultrafine particles and CAPs has also resulted in changes in local and systemic immune responses and/or pulmonary inflammation, mechanisms of key importance in the development and exacerbation of asthma. Despite major progress, large uncertainties exist on the scope and significance of experimental data in explaining the epidemiologic findings on the risk of PM. Furthermore, the most hazardous components of PM remain to be identified; although the field has been narrowed, a large list of potential candidates exists. Answering the key questions concerning the hazardous components of PM will be a central focus of the next generation of research studies. It is unlikely that a single component will be responsible for causing the range of clinical effects described to date but rather that different components will be linked with specific health outcomes.

Discussion:

The studies describing changes in immune function and production of IgE have been performed only with diesel particles; it would be important to see whether other types of particles at near ambient concentrations would also result in alterations of immune function. Furthermore, it will also be interesting to determine if inhalation of diesel particles causes the changes in IgE production that have been reported after nasal instillation.

Douglas Dockery, *Epidemiology of PM Health Effects: Are We Underestimating Benefits?*

The ACS Cancer Prevention Study II study and short-term mortality studies (within 1-3 days) produced estimates of PM-attributable net mortality. One of the greatest values of the ACS study was that it sampled 50 representative cities across the U.S., matching people with EPA AIRS data based on zip code. The sulfate and PM2.5-associated mortality risks of 17% and 15% were statistically significant. The Harvard Six Cities study also found a high correlation between mortality rate and increasing PM2.5 concentrations. In a comparison of increased mortality risk, the two studies generate similar total and cardio-pulmonary lifetime mortality risk. Even though the error bars for the two studies overlap, the ACS estimates are consistently lower than the Six Cities study. This discrepancy may be caused by individual confounders, but most likely by a worse estimate of exposure due to local influences and spatial disaggregation. Getting more data will not change the studies, only narrow the confidence intervals. The Six Cities study examined smaller geographical units than ACS. The Netherlands Cohort Study (NLCS), a study of traffic-related air pollution exposure in the Netherlands, used even smaller units of population – actual street addresses. It has higher risk estimates for total and cardio-pulmonary activity than Six Cities and ACS, but its small sample size produces very wide confidence intervals. These observations illustrate the trade-off between reducing confidence intervals and improving exposure assessment. Coarse spatial studies may underestimate the health effects of PM exposure. According to the Six Cities follow-up, the particulate matter levels had gone down in all the cities. Consistent with the original hypothesis, mortality rates have gone down as PM concentrations have dropped. The 1952 London Fog episode's impact on Dublin illustrates the importance of extending the time lag for PM-associated mortality. The observed delay between acute pollution events and the number of deaths is longer than previously expected. The black smoke event produced statistically significant effects in Dublin, in the form of cardiovascular and respiratory-related deaths. The biggest effect occurs on the first days after the episode, but approximately 10 days past the episode, a negative effect occurs because of "harvesting." Acute pollution exposure advanced the date of death for those who would have otherwise died a few days later. Cardiac effects are very immediate, and they go away after very few days. Respiratory effects have even larger immediate effects, and then drop below zero after 10 days (harvesting), and then produce a large delayed effect between 2 and 3 weeks after the event. Neglecting delayed effects underestimates the effects of pollution in these acute studies. When the Dublin government banned coal sales in 1990, black smoke levels dropped by 75%. Using an extended time period, it was observed that cardiovascular events went down because of the ban. Current chronic effect studies have underestimated PM-related mortality. Studies with better exposure assessment indicate higher estimates of health effects. Time series studies which only focus on 1-3 day associations are likely to underestimate PM related mortality.

Discussion:

The studies adjust for the age distribution of the population in all the cities. One possible confounder could be the quality of health care, but HEI's reanalysis of Six Cities did account for the number of doctors per person in each city. Including this factor did not change the results. However, there is still the possibility of certain factors changing over time. For example, one city's health care may improve over time, and this is not included in the studies. Unusual events, such as the Canadian forest fires could cause spikes in PM levels. In the case of the forest fires, the plume moved over New England, affecting communities in just a few hours. There is a definite trade off between improving exposure assessment and obtaining larger sample sizes. It may be important to consider the duration of exposure since some cities suffer from prolonged exposure rather than peak exposure. Multiple exposures would be additive, and show up in the mortality rates. Nevertheless, the air quality standards focus on peak exposures.

Ted Russell, ***Atmospheric PM Modeling: Urban to Global Issues***

The PM models currently used are actually evolved ozone models, but they differ in that PM models have organic and inorganic aerosol components. Organic aerosols are very complex and their quantity is very large, but they are usually lumped into a condensable organic species. Meanwhile, particles are divided into size categories, like PM10 and PM2.5. Researchers are now working with more compounds, more phases besides gas, larger spatial domains, longer time periods, and more complex grid structure. Despite advances in technology and knowledge exchange, there are still computational limits. The most problems exist in the evaluation of the model because of inadequate monitoring and, subsequently, the lack of data. Ozone modeling, which is performed well, is the benchmark for checking the status of PM modeling. Among all the various types of particles, there is a high level of confidence in the models for sulfate particles. Organic carbon and nitrate modeling have a lot of errors. Predictions still deviate substantially from measurements. Poor performance stems from the estimated carbon component of the emissions, non-resolved chemistry and lack of knowledge in gas-particle conversion phenomena. On the gas phase side, current models rather accurately simulate ozone and associated species. In the condensed phase, many components are simulated relatively well some of the time. However, PM modeling is a decade behind ozone modeling. The main obstacles in PM modeling are organics and nitrate. Emissions predictions are getting better for ozone precursors but primary PM and ammonia estimates are still uncertain. There is significantly more monitoring now, but it is mainly for 24-hour time period rather than hourly averages. Nitrate "bounce-back" occurs when sulfate reductions are reduced, thereby freeing ammonia to react with nitric acid to form ammonium nitrate aerosol. When SO2 is reduced, sulfate is reduced but nitrate emission increases, but by less than an order of magnitude compared to sulfate reductions. Most SO2 reductions come from in-state reductions, while some come from neighboring states. Therefore, long-range transport is less of an issue than is publicized. Most reduction benefits stay in-state. The radiative forcing potential of tropospheric aerosols is highly uncertain. There is a large amount of uncertainty for an indirect effect when doing forward calculations, but there is less uncertainty in inverse calculations. Black elemental carbon's significant light absorption makes it an important contributor to radiative forcing. Climate change concerns may be another reason to clean up diesel emissions. Uncertainties about the soot mixing state and aerosol forcing exist. Ammonia, OC, and EC emissions are very uncertain, and have very different emission scaling factors. Supersites, monitoring, EPA organic carbon projects, Regional Planning Organization (RPO) modeling, and increased attention to precursor modeling offer prospects for rapid advancement in PM modeling. The greatest needs for future research are on emissions, esp. in ammonia, organic carbon, and short term measurements.

Discussion:

There are results from the late 1980s on the effects of sulfur control strategies implemented for acid rain, and the trends are heading in the right direction. The uncertainties associated with nitrate are easier to understand because it is one species. Organic carbon is much more complex because of gas model partitioning. Compounds which are directly emitted or created chemically may be used as tracers to measure other compounds. There has been less academic research in aerosols than there has been with ozone models. There is also a lack of concentrated sensitivity analyses with aerosols. Sensitivity analysis of rate constants, yields, and gas-particle partitioning coefficients is currently underway.

Axel Friedrich, *Umweltbundesamt, PM-Control Strategies in Europe*

Data from European epidemiological studies indicates that equipping all diesel engines with filters would avoid 14,400 deaths annually. Sensitivity analyses with different model assumptions reveal that this estimate could be larger. In the eastern part of Germany, fine particle concentrations have gone down, but ultrafine concentrations have gone up because of the greater number of diesel cars. Germany supports further reduction of NOx and PM, in the form of obligatory emission standards effective in 2010. These standards can continue to be a basis for fiscal incentives. Germany's desire for more stringent diesel engine requirements may prove a hardship for the poorest people, who tend to drive the dirtiest vehicles. The number of diesels in Europe has increased in every country in Europe. In spite of more stringent PM standards, the overall PM emissions of passenger cars have been higher than those of heavy-duty vehicles. Since passenger cars are more likely to be driven in urban areas, they contribute to a higher health risk. Trap-equipped diesels emit a lower particle number than even gasoline vehicles. The PM diesel standards are eight times less stringent than gasoline standards. NOx emissions from diesel vehicles are higher than from similar gasoline vehicles. A small diesel engine needs more power so therefore it has higher NOx emissions than a larger diesel engine. Although the proposed Euro V standards are not effective until 2010, tax incentives are effective in 2005 because cleaner engines are already technologically feasible. A high tax incentive can be attractive enough to make it as effective as a law. NOx emissions of HDV have been underestimated in Germany, which must follow two directives. Germany has introduced a road tax for heavy-duty vehicles, depending on the emissions of the truck. Combining existing filter and SCR technology puts a vehicle far below the current Euro V limits. Manufacturers have decided to go with urea SCR systems. SCR reduces fuel consumption whereas the NOx trap results in greater fuel consumption. 2010 is too late for Euro V to come into effect. Since the EU commission is the only group that can make a proposal, the German and French governments are working together to pressure the EU to make a proposal soon.

Discussion:

When the EU moved from the Euro I NOx standards to Euro II, European engine manufacturers were able to increase emissions at speeds unmeasured by the certification tests. This was legal but not good for the environment. Since U.S. and Europe have different driving cycles, the data must be adjusted for those variations, but differences were not that large. An oxidation catalyst for diesel vehicles increases NO2. Oxidation catalysts without filters make the particles smaller, which penetrate more deeply into the lungs. Filters can also be installed for stationary diesel engines. In Germany, heavy-duty vehicles turn over in 5 years and 1 million km, much faster than in the U.S. Even smaller vehicle engines can be retrofitted with filters. Congestion pricing works in London because of the city's traffic patterns. It is relatively easy to control because there are only a few roads going into the city. Most Germany cities have a lot of inner city traffic, so London's strategy would not work. Germany's solution is to change the length of traffic lights to limit the number of vehicles in the cities. There is a need to estimate the air pollution impacts of traffic management approaches. Some environmentalists actually like congestion because it discourages driving and thereby reduces emissions.

John Watson, *Applications of Receptor Methods to Air Pollution Problem Solving*

Dr. Watson summarized in his talk the basic mathematical approach and use of receptor models to establish source apportionment in receptor sites. He summarized the types of receptors models and their use. In receptor models you measure air pollution concentrations and determine the possible sources that are contributing to air pollution in a receptor site. Equations, parameters and variables involved were described as well as the differences between receptor and source models. In the case of receptor models there are different solution methods and usually they are called statistical models, but they are not. The model is physically based, with assumptions and evaluation of deviations as any mathematical model. The eyes and noses are the first receptor models. We detect and see pollution and can identify the possible source. However the system is more complex when different sources and pollutants exist. In this case it is necessary to identify markers (usually called tracers) to run more complex receptor models. Several examples of receptor model applications were given by Dr. Watson. He discussed the type of model based on the mass balance equation for different markers (CMB Model). The first step is to have a chemical description and percentage of markers in receptor sites. The second step involves source profiles, where the markers are identified in several sources and used to set up a set of mass balance equations to be solved. The problem is that analysis of samples and sources are tedious and expensive. Differences in fuel components are an example where key components identify their possible sources, like gasoline or diesel vehicles. Time resolution of data is also an important element that helps to identify possible sources. Several applications and results obtained for Houston, Mexico City and other places were presented. Dr. Watson discussed several examples of how secondary pollutants may be identified with receptor models. Another important application is that it is possible to evaluate the effectiveness of control measures by looking at marker trends. Receptor models can be used to predict future conditions and used for planning. He discussed a case where the use of different models leads to different results. The analyst should be aware of the variability of results using different models. Another important aspect is that discrepancies in the model help to improve the analysis process and to improve, for example, the quality of the data in an emission inventory. He commented the approach suggested by EPA to use of receptor models in SIPs. Dr. Watson finished by commenting on the needs of receptor models and the steps to obtain reliable results through calibration, validation and reconciliation of data.

Discussion:

Dr. Watson answered questions related to reliability of emission inventories, coarse fraction apportionments, the connection between inverse modeling and receptor models, and the use of different methods to obtain PM profiles. He mentioned that there will never be enough resources to build up a reliable emission inventory and studies need to be performed with the data available. Better apportionment can be achieved with better information of time resolution and particle size distribution. Inverse modeling is basically a receptor model and there is always some degree of uncertainty in the application of the models.

Praveen Amar, *Controlling Emissions from Industrial Sources of PM and its Precursors*

Dr. Amar talked about control technologies and costs for NOx, SO_2, PM and Hg, some possibilities for technology transfer and guides for optimum control strategies. Sources of fine particles in western and eastern cities of the US were compared. Major sources of emissions for SO_2, NOx and Hg in the US were shown and a US map with the annual average of particle concentrations was described. Control technologies used for NOx emissions in Power Plants were discussed it was emphasized that transportation is the main source of NOx. The contribution in NOx emissions of different fuel use in utilities plants was discussed. In this case coal burning is the main source. Dr. Amar commented that control technologies are based on primary and then secondary control. Primary control reduces the production of NOx and secondary control reduces NOx already in the flue gas. The basic form of primary control consists in the control of the air/fuel mixture. The secondary control is based on the use of ammonia and its physical and economical requirements. Dr Amar discussed the evolution in time between regulations and NOx control in the US and the NASCAUM/MARAMA report on seasonal NOx control. Benefits of better control can be obtained with a small additional investment. The results of a study with the objective of having the largest reductions of NOx for a given investment were discussed. Dr. Amar commented on the characteristics, costs and legislation related to sulfur control, where scrubbers are the main device used. It is recommended to look at costs in the future and not only the actual costs in the control of sulfur emissions. Several processes for sulfur control were described. In this case the cost of control is higher than for NOx. The characteristics and efficiency technologies for fine particles control were described. Dr. Amar discussed the mercury removal trends with ACI for three sources, the costs and removal efficiency for each source and the costs of Hg control and NOx control. The controls in heavy diesel machinery used in the big dig project in Boston were described and the state inventory results for emission permits were summarized. Ammonia emissions should also be considered. Dr. Amar commented on the increase of ammonia emissions in the US, the role of acid formation and secondary aerosols and the need for a better estimate of primary PM2.5 and speciation. He finalized mentioning that SOx and NOx have an important role in acid aerosols and secondary aerosols formation.

Discussion:

Dr. Amar answered several question about disposal of Hg collected, sources of PAHs, use of fuels like CNG, and economic impacts in the use of CNG. He commented that Hg must be disposed properly and that PAH sources are important but data is not available and something must be done. About CNG, it is important to keep track of the use and costs associated with its use and the possible benefits, although this is not simple. A discussion of possible costs and implications followed this comment.

Steve Cadle*, Non-road Mobile Source Emissions*

In his presentation Cadle described the major categories of non road sources and the model used to estimate their emissions. In California, non-road sources are called off-road and off-highway sources. These sources are categorized by the type of fuel used. Both diesel and gasoline categories were discussed in his presentation. Regulation of nonroad sources was authorized by the 1990 CAA amendments. Tier 1 regulations went into affect in the mid-1990s. The emission standards for non road diesel engines as a function of their rated power and the program to meet the Tier 1, 2, 3, and 4 standards were described. The emission standards for marine diesel engines spark ignition engines were also discussed. Mr. Cadle described the NONROAD emission inventory model. The emission inventory model for non-road emissions is similar but simpler than for on-road sources despite the complexity of non-road sources. The NONROAD model will be merged with the MOVES model in the near future. Recent changes to the NONROAD emission inventory model and details of the national PM emission inventory were discussed. The contribution of different nonroad sources to the nonroad PM and NOx emissions inventory was presented along with the contribution of the different sources to the national PM2.5 emission inventory, and the contribution of the different sources in the SCAQMD PM2.5 emission inventory. The conclusion is that non-road sources are a significant source of NOx and PM2.5.

Discussion:

Cadle answered questions about the estimated CO and VOC emissions, and adjustments on estimates of fugitive dust. He commented that there are some estimates of CO and VOC emissions, but they need to be reviewed. There were some comments on the age and retrofit of non-road sources and alternative technologies that are being used. Cadle did not know if EPA is doing something to adjust estimates of fugitive dust, but he stated that these emissions may be important at local level.

Dave Kittelson, *Nano Particles from Present and Future Engines*

In his presentation, Mr. Kittelson described the origin and formation of nanoparticles, their composition and the characteristics of present and future engines. Initially, nanoparticle measurements were focused on filter mass, but now other characteristics are of interest, like size, number, surface, etc. The major concern is that diesel engines are important sources of nanoparticles. Usually they are formed from cooling of gases. Mr. Kittelson described a typical particle size distribution coming out of an engine. He discussed the formation, typical composition and structure of nanoparticles in diesel engines. The process of formation starts with carbon formation followed by ash condensation, exit in tailpipe, sulfate nucleation and growth, to finally reach its receptor. The nucleation consists of volatile precursors, creating particles in the range of 30 to 500 nm. The characteristics of the thermal denuder measurements were described. The results show that the nuclei mode is usually volatile. Mr. Kittelson discussed the results of a study performed with diesel engines where a mobile laboratory was used to study the formation of nanoparticles in the atmosphere. The results of the CRC E-43 program to investigate the formation of the nuclei mode on road and in the laboratory and the conditions that may influence the formation of nanoparticles were presented. The size distribution results for diesel and spark ignition engines and the fuel specific emissions results of a summertime highway cruise study were discussed. Mr. Kittelson mentioned possible sources of emissions that need to be considered, like cold starts and changes in speed. He finished describing the volume distribution of nanoparticles formed and the influence of fuels.

Discussion:

Mr. Kittelson answered questions about the nucleation process and the influence of filters, loss of mass by volatilization and the half-life of particles. He commented programs to improve estimates of nucleation. Some measurements show that evaporation is important. There are some studies made by Pandis to study the evolution of nanoparticles.

Matti Maricq, Which vehicle technologies have low PM emissions and how do you tell?

Maricq started his presentation addressing issues and conceptions about diesel and gasoline vehicles, the use of CNG, and the influence of vehicle age on PM emissions. A comparison of PM emissions measurements based on gravimetric mass, particle size distribution, on road chase, and wind tunnel data was presented and the characteristics of the emissions laboratory were described. CNG vehicles as well as properly functioning new and high mileage gasoline vehicles have low PM emissions, while conventional diesel engines have high emissions that can be reduced greatly using a diesel particulate filter (DPF). The particle size distributions of PM from gasoline and diesel engines and their emissions as a function of time during operation were described. The cold start and the influence of the stoichiometric ratio are both important parameters in the production of PM in gasoline vehicles. Maricq described the emissions and particle size distributions obtained from chase studies of light duty diesel vehicles, and described how higher sulfur content in the fuel can lead to particle nucleation as the exhaust exits the tailpipe and cools. He presented results from wind tunnel studies of gasoline PM emissions, where PM emissions above background were observed only during transient accelerations, and where particle nucleation was not observed even as the sulfur content was raised. The second half of the talk addressed the important problem of how to measure PM emissions at low levels and the question "What do filters really measure?". Experiments using multiple filters in series showed nearly equal mass on all three filters from a DPF equipped low emitting diesel vehicle, indicating that the filters were primarily measuring gaseous hydrocarbons and not PM. Comparisons showed that the two regulatory filter methods have large disagreements in the "PM" mass they record at low levels, and that both overestimate the PM mass as derived from aerosol instrument measurements. Results of PM mass measurements from a European GRPE-PMP cross test showed similar disagreements at low PM emissions. Maricq concluded comparing the characteristics of low PM emitters and high PM emitters. Proper design and operation of vehicles may result in a low emitter, whereas with poor design or malfunction any vehicle may become a high emitter. Gravimetric PM measurements are not reliable at the new low PM emissions standard because of their sensitivity volatile HC.

Discussion:

Mr. Maricq answered a question related to calibration of instruments at the conditions of measurement. He mentioned that it is not only calibration important; you need to make sure that the instrument actually measures the PM that you are interested in, and not something else.

John Fairbanks, Overview of Issues Involving Diesel and Natural Gas Engine Buses

In his presentation, Fairbanks gave a summary of major studies on PM emissions of diesel buses. The emissions of CNG and diesel buses as well as emissions of other fuels used and the potential for cancer potency were commented. Results show that low emitting diesels have low cancer potency compared with CNGs mostly because of formaldehyde emissions. However results in Sweden show that diesels may have a higher cancer risk that can be reduced meeting the new emissions standards. Fairbanks compared the emissions from different vehicles and he found that diesels seem to have low emissions. The cancer risk index is also higher for gasoline vehicles than for diesel vehicles. He mentioned that traps will be used in European cars to reduce PM emissions. New control technologies include a device based on ionizing particles so they agglomerate and can be captured easily. Results in PM emissions reductions using this device were discussed as well as other technologies to reduce PM emissions. A summary of results are that nanoparticles are of major concern and diesels should be fitted with DPT (diesel particle traps). Fairbanks finished mentioning that diesels are more efficient and durable then CNG buses, providing significant cost advantages.

Discussion:

Fairbanks answered a question about the operation of CNG vehicles. He mentioned that there are differences in the operation of CNG vehicles at lean or stoichiometric conditions.

Doug Lawson, DOE's Gasoline/Diesel PM Split Study

Lawson presented and discussed results of the DOE's Gasoline/Diesel PM Split Study. The emission inventory data predicted a reduction in HC from mobile sources in the order of 70%. However, results from 1990 do not show this and now the same objective is pursed for 2010. Ozone trends in the South Cost Air Basin were discussed. Although the VMT have increased, the ozone violations have decreased, mainly because of the introduction of better fuels and vehicle technologies. Old cars are dirtier, although there is a fraction of high polluting new cars. They conducted a study to estimate emission rates for different vehicles at different temperatures and winter indoor and outdoor conditions. Lawson discussed mobile source profiles obtained with receptor modeling. He presented a study to determine differences in PM emissions from gasoline and diesel powered light-duty vehicle engines with different accumulated mileages. The characteristics of the vehicles tested and the equipment used to run the tests were described. They found that emissions of PM are higher during the cold start. Trucks of different capacities were tested too. The tests were run using California diesel and the results showed differences depending on driving patterns. Lawson finished by describing the remaining work to finish the study.

Discussion:

Lawson answered questions about the use of the CMB model and the I&M programs. He mentioned that the CMB model has not been used, but the data is available. I&M programs test vehicles' exhaust and emission components. Failing vehicles are not allowed to obtain a registration until they can pass the test. There is evidence that the I&M programs are not as effective as thought. A comment was made that on-road data showed Virginia's I&M program was effective at reducing emissions.

Wayne Miller, *Effect of Driving Cycles on HDDV PM Emission Rates for PM Mass, EC and OC from In-use Heavy-duty Diesel Engines*

Elemental and organic carbon can make-up over 90% of the PM mass emitted from diesel engines, and our research focuses on mobile sources where much of the PM10 emissions come from. These factors, along with the evidence that OC contains carcinogenic compounds, highlights the importance of the investigation of in-use, mass emission of PM, EC, and OC from heavy-duty diesel trucks. Miller showed a graph with an engine's NOx emissions vs. fuel usage rates at different operating modes for modern engines with electronic engine controls. One data cluster represented the certification emissions and another cluster represented the fuel-efficient mode. Because each engine manufacturer has a different set of data, these nonlinear data show the importance of in-use measurements.
UC Riverside's mobile emission lab is mounted in a truck where the full exhaust goes into a full-dilution tunnel. A secondary dilution system is set up to control the temperature for PM sampling. With this configuration the group analyzes both regulated and non-regulated emissions. Since there is no ASTM standard to compare the results from their in-use testing, the group has to rely on internal calibration. Verification testing was performed at CARB's HDDT test facility. The results from UCR and CARB were comparable to other cross laboratory studies. The test protocol involved Class 8 tractors, <15 ppm sulfur, and CARB's 4-mode HHDDT test cycle. This cycle is comprised of cold-start idle, creep, transient, and cruise. Certification cycles typically take all the data from real driving, and condense it into 20 minutes so it is difficult to understand the impact of various driving cycles. Tests were repeated on 3 non-consecutive days, with good test-to-test repeatability and good precision in the covariance, especially during the cruise part of the cycle. During the cold-start/idle, the organic carbon emissions dominated, which was not a surprise. In the transient mode, elemental carbon dominated over organic carbon. Total emission rates decrease in cruise mode and the fraction of elemental carbon increases as the driving cycles move to higher sustained speeds. EC and OC emission factors are strongly dependent on driving mode. As compared to other engines in the same family, one engine acted as an anomaly because it was performing badly and could not go at the high speeds in the cruise cycle. Since the cruise mode has relatively lower PM emissions than the other modes, congested conditions lead to more emissions per mile. This could have significant health effects for those who commute for long periods of time in heavily congested conditions. For steady-state backup generators, the team has followed the ISO standard, which calls for a 5-mode steady-state cycle. Most backup generators mainly run for maintenance reasons. Diesel oxidation catalysts reduce PM in newer backup generators (BUGs) by about 15%, but OC dominates in older engines, where the EC/OC ratio is less than 1, so it is possible to reduce the organics by as much as 40%.

Discussion

The audience recommended testing on a variety of driving and temperature conditions. It was even mentioned that dynamometer testing still has its merits over mobile lab testing. It was commented that sometimes truckers may dope their fuel with various additives.. However, based on the industrial experience, most truckers do not use additives because they are expensive. Those that do use additives are not representative of most fleets.

Tim Johnson, *Update on Diesel Exhaust PM Control Technologies*

PM filters are being widely applied and are in a stage of optimization, but technology needs to match the regulations. Japan will have the tightest tailpipe regulations with heavy-duty filters in 2005, after that U.S. will follow in 2007. Euro IV in 2005 is coming next, with significant PM and NOx tightening. Even though filter technology has been around for a while, there are still some complications. Filters can be applied to 90-99% of the cases but 1% failure is unacceptable in the market. The optimization includes regeneration, secondary emissions, backpressure and ash management. Using PM filters is only part of the solution; integrating NOx control is also important. EU, Japan, and U.S. regulations are tightening on PM and NOx. In the year 2005, filters, diesel oxidation catalysts (DOCs), and selective catalyst reduction (SCR) will be used. Japan will use diesel particulate filters (DPFs) and advanced combustion to get to 2005 regulations. Also in 2005, some of Europe's heavy-duty diesels (HDD) will use DOCs or engine-out technology. The rest of Europe's HDD will use 70% SCR, and they will not need filters because Euro V is similar to Euro IV in PM. NOx is the most difficult pollutant to go after and it is very difficult to meet the Tier 2 Bin 5 standards with light-duty diesels. California, Japan and Switzerland have mandated retrofits while the rest of the U.S. has a voluntary target. In U.S. the retrofitting has started with school buses because of sensitivity of children to air pollution. Hong Kong is requiring retrofits with DOCs, and maybe filters. Because of the nature of the fiscal incentives in Tokyo, manufacturers are using up all filters currently in production. DPFs can get clogged with soot, so catalysts are used to facilitate the oxidation of the soot. But because filters operate when most of particulates are in gaseous phase, the oxidation catalysts do well for the gaseous state, while particulate filters have higher efficiency for dry soot (particles). Filters are considered effective enough such that tailpipe emissions are less than ambient levels in laboratory. Wall-flow cordierite and SiC, and metal mesh/foam are the most popular filters. Peugeot has the most advanced filter regeneration strategy, which uses both an oxidation catalyst and particulate filter. Temperatures are increased such that the soot can be burned up in the filter after it is oxidized by the DOC. Regenerating filters is difficult and potentially unsafe under the entire range of conditions, especially when they have a large amount of soot and the temperature becomes too high. There are, however, filter maps that can show the conditions for a safe regeneration. The goal is to not exceed the temperature limit and still reach 100% regeneration. There are advantages of regenerating frequently because fresh soot is highly reactive and easier to burn off. Sulfur needs to be removed from fuel or else sulfate is formed in the DOC. In the case of ash management, there are different suggestions for cleaning ash. Washing with water may work for uncatalyzed filters, but not for catalyzed ones. There are 5 trucks in the U.S. running with DPF and SCR. They have NOx traps and filters being used together. There are fuel economy benefits by minimizing the amount of exhaust that needs to be made rich. The NOx adsorber has a 1 to 4% fuel penalty, which is comparable to the effective urea fuel penalty.

Discussion

A lot of retrofit applications depend on what type of vehicles you are doing the work on. It might be easier on a larger truck, but much tougher on an ambulance because of the idling and cold temperatures. Despite that, there are many trucks that could be readily retrofit. Eventually there will be economical programs that will help. Governments can use tax incentives to encourage companies to perform retrofits. There are some companies who have benefited from that.

Spyros Pandis, ***Atmospheric Aerosol Source-Receptor Relationships: Insights from the Pittsburgh Supersite***

Urban sources of particles and ways to control them are being investigated in Pittsburgh as one of the country's "Supersites" efforts. Measurements every two hours over a year and a half period have generated a lot of useful data. Results indicate that the fine PM is made up largely of organics and sulfate. Sulfate was significant in the summer and lower in the winter. While organic matter was mostly consistent in all seasons, nitrate was larger during the winter. Initially, neglecting the inclusion of water in mass calculations resulted in errors when adding up the particle mass totals for the summer months. Evaporation was not a likely explanation. There is a tendency to underestimate the amount of water, and assume that water is only in the organics. A method was developed to estimate water content every 10 min in the PM phase. With this method, the predicted and the measured water were in reasonable agreement. Using this tool they estimated the water content in the filters collected, allowing them to connect the measurements with the FTR results. The analysis of the measurements focused on sulfate and long rage transport using simulation tools. The continuous measurement of sulfate allowed following specific sulfate events connected with meteorology. Continuous measurements facilitated the investigation of the evolution of PM peaks for specific events and not only the average. There are a lot of complex interactions between fine PM constituents and their precursors. Therefore, it is not a good idea to focus on one pollutant and neglect its effect on others. One hypothesis is that a significant fraction of the sulfate reduced will be replaced by nitrate when SO2 emissions are reduced. In the model, the predictions match the observations quite closely, especially with the spikes and summer-winter differences. The model can report the expected change in nitrate when sulfur emissions are lowered. When reducing sulfur emissions, the total inorganic PM2.5 is not lowered proportionally because nitrate increases. Controls of SO2 reduce sulfate and PM2.5 in all seasons, but a fraction of the existing sulfate will be replaced by nitrate. Moving nitric acid to the particle phase (e.g. nitrate) extends its lifetime. Since Pittsburgh is an ammonia-controlled region, ammonia controls in all seasons can minimize the replacement of sulfate by nitrate. NOx controls will help reduce the nitrate during the winter but they will have little impact during the summer. The nitrate formation reaction is favored at low temperatures and high relative humidity. Therefore, the lifetime of nitrate will increase during summer because it will move from the gas to the aerosol phase. Nitric acid vapor needs to be measured because this is the reservoir that can then be turned into particle phase. Substantial effort has gone into dividing up organic aerosol into categories (e.g. primary/secondary). Because the temporal ozone trend coincides with OC/EC ratio during the day, this can be used as a sign of secondary pollutant formation. Precisely measuring EC and OC may be hard, but black carbon can be used as a tracer for OC. There are no primary biogenic contributions in the winter, so the sources are secondary. For other sources, such as woodsmoke and vehicle emissions, we can measure with tracer compounds. Having two tracers per source that are comparable provides good verification and it allows researchers to see seasonal variations.
A sampling site of EC, OC and metals downwind of the 3-mile coke processing plant in Pittsburgh gave a nice "fingerprint" of the source. By comparing measurements with background conditions and detecting specific pollutants unique to a plant using a single Particle Mass Spectrometry instrument, researchers could identify the exact facility that is producing the emissions. It is questionable whether reducing particle mass is a positive thing. The researchers examined the PM size distribution evolution throughout the day. A well-distributed peak during the middle of the day, starting at morning rush hour and tapering off in the evening seems very normal, showing the nucleation and growth a few hours after sunrise. On the next day, however, there was in situ formation of particles in the atmosphere. It was not caused by traffic since it started in the late evening. Surprisingly, nucleation was occurring on the clear days, when particle size counts would be expected to be low. Nucleation was quite frequent, happening on one-third of the days. As we reduce mass, we will be moving to more particles. Then the question is: What is making these particles? The growth of these particles is partially due to sulfate but there is good evidence that these particles have something to do with sulfuric acid in the morning. There is no instrument that can see down to one nanometer. However, there are some theories about what is happening. The nucleation model is good at reproducing what actually happened in all 20

nucleation days. There is strong evidence that the nuclei are sulfuric acid, ammonium, and water clusters. It does not seem that organics are an important part. Assuming the model is correct, the best solution is to reduce ammonia by 5-10%, which can produce nucleation changes by a factor of 10,000. Reducing sulfur dioxide is unreasonable because reductions of 99% would be needed for noticeable change. Simulations of particle formation and transport in regions over time offer many insights about PM2.5. There are a lot of biogenic aerosols in the South, but a lot of anthropogenic aerosols in the Northeast. The models were checked against hourly data, which matched quite well. The differences come from meteorological factors (delayed front by 2 hours) and ammonium-nitrate discrepancy. The OC and EC do not match on some days, but for the first try, it is not bad. More simulations will reduce the discrepancies. Reducing SO2 by 30% does not result in a substantial PM2.5 reduction because of the non-linearity of sulfur dioxide to sulfate and the nitrate substitution. The following are the main conclusions: They feel comfortable calculating the amount of water on the worst days. A major benefit of the model is that it does not depend on emission inventories. There is a lot of primary biogenic material in the summer. Transportation and biomass burning are the other significant sources in the area. There are some new technologies: single particle mass spectrometry and semi-continuous metal measurements. Ammonia appears to be the limiting reactant for most nucleation events, so reducing ammonia may be the solution. Supersite data together with the results from other studies and networks will enhance our understanding of atmospheric PM in the U.S.

Discussion

Given the amount of information that can be collected in Supersites, the audience commented on the possibilities for continuing measurements in such type of studies. Most of the other Supersites also conduct measurement activities. In the case of Pittsburgh, the money has already been used up for measurements, and now the simulations by computers and analysis are taking place. At this point the research team is digesting what they have found. Besides, it is always good to consider that taking more measurements is very costly and time-consuming. Regarding the differences in EC/OC ratios on weekends versus weekdays, they found that more than 80-90% of aerosols are imported from outside Pittsburgh. These are traffic particles that have been in the atmosphere for a day or two. The signatures of weekday and weekends start to disappear in the organics data. Because of that, what can be observed on a weekend may in fact have been emitted on a weekday. One commenter pointed to other work that was done where ammonia/sulfate was made up largely of water. About half of EC in Pittsburgh is local, and half is from outside.

Wednesday, August 13, 2003
Afternoon Session/Discussion

<u>If I were King, what would be particulate control policy? What would be particulate research objectives?</u>

Alan Lloyd, *California Air Resources Board, The PM Challenge in California*

There are some control measures which can be implemented now, such as requiring low-sulfur fuel in on-road, off-road, and marine vehicles. While there should be continued research, waiting for findings should not be an excuse to delay controls. Research should look at particle size and composition, with consideration of the impact of new technologies. For vehicles, approaching zero tailpipe emissions is the ultimate goal. Air quality in California is improving, and California's annual and 24-hour PM standards are stricter than the national standards. However, since almost all the state is still a non-attainment area, more needs to be done. There are significant health benefits in reducing PM2.5 to the natural background. Environmental justice concerns are tied to reducing emissions near heavily used roads. People who are driving behind a clean vehicle benefit from vehicle emission reductions. The time frame for the heavy-duty standards should be accelerated. This means getting the sulfur content in fuels to near zero as soon as possible. Sulfur in lube oil must also be reduced. On the light-duty vehicle side, standards should be implemented faster. It is important to support global standards for cleaner fuels, engine retrofits, in-use durability requirements, standards harmonization, and trucks/ships/aircraft standards. Although CARB has done a good job of pushing new technology, CARB has done a poor job of getting old vehicles off the road. Financial incentives or mandates to take one vehicle back for every three new vehicles sold can help to take dirty vehicles off the road. There are many proposed technological advances for heavy-duty trucks and off-road engines. Transferring technologies from on-road to off-road will be a challenge. A lot of the emissions come from sources that are still under federal control so California will try to work with the new EPA Administrator to give states more flexibility. Even as hydrogen is anticipated as the one key solution for the future, it is very important to continue cleaning up existing fuels.

Tom Grahame, *Department of Energy*

Ideally, there would be more knowledge before regulatory decisions are made. All sources of black carbonaceous material are likely to be unhealthy: woodburning, diesel, cooking, fires, and uncontrolled residential coal burning. U.S. coal fired power plants, however, do not emit black carbon (or any carbon). EPA should perform a better inventory of woodsmoke emissions: studies suggest health effects could be important, but we don't know ambient levels in many parts of the country. There should be more toxicological testing of most types of PM, including fly ash from coal plants. In CAPs (concentrated ambient particles) studies and in a heart rate variability study, some types of particulates do not seem to have adverse effects, because on some days, even though the CAPs or PM levels were high, there were no adverse affects, whether in animal or human studies, based on the endpoints studied. Efforts should be made to identify the pollutants missing on "no effect" days, as well as identifying the emissions that are present on "no effect" days. "No-effect" days should be examined when other endpoints are included. If certain types of PM do not show toxic effects, their regulation for protection of health would seem to be counterproductive. Unnecessary costs would be incurred, and other, more harmful pollutants might go unregulated. Based on the risks statistically associated with CO, there should be research on whether CO can lead to cardiopulmonary events at today's lower levels. Standardized regulatory toxicology would help identify the types of PM or PM mixtures requiring regulation. This would require testing various pollutants at the same multiples of their ambient concentrations against the same health effects, to determine which pollutants trigger an effect at a low multiple of their ambient levels, and which trigger an effect only at a high multiple. Those pollutants triggering an effect at a lower multiple would be more likely to harm people. "A-frame research" would help determine the pollutant or pollutants which are the worst along roadways. One policy recommendation could be to establish private vehicle-free zones or fee-based zones in central cities. Reducing the number of vehicles reduces travel time and improves emissions. During the 1996 Olympic Games, Atlanta restricted traffic and saw reductions in hospital admissions for asthma.

Allen Schaeffer, Diesel Technology Forum

The symposium has challenged many stereotypes of diesel. Although there has been a debate about the qualities of CNG versus diesel, there are roles for all the technologies in different applications. Research should take a bottom-up approach, starting with the question, "What would it take to get every dirty diesel off the road?" Diesel is going to be around for a while, so it is important to figure out what it would take to get truckers and operators to trade in their own vehicles. Because we need to think about where were will be 20 years from now, the work on nanoparticles is important. Every state that is accepting federal money for congestion management program should use it for financial incentives to reduce diesel emissions. All states should perform in-use emission testing for diesel vehicle inspection and maintenance. It creates a mindset of shared responsibility for clean air. Diesel should have I&M programs like gasoline vehicles. Addressing idling is low-hanging fruit, so we should adopt policies that get operators take responsibility for how they operate equipment. Customers want better fuel economy or reliability, but seldom demand better air quality. Ultimately, it will be the dealers that are responsible for a lot of the measures, so we should work with those who buy and operate the equipment.

Vickie Patton, Environmental Defense, Particulate Matter from the Vantage of the Plebes

There is a lot of work being done for transportation issues at the federal level. EPA is finally dealing with non-road diesels, which have not been regulated as much as on-road cars and trucks. A number of worldwide agencies have stated that diesel exhaust is a probably or likely carcinogen. EPA non-road regulations are less protective on the small engine side than for the larger engines. EPA's pursuit of a 2-tiered sulfur level approach is delaying the emission standards timetable. Environmental Defense is concerned with large and small engines, locomotives, commercial marine vehicles, and ocean-going vessels. EPA's process for lowering diesel fuel sulfur levels is taking too long. Meanwhile, stationary diesel engines have been overlooked. Even the non-road and on-road vehicle classifications make it difficult to determine whether an engine falls into the new standard. Since standards take a long time to kick in, and engines have a long life, there must be a "bridge" to new emission standards. A national diesel retrofit program would act as that bridge. EPA should use its authority to address stationary source contributions in a multi-pollutant way, instead of waiting for uncertain Congressional action. The transport rule should be passed before the non-attainment SIPs are due in 2007. Research is needed in the following areas: health effects of short-term PM2.5, full-blown risk analysis of diesel market penetration in the light-duty sector, sulfate/nitrate replacement, and long-term monitoring and assessment.

Ken Colburn, NESCAUM

In an ideal kingdom, we would know about the most dangerous types of PM2.5. We would be able to directly link exposure to death and health problems. There would be stable statistical analyses, a cheaply measurable biomarker, reliability, and an easy and straightforward test to integrate epidemiological data. All information would be highly resolved temporally, physically, chemically, and geographically. The annual PM2.5 standard would be revised and the daily PM2.5 standard would be lowered relative to the current federal standard. Shorter-term exposures seem to have cardio-pulmonary results, so a sub-daily standard (2-3 hours) should be adopted. Regional standards have the promise of elevating the "bang for the control" buck. The extraordinary progress in PM monitoring demonstrates the worth of reprising the investments of the last 5 years. Such research money could support research for Supersites, gas-to-particle work, measurements, and ultrafines. Health data should be more accessible and easier to integrate. To improve exposure assessments, we should look at data at the neighborhood level. Time should not be spent on searching for a "missing link" because there are probably a lot of missing links. We should assume "all particles are guilty until proven innocent." There are several low-hanging fruit to pursue: Retrofitting vehicles, lowering fuel sulfur levels, installing bag houses and flue gas desulfurization in power plants, and strengthening ammonia control. However, only picking low-hanging fruit and reducing uncertainties do not seem very ambitious. There are some broader things that can be done. Delaying action may lead to worse outcomes, so we should accept uncertainty in our decisions. The focus should be on efforts that genuinely address multiple pollutants, such as concerted energy efficiency, renewable energy, CAFE technologies. Clear Skies is packaged as multi-pollutant but it is just a coincidence. Clear Skies does not take a macro perspective, eliminating some pollutant standards just to tighten others. Monitoring should be stressed over modeling. The federal government should not interfere with states' attempts to enact stricter legislation than EPA. We should move ahead with a mixture of prudence and aggressiveness.

John Shanahan, U.S. Senate Committee on Environment and Public Works

It is important to understand the framework in which policy makers make policy. Policymakers are faced with an array of competing concerns. To set good policy and reduce uncertainty, it is important to reduce policymakers' skepticism about the quality and "slant" of science by providing them with objective, relevant information. Data gathering should be separated from policymaking, because one is a subset of the other. But data gathering is a critical foundation for those decisions. Only when this happens is it possible to achieve the true goal of policymaking: "getting the biggest bang for your regulatory buck." Three things should be stressed: good credible science, risk analysis, and cost-benefit analysis. Certain studies have been dismissed because their findings go against popular views. Instead, there should be a willingness to follow wherever the science leads instead of pursuing a "book-burning" mentality in science. Risk analysis is especially applicable when comparing particle mass and particle size or surface area. There should be more rigor used in cost-benefit analysis, as well as greater public participation. For example, the IPM model is proprietary, but this should not be the case with public models. We need to have a more open process. When control strategies are analyzed, there should be improved assessment of risks, including "disbenefits." The possibility of increasing one risk when regulating another should be examined. The evaluation may not change what we regulate, but how we regulate. We need to improve our estimates of benefits and costs, especially when the benefit-cost ratio is near 1. There is a limit in the ability to regulate because there is a limit to which the economy can absorb these regulations. Waiting for certainty to legislate or regulate is not necessary. But the more the emissions inventory and other relevant criteria underlying the policymaking process is improved, the better crafted and more beneficial -- both environmentally and economically -- our policies will become. Even though coal-fired power plants are seen as the primary fine PM culprit, there are many other sources. Policies that target coal-fired power plants too aggressively will constrict the electricity supply and cause price spikes. There needs to be a more holistic strategy, such as the Clear Skies Initiative.

Chris Miller, U.S. Senate Committee on Environment and Public Works

PM2.5 is a pollutant that should be addressed quickly, since ample evidence shows that it has harmful effects. It is not a big surprise that the fossil fuel combustion cycle is causing harmful health effects. But it is surprising how long it has taken us to address it, starting most seriously with amendments to the Clean Air Act in 1990. Some type of SOx transport rule is needed because those amendments did not go far enough. The effects of acid rain are clear in parts of the U.S., such that an 80% reduction of SOx is necessary to allow the ecosystem to recover. We may need to separate our PM-2.5 strategy into two parts - control in the near term, and research for the mid-term. In the near term, the most cost-effective control options should be pursued immediately. EPA has been behind on its review of the PM NAAQS. The Agency has implied that coal-fired power plant reductions are the most cost-effective. As part of the mid-term strategy, there needs to be a comprehensive health-tracking system and an improved monitoring and data collection system. This is the only way to overlay adverse health outcomes with pollution levels. Solely relying on epidemiological research is not sufficient for assessing efficacy of control options. The reliance on conventional fossil fuels is the elephant in the room that has not been discussed. It will be difficult to change this in the near term. A fuel tax or an economy-wide cap on CO_2 is unlikely to work given our current political climate. Senators Jeffords or Carper's bill may get us started on carbon, and also address other pollutants. We have to at least work towards attainment of the ozone and PM-2.5 standards on the Clean Air Act's schedule. The Clear Skies Initiative does not fit with that attainment schedule. People will have to take action at the local level earlier to achieve attainment of the health standards. Deferred attainment should not be an option. The Act and the 1990 Amendments provided substantial authorities for protections under the Clean Air Act that should not be taken away as they would be under Clear Skies; instead, EPA rules should be expedited. EPA is in violation of CAA because it has not implemented the "maximum achievable control technology" standards for mercury and other air toxics from power plants. The Energy Bill and the multi-year, multi-billion dollar transportation reauthorization bill are opportunities to address fine particulate matter emissions. Unfortunately, it does not seem likely that we will get to an energy bill, transport bill, or multi-pollutant bill because campaign season is approaching. This may be a missed opportunity such that "instead of a revolution, we may be looking at a 'Les Miserables.'"

Open Discussion

New Hampshire has a CDC grant to integrate data systems such that people have easier access to health effects and monitoring research activities. At the meeting for this project, no one from EPA was present. There seems to be difficulty in getting two federal agencies, such as EPA and CDC, to cooperate. The NAS panel which guides the U.S. investment in PM research recommended better agency coordination. At some joint meetings, there was initial sharing, but eventually a division of viewpoints. It is hard for health and environmental science communities to get together because they each have their own "language." The CDC sees their mission on the health side as very separate from the regulatory side. Their fundamental research goal is not problem-solving, but rather an understanding of the human condition and all its threats. It seems very frustrating at first, and it takes several meetings to get agencies to exchange.

One of the attendees remarked that no one mentioned land use planning during the meeting. There should be a requirement for an impact assessment of any government decision on transportation.

The HEI analysis of the ACS and Six Cities studies had a problem with the S-Plus statistical analysis. The reanalysis changed some of the relative risk numbers but the confidence intervals and statistical significance did not change. The fundamental conclusions remained the same, but the reanalysis has again brought up industry's concern about the problem of comparing heterogeneous cities. Relative risks are important to examine because it implies where we should spend our money and what the time frame should be. Policy makers need to be comfortable with the level of uncertainty and be assured that the uncertainties have been dealt with. In the ACS study, there were some cities with negative correlation. It is not enough information to understand the heterogeneity in the types of pollutants.

Environmentalists have not really addressed the closure of some Amtrak lines on the Northeast, such as on Cape Cod. It is not clear whether it is better to maintain access by rail in some locations or to rely on road transport.

Public transportation is a good method to avoid vehicle congestion and reduce pollutant emissions. One participant questioned whether people have given up public transportation and land use planning. Mobility, land use, public transportation, road transport, etc. are intricately linked. Minimizing air pollution and maximizing mobility should be pursued jointly.