UCI
University of California, Irvine

4/29/2002

Dr. Alan C. Lloyd, Chair
California Air Resources Board
1001 I Street
Sacramento, CA 95812

Sacramento, CA

Dear Dr. Lloyd:

The Air Quality Advisory Committee met on January 23 and 24, 2002 to evaluate the draft document "Review of the California Ambient Air Quality Standards for Particulate Matter and Sulfates: Report to the Air Quality Advisory Committee." The examination of the current air quality standards and the recommendations for modification of those standards derived from the Children's Environmental Health Protection Act (Senate Bill 25) and a resulting document "Adequacy of California Ambient Air Quality Standards: Children's Environmental Health Protection Act" which was published as a staff report in 2000. SB 25 prompted an analysis of the scientific basis of the California air quality standards for particulate matter, sulfates, ozone, carbon monoxide, nitrogen dioxide, lead, and sulfur dioxide.

In response to SB 25, an up to date examination of the scientific information relevant to each of these standards that was published in peer reviewed documents was commissioned to determine if the current California standards were adequately protective of children's health. The staff of the Office of Environmental Health Hazard Assessment (OEHHA) made an analysis of the findings and recommended a list of standards that required re-review. The OEHHA analysis was deliberated by AQAC in a public meeting and the list of standards to be reviewed was prioritized. The standards for particulate matter and sulfate were deemed to be those with the highest priority for modification to protect the health of California's children.

In most respects, the committee was pleased with the document "Review of the California Ambient Air Quality Standards for Particulate Matter and Sulfates: Report to the Air Quality Advisory Committee." The committee went on record to complement the staffs of the ARB and OEHHA for performing a very comprehensive and careful compilation and analysis of the peer reviewed literature on sources, monitoring and health effects of ambient particulate matter. There were, however, some areas in which the AQAC required additional clarification and one key issue with which the AQAC disagreed with the OEHHA/ARB recommendations.

The draft document made the following recommendations that were endorsed by the AQAC.

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- PM10 Annual-average standard – Lower the standard from the current 30 μg/m^3 to 20 μg/m^3 and revise the averaging method to an annual arithmetic mean.
- PM10 24-hour-average standard – Retain the current standard at 50 μg/m^3.
- PM2.5 Annual-average standard – Establish a new annual arithmetic mean standard at 12 μg/m^3.
- Sulfate 24-hour-average standard – Retain the current 25 μg/m^3 standard.
- For all of the PM standards, the concentrations noted above are to be established as "not to be exceeded."

The AQAC, however, did not agree with the assessment in the draft document that there was not sufficient scientific basis for establishing a 24-hour average PM2.5 standard. The AQAC requested the OEHHA and ARB staff to develop acceptable methodology for establishing a 24-hour PM2.5 standard and determined that the level and form of that standard.

The resulting recommendation was made.

- PM2.5 24-hour-average standard – Establish a new standard of 25 μg/m^3, not to be exceeded.

The AQAC met on April 3, 2002 and unanimously endorsed this recommendation and the statistical form of the standard that was proposed.

The specific comments of the AQAC on the draft document are appended to this letter.

The AQAC is extremely appreciative of the responsiveness and expertise of the the staffs of OEHHA and the ARB. We commend them on the excellent job they did in reviewing and summarizing the scientific literature in the complex area of particulate matter and in establishing a set of ambient air quality standards that will protect the health of California's citizens and especially their children.

Sincerely,

Michael T. Kleinman, Chair
Air Quality Advisory Committee

Cc: Bart Croes, Research Division
Richard Bode, Research Division

Summary Comments of the Air Quality Advisory Committee

The staffs of OEHHA and the ARB provided an excellent review of the current literature relevant to the sources, transport and health effects of ambient PM. The review provided a firm basis for establishing the needs for PM air quality standards and the committee was unanimous in its appreciation of the effort and diligence involved in producing the report.

The Air Quality Advisory Committee (AQAC) provided comments on a chapter by chapter basis and also addressed specific overarching questions that were submitted to them during their review of the report.

Children's protection, with an adequate margin of safety, is of paramount importance to public health. While the measurable injury and morbidity may be small, the degree to which PM exposures early in life contribute to lung compromise later in life (i.e. effects may be cumulative) has not been adequately researched. In addition, children with chronic lung diseases such as bronchopulmonry displasia, asthma and cystic fibrosis may be at special risk but, with the possible exception of asthma, there has been little research effort in these areas. Since asthma affects nearly 10% of the child population, the effects of PM on this group is of special importance. Although commented on in the draft document, it is important to recognize that children have higher minute ventilation rates per unit lung volume than do adults, hence their lungs receive greater doses of inhaled particles than do adults for comparable exposures.

The potential effects on children and the substantial evidence for short-term mortality and morbidity effects of PM in adults led this committee strongly identify that the major lacking of the report was the failure to set a 24-hour PM2.5 standard. The arguments for not having such a standard were judged to be weak. The specific justifications for considering that the justification was weak was addressed more fully, as per the specific comments below, and the comments were made available to the staffs of OEHHA and the ARB. The draft report had a very strong focus on mortality and certain chronic endpoints. Sufficient weight was not given to the large numbers of studies that provide data on short-term effects, including morbidity, that could have been considered as part of the basis for the 24 hour PM2.5 standard. The committee recommended that *a priori* criteria be established to guide decisions about the appropriate level and that a 24 hour PM2.5 standard be set.

Specific Comments on the Draft Report:

1. Executive Summary

Page 2, line 13-4, *"there are fewer studies.."* This statement is false and needs to be corrected.

2. Introduction

Regulations require that standards be reviewed when 'substantial new information becomes available' or at least once every 5 years. The committee suggests that some specific triggers for re-review might be new information on effects in susceptible populations that might indicate erosion of margins of safety, or information bearing on the need for additional standards, e.g. a coarse particle standard (PM2.5-10).[1]

There are also data that suggest that ultrafine particles may be a size fraction that plays an important role in health effects. There are also metrics, other than mass of particles in a given size fraction, that might be better predictors of effects on health, including:

- Aerosol Acidity
- Aerosol Oxidant (peroxides, radicals)
- Ames Test Activity
- Polar and non-polar PAH
- Ultrafine Component ($1\text{nm} \leq d_p \leq 0.1\ \mu\text{m}$) [2]

An integrative approach to standard setting should be developed. Such an approach would improve ability to identify possible interactions between pollutants that might impact on the level set for a particulate standard. Such an approach might make it easier to recognize whether there are un-needed redundancies in standards. For example, it might be determined that a separate sulfate standard is not needed in the future. The chapter should be expanded to delineate future possibilities and triggers.

3. Physics and Chemistry of Particles

Pg 9 L 38 ultrafine are usually defined as $dp \leq 0.1\ \mu\text{m}$ (100 nm).

p. 12, l. 46, add reference Friedlander 2000[3]

4. Sources and Emission of Particles

It would be useful to contrast the emission inventory in Figure 4.1 with a pie chart derived from source-receptor modeling to show the impact of atmospheric chemistry, particle deposition and secondary formation.

5. Measurement of Particulate Matter

The committee agrees with the recommendations for changes to Title 17, California Administrative Code, Sections 70100(j) and 70200 to delete the current Method P and

[1] Professor Philip Hopke (Clarkson University), who is the Chair of the U.S.E.P.A. Clean Air Scientific Advisory Committee (CASAC) provided the following statement "In the decision by the U.S. DC Circuit Court of Appeals in American Trucking Associations, Inc., et al. vs. United States Environmental Protection Agency (97-1440), the court ruled that PM10 is an inappropriate indicator for coarse particles since it is confounded by the presence of PM2.5. EPA has not appealed this portion of the decision and thus, a new NAAQS for coarse particles, PM(10-2.5), will be promulgated in conjunction with the reconfirmation of the PM2.5 NAAQS. The proposal for measurement will be to use two side-by-side PM2.5 FRM samplers where the WINS impactor will be replace in one sampler with a straight tube. The difference between the two filter-based mass concentrations will be the measure of the coarse particle indicator. No decision has yet been made public as to the form or possible concentration ranges for this new PM coarse standard."

[2] Xiong and Friedlander, "Morphological Properties of Atmospheric Aerosol Aggregates", PNAS, Vol. 98, no. 21, pp. 11851-11856, 2001

[3] Friedlander, S. K., Smoke, Dust and Haze: Fundamentals of Aerosol Dynamics, 2nd edition, New York, NY: Oxford University Press, 2000.

replace it with a new Method P "Measurement Method for Particulate Matter in Ambient Air" Part I – Measurement of PM10 and Part II – Measurement of PM2.5. The committee also agrees with the recommended methods for adopting samplers that meet the Federal Reference Method requirements for PM10 and PM2.5 and to include continuous monitors whose data can be integrated and can be shown to correlate with co-located FRM samplers. The phrase 'high degree of statistical significance' (pg 43, L39; pg 44 L 4) is ambiguous and a more quantitative expression should be used.

The committee was especially supportive of the efforts being undertaken by ARB to validate continuous monitors. Continuation of these efforts is important because the possible health impacts of short-term, high level, excursions are not well understood and lack of adequate accurate short-term PM monitoring data is a primary reason for this.

The issue of sampling artifacts was raised in discussions. These included losses of volatile components under some sampling conditions and adsorption and conversion of gaseous species to particulate species on the surface of filters during sampling.[4] The use of quartz filters to avoid sulfate artifacts may lead to an overestimation of PM because of adsorption of organic vapors.[5] The possible impact of artifacts on air monitoring data from filter samplers, and methods to reduce the impacts of artifacts, should be discussed more fully in Chapter 5.

The committee makes the following recommendations:

a. Continue to evaluate continuous PM monitors for coarse and fine PM fractions.

b. Sample for coarse and fine PM separately, as opposed to using the difference between PM2.5 and PM10 filter weights.

c. Evaluate commercial continuous sulfate monitors to determine if they eliminate potential artifacts.

d. Chemical speciation should be performed to a much greater extent in California air samples. This data can be important for a number of reasons including source identifications using tracer, chemical mass balance and/or factor analytic methods. While the committee was split on whether chemical speciation would improve the

[4] Professor Freidlander has given the following example. The accumulation mode contains most of the aerosol water and serves as a site for sulfate formation by the SO2/H2O2 reaction. There is a possibility for additional sulfate formation in the aerosol filter used for sampling by reaction of SO2 and H2O2 which can dissolve in water containing aerosol already deposited in the filter. For example, consider the sequential passage through the filter of the parcels of gas, one high in SO2 concentration (from a power plant) and the other high in H2O2 (from vehicular emissions and photochemical processes). The gases may dissolve and react in the previously deposited water-containing aerosol. This would lead to artifact sulfate formation in the filter that might not have occurred in the air. In addition, the rate of diffusion from gas passing through the filter to collected aerosol is higher than the rate from a gas to a suspended particle because the diffusion rate increases with relative velocity between the gas and the deposited particles. Water vapor will continue to condense from the air on the deposited aerosol as the sulfate mass in the aqueous phase increases because of the hygroscopicity of the dissolved salts and polar organic compounds.

[5] Sioutas, personal communication, 2002

standard setting process, per se, it was clearly in favor of having more extensive analyses of the composition of ambient particles.

6. Exposure to Particles

The figure captions and legends are not informative. Most of the figures were not numbered. Even careful reading of the text left considerable confusion. Size distributions commonly are graphed with particle size increasing along the X-axis. Average total mass should be shown with each of the pie diagrams so that both the mass as well as fraction can be estimated for separate aerosol components.

Table 6.1 should also show annual arithmetic mean values, since this is the metric selected for the proposed standard.

Tables 6.1 and 6.2 need an explanation of the meaning of 'Max. Annual Avg.'

The differences in seasonal variation of PM10 and PM2.5 shown in the figures in this chapter need to be considered with respect to ability of PM10 regulations to also control PM2.5 exposures. The differences in sources and chemical composition underscore the importance of considering these separately with respect to setting regulations.

PM compounds with considerable spatial variability, such as ultrafine PM, transition metals, polar or non-polar polycyclic aromatic hydrocarbons (PAH) or elemental carbon may be potentially far more important toxicologically than PM2.5 mass, which is relatively uniform, spatially. There is considerable spatial variability of these species within a metropolitan area, consequently individual exposures to any of these compounds or size ranges may vary substantially. For example, in Los Angeles, while $PM_{2.5}$ and PM_{10} concentrations measured at various distances from highways (10-1000 meters) showed little spatial variability, particle number black carbon and organic carbon concentrations decreased rapidly with distance from highways (Zhu, et al., 2001). If these compounds are toxicologically more important than PM mass, individual exposure (and ultimately dose) may differ by more than one order of magnitude (depending on where individuals reside or spend the majority of their time) in areas where stationary PM10 or PM2.5 monitors would indicate relatively uniform population exposures.

Furthermore, ambient PM10 or PM2.5 aerosol consists of particles in size ranges spanning over 3 orders of magnitude, with equally variable deposition rates (and sites) in the respiratory tract. Exposures to aerosols at different locations/seasons with different size characteristics would result in vastly different PM doses of the exposed population. The stationary PM2.5 or PM10 data provide an overly simplified estimate of exposure, which will inevitably lead to substantial errors and uncertainly in linking health outcomes to PM mass concentrations.

The chapter summary (6.5.7) identifies various difficulties in using air quality monitoring central site data to develop and implement air quality standards. A more explicit discussion should be added explaining how such uncertainties are dealt with in the standard setting process.

7. Health Effects of Particulate Matter

The chapter was written in a somewhat fragmentary way and so rather than try to comment in a narrative fashion as was done for most of the other chapters, the committee's comments are provided on a page or section basis.

Page 116, lines 10-11, *"To the extent that PM may be causally related to*…". This statement ignores the fact that there may be real weather effects which confound PM effects away from the null, particularly in the colder-PM season in California. A more circumspect statement is required here.

Page 117, lines 35-43, *"In a separate study restricted to out-of-hospital*…". The thesis of this paragraph is not supported by some studies (see Levy, *et a*l., Epidemiology, 2001).

Therefore, this speculation needs to be tempered. This same comment applies to page 129, lines 36-43.

Page 131, 3 rd bullet. This statement is too strong. We really do not have a good qualitative estimate of the relative contribution of harvesting versus real shortening of life based on short-term studies

Page 142, lines 2-13. It also should be noted that cross-sectional studies are potentially

compromised by survivor bias, which would tend to lead to an underestimate of effect.

Page 143, lines 8 lines from bottom, *"…these effects were somewhat greater than*…". This reason does not seem very cogent in terms of the point being made. It would not at all be surprising if many years of exposure to PM carried a risk similar to that of 7 pack-years of smoking.

Page 155, lines 28-33. This statement needs to be more circumspect. The exposure evidence, to date, is weak at best, in relation to exposures likely to be experienced under ambient conditions by humans.

Page 163, lines 38-48. The argument here is not compelling. Moreover, the statement about the purpose of significance testing is simply wrong. The p-value expresses the long-range (i.e., over many repetitions of a study) of the probability of observing a result that actually observed, given some specified or unspecified null value. The p-value does not express the likelihood of results in a given study realization. A recent series of papers in Epidemiology on p-values should be consulted for a more useful discussion.

Page 167, lines 18-19. The quoted relationship between level of exposure and precision is not a causal argument at all. This statement should be removed. There could be a number of non-causal reasons—e.g., differential accuracy of measurement of exposure.

Page 170, L 46 Better justification for the assumption that 'only the fine particle share of PM10 is toxic' is required. The statement, per se, is not justifiable, scientifically and several papers are cited earlier that indicate that under some circumstances coarse PM is more toxic than fine PM. It would be useful to provide an analysis of the impact of that assumption on the level at which a standard should be set.

Page 170, L43-48, Given the almost 70 papers cited in Table 7.1 the emphasis placed on a single (Krewski) study needs explanation and justification. It is also important to differentiate how the OEHHA analysis that arrived at an annual average PM2.5

standard of 12 µg/m^3 from the USEPA analysis that used the same data but arrived at a 25 µg/m^3 annual average standard.

Page 172-173—Risk Estimates. There were a number of concerns with this section.

a. There needs to be a better explained rationale as to why 12 µg/m ^{3} was chosen as the level for the 24 hours standard. Why not 11 or 13 µg/m^3 ?

b. Improved methods for estimating the range of risk need to be incorporated into the standard setting process. Confidence intervals, although used by others, may not be appropriate. The use of a range of parameter estimates based on a variety of studies, preferably several that span the range of statistical approaches and study locations to quantitate the range of health effects that might be expected based on current data might be a better indicator. Expand the discussion on the potential effects of measurement error, and other sources of bias, on the estimates. The current discussion is sparse and excludes important papers such as Chen's EHP, 1999 paper on the consequence of poor model fitting for the occurrence of bias in effect estimates.

c. More emphasis should be placed on the respiratory morbidity effects in the risk assessment since they affect a large part of the population, especially children.

d. Some discussion is needed to explain why the relative incidences of acute morbidity effects are less than one might expect from the mortality estimates.

Page 174 L40 Can a % of population protected be suggested rather than 'nearly all?'

Page 178, 2nd paragraph It should be stated that studies of PM effects on the upper respiratory tract are few and far between, hence the question of whether particles 10 µm in diameter (that mainly deposit in the URT) will cause effects is unresolved. The statement 'not likely to cause serious health impacts' is an overstatement.

Page 179, Lines 30-34. The argument offered here as to why a 24 hour standard cannot be set does not make sense and is not consistent with the linear exposure-response relationship that has been observed across all short-term exposure time series studies. If the level of chronic exposure were confounding these effect estimates, it is hard to see how all of the studies would be consistent with a linear exposure-response function since each day's deaths would be the result of some people who die from chronic exposure and some who die from acute exposure. One would expect that areas with high chronic exposure would have more deaths/day due to the chronic effect in addition to those due to acute effects. On this basis, it is hard to see how a linear exposure-response relationship (on the log scale) would be observed across all short-term studies with varying levels of chronic exposure. Therefore this is not a valid argument for not setting a 24-hour PM2.5 standard. This same critique applies to the arguments on page 183, lines 26-30.

Page 180, paragraph 2. The argument that mortality rates are greater per unit change in PM concentration for long term studies versus short term studies is questionable. Although the rate may be higher for long term effects, the day to day PM variation is an order of magnitude greater than the year to year variation.

Page 181, Line 42-43 There are disconnects between PM10 and PM2.5 concentrations at some seasons of the year (as clearly shown in the figures in Chapter 6). It is not clear that the short term PM10 standard will adequately control PM2.5 daily concentrations.

Page 187, paragraph 1 The committee disagrees with the OEHHA conclusion to not recommend a short term (24-hr) PM2.5 standard. As discussed in detail above, there are several arguments put forth but the committee felt that an adequate scientific rationale does exist for including a 24-hr PM2.5 standard in the recommendations.

Data on 4 major potential mechanisms (lung injury, inflammation, increased blood coagulation, and cardiac arrhythmias) suggest important short term effects.

8. Welfare Effects of Particulate Matter

The committee did not comment on welfare effects since our charge was the health effects basis for PM standards. The Chapter, however was a useful review of the topic.

9. Controls and Regulation of Particulate Matter

The summary of existing controls was not commented on. Again this provided a useful review of existing standards and controls.

10. Quantifying the Adverse Health Effects of Particulate Matter

Given the extensive list of morbidity outcomes that have been established and the large numbers of people affected, the emphasis on mortality as the sole rationale for PM standards seems unbalanced. The committee recommends that some method for integrating all of the health effect data into the process of arriving at protective air quality standards is needed.

Following submission of the initial AQAC comments to the staffs of OEHHA and the ARB, a reanalysis of the 24-hour PM2.5 standard was conducted. In developing a recommendation, the OEHHA and ARB staff:

- used statistical methods to examine the shape of the exposure-response relationships using two California data sets, and compared the results with those reported for other non-California data sets;
- tabulated the results of all time-series studies published in English, for which direct PM2.5 monitoring data were available, that have explored associations between low levels of ambient PM2.5 and daily mortality; and
- examined, with technical assistance from ARB staff, the upper tail of the PM2.5 distribution in California consistent with an annual average of 12 $\mu g/m^3$, based on data collected throughout California in 1999 and 2000.

Based on the results of these analyses, OEHHA recommended that the 24-hour PM2.5 standard be established at a level of 25 $\mu g/m^3$, not to be exceeded. The adoption of the recommendation for an annual PM2.5 standard of 12 $\mu g/m^3$ was considered to be an integral component of the proposal.

The AQAC had been concerned that the proposed standard based on attaining a 12 $\mu g/m^3$ annual average did not adequately protect against brief (i.e., one to several days) increases in PM2.5 levels. It was recognized that attainment of the recommended annual standard would help shift the entire PM2.5 distribution to the left, and would influence peak concentrations. The committee indicated that a 24-hour standard would better protect Californians against significant short-term elevations of PM2.5.

The committee met in a public forum on April 3, 2002 to discuss the proposed 25 $\mu g/m^3$ PM2.5 24-hour standard. The AQAC endorsed the both the proposed standard and the process used to arrive at the standard. The committee agreed that the “not to exceed” form of the standard was appropriate.

This standard, in the AQAC’s opinion, represents a balance between some competing issues. For example, in some areas, the 24-hour standard may dominate over the annual standard. However this competes with the need for the standards to provide an adequate margin of safety (as demanded by the legislature) and to take into account the potentially greater susceptibility of children to the effects of PM.

Specific Questions Addressed by the Committee

1. Have the key studies relevant to the recommendations been identified and appropriately interpreted? Are there any critical studies (published prior to 8/1/01) that have been omitted from review in this draft recommendation? Reviewers should bear in mind that the scientific foundation for the recommendations represents a focused evaluation of the critical literature, not an exhaustive compendium of all potentially relevant research.

   The OEHHA Staff has attempted a critical review of a very large, complex, and dynamic field involving different disciplines. The draft document is provides excellent reviews of current literature on PM exposure, epidemiology and toxicology. This does not mean that there are not major uncertainties and issues that need to be resolved about the toxic effects of PM, but the available (and quite exhaustive) literature has been properly reviewed and cited.

2. Have susceptible subpopulations been appropriately identified? Are there other sub-populations that may be at least as sensitive to PM exposure as those identified in the document? Is the scientific evidence related to infants and children correctly interpreted?

   Diabetics should be considered. In several single-city studies, the risk of PM-associated hospital admissions for heart disease for diabetics was double that for the general population (Zanobetti and Schwartz, 2001b; Zanobetti and Schwartz, 2001c). In addition, diabetics were found to have an increased risk of PM-associated mortality (Bateson and Schwartz, 2001). The scientific evidence regarding children and infants should also be considered beyond the immediate health effects. The impact on their caregivers (lost time from work and financial issues) and lost time from education could have significant societal effects.

3. Is there additional critical information that should be considered in estimating PM-related impacts on public health?

   Yes. The PM impacts on public health are estimated assuming population-based exposure models and PM mass concentrations measured at single outdoor monitoring sites as surrogates of population exposures to ambient air PM. The extent to which outdoor measurements accurately reflect PM exposures has been the subject of considerable scientific debate. Results from early exposure studies such as those conducted as part of the Harvard Six Cities Study and the EPA Particle Total Exposure Assessment Methodology (PTEAM) Study, for example, suggested that personal PM exposures might differ substantially from outdoor concentrations due to contributions from indoor sources.

The link between central site and personal exposures need to be better defined and should be considered in future standard evaluations.

Also, as mentioned in the specific comments, above, the temporal and spatial variations in components of PM may significantly modify dose and biological responses. This is not given sufficient weight in the current standard setting process.

4. Have the uncertainties concerning the health effects of exposure to PM been adequately described?

   Major uncertainties that could be better discussed include the influence of indoor exposures, the link between central site and personal exposures, and the spatial and temporal variation in concentrations of toxic PM components.

5. Have potential differential exposure patterns among infants and children been examined sufficiently in the document?

   There are very scant data on this topic. This should be an area for additional research.

6. Is the overall approach to developing the recommendations for ambient PM standards transparent and appropriate? Specifically, are the recommendations for PM ambient air quality standards for California adequately supported by the underlying scientific rationale, specifically the:

   annual average for PM10?

   annual average for PM2.5?

   24-hr average for PM10?

   24-hr average for sulfates?

   The committee endorsed the recommendations for above four standards for the current period. There was discussion of the need for a future evaluation of the possibility that there is overlap between PM standards and the sulfate standard, to the extent that the sulfate standard might be considered redundant.

7. Given the state of the science, do you concur with OEHHA staff that there is insufficient evidence at present to develop a 24-hr average (or other short-term) standard for PM2.5?

   The committee recommended that a 24-hr PM2.5 standard be developed. This was accomplished and reviewed by AQAC on April 3, 1002. AQAC endorsed the new recommendation.

8. What do you see as the most important research issues to be addressed prior to the next cycle of review for PM?

- Evaluate regional differences in relationships between PM and gaseous co-pollutants;
- Characterize short-term PM exposures using validated continuous monitors;
- Speciate PM (metals, EC/OC, PAH's, NO_3);
- Characterize ultrafine exposures (Indoor, Outdoor, personal);
- Validate new or improved monitoring techniques, especially continuous monitors of PM2.5, PM10, coarse PM, sulfates that will allow specific questions to be addressed as to the most relevant averaging times for health-based particle standards;
- Increase our understanding of respiratory dosimetry and particle fate and transport in infants and children;
- Expand the base of studies on susceptibility of diabetics;
- Evaluate the relationship and mechanism of PM exposure and prenatal/neonatal health effects;
- Determine relationship(s) between ultrafine and coarse particulates versus different health outcomes;
- Define health effects/mechanisms of coarse, fine, and ultrafine PM and co-pollutants;
- Examine effects and mechanisms in cardiovascular subjects exposed to different size cuts of particles;
- Explore the roles of different chemical or metal constituents of PM in causing health effects.
- Using already established PM source emissions profiles and new state-of-the-art personal monitoring techniques, assess degree to which specific outdoor sources contribute to personal PM concentrations.
- As control strategies are implemented to achieve the proposed standards, it will be important to determine whether or not children and adults living in less affluent, more highly polluted, communities are receiving adequate benefit and protection.
- Our knowledge of the intractive effects of pollutants is inadequate for the development of comprehensive air quality improvement measures. The research base must be expanded and supported.