Ambient Air Quality Monitoring and Health Research: Summary of April 16-17, 2008 Workshop to Discuss Key Issues

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Office of Air and Radiation/Office of Air Quality Planning and Standards

DECEMBER 2008

[This page intentionally left blank.]

EPA 452/S-08-001
December 2008

Ambient Air Quality Monitoring and Health Research: Summary of April 16-17, 2008 Workshop to Discuss Key Issues

U.S. Environmental Protection Agency

Office of Research and Development

and

Air Quality and Assessment Division
Health and Environmental Impacts Division
Office of Air Quality Planning and Standards
Office of Air and Radiation

Research Triangle Park, North Carolina

December 2008

DISCLAIMER

This workshop summary report serves to document recommendations presented at a recent workshop held by the U.S. Environmental Protection Agency's Office of Research and Development (ORD) and the Office of Air Quality Planning and Standards (OAQPS) within the Office of Air and Radiation (OAR). The recommendations described in this report have been modified to reflect information developed during the review of this document and may be modified in subsequent discussions with internal and external experts. ORD and OAR will use the recommendations presented in this document as a tool to consider and prioritize both short- and long-term actions for EPA and others to undertake in the development and implementation of ambient air monitoring and health research strategies. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

TABLE OF CONTENTS

LIST OF ACRONYMS

The following acronyms have been used for the sake of brevity in this document:

AMTIC	Ambient Monitoring Technology Information Center
AQS	Air Quality System
ARMs	Approved Regional Methods
AQI	Air Quality Index
BC	Black carbon
BOSC	Board of Scientific Counselors
CAA	Clean Air Act
CAAAC	Clean Air Act Advisory Committee
CASAC	Clean Air Scientific Advisory Committee
CMAQ	Community Multiscale Air Quality Model
CSN	Chemical Speciation Network
DASH	Denver Aerosol Sources and Health
DEARS	Detroit Exposure and Aerosol Research Study
DRI	Desert Research Institute
DRUM	Davis Rotating Uniform size-cut Monitor
EC	Elemental carbon
EPA	Environmental Protection Agency
FDMS	Filter Dynamic Measurement System
FEM	Federal Equivalent Method
FRM	Federal Reference Method
GEO	Group on Earth Observations
GIS	Geographic information systems
HEI	Health Effects Institute
IMPROVE	Interagency Monitoring of Protected Visual Environment
KML	Keyhole markup language
MESA	Multi-Ethnic Study of Atherosclerosis
MYP	Multi-year Plan
NAAQS	National ambient air quality standards
NACAA	National Association of Clean Air Agencies
NARSTO	North American Research Strategy for Tropospheric Ozone
NCER	National Center for Environmental Research
NCore	National Core Monitoring Network
OAQPS	Office of Air Quality Planning and Standards
OC	Organic carbon
ORD	Office of Research and Development
PM	Particulate matter
$PM_{2.5}$	particles generally less than or equal to 2.5 μm in diameter
PM_{10}	particles generally less than or equal to 10 micrometers (μm) in diameter
$PM_{10-2.5}$	particles generally larger than 2.5 and up to 10 μm in diameter
PQAO	Primary Quality Assurance Organization
QA	Quality assurance
SEM	Scanning electron microscopy
SLAMS	State and local air monitoring stations

STAR	Science to Achieve Results
STN	Speciation Trends Network
TC	Total carbon
TEOM	Tapered Element Oscillating Microbalance
TTN	Technology Transfer Network
TOR	Thermal-optical reflectance
TOT	Thermal-optical transmittance
XRF	X-ray fluorescence

AUTHORS AND CONTRIBUTORS

AUTHORS

Dr. Dan Costa, National Program Director for Air Research, Office of Research and Development, US Environmental Protection Agency, Research Triangle Park, NC

Mr. Neil Frank, Office of Air Quality Planning and Standards, Office of Air and Radiation, US Environmental Protection Agency, Research Triangle Park, NC

Dr. Barbara Glenn, National Center for Environmental Research, Office of Research and Development, US Environmental Protection Agency, Washington, DC

Mr. Tim Hanley, Office of Air Quality Planning and Standards, Office of Air and Radiation, US Environmental Protection Agency, Research Triangle Park, NC

Ms. Beth Hassett-Sipple, Office of Air Quality Planning and Standards, Office of Air and Radiation, US Environmental Protection Agency, Research Triangle Park, NC

Dr. Bryan Hubbell, Office of Air Quality Planning and Standards, Office of Air and Radiation, US Environmental Protection Agency, Research Triangle Park, NC

Mr. Phil Lorang, Office of Air Quality Planning and Standards, Office of Air and Radiation, US Environmental Protection Agency, Research Triangle Park, NC

Mr. Nick Mangus, Office of Air Quality Planning and Standards, Office of Air and Radiation, US Environmental Protection Agency, Research Triangle Park, NC

Dr. Lucas Neas, National Health and Environmental Effects Research Laboratory, Office of Research and Development, US Environmental Protection Agency, Chapel Hill, NC

Dr. Venkatesh Rao, Office of Air Quality Planning and Standards, Office of Air and Radiation, US Environmental Protection Agency, Research Triangle Park, NC

Ms. Joann Rice, Office of Air Quality Planning and Standards, Office of Air and Radiation, US Environmental Protection Agency, Research Triangle Park, NC

Mr. Geoffrey Sunshine, Health Effects Institute, Boston , MA

Mr. Tim Watkins, National Exposure Research Laboratory, Office of Research and Development, US Environmental Protection Agency, Research Triangle Park, NC

Mr. Lewis Weinstock, Office of Air Quality Planning and Standards, Office of Air and Radiation, US Environmental Protection Agency, Research Triangle Park, NC

CONTRIBUTORS

Dr. Sherri Hunt, National Center for Environmental Research, Office of Research and Development, US Environmental Protection Agency, Washington, DC

Ms. Sascha Lodge, National Center for Environmental Research, Office of Research and Development, US Environmental Protection Agency, Washington, DC

Ms. Stacey Katz, National Center for Environmental Research, Office of Research and Development, US Environmental Protection Agency, Washington, DC

Dr. Marc Pitchford, Office of Air Quality Planning and Standards, Office of Air and Radiation, US Environmental Protection Agency, Research Triangle Park, NC

Ms. Gail Robarge. National Center for Environmental Research, Office of Research and Development, US Environmental Protection Agency, Washington, DC

Mr. Rich Scheffe, Office of Air Quality Planning and Standards, Office of Air and Radiation, US Environmental Protection Agency, Research Triangle Park, NC

Ms. Laurel Schultz, Office of Research and Development, US Environmental Protection Agency, Research Triangle Park, NC

Dr. William Wilson, National Center for Environmental Assessment, US Environmental Protection Agency, Research Triangle Park, NC

Dr. Darrell Winner, National Center for Environmental Research, Office of Research and Development, US Environmental Protection Agency, Washington, DC

INTRODUCTION

Air pollution continues to have adverse impacts on the human and environmental health of the United States, despite clear evidence that overall air quality has improved. To understand the relationships between air pollutants and adverse health and welfare effects, researchers utilize ambient air measurement data collected through monitoring networks operated almost exclusively by State, local and Tribal air monitoring programs. These networks provide data for characterizing ambient air concentrations of the criteria air pollutants (particulate matter (PM), ozone, nitrogen dioxide, sulfur dioxide, lead, and carbon monoxide) as well as toxic air pollutants. However, the ambient air monitoring networks do not capture data everywhere or every day. Thus, in April 2008, the Environmental Protection Agency's (EPA's) Office of Research and Development (ORD) and Office of Air Quality Planning and Standards (OAQPS) within the Office of Air and Radiation (OAR) co-sponsored a workshop to discuss which modifications to the current ambient air quality monitoring networks would advance our understanding of the impacts of criteria air pollutant exposures on public health/welfare in the most meaningful way. In particular, EPA sought advice on concrete steps that could be taken to prioritize monitoring sites and/or specific fine particle components for more frequent monitoring in order to improve our understanding of the impact of these components on public health[1].

The purpose of this document is to present a summary of the April 2008 workshop and the recommendations emanating from the workshop discussions. This document is not intended to be a commitment to actually implement the recommendations but rather it will serve as a tool to consider and prioritize near- and long-term actions for EPA and others to undertake. To the extent that these recommendations can be incorporated into routine monitoring networks, they will help expedite research, better inform future reviews of the national ambient air quality standards (NAAQS), and, ultimately, reduce air pollutant exposures that are associated with adverse health and welfare effects.[2]

---

[1] Research specific to the protection of public health remains a top priority and EPA has targeted PM as a high-risk pollutant. In the last PM NAAQS review, EPA focused on particle mass and primarily distinguished between two categories of particle pollution based on size (i.e., fine- and coarse-fraction particles), and conducted parallel evaluations of the available scientific evidence relating to each category. The importance of specific PM components and sources was evaluated within the context of this basic size differentiation. In the current PM NAAQS review, EPA is considering the extent to which new information has become available to assess and determine how particle pollution is defined. Specific characteristics to consider will include particle size/mass, composition, and sources/environments (e.g., urban and rural areas). This information will inform decisions related to whether sufficient evidence exists to warrant consideration of alternative indicators for PM, and, if appropriate, the development of new NAAQS. See http://www.epa.gov/ttn/naaqs/standards/pm/data/2008_03_final_integrated_review_plan.pdf for more information.

[2] In a related effort, EPA recently issued the Clean Air Research Multi-Year Plan 2008-2012 which describes the objectives of leading-edge research to support regulatory decision-making. This plan outlines research that will provide critical information to add to the existing scientific foundation to inform the reviews of the NAAQS; develop regulations and advanced tools and models to implement the NAAQS; and improve methods to track progress in achieving health and environmental improvements. (See http://www.epa.gov/ord/npd/pdfs/Air-MYP-narrative-final.pdf) The multi-year plan builds upon recommendations from EPA's OAR as well as several scientific advisory boards. See also National Academy of Sciences (NAS) National Research Council (NRC): Research Priorities for Airborne Particulate Matter at http://books.nap.edu/catalog.php?record_id=10957; Board of Scientific Counselors (BOSC) Report on the PM-Ozone Program Review: April 2005 at http://www.epa.gov/osp/bosc/pdf/pm0508rpt.pdf; and Clean Air Act Advisory Committee (CAAAC) Report on Air Quality Management in the United States at http://www.nap.edu/catalog/10728.html.

Background

The EPA is interested in having an open and continuing dialogue with representative experts regarding health research priorities for ambient air quality monitoring data that would best advance our understanding of the impacts of air pollutant exposures on public health. This dialogue was significantly advanced at an initial meeting co-sponsored by the Health Effects Institute (HEI) and EPA in late 2006. At that meeting, the primary focus was to discuss how the use of the accumulating data derived from nationwide monitoring of fine particulate matter ($PM_{2.5}$) components could facilitate current and future health effects studies and improve comparisons of risk estimates across studies. The workshop illuminated issues associated with accessing and analyzing monitoring data and identified needs of the health effects research community regarding monitoring of fine particle components.[3]

In April 2008, EPA's ORD and OAQPS co-sponsored a follow-up workshop bringing together approximately 80 EPA and external air quality, monitoring, exposure, and health scientists[4]. As briefly described above, the major goal of the workshop was to discuss recommendations for modifications to the current ambient air quality monitoring that would advance our understanding of the impacts of criteria air pollutant exposures on public health/welfare in the most meaningful way, specifically for understanding the impact of PM and $PM_{2.5}$ components. In addition, the workshop was designed to continue to facilitate communication and scientific interactions across disciplines (e.g., epidemiology, toxicology, atmospheric science, monitoring, risk/exposure assessment) to improve the availability and interpretation of air quality monitoring data for air pollution health studies dependent upon the national networks.

The impetus for these two meetings was the growing recognition that current and future changes to the air quality monitoring system could significantly affect ongoing and future epidemiology research. This research serves as a foundation for EPA's reviews of the NAAQS. Yet resources at the Federal and State/local/Tribal levels for air pollution monitoring continue to diminish, while increasing demands (such as potential expansion of the lead ambient air monitoring network) tied to various aspects of NAAQS compliance continue to grow. Prominent health researchers have increasingly questioned EPA's commitment to health research in planning its monitoring programs, while the State and local monitoring experts who design and operate the monitoring programs wonder why some current data resources are not fully or properly accessed to explore opportunities to address some of the questions that are important to the health researchers with existing data sets. Clearly, improving the understanding of the objectives/mandates of each of these communities and fostering collaborative efforts between these communities is critical to moving forward in a positive manner.

Workshop Structure, Objectives, and Outline of Session Summaries

The April 2008 workshop began with introductory remarks by EPA's National Program Director for Air Research, Dr. Dan Costa, and by senior OAQPS managers, Ms. Lydia Wegman and Mr. Richard (Chet) Wayland, expressing their support for this effort. Dr. Morton Lippmann from New York University highlighted successful research that has benefited from collaboration among air quality experts and health researchers. Thoughtful discussions centered around five specific panel sessions, each facilitated by two co-chairs (one EPA and one non-EPA representative), addressing the following topic areas:

[3] See http://www.healtheffects.org/AQDNov06/AQDWorkshop.html for more information.
[4] The workshop agenda and list of participants is included in Appendix A.

- Session I: Elemental and Organic Carbon Measurements
- Session II: Accessing Ambient Air Monitoring Data
- Session III: Ambient Air Monitoring for Health Research
- Session IV: Thoracic Coarse Particle Components and Potential Public Health Impacts
- Session V: Ambient Air Monitoring Realities – EPA/State/Local Perspectives

The primary workshop objectives included:

- To reexamine and assess progress to date on key issues identified at the earlier HEI/ EPA-sponsored workshop and in follow-up conference calls with the PM Research Center Directors, HEI National Particle Component Toxicity (NPACT) Principal Investigators, and other researchers.
- To discuss specific recommendations for concrete steps that EPA and other organizations could take in the ambient air monitoring program to advance health research for the criteria air pollutants.
- To seek constructive feedback on five draft "white papers"[5] developed to aid in a common understanding of the issues under discussion. These draft white papers are included in Appendices B through F of this draft document.

The summaries of the five workshop sessions presented below include:

- Session overview,
- Panel members,
- Major points identified by the workshop participants, and
- Recommendations
  - Presented at the workshop and/or
  - Developed by EPA staff based upon the workshop discussions

Initial Successes and Next Steps

This workshop was a major step in a series of interactions to foster improved long-term communication between air quality experts and health researchers. The air program has continually emphasized integration across disciplines, labs and EPA programs. Although this requires significant investment of time and effort for all involved, we believe such an investment is necessary to ensure that the ambient air monitoring program offers, and health researchers use, the best and most appropriate data possible to support the health research that serves as a foundation for EPA's NAAQS reviews. While follow-up from this workshop continues, there are already demonstrable outcomes from the efforts involved in planning, as well as holding the April workshop. A few examples of initial successes include:

- Monitoring staff, in EPA and State/local agencies, are becoming aware of the need for daily measurements of PM components and have expressed willingness to save filters used for daily measurements of $PM_{2.5}$ mass so that they can be used to analyze PM components for health researchers.

[5] The draft white papers presented relevant background information and critical issues, opportunities for improvement including draft EPA recommendations for possible short- and long-term activities, and, as appropriate, charge questions to stimulate discussion at the meeting.

- Science to Achieve Results (STAR) grantees voluntarily analyzed data sets to help determine whether changes to the measurement method for organic carbon would affect the findings of ongoing epidemiological studies.
- Based on information they received from air quality experts at the workshop, STAR grantees have acknowledged making changes to the designs of their health studies that will improve validity of results as a result of better information on spatial variability of PM components.
- OAQPS monitoring experts and ORD epidemiologists and exposure scientists are working together to examine the covariance of specific PM components (e.g. metals) across various cities to develop a network of sites for refined epidemiological study.
- ORD's National Center for Environmental Research has conducted a preliminary survey of EPA-funded health researchers to identify specific ambient monitoring sites that are being used in current epidemiological studies[6]. This information will be useful to State and local air agencies as they consider any future changes to their monitoring networks.

A draft of this document was distributed to the workshop participants for review and comment. This final summary document incorporates the comments that were received. In addition, EPA has identified additional next steps that will be taken, including:

- Stratifying the recommendations in this document as to their feasibility and prioritizing actions to be taken. These include providing important input into the strategy for the revised monitoring network (NCore[7]). EPA's ORD and OAQPS will work together to facilitate the incorporation of these recommendations into both short- and long-term monitoring strategies and leveraged program plans. This will include EPA staff briefing and receiving direction from senior management during planning cycles for both monitoring network design and health research planning.
- Implementing data access improvements and communication tools as soon as possible to prevent disruption of data streams, loss of important monitoring sites, and developing a clearinghouse for other datasets not readily formatted to the Air Quality System (AQS) data system.
- Requesting periodic consultations on the enhanced monitoring program with the Clean Air Scientific Advisory Committee (CASAC) and its Ambient Air Monitoring and Methods (AAMM) Subcommittee.

[6] See Appendix G.
[7] See http://www.epa.gov/ttn/amtic/ncore/index.html for more information on the NCore Multipollutant Monitoring Network.

SESSION I: ELEMENTAL AND ORGANIC CARBON MEASUREMENTS

Background/Objectives

EPA has made changes in the urban Chemical Speciation Network (CSN) carbon sampling and analytical protocols for measurement of particulate carbon in order to address inconsistencies between the procedures previously used in that program and the rural Interagency Monitoring of Protected Visual Environments (IMPROVE) program. Health researchers have expressed concerns about this methodological change and potential impacts on monitoring data that are used for long-term time-series analyses. The session objectives were to:

- find ways to minimize disruption to epidemiological studies, both current and future,
- determine the extent of measurement change/error that is problematic,
- determine which of the CSN changes are of most concern to epidemiological studies,
- assess whether past and planned measurement comparisons are adequate, and
- consider how blank filters and sampling artifacts should be handled.

Session Overview

This session contained two components: (1) a series of factual presentations on the measurement methods, the changes and/or errors that may occur, and the importance of carbonaceous aerosol sampling to the health research community and (2) a panel discussion to address approaches that can be used to assess potential types of measurement error, needed measurement comparisons, impacts on epidemiological studies, and additional steps necessary to identify and address information gaps.

The presentations included:

- **Overview and Introduction to Key Issues**---Venkatesh Rao (EPA) and Barbara Turpin (Rutgers University)
- **A Health Researcher's Perspective: What's so Special About Carbon?**---Ed Avol (University of Southern California)
- **CSN Carbon Monitoring Changes and Issues**---Joann Rice (EPA)
- **Carbonaceous Aerosol Sampling Artifacts in the National Monitoring Networks**---John Watson (Desert Research Institute)
- **Transitions**: **Relating "Old" to "New" Methods**---Warren White (University of California-Davis)
- **Predicting Carbonaceous Species Concentrations with Partial Least Squares**---Philip Hopke (Clarkson University)
- **Impact of Method Transitions to Health Research**---Michael Hannigan (University of Colorado-Boulder)
- **Air Quality Monitoring: Perspectives from East and West**---Dirk Felton (NY Dept. of Environmental Conservation)

Members of the discussion panel included:

- Venkatesh Rao, co-chair, EPA, OAQPS
- Barbara Turpin, co-chair, Rutgers University
- Ed Avol, University of Southern California

- Michelle Bell, Yale University
- Judith Chow, Desert Research Institute
- Neil Frank, EPA, OAQPS
- Philip Hopke, Clarkson University
- Michael Kleeman, University of California-Davis
- Allen Robinson, Carnegie Mellon University
- Warren White, University of California-Davis

This session provided a good forum for the exchange of information among diverse interests in monitoring, analysis, and health impacts. The panelists and those who spoke up from the floor shared the view that the impact of measurement changes on health research is unknown and complex, as is how much detail is needed to better understand the impact on epidemiological studies and resulting correlations with health effects. There was also agreement among those speaking about a need to: (1) collect more information from collocated measurements for an extended period of time at multiple sites; in order to (2) better document uncertainty, and associated differences between elemental carbon (EC) and organic carbon (OC) measurements for the new and old methods. Spatial location and source dependent differences in monitoring sites are important considerations, as are potential differences by season. Specific action items were not identified at this session, but there was a general consensus amongst the speakers about the proposal (see below) for more extensive co-located monitoring, and several researchers called for such analyses in a wide range of locations and seasons. Little discussion took place of other related issues that had previously been identified in the agenda (this included how to handle artifacts, how to handle field blanks vs. back-up filter measurements, and which measurement errors are most problematic for epidemiological studies). Additional background information is provided in Appendix B.

Major Points Raised by Participants

General

- Health endpoints are affected by the physical, chemical and toxicological properties and attributes of carbon-containing particles as well as by the emission sources represented by the air quality measurements. These characteristics are not routinely measured, and currently can only be inferred—very indirectly—from the relative proportions of EC and OC. The reported proportions of EC and OC are likely to change as a result of the changes in the measurement protocol; this could be more important in assessing the impact on health than individual uncertainties in the OC and EC measurements.

- Changes made in the CSN carbon measurements can be documented, but sampling artifacts (organic vapors adsorbed within the filter) are still being explored. Charring of these vapors within the filter is the main cause of differences between transmittance and reflectance corrections for OC charring (Chow et al., 2004 Relating the results of "old" and "new" methods is ongoing. The co-location of old/new monitors can provide information important to understanding the nature of changes in measurements.

- In the past, EPA used several samplers in their chemical speciation network, which resulted in good agreement for EC, but poor agreement for OC and total carbon (TC) – which was a function of the differing sampling flow rates and having no good way to address the sampling artifacts. In the future, one sampler that is IMPROVE-like will be used for CSN with a higher flow rate, smaller filter, back-up quartz filters, and better field blanks (this will

likely ensure uniformity of the OC measurements, but more work will likely be needed to understand what is actually being measured).

- The change in the analytical protocol will change the OC-EC split in some cases, yielding more reported EC and less reported OC. The analytical change is not expected to change reported TC. The changes in sampling protocol will affect the sampling artifact, and thereby reduce reported TC and OC. The sampling change is not expected to change reported EC.

- Hannigan et al. [2008] suggest that in the DASH (Denver, CO) study, EC would remain significant as an indicator for health endpoints. Of course, Denver is only one location in space, and generalizations cannot be made about the health effects of EC until more studies are completed.

- For considering impacts of PM on health, measures of bias and of uncertainty are both important in determining health outcomes.

- There is a need for semi-continuous OC/EC measurements as well as other PM chemical components. As important as the increased temporal resolution that will result from use of semi-continuous methods is the affordability of these measurements (daily (and shorter interval) sampling at multiple sites becomes more feasible). This can be important for better understanding sources of carbon since more detailed spatial and temporal information can aid in source attribution studies. The shorter sampling times associated with semi-continuous instruments also produce samples with much smaller variation in sampling conditions (good in terms of minimizing the potential for redistribution between the gas and particle phases).

- In addition, there currently are sites with Sunset semi-continuous OC/EC analyzers, McGee aethalometers, and Thermo-Scientific MAAPs operating through the transition period and beyond. Some researchers suggested that the locations of these analyzers at sites important for epidemiologic studies (cities where health effects have been shown) and at other important sites should be identified so that the usefulness of these data for epidemiological studies and for "harmonizing" efforts can be identified. However, the Sunset Labs instrument collects material at a somewhat higher than ambient temperature, like the TEOM does. Thus, Sunset Labs' OC values may be somewhat smaller than those made at ambient temperature. Others noted that health research should not be limited to the locations of on-going studies due to the many studies that are national in design and the need to understand regional variation in health effects.

- One presenter indicated that the sub-fraction measurements of OC and EC made in the IMPROVE and new CSN protocols can also add valuable information to source attribution studies. However, low temperature (i.e., volatile) OC1 and OC2 fractions are most sensitive to temperature changes during the analysis and during sample handling (Chow et al, 2007, Dillner et al., 2008).

- The type of measurement error that is most important to a specific epidemiological study will depend on the study design, and on the scientific questions it aims to address (e.g., acute versus chronic effects). In other words, there is no single factor or set of factors that is the critical need for epidemiological researchers. The impact of measurement changes will

affect various epidemiological studies differently, depending on their design. This issue needs to be sorted out and discussed further.

What types of measurement error are problematic for epidemiologic studies?

- All types of measurement errors are of potential concern. There is a need for a qualitative understanding of what the measurement error is comprised of, and how this might vary spatially. The analytical measurement error of the monitor is usually much smaller than the measurement error associated with using a centrally located monitor to represent an entire community, particularly when evaluating pollutants that are measured once every three or six days and in assessing pollutants that are heterogeneously distributed in the ambient air. Measurement error clearly matters when evaluating epidemiological evidence, but for time-series analyses, most of measurement error is Berkson, and hence does not include bias, just reduced power. The way to solve that problem is with more data, which again points to the need for daily measurements.

- Changes in carbon components (bulk OC and EC) are important, as are changes in the percent measurement error of the components. Are there differential errors in EC and OC? We need to define "error" better.

- Representativeness of sites is affected by spatial variability and by source types.

- Balance can be attained by a central $PM_{2.5}$ speciation monitor plus satellite sites (with lower costs) that indicate how representative the information collected at the central site is (and address how spatially divergent some EC/OC and other components are). Satellite sites must be based on lower-cost methodologies, for example, should optical measurements from Teflon filters be considered? Note: panelists did not address how we can be certain that relationships between "reference" and "cheap" methods observed at central sites will be the same at satellite sites.

Are past and planned measurement comparisons adequate?

- In evaluating the transition between carbon monitoring methods, workshop participants voiced concerns that the current process to conduct two months of measurement comparisons is too limiting, since seasonal variability is important; there is a need for more data to compare the different methods and inform the epidemiological research. There are 6 co-located CSN/IMPROVE sites ongoing (as identified in the draft White Paper for Session I, see Appendix B) and more discussion of how these could be used would be helpful. It is unlikely that we will be able to afford one year's worth of co-location at every site converted. So, it's important to specifically know where longer-term comparisons are required for health research or to know how to generalize from a small set of locations to the larger network. (see next bullet as well).

- It might be useful to consider a whole year of data with less frequent measurements; also consideration of a limited number of samples at more individual sites would be helpful. As such, there is a need to know what kinds of locations are of most importance for health research studies. Some suggested that a wide range of locations representing different particle mixtures and sources would be useful.

- There is a need to better understand uncertainty information. Proportional changes in EC & OC may create proportional changes in epidemiological studies; if changes are not proportional for different components, then there may be a problem.

- In selecting sites for possible increased co-location of old and new measurements, the influence of variations in sources needs to be considered. These could include sites influenced by wood-smoke, mobile sources, large stationary sources, and a mix of all sources.

Recommendations/Actions for Consideration

Suggested by Workshop Participants:

- There was general consensus on a proposal to run co-located "old" and "new" CSN measurements for a whole year; with consideration of potentially measuring every 6th (or 12th) day at 6 – 9 sites. Many researchers felt it was important to ensure that the specific sites include those currently being used for epidemiological studies where associations or relationships with OC or EC are being studied, although many other researchers noted the need for selection of sites that represent a wide array of locations and particle mixtures, as noted below. Inclusion of locations where carbon has been found to be associated with health effects may allow us to more easily determine if the measurement change has an impact on their health impact findings. Potential sites include Seattle (Beacon Hill), Rubidoux (CA), Bronx (New York City), Atlanta, Detroit, Cleveland, Denver, and an additional southern location.

- Several individuals supported selecting sites based on source distribution/mix, not just on-going or planned epidemiological studies. Using this approach, consideration could be given to variations in soils, industries, and mobile sources in the source distribution. A site selection process could incorporate both this concept and that listed above, to include locations of ongoing studies.

- There was also general consensus that this proposal be reassessed after a year of data collection in order to evaluate whether a longer study period or more sites are needed.

- A limited number of individuals also supported an investigation of the availability of semi-continuous OC/EC data and its potential role in "harmonizing" old vs. new carbon measurements.

- A limited number or participants also supported achieving better spatial resolution by implementing a main site and satellite sites for species with large spatial variability, to better characterize population exposures.

Developed by EPA Staff Based on Workshop Discussions:

- Continue UC-Davis (January 2008) "Carbon Summit" process:

    - Selected archived samples from IMPROVE and collocated IMPROVE/CSN network sites will be analyzed by the new IMPROVE carbon analysis methodology to develop

additional data, which will be used along with the routine data collected by the two networks to better characterize the relationships between the various old carbon analysis methods and the new IMPROVE analytical method (i.e. the approach that is used now for both networks).

- Changes will be made in the operations of both IMPROVE and CSN networks to increase the number and utility of carbon blanks and backup filters collected in order to further investigate and if possible develop more credible approaches to adjust for sampling artifacts.

- Continue to conduct periodic assessments of the quality and comparability of PM carbon data from both networks and over time (i.e. as methods have changed) paying particular attention to data from continued operations of collocated monitoring sites. The results of these efforts to be the subject of possible future joint network workshops, publications and web postings.

- Further evaluate the performance of the Sunset EC/OC and other continuous analyzer and determine the role of continuous measurements to support daily monitoring and harmonize old and new CSN. Filter-based measurements will still be needed, but can be collected on a much reduced frequency. This idea can then be extended to other semi-continuous instruments, like the Aethelometer, MAAPs, and photoacoustic spectrometer which measure light absorption, strongly correlated with EC.

- Make a more targeted request (with much more specificity than was done for this workshop) to health researchers to help us better understand the sensitivity of their results to changes in carbon measurements.

- Further discussion of the topic "optimal OC artifact correction for large networks" is warranted.

SESSION II: ACCESSING AMBIENT AIR MONITORING DATA

Background/Objectives

EPA's Air Quality System (AQS) is designed to collect and store ambient air monitoring information. EPA recently introduced the AQS Data Mart to facilitate access to this monitoring information. The AQS Data Mart is a generic "retrieval" tool that provides the ability to query any information, but it does not provide significant data exploration or analytic capabilities. These capabilities are left to the "analytical" tools. Various analytical tools, or interfaces, are available including the Health Effects Institute's (HEI's) Air Quality Database, which focuses on ambient air measurements of $PM_{2.5}$ components and gaseous pollutants at and near STN and SLAMS sites. This session focused on data access issues and how to help health researchers obtain monitoring data for fine particle components and other critical pollutants more easily.

Session Overview

In general, access to ambient air monitoring data to support health research/ assessments falls into four general categories:

- epidemiological studies,
- exposure/risk assessments,
- public health surveillance, and
- health impact assessments

Keeping these broad categories in mind, and understanding that the goal is to provide a framework for delivering consistent, well-documented monitoring data to users including the health research community, the broad topics discussed in this session included:

- To what key data do health researchers need access?
- What formats are most useful?
- What kind of access is most appropriate for health research uses?
- How can the overall data context be improved and preserved in delivering the data to users?

Members of the discussion panel included:

- Michelle Bell, co-chair, Yale University
- Bryan Hubbell, co-chair, EPA, OAQPS
- Sara Adar, University of Washington
- Kaz Ito, New York University
- John Langstaff, EPA, OAQPS, Health and Environmental Impacts Division
- Nick Mangus, EPA, OAQPS, Outreach and Information Division
- Richard Poirot, Vermont Department of Environmental Conservation
- Betty Pun, AER
- Rich Scheffe, EPA, OAQPS

The panel members were asked to be specific in their data needs, e.g., to clearly identify what specific documentation is needed, rather than just providing general recommendations to provide "more documentation." A special focus on versioning of the data was also recommended for the discussion.

To lead off the session, two introductory presentations were provided by Nick Mangus and Rich Scheffe of EPA. Nick Mangus provided an overview of the draft white paper entitled "Access to EPA's Air Quality Data for Health Researchers (see Appendix C)," while Rich Scheffe provided a summary of the outcomes from a recent EPA-sponsored Air Quality Data Summit, held in March 2008.[8]

Major Points Raised by Participants

Several persons mentioned the high value of EPA air pollution datasets, and noted that access has greatly improved over the years. Several broad themes emerged from the discussion:

Versioning

The most important theme seemed to be versioning of the EPA datasets. Several people expressed concerns over the current system, where researchers can download different datasets without realizing they differ. Currently, there is no way of knowing whether data files have changed, or merely been updated. This causes problems with reproducible research and with researchers not knowing whether to get new data due to corrections being made. It also is an issue when researchers update an epidemiological analysis with a new year of data; they need to know if there have been changes in the air quality database for previous years as well. It was noted that changes to data include not only updates of new data, but corrections to old data, even 10 years previous. Multiple options to address this issue were discussed:

- time/date stamp every observation
- version numbering (e.g., Version 10Jan08.7, etc.)
- maintenance of snapshot datasets that are static
- notice of changes to datasets
- maintenance of datasets used by researchers

Concerns were raised regarding the cost and storage of some of these options.

Data Availability

The draft white paper included in Appendix C provided background information for this session. This paper described and contrasted the data available through the AQS Data Mart and the HEI Air Quality Data Base, and other sources of information. Specific issues discussed related to data availability included:

- EPA vs. other organizations' roles in providing access to data. Several participants expressed support for HEI or some other organization outside the EPA continuing to support analytical tools, or interfaces, to disseminate air quality data "packaged" with other relevant data for health researchers.

- Information previously available through AQS that is no longer available. There were some concerns expressed that certain types of data, e.g. the TEOM data had been removed from the AQS archive website. EPA clarified that TEOM and FRM data were different and that the TEOM data were removed so unknowing users would not incorrectly compare it to FRM data. EPA has mitigated this issue by changing how we identify $PM_{2.5}$ data and will

[8] See http://wiki.esipfed.org/index.php/Air_Quality_Data_Summit#Documents.

reconsider putting the TEOM data back on the website. It was noted that some local TEOM data are being adjusted to match FRM data as part of the joint CDC/EPA PHASE project.

- Additional information for monitor locations. It was suggested that photographs of the monitoring station be easily accessed and keyhole markup language (KML) files be created. While the land-use around monitors could change, this would provide researchers with some guidance on the monitor location.

- Information from other sources. The concept of a data clearinghouse providing links to non-EPA data sets was suggested, for example, access to additional State, local, and tribal air quality data that are not entered into AQS (e.g., AirNowTech data), special studies data, Supersites data, etc. EPA clarified that the Supersites data are available on the NARSTO website. However, workshop participants made it clear that the data on the NARSTO site is not in a format that is comparable to the FRM data available on AQS. Workshop participants noted that it would be helpful to have all the air quality data in one location, and provided in a similar format or have scripts for reading data from different formats into common software programs like SAS, R, or S-Plus. The need to leverage existing IT capabilities to gain efficiencies in creating a data clearinghouse was highlighted. Please see discussion of this issue below in the section Actions Items Under Consideration.

- Requesting data from State, local, tribal air agencies directly. EPA maintains a listing of regional, State, and local level air quality data contacts available on its website. Workshop participants noted that when going to State contacts for data, some provide data faster than others, and often in very different formats (sometimes still providing paper copies only). It was suggested that it would help State/local air agencies if health researchers would share final products (e.g., health studies) with these agencies so they could be better informed about how the air quality data are used and future research needs.

Data Quality

Some mention was made of data quality, and the need for researchers to be aware of data quality problems, even in EPA-vetted datasets. Examples provided included:

- Quality and accurateness of existing metadata are varied, metadata can be wrong, and that there are often not even flags to note suspicious outlier values that might result from a misplaced decimal. For example, if ozone data at low levels are a decimal place off, this could play a major role in studies of thresholds and effects at low concentrations.

- Incorrect identification of latitude/longitude has been noted for a subset of monitor sites as well as a high frequency of missing data in some of the critical fields (e.g. no monitoring objective listed for some sites). EPA notes that all data in AQS passes the EPA's QA checks for the tests we need for regulatory purposes. This may not be sufficient for some scientific applications. All metadata (and data) are ultimately controlled by the submitting State/local/tribal agency and EPA cannot change it. So improving quality is a community effort. This is another reason why researchers might want to engage the agencies whose monitors they are using for studies.

- It was recommended that the data be stored at the finest spatial and temporal granularity possible, and then aggregated up as needed by the user.

User Friendliness and Documentation

It was noted that some data users are novices, some are expert, and each needs different levels of data access and, therefore, would have different needs. Many participants voiced the opinion that epidemiologists tend to be "very opportunistic," making use of whatever air quality data are provided. As such, epidemiologists will utilize available data, but would like more guidance as to what uses of the data are valid and/or appropriate (e.g. provision of data on the percent valid observations, monitoring objectives, monitor scale, use of flagged data).

The need to increase user friendliness was discussed, such as with the ability to download specific States' data rather than data for the whole US for some data sources. Within the discussion of user friendliness, there was a general consensus that documentation needs to be improved. In addition, documentation is perhaps a bit scattered throughout various EPA sites. The point was made that "user-friendliness" is dependent on the needs and skill level of the user, so that no standard form will be perfect for all users.

The issue is that it takes more effort to find and interpret documentation of the data than it does to obtain the data; and missing descriptive information can be devastating to an analyst. There are many attributes of the data that are not well understood by users (metadata is not owned by EPA and therefore can be outdated or data can be updated by the owner at any time; EPA data storage labels are in flux with regulation and policy changes; etc.). Users having a single site for documentation will greatly reduce the likelihood of incorrect interpretation.

Secondary Data

The panel discussed whether non-air pollution data would be useful to include in the air pollution datasets. Examples were weather, land-use, and census data. Some people thought this would be useful. Others thought this was less useful, given that such data are available elsewhere. This seemed to be far less of an issue than the versioning. Thus, resources might better be spent on the versioning issue than on incorporating secondary data.

Recommendations/Action Items for Consideration

The recommendations listed below include items discussed at the workshop as well as additional recommendations developed by EPA staff based upon the workshop discussions.

Data Versioning

- Explore options for adding the date (and time) of last modification to all data measurements in AQS (and the AQS Data Mart).

Notes: Data in AQS can change at any time. Generally, EPA limits the ability of data submitters to change data for only the last few (3-5) years. However, we do open time windows where older data can be changed. There are implications to the submitter for changing data and the volume of older data changes is low, but they do happen. Researchers need to know if these data changes affect their analyses. Adding a date-of-change to each measurement would allow a data user to query the space and time domain of their initial query to see if any data had changed. EPA would not keep a record of the change, but new or changed values would be indicated with their date of creation/update. It would still be incumbent on the user to maintain the original data set and compare changed data to assess possible ramifications. Any change to a measured value or metadata (like the monitoring method or uncertainty) would trigger the date stamp to be updated.

Data Availability

- Continue to encourage HEI and other organizations support of analytical tools and interfaces to make the AQS data more useable for the health research community. Follow-up with HEI regarding the plans for continuing to support the HEI Air Quality Data Base.
- Explore options for creating and maintaining a Clearinghouse of non-EPA datasets

There are a lot of air quality data which are not in AQS. Some of these data have been collected by State and local air pollution control agencies and have not been reported to AQS for one reason or another (e.g., continuous data are collected on a minute basis, and EPA only requires that hourly averages be submitted; the information does not pass the regulatory quality assurance requirements, even though the quality may be high enough to fill a gap in a research time series; etc.) Another source of data that EPA does not have is data collected from special research studies run by academic or State/local public health organizations. This is generally high density data (in space and/or time) used to better understand the variability of measurements over smaller scales than regulatory monitoring requires. Even the other Federal air quality storehouse, AirNow Gateway will have State/local/tribal data that does not meet the policy requirements of AQS. Having a single location as the starting point for a dataset clearinghouse will dramatically help improve the inventory of available air quality information.

- Location of Monitoring Sites. Make keyhole markup language (KML) files with AQS air monitoring site locations should be made available.

KML files describe locations and can be used by most modern map-drawing applications. Including links within the KML file will allow users to download the actual measurements. Making these available would better allow people to visualize the monitoring network they would also confirm the monitor location when the listed latitude and longitude were suspect.

- Develop new content and format for data on AQS archive page. Request feedback from key users on how to improve the AQS "Data Archive" (data download) page on EPA's website and update accordingly.

Users complain about the limited number of parameters available, the frequency of updates, the format, and the size of the files. If agreement can be reached on how to improve these problems, EPA could make the appropriate changes.

- Continue Data Summit follow-up to provide a system-of-systems for data integration and display. OAQPS will provide base data from Federal monitoring networks via the AQS Data Mart.

The purpose of the data summit work is to make use of "interoperability" frameworks like GEO (Group on Earth Observations) for system developers to identify what part of the data value-chain they belong in and successfully connect with those up- and down-stream from them. The value-chain has roughly these divisions: base data provision, metadata provision, data integration, data processing (aggregation), data visualization, and communication. It is expected that the architecture standards board convened as a follow up to the Air Quality Data Summit will adopt specific recommendations on web services (machine queries) of data that all participating systems should support. If all systems agree to the web services, data integrators and interface builders would have a much easier time obtaining data from multiple systems. For example, the HEI Air

Quality Database could be updated more frequently, and include more information about the progeny of the data.

- Explore opportunities to encourage discussions between health researchers and State/local monitoring experts. For example, encourage health researchers to share published results with State/local monitoring community, specifically studies that use monitoring data collected by the State/local air agencies and encourage participation of a variety of experts in regional and national meetings (e.g., health researcher participation in monitoring meetings).

User Friendliness and Documentation

- Explore ways to highlight if a significant change in AQS has occurred. For example, EPA could provide an explanation on the AQS website so that regular AQS data users would be aware and know where to go to access the data.

- Use the IMPROVE metadata as a model for developing AQS metadata, including the IMPROVE "Data Advisories" noting any changes or issues with the data.

- Request that supplemental data be presented in the same format as primary data.

SESSION III: AMBIENT AIR MONITORING FOR HEALTH RESEARCH

Background/Objectives

The purpose of Session III was to provide a discussion among a panel of health and exposure researchers who use ambient air monitoring data in their studies and to highlight the value of these data for the continued progress of research linking particulate matter (PM) sources, exposure and health effects. This session was intended to stimulate a discussion of the issues and identify creative solutions for the provision of daily speciation data in key locations while working within current resource constraints faced by local, State and Federal air quality agencies. For example, resolving key policy questions about health effects of specific size fractions, components and gaseous co-pollutants related to PM, requires more intensive temporal and spatial air quality data than are currently available. Background information for this session is included in Appendix D.

Session Overview

The panelists discussed the major sources of uncertainty that must be considered when designing and interpreting the results of studies of ambient PM mass, components and health. A number of important research questions were raised in this context that could be addressed if some changes were made to monitoring networks in some locations. If daily measurements of PM species were available in informative locations, studies would be better designed to detect the relative importance/toxicity of PM species and size classes. Studies designed to detect health effects of short-term exposure would develop more precise and valid exposure estimates and would be better able to generate hypotheses that address possible mechanisms for the observed health responses to PM. Although the panelists primarily focused on issues as they relate to epidemiology studies, the point was made that toxicological assessment of ambient particles must be generalizable to human exposure and be interpretable in relation to epidemiological results.

Members of the discussion panel included:

- Barbara Glenn, co-chair, National Center for Environmental Research, EPA
- Joel Schwartz, co-chair, Harvard School of Public Health
- John Godleski, Harvard School of Public Health
- Patrick Kinney, Columbia University
- Lucas Neas, National Health and Environmental Effects Research Lab, EPA
- Roger Peng, Johns Hopkins University
- George Thurston, New York University
- Jay Turner, Washington University in St. Louis

Major Points Raised by Participants

Uncertainties

Epidemiology studies must deal with several sources of error in estimating personal exposure to ambient PM. These include:

- Instrument measurement error. Is the monitoring technique adequately measuring pollutants at the site of the monitor? The observation was made that while exposure measurement error

at the monitor introduces uncertainty in estimates of ambient concentrations, this error is smaller than other measurement errors in epidemiology studies.

- Spatial variability. How geographically homogenous are the particle concentrations in the cities where we are conducting epidemiology studies? Is the concentration of PM species measured at the monitor representative of the ambient concentrations experienced by human populations living and working in the city?
- Temporal variability. Monitoring schedules of every third or sixth day results in data gaps that severely limit the ability to explore variations in the time lag of response for different PM components. Different PM components are believed to target different biologic pathways in generating health responses and the flexibility to explore a variety of time lags between exposure and outcome is necessary to reveal these effects. In addition, health events relevant to days with missing air quality data must be excluded, thus reducing sample size. Alternatively, air quality concentrations may be interpolated in some manner which increases uncertainty in exposure estimates. Interpolation results in a reduction of daily variability in PM concentration data with resulting loss of statistical power, and increases the correlation between concentration estimates for PM components in datasets. This inhibits efforts to differentiate species-specific toxicity.
- Other errors in estimation of personal exposure based on ambient measurements. Infiltration of PM components indoors, time-location during the day etc. The comment was made that use of air conditioning during the summer months has a large effect on health models for certain geographic locations.

Time scale

Research has shown that the health effects of air pollution exposure on one particular day are spread out over several subsequent days. Therefore, the effects (e.g., death) observed on one day are the result of air pollution that occurred during a period of days on and before the deaths were recorded. Epidemiologists need to use pollution concentrations on a defined number of days before the date of an effect to study hypotheses regarding the relevant time between exposure and effect. These time scales likely are different for different PM components and different health outcomes (e.g., heart attack, asthma etc). The relevant time lags for a particular outcome also may vary by season and location as well. The study of time lags informs mode of action.

In the absence of daily speciation data, PM components with a very acute or immediate effect (short-lags) on health would have less measurement error and thus an apparently stronger association with health outcomes than PM components with more delayed effects spread over several days (long-lags). This differential error could lead to a misattribution of PM effects to specific sources. Monitoring on a daily basis is needed in a reasonable number of cities to evaluate this variation.

Statistical Power to differentiate between components

The panel listed several key factors that influence the statistical power of an epidemiology study. These include:

- Number of daily health events – need large population size.
- Variability in estimated exposure (indicated by variation in pollutant concentration across space for long-term cohort studies or change in daily concentration for time-series studies). We want to maximize variance and minimize covariance.

- Maximize measurement of concentration variance. Daily speciation measurements in a location will provide a dataset that documents the day-to-day variation in concentration that occurs at the monitoring site. The point was made that concentrations vary a great deal within a 24-hour period and, therefore, temporal variation in PM species within an area could be better quantified using continuous monitors. Continuous methods also would minimize concerns about artifacts. Local sources are another determinant of variation in PM species concentrations. Better spatial resolution in the data will better account for local sources.
- Minimize covariance between PM components in datasets. Panelists emphasized that studies are not able to differentiate the relative importance of PM components in associations with health effects if concentrations are highly correlated in a study location. To avoid this problem they recommended that study sites be selected where covariance between PM components is minimized or different. The point was made that meteorological factors are a key determinant of correlation in daily concentration change for PM components, which poses analytical difficulties. Toxicology studies will help to sort out relative toxicities among PM components.

Spatial scales

For time-series studies, if daily change in pollutant concentration is homogenous across the population, then one "central" monitor will adequately characterize daily change in ambient concentration for that city. This assumption needs to be explored at multiple study sites. For long-term cohort studies, better within-city spatial resolution provides better estimates of annual average concentrations for individual study members, and increases the variation in exposure data. This results in an increase in statistical power.

Some panelists emphasized that exposure estimates based on concentration data from one PM speciation monitor in the middle of the city will not add much information for epidemiology studies because exposure measurement error for the overall population is too large. Spatial variability in PM component concentrations is an important issue. Participants also were urged to integrate models that take into account meteorology and source information over space, such as CMAQ, into exposure estimation. At the same time, toxicology studies will have to play a large role in understanding PM component influences on health. Participants were cautioned that toxicology studies also are complex, and the use of pure components in toxicology studies has been disappointing. It is very difficult to generalize results from these studies to draw conclusions about responses to the ambient mixture.

The influence of local sources in the vicinity of a monitor needs to be understood before those data are assumed to represent exposure for the population in a city. One panelist emphasized that during certain periods of time, local sources have been observed to highly influence ambient concentrations of a PM component measured by a speciation monitor. The point was made that the CSN monitors are sited to implement the NAAQS and assure compliance, not to support health effects studies.

Recommendations

Desirable Attributes of Locations Selected for Daily Speciation Measurements

The following location characteristics were suggested as criteria for selecting a set of metropolitan areas to support daily speciation monitoring:

- Population size. This is the most important attribute since the number of daily deaths in a city is the major determinant of statistical power of a time-series or case-crossover study. Large metropolitan areas, including New York City, Los Angeles, and Chicago were proposed. However, the comment was made that very large urban centers, such as New York City, have characteristics, such as street canyons, that increase spatial variability. Other less large cities with more homogenous geography may be better candidates. Once the population size is relatively large, resulting in daily deaths of around 20, then other selection factors should play a much greater role in the selection of urban areas for additional sampling.

- Different covariance structure between PM species in different cities.

- A variety of source contributions.

- Location of speciation monitor(s) in the city that minimizes the influence of local sources of PM.

- Topography and city attributes that increase the likelihood that one or a few monitors will characterize daily change appropriately.

- Expertise and support of State and local air monitoring personnel to collect daily filters and maintain semi-continuous monitors.

- Existence of additional monitoring data in that location to supplement information on spatial and temporal distribution of PM components and other pollutants.

- Special State/local or academic studies using multiple monitors may have been conducted in the location to better characterize spatial and temporal variability and could be made available for analysis. FRM filters may have been archived by State/local air quality agencies and may be available for speciation analyses. The existence and availability of these studies and filters needs to be explored. A panelist commented that these filters are a national resource and need to be inventoried and kept, not thrown away.

- Consider the impact of weather and seasons, differences in behavior that affect exposure.

The Children's Health Study in Los Angeles was referred to during the discussion of site selection for additional monitoring. Twelve communities were initially chosen based on the hypotheses of interest for $PM_{2.5}$ mass, the need to obtain a 3 – 5 fold difference in ambient concentrations, and an emphasis on long-term health effects. Hypotheses concerning different PM size fractions would result in selection of different communities. The design of the CHS was considered innovative because a monitoring approach of 26 two-week sampling periods was conducted which minimized the number of samples taken while capturing seasonal differences in ambient concentration.

Action Items for Consideration

- Develop a recommendation on the best locations to conduct additional sampling. More information must be collected to inform selection of proposed study sites and the minimum number of locations to conduct additional sampling.

- Agree and prioritize important criteria for site selection.

- Analyses and presentation of the correlation structure between PM components and between PM components and other pollutants at the CSN speciation monitors. Kaz Ito, New York University, volunteered to assist with this effort. Analyses are currently being conducted by EPA's OAQPS and ORD.

- Identify locations with appropriate data from special studies on daily PM species concentrations or spatial variability.

- Evaluate the feasibility of analyzing archived FRM filters from specific locations (for certain components as appropriate).

- Develop a table summarizing relevant information. Information characterizing additional criteria will be obtained and the table filled in (ORD, OAQPS).

[*] Kunzli, N.; Avol, E.; Wu, J.; Gauderman, W.J.; Rappaport, E.; Millstein, J.; Bennion, J.; McConnell, R.; Gilliland, F.D.; Berhane, K.; Lurmann, F.; Winer, A.; and Peters, J.M. (2006). Health effects of the 2003 Southern California wildfires on children. Am. J. Respir. Crit. Care Med., 174(11):1221-1228.

Wu, J.; Lurmann, F.; Winer, A.; Lu, R.; Turco, R.; and Funk, T. (2005). Development of an individual exposure model for application to the Southern California children's health study. Atmos. Environ., 39(2):259-273.

SESSION IV: THORACIC COARSE PARTICLE COMPONENTS AND POTENTIAL HEALTH IMPACTS

Background/Objectives

In September 2006, the EPA revised the NAAQS for PM and amended the associated national air quality monitoring requirements.[9] As part of the amended monitoring requirements, EPA finalized a Federal Reference Method (FRM) for thoracic coarse particles (i.e., $PM_{10-2.5}$), even though a NAAQS for $PM_{10-2.5}$ was not adopted. This was done to facilitate consistent research on $PM_{10-2.5}$ air quality and health effects and in promoting the commercial development of Federal Equivalent Methods (FEMs) (71 FR 61212). The amended monitoring requirements require the addition of $PM_{10-2.5}$ measurements at 75 multi-pollutant monitoring sites (National Core or NCore sites) starting on January 1, 2011. A subset of these monitoring sites will include speciated coarse particle measurements. The purpose of this session was to discuss issues related to and relative priorities for EPA to consider as speciation of thoracic coarse particles is added to the monitoring networks to support future exposure and health studies.

When discussing issues and priorities of thoracic coarse particle measurements to support health studies, it is important to acknowledge that we are starting from a different place than with fine particle measurements. This presents both challenges and opportunities. First, while there is an extensive network to monitor PM_{10} and $PM_{2.5}$, there exists no national network with the specific intent to consistently and accurately measure $PM_{10-2.5}$.[10] As a result, the amount of $PM_{10-2.5}$ air quality data available and associated analyses are available at fewer locations than PM_{10} or $PM_{2.5}$ measurements. Second, there have been fewer health studies conducted to investigate relationships between thoracic coarse particle concentrations and health endpoints, which is due in part to the first challenge – limited available air quality data. Some health studies have been conducted using PM_{10} measurements in areas where the PM concentrations are dominated by thoracic coarse particles. Other thoracic coarse particle air quality and health studies have relied upon data from locations where co-located PM_{10} and $PM_{2.5}$ monitors exist, but there are uncertainties in the consistency of these data because the protocol for the PM_{10} and $PM_{2.5}$ measurements is not usually identical.[11] Despite these challenges, significant opportunities exist to inform the design of future thoracic coarse particle monitoring programs and to better harmonize thoracic coarse particle measurements with the needs of health effect researchers.

Session Overview

To investigate health effects associated with exposures to thoracic coarse particles will require an improved understanding of the intra-urban, inter-urban, and urban-rural variability of ambient thoracic coarse particle concentrations. Key uncertainties associated with intra-urban ambient thoracic coarse particles concentrations include spatial, temporal, and compositional variability, while key uncertainties with inter-city and urban-rural comparisons include variability in

[9] See http://www.epa.gov/oar/particlepollution/actions.html for more information on amendments to EPA's National Air Quality Monitoring Requirements.

[10] U.S. EPA. (2005) Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information, OAQPS Staff Paper (June 2005). U.S. Environmental Protection Agency, Washington, DC, EPA-452/R-05-005.

[11] U.S. EPA. (2005) Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information, OAQPS Staff Paper (June 2005). U.S. Environmental Protection Agency, Washington, DC, EPA-452/R-05-005.

composition and temporal differences (e.g., seasonal). Ambient air monitoring networks can provide insights to address these uncertainties. As a result, general questions that were posed to the panelists in this session were as follows:

- What is the relative value of thoracic coarse particle speciation at planned monitoring locations versus additional mass measurements?
- What is the relative value of understanding intra-urban versus inter-urban/rural variability in thoracic coarse particle mass and composition?
- What recommendations can be made to inform the design of a thoracic coarse particle monitoring network?

Members of the discussion panel included:

- Timothy Larson, co-chair, University of Washington
- Tim Watkins, co-chair, EPA, ORD
- David Diaz-Sanchez, EPA, ORD
- Richard Flagan, CalTech
- Terry Gordon, New York University
- Michael Hannigan, University of Colorado
- Thomas Peters, University of Iowa
- Joann Rice, EPA, OAQPS
- Jamie Schauer, University of Wisconsin

There was a general consensus that thoracic coarse particles are very complex and pose significant challenges for both air quality and health scientists. Thoracic coarse particles differ from fine particles and, in many cases, present greater challenges. For example, thoracic coarse particles may exhibit larger spatial and temporal variability than fine particles and the composition of thoracic coarse particles can vary in rural versus urban areas. The composition of thoracic coarse particles can also differ from fine particles with introduction of biological materials and the increased importance of metals. In addition, thoracic coarse particles also present new challenges related to measurement technologies. The current FRM is based on the difference between measurements taken with co-located PM_{10} and $PM_{2.5}$ integrated filter samplers. While this method provides a good measurement of thoracic coarse particle mass, there is no direct thoracic coarse particle sample collected. Other methods exist, such as dichotomous or continuous mass samplers, which can provide valuable information about particle composition and temporal variability, but these methods need to be evaluated further. In addition, the use of emerging passive monitoring approaches may also provide opportunities for obtaining thoracic coarse particle data.

The thoracic coarse particle monitoring program is still evolving, and EPA's OAQPS is seeking feedback and input on thoracic coarse particle network design issues. EPA should apply lessons learned from the fine particle monitoring program and closely follow ongoing research efforts, while moving forward with implementation of a thoracic coarse particle monitoring program. The emerging thoracic coarse particle monitoring program should include continuous monitoring technologies, where possible, and any speciation efforts should use consistent methodologies. Ongoing research may also yield important insights for designing a thoracic coarse particle monitoring program. The EPA's ORD recently awarded a series of grants to investigate the sources, composition, and health effects of thoracic coarse particulate matter. These grants integrate atmospheric measurements with toxicological and epidemiological investigations. ORD's in-house research program will also produce relevant research results to consider when designing a thoracic coarse particle monitoring program. Data from completed field efforts, such as the Detroit Exposure

and Aerosol Research Study (DEARS)[12] and FRM evaluations, should be analyzed to provide additional information about the intra- and inter-urban variability of thoracic coarse particles. Also, ongoing and planned studies, such as the Birmingham Saturation Sampling study and Near Roadway studies[13], will also provide valuable information pertaining to thoracic coarse particles. Finally, ORD's in-house health research program includes thoracic coarse particle toxicological studies integrated with exposure and source apportionment analyses. While these research programs may produce results to inform decisions regarding thoracic coarse particle measurements (e.g., methods, monitoring locations, and components measured), the timing of the results will be critical since the initial thoracic coarse particle measurements will be required at NCore sites on or before January 1, 2011.

Major Points Raised by Participants

The following questions and the accompanying responses summarize the major points of this session:

What lessons can be learned from the $PM_{2.5}$ chemical speciation network and applied to designing a thoracic coarse particle speciation network?

- Monitoring Methods
  - Use consistent monitoring methods
  - Use continuous methods, where possible
  - Evaluate speciation methods now and conduct hypothesis driven pilots
- Frequency of measurements
  - Consider conducting daily measurements at some thoracic coarse particle monitoring locations.
- Archiving filters for future analyses

What is the relative value of thoracic coarse particle mass versus speciation measurements?

Initial efforts to monitor thoracic coarse particles should focus on mass measurements to inform our understanding of spatial and temporal variability. We need to learn more about the components of thoracic coarse particles and how composition varies across urban and rural areas, as well as, speciation measurement techniques before making significant investments in speciation monitoring. There is a significant amount of variation in thoracic coarse particle toxicity and we do not know enough to invest heavily in speciated thoracic coarse particle measurements at this time.

What, potentially, are the most important thoracic coarse particle components to measure?

Based on toxicology studies, metals, especially soluble metals, may play an important role in effects associated with thoracic coarse particle exposures. In addition, the role of biological materials in thoracic coarse particle health effects is unclear but it is also potentially very important. Analytical challenges limit our health-based hypotheses. Organics are quite different in thoracic coarse particles and difficult to measure. Furthermore, a significant mass fraction of many thoracic coarse particle samples is unknown/unidentified.

[12] See www.epa.gov/dears for more information.
[13] .add reference/link

What methods are available to measure thoracic coarse particles?

There are several methods available for thoracic coarse particle measurements and we need to continue to evaluate these methods for measuring thoracic coarse particles. The current FRM for thoracic coarse particle is based upon the difference between PM_{10} and $PM_{2.5}$ measurements (using identical protocols and flow rates). Dichotomous instruments provide a separate measurement for thoracic coarse and fine particles. EPA studies show good agreement between the difference method and dichotomous measurements for both thoracic coarse particle mass and speciation, although additional analyses of speciation results from each method would be valuable. There are also continuous methods (e.g., FDMS Dichotomous TEOM) available for thoracic coarse particle measurement. In addition, other thoracic coarse particle sampling techniques may present opportunities for collecting more data for potentially lower costs. For example, the DRUM sampler may provide speciated size segregated measurements with a reduced operational burden. However, additional research is needed to evaluate the DRUM (Davis Rotating Uniform size-cut Monitor) sampler and compare results with other methods. Another promising monitoring approach uses passive techniques in combination with scanning electron microscopy (SEM) to provide thoracic coarse particle mass and speciation (elemental and morphological). These passive techniques can be deployed at relative low cost in a variety of locations which provides opportunities for improved spatial analyses of thoracic coarse particles.

In what locations should thoracic coarse particle measurements be made?

Consider monitoring in areas that are not in attainment for PM_{10}, but in attainment for $PM_{2.5}$ (see Table 1 below) or at least areas with higher PM_{10} and lower $PM_{2.5}$ concentrations. Analyses of data collected in these areas will provide insights into the thoracic coarse particle components or sources which are driving non-attainment (or high levels of thoracic coarse PM). Subsequent health studies can then provide information regarding the potential for health effects associated with exposure to these thoracic coarse particle components and sources. Rural locations should be included as well to improve understanding of differences between urban and rural thoracic coarse particle concentrations.

At what height should thoracic coarse particles be monitored?

Additional research is needed to understand the vertical profile of thoracic coarse particle concentrations and to identify the effect of monitoring height on thoracic coarse particle measurements (current requirements for thoracic coarse particle monitoring height range from 2 to 15 meters).

How can the sources of thoracic coarse particles be identified?

Research is needed to identify tracers or marker compounds for thoracic coarse particles for source apportionment analyses. Thoracic coarse particle sources likely fall into one of the following categories: direct emissions from mechanical processes that crush or grind larger particles (e.g., from industrial operations, construction and demolition activities, and agricultural and mining operations), resuspension of dusts (e.g., traffic-related emissions from tire and brake wear), biological materials, and secondarily formed aerosols. The influence of local sources will likely be relatively more significant for thoracic coarse particles than for fine particles.

Why should State/Local/Tribal agencies be interested in thoracic coarse particle monitoring?

Thoracic coarse particle monitoring in PM_{10} non-attainment areas (particularly areas that are in attainment for $PM_{2.5}$) could provide valuable information for State and local agencies, while also providing valuable information for air quality and health researchers that can be used in the design of thoracic coarse particle monitoring programs.

What other tools are available for analyses of ambient thoracic coarse particle concentrations?

Tools such as land use regression models, GIS, satellite data, and atmospheric dispersion models can supplement thoracic coarse particle monitoring data to provide enhanced information regarding spatial and temporal distributions of ambient thoracic coarse particles. However, it is important to note that there are uncertainties with outputs from these tools and while these tools were acknowledged at the workshop, detailed discussions regarding their potential application were beyond the scope of this workshop. The application of these tools may be included in future workshop discussions, as appropriate.

Are there unique issues associated with thoracic coarse particle health studies?

There are some unique issues related to thoracic coarse particle health studies. First, *in vivo* toxicology studies are more difficult because efficient animal models are not available, in part because inhalation toxicological studies are not possible in rodents. Differences in thoracic coarse particles typically found in rural versus urban areas also present challenges. Epidemiological studies in rural areas may not have enough statistical power. Finally, the role of exposures to biological components in health outcomes presents additional challenges.

Are there existing data available to analyze?

Various states, including Californian, New York, and Washington, have thoracic coarse particle data available for mass and composition analyses. For example, the state of California has collected and analyzed thoracic coarse particle measurements for spatial, temporal, and compositional patterns.[14] In addition, data and results from previous research studies that included coarse particle measurements exist. One such study was conducted around major industries in southern Chicago.[15] EPA also has thoracic coarse particle data available from previous field studies (e.g., FRM evaluations, source apportionment studies). Key science questions need to be developed for thoracic coarse particle monitoring and then the existing data sets need to be identified that could potentially be analyzed to address some of these questions.

Recommendations/Actions for Consideration

Building upon the general summary and major points above, the following is a list of recommendations expressed at the workshop or developed by EPA staff based on the workshop discussions.

---

[14] ***Croes, B.E.*** (2003). Particulate matter in California: Part 2 - Spatial, temporal, and compositional patterns of PM2.5, PM10-2.5, and PM10. *J. Air Waste Manage. Assoc.*, **53**(12):1517-1530.

[15] ***Watson, J.G.***; Chow, J.C.; Kohl, S.D.; Kuhns, H.D.; Robinson, N.F.; Frazier, C.A.; and Etyemezian, V. (2000). Annual report for the Robbins Particulate Study - October 1997 through September 1998. Prepared for Versar Inc., Lombard, IL, by Desert Research Institute, Reno, NV.

- When making decisions regarding investments in speciated thoracic coarse particle measurements, consider the following:

    - Analyze existing thoracic coarse particle data sets first. Such analyses could begin to address issues such as:
        - How does thoracic coarse particle composition vary across cities and in urban and rural areas?
        - To what extent do speciation analyses using samples collected via the difference methods differ from speciation of dichotomous samples?
    - Conduct targeted thoracic coarse particle speciation monitoring which is hypothesis-driven to decide what components to monitor and how.
    - Consider evidence generated from toxicological studies to inform decisions on which components to monitor.

.

- When evaluating potential locations for thoracic coarse particle monitors, consider areas that are in attainment for $PM_{2.5}$ but not for PM_{10}. Speciated thoracic coarse particle monitoring in these locations may provide insights regarding sources that may be contributing to non-attainment.

- Consider a thoracic coarse particle network design that includes a central site monitor collecting mass and speciation measurements with satellite locations that could potentially use alternative lower cost methods (e.g., passive methods).

- Consider collecting daily thoracic coarse particle measurements at some subset of locations.

- Encourage the use of thoracic coarse particle continuous methods, where possible.

- Continue to evaluate thoracic coarse particle sampling and analytical methods.
    - Sampling methods to be evaluated include FDMS Dichotomous TEOM, DRUM, and passive sampling approaches.
    - Identify and evaluate potential methods to analyze biological components in thoracic coarse particles.

- Incorporate thoracic coarse particle monitoring objectives in planned research field work. Examples objectives include:
    - Identification of marker compounds for thoracic coarse particle source categories.
    - Characterization of vertical distribution of ambient thoracic coarse particles and the associated implications for monitoring height.
    - Identification of composition and sources of unidentified thoracic coarse particle mass.

- Consider application of land use regression models, GIS, satellite images, and atmospheric dispersion models in conjunction with ambient thoracic coarse particle measurements to conduct spatial and temporal variability analyses and to inform monitor locations.

- Closely follow ongoing research for potential insights for thoracic coarse particle monitoring programs. The following research efforts may be particularly valuable:
    - EPA STAR Grants[16]

[16] See http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.rfa/rfa_id/450 for more information

- Sources, composition, variability and toxicological characteristics of coarse ($PM_{10-2.5}$) particles in Southern California (University of Southern California)
- Sources, composition, and health effects of thoracic coarse particulate matter (University of Colorado at Boulder)
- Cardiovascular effects of urban and rural thoracic coarse particulate matter in African American and white adults (University of Michigan)
- Spatial investigation of sources, composition and long-term health effects of thoracic coarse particulate matter ($PM_{10-2.5}$) in the Multi-Ethnic Study of Atherosclerosis (MESA) cohort (University of Washington)
- Comparative Toxicity of Thoracic coarse Particles (New York University)

o EPA In-House Research[17]
- Detroit Exposure and Aerosol Research Study (DEARS)
- Birmingham Coarse Particle Study
- Near Roadway Research Program
- Cleveland Source Apportionment Study
- Pinal County PMc Characterization Study (Region 9 RARE Project)

[17] add a link to descriptions of these studies

Table 1. PM_{10} Non-Attainment Areas with $PM_{2.5}$ Designations (Source: EPA TTN Website)

Area	Approximate Population	EPA Region	PM_{10} Non-Attainment Classification	PM2.5 Attainment?
Phoenix, AZ	3,110,000	9	Serious	Yes
Clark Co, NV	1,380,000	9	Serious	Yes
Sacramento Co, CA	1,220,000	9	Moderate	Yes
Salt Lake Co, UT	898,000	8	Moderate	Yes
El Paso Co, TX	564,000	6	Moderate	Yes
Utah Co, UT	369,000	8	Moderate	Yes
Washoe Co, NV	339,000	9	Serious	Yes
Eagle River, AK	195,000	10	Moderate	Yes
Coachella Valley, CA	182,000	9	Serious	Yes
Eugene-Springfield, OR	179,000	10	Moderate	Yes
Imperial Valley, CA	120,000	9	Serious	Yes
Mun. of Guaynabo, PR	92,400	2	Moderate	Yes
Yuma, AZ	82,300	9	Moderate	Yes
Ogden, UT	77,200	8	Moderate	Yes
Missoula, MT	52,400	8	Moderate	Yes
Bonner Co (Sandpoint), ID	36,800	10	Moderate	Yes
Butte, MT	34,600	8	Moderate	Yes
Nogales, AZ	24,600	9	Moderate	Yes
Sheridan, WY	15,800	8	Moderate	Yes
Paul Spur/Douglas (Cochise County), AZ	15,700	9	Moderate	Yes
Kalispell, MT	15,100	8	Moderate	Yes
Miami, AZ	14,600	9	Moderate	Yes
Juneau, AK	13,800	10	Moderate	Yes
Shoshone Co, ID	10,500	10	Moderate	Yes
Ajo (Pima County), AZ	7,590	9	Moderate	Yes
Coso Junction, CA	7,000	9	Moderate	Yes
Owens Valley, CA	7,000	9	Serious	Yes
Mammoth Lake, CA	6,460	9	Moderate	Yes
Hayden AZ	6,050	9	Moderate	Yes
Flathead County; Whitefish and vicinity, MT	5,030	8	Moderate	Yes
Polson, MT	3,780	8	Moderate	Yes
Columbia Falls, MT	3,780	8	Moderate	Yes
Trona, CA	3,500	9	Moderate	Yes
Lane Co, OR	3,420	10	Moderate	Yes
Anthony, NM	2,590	6	Moderate	Yes
Ronan, MT	2,520	8	Moderate	Yes
Pinehurst, ID	1,700	10	Moderate	Yes
Sanders County (part);Thompson Falls & vicinity,MT	1,180	8	Moderate	Yes
Fort Hall Reservation, ID	553	10	Moderate	Yes
Lame Deer, MT	536	8	Moderate	Yes
Rillito, AZ	506	9	Moderate	Yes
Mono Basin, CA	258	9	Moderate	Yes
Los Angeles South Coast Air Basin, CA	14,600,000	9	Serious	No
San Joaquin Valley, CA	3,080,000	9	Serious	No
New York Co, NY	1,540,000	2	Moderate	No
San Bernardino Co, CA	199,000	9	Moderate	No
Libby, MT	3,230	8	Moderate	No

SESSION V: AMBIENT AIR MONITORING REALITIES – EPA/STATE/LOCAL PERSPECTIVES – SUMMARY AND RECOMMENDATIONS

Background/Objectives

This session was designed for EPA and State/local staff who manage monitoring programs to share their reactions (i.e., a reality check) to topics discussed in earlier sessions of the ambient air quality monitoring and health workshop. This included providing recommendations for addressing "low hanging fruit" as well as identifying significant challenges to making progress in ambient air monitoring to advance health research for the criteria and related (e.g., chemical speciation) air pollutants.

Session Overview

For this portion of the workshop a panel of experts in ambient air monitoring was assembled to provide their reaction to the papers, presentations, and discussions at the workshop. The panel included several staff and managers from EPA and State and local air agencies who are responsible for implementing and overseeing the operation of routine ambient air monitoring programs for air toxics, criteria, and other related air pollutants.

Members of the panel included:

- Dirk Felton, co-chair, New York State Department of Environmental Conservation
- Tim Hanley, co-chair, EPA, OAQPS
- Mike Gilroy, Puget Sound Clean Air Agency (Seattle, WA area local air agency)
- Richard Payton, EPA Region 8 (Lead Monitoring Region)
- Scott Reynolds, South Carolina Department of Health and Environmental Control
- Eric Stevenson, Bay Area Air Quality Management District (San Francisco, CA area local agency)
- Susan Zimmer-Dauphinee, Georgia Department of Natural Resources

Major Points Raised by Participants

The panel provided input and reactions on a range of topics from the workshop. Common themes across the panel members can be grouped into four categories: daily speciation sampling, $PM_{2.5}$ continuous mass data, data management, and communications.

Daily Speciation Sampling

One of the major needs identified by health researchers is to have daily speciation in up to the largest 20 urban areas in the country. EPA currently works with State and local agencies to provide a Speciation Trends Network (STN) operating at midnight to midnight every third day at 53 locations around the country, plus an additional 120 locations identified as "supplemental speciation" that mostly operate on a sample schedule of every sixth day. Together the STN and supplemental stations comprise the Chemical Speciation Network (CSN). The CSN data together with collocated criteria pollutant gas measurements reported to AQS form the largest single source of ambient air pollution data used by the health community in researching the health effects of air pollution.

Concerns

The panel overwhelmingly supported the value of speciation data for use in health studies as well as to directly support State and local data uses such as source apportionment of fine particles and tracking control programs. However, the panel shared their concerns with the ability of State and local agencies to take on the workload and cost associated with daily sampling via filter-based speciation samplers. Even if funding were available to support the cost of the laboratory analysis, monitoring agencies would have a difficult time supporting the field operations due to frequent site visits and other logistical concerns. The panel identified that monitoring agencies were in some cases already proposing to cut back on existing monitoring systems due to diminishing resources via EPA grants and their own agency budgets. At the same time EPA's national contract laboratory has a pre-negotiated price increase each year. Therefore, even under the best of scenarios, which is usually flat funding, agencies are receiving less direct awards to support field activities every year. While the panel expressed their doubts that anything substantive could be accomplished through daily filter-based speciation, they did share thoughts on possible opportunities utilizing semi-continuous speciation methods.

The panel also discussed the comparative uncertainty of health effect studies versus uncertainty in the ambient air monitoring data. Panel members suggested, and no one disagreed, that the uncertainty in the ambient air monitoring data was very small compared to the uncertainty in health studies. Health researchers pointed out that it was not just an issue of not having daily data to reduce uncertainty, but also an issue with interpreting the potential lag of health effects if daily characterization of particle species is not available. After the meeting, panel members suggested that through use of available $PM_{2.5}$ filter-based mass, continuous mass, and filter-based speciation, reasonably good estimates of daily speciation could be derived (e.g., statistically interpolating chemical speciation on days 2 and 3 that the CSN sampler did not operate) for most major metropolitan areas. EPA could work with a group such as HEI to make such estimates available.

Another option that could potentially support daily speciation is the rotating drum sampler, discussed in the white paper found in Appendix D entitled "Air Quality Sampling: Benefits and Costs of Daily Health Targeted Monitors for Fine Particle Components." The drum sampler was identified as a possible alternative measurement technology to support high time resolution (every six hours) of chemical speciation. The drum sampler measures various size classes of PM mass and PM components which would allow for a more comprehensive characterization of the sizes of PM by species. However, there is limited use of the drum sampler in applications other than special studies with anecdotal stories that it does not perform well. The panel expressed concern that the technology was not ready for routine application in State and local air monitoring networks, but were open to reconsidering the technology farther down the road if additional development and testing demonstrated that it would be easier to use than the current equipment and agencies would have at least the same confidence in the data as is available from the existing speciation sampling platform (i.e., the Met One SASS/SuperSASS for elements and ions). Even if the drum sampler advanced to the point of having comparable sampling performance to the existing CSN samplers, there remain two important issues that will need to be addressed. The first is the request made by health researchers to have a consistent method over the entire study period that they are researching and the second is ensuring data reporting to the AQS data system for integration with other ambient air monitoring data.

Opportunities

Acknowledging the value of highly time-resolved speciation data, the panel did express an interest in characterizing speciation on a daily basis utilizing some combination of semi-continuous and filter-based methods. Such an approach could be beneficial to both the health research community as well as supporting data needs of State and local agencies; which is very important in order to gain the support of senior management across monitoring agencies. The panel discussed how several agencies are reporting good results with semi-continuous methods such as the Sunset carbon analyzer, Aethelometer, and Thermo sulfate analyzer. Other semi-continuous speciation samplers exist, but have not been demonstrated to be comparable to filter-based methods or are so complex that data completeness and quality suffer due the instrument needing constant attention in the field. Utilizing some combination of semi-continuous carbon and sulfate characterization plus providing for elemental analysis via XRF analysis on daily Teflon filters may provide a reasonably complete characterization of the chemical speciation of most interest. The major species missing from such a protocol would be semi-volatile nitrate and organic carbon. A possible surrogate for the missing semi-volatiles could be the volatile channel of the Filter Dynamic Measurement System (FDMS) monitor, which provides highly time resolved characterization of stable and volatile PM. A protocol of semi-continuous and limited filter–based speciation for elements would be of interest to a number of State and local agencies to provide a more complete characterization of the source apportionment of their networks, especially on days above the NAAQS. Researchers are believed to value such a data set on all days to improve our understanding of potential health/welfare effects associated with ambient concentrations at or below the current standards. Review of existing collocated continuous speciation and filter-based method data (CSN or IMPROVE) available in AQS or from Regional or State monitoring organizations could provide an opportunity for health researchers to evaluate the potential value of semi-continuous speciated data and the need for filter based, co-located sampling.

$PM_{2.5}$ Continuous Mass Data

Several of the panel members commented on the availability of $PM_{2.5}$ continuous mass data and potential value to the health research community. Some panel members were surprised to learn that these data were not being widely used in health studies. Across the country there are over 600 $PM_{2.5}$ continuous mass monitors reporting hourly data with every major city covered by one or more stations. These data are stored and reported in near real-time through State and local agencies web sites and nationally through the AirNow program; see www.airnow.gov[18]. Long-term archiving of $PM_{2.5}$ continuous data is provided for in the AQS data base. Acknowledging the variety of $PM_{2.5}$ continuous methods used and their performance according to climate and measured aerosol components across the country, EPA set–up new AQS data storage protocols in 2006 so agencies could store their data in a way that allowed data users to better utilize the $PM_{2.5}$ continuous mass data. Principally among the data storage protocols, data users can pull hourly data for the parameter "Acceptable $PM_{2.5}$ AQI & Speciation Mass" (parameter code 88502). This parameter code is intended to represent the $PM_{2.5}$ continuous mass data where the method meets performance criteria

[18] www.airnow.gov provides illustrative maps of near-real time air pollution data and forecasts according to the EPA's Air Quality Index (AQI). These maps are intended for the general public and as such are color coded according to the AQI. Detailed near real-time air pollution and meteorology data from across the United States and Canada are available through www.airnowtech.org. This site is intended for technical users of the data. Health researchers or any other data user with a valid use for the information can request access to the site through the log-in screen on the web site.

suitable for reporting the AQI[19]. In March of 2008, EPA-ORD approved the first Federal Equivalent Method (FEM) for $PM_{2.5}$ (Met One BAM 1020). Data from this method will be stored under the parameter code "$PM_{2.5}$ at local Conditions" (88101) as are all currently reporting $PM_{2.5}$ FRM's, since these methods are approved for comparison to the NAAQS. All the available parameter codes (sometimes referred to as pollutant codes) for storing $PM_{2.5}$ continuous data in AQS are provided below.

Parameter Name	Parameter Code	Purpose	~Active Samplers/ Monitors	
$PM_{2.5}$ LOCAL CONDITIONS	88101	Code for all FRM's, FEM, and ARM's. Continuous FEM's will be stored with this parameter code. Data reported to this parameter code are generally eligible for comparison to the NAAQS.	940 FRM's (~150 operate daily)	
$PM_{2.5}$ TOTAL ATMOSPHERIC	88500	Valid data from methods measuring total $PM_{2.5}$ aerosols in the atmosphere. FDMS is the method currently stored here	100	In total, there are ~ 600 operating $PM_{2.5}$ continuous monitors; some monitors dual report
$PM_{2.5}$ RAW DATA	88501	Valid uncorrected data that does <u>not</u> meet DQO's for reporting at least the AQI	300	
ACCEPTABLE $PM_{2.5}$ AQI & SPECIATION MASS	88502	Valid data that <u>does</u> meet the DQO's for AQI reporting with or without a correction or the mass data from the CSN network. Data reported to this parameter code are <u>not</u> eligible for comparison to the NAAQS.	400 $PM_{2.5}$ continuous mass; 200 CSN	
$PM_{2.5}$ VOLATILE CHANNEL	88503	Store important related data such as the FDMS reference channel.	50[20]	

With the availability of data from a large number of $PM_{2.5}$ continuous mass monitors, health researchers could utilize highly time-resolved data that can be used as a surrogate for the types of exposures in an urban area and combined with FRM data as a tool to better understand $PM_{2.5}$ continuous mass measurements with a positive bias relative to the FRM. $PM_{2.5}$ continuous mass data can be used to characterize different types of exposures by the time of day. For instance, weekday morning rush hour would be an indicator of automotive emissions, while early mornings in the winter might be an indicator of home heating (e.g., oil or wood smoke, depending on the neighborhood). In some cases, the measurement principle and time resolution of a $PM_{2.5}$ continuous method results in data that have a positive bias relative to a 24-hour measurement on the filter-based $PM_{2.5}$ FRM. The positive bias with $PM_{2.5}$ continuous methods are most likely associated with semi-volatile organics and nitrate that are not fully captured on the FRM due to evaporative losses that are exacerbated in warmer months when the sample filter is exposed at ambient conditions. These differences should be explored and included in analysis to health research data as the data are

[19] Where bias is controlled to within +/- 10% and correlation is at least 0.9 (R^2 of 0.81) compared to collocated filter-based FRM's

[20] Every FDMS monitor provides outputs of the volatile channel; however, some monitoring agencies have data management system limitations at their sample station; therefore only half the FDMS units (50 out of 100) in operation are reporting this channel. EPA will be working with monitoring agencies to improve reporting of this channel.

already available and would help focus future research efforts on the most important particle species (e.g., to what extent do the semi-volatile organics have a stronger or weaker association with health effects?).

Data Management

The panel discussed several aspects of data management. One issue uncovered was the discovery that at least two major metropolitan areas were providing for daily sampling and analyses of the major fine particle species - elements, ions, and carbon (i.e., Los Angeles and Denver). The panel suggested that the applicable State and local agencies would highly value this additional speciation data being utilized by health researchers. To ensure data are utilized, it was suggested that, where appropriate, these important measurements be reported to the AQS data system. Specifically, in cases where health researchers are utilizing monitoring agency filters, plans should be made to load the data to AQS. In cases where health researchers are performing their own sampling, there would still be value in making the data available to a wider audience of users; however, monitoring agencies and health researchers would need to ensure data comparability with the existing network so other data users understand the usefulness of the data.

Panel members offered that many agencies use EPA's AQS data system as the sole long-term repository of their data, but there were exceptions. While all routine State and local agency data make their way to AQS, in some cases agencies have their own long-term data record with unique or even routine measurements that are not in AQS. Health researchers should ask monitoring contacts about any such data when discussing availability of ambient air monitoring data with State and local agencies

Panel members also offered that they can usually assist health researchers in the retrieval of data from their network, even when data are located on the AQS data system.

Communications

Each major stakeholder group (EPA health and monitoring programs, external health researchers, State and local air programs) has dozens of other groups that they communicate with. One of the goals of this workshop is to establish better communication between decision makers in routine ambient air monitoring programs and researchers that perform health effects studies that are used to inform NAAQS reviews. EPA, the routine ambient air monitoring programs, and the external health research are all motivated to invest time to improve communication that can lead to better use of ambient air monitoring data; however, all groups also have responsibilities to other stakeholders as well. So while monitoring programs and health researcher are making important strides to improve the use of data and therefore provide better products that can inform NAAQS reviews, each group also has a responsibility to other data users and clients of the health effects research studies.

The panel suggested that there are already examples of good communications between health researchers and State and local air monitoring programs; however, communications could be improved. Developing a collaborative relationship is critical to maximize the benefit of both kinds of organizations. Health researchers will be able to better influence network decisions, and monitoring agencies will be able to better utilize health research results produced from their own ambient air monitoring system. Panel members cited examples where they had a good line of communication between health researchers and cases where they did not, even with their own sister

health agencies in State governments. Panel members strongly support having health researchers review their annual monitoring network plans and to develop a line of communication as early as possible for identifying the most important monitoring stations being used in a health study. Where available, health and research community participation in plan review and development could be advantageous to all parties. Panel members suggested that they do usually attempt to accommodate the health research needs in cases where data are already being collected, especially if the researchers can identify the specific need and product in advance of a planned change in monitoring at a site.

A couple of panel members commented on State/local review of grant proposals and how early involvement of air programs may help strengthen this review. For example, if EPA, the external health community, and State and local air monitoring programs already had a good line of communication, then research plans for a specific research study could be strengthened by making use of existing State and local monitors and data. Research resources could then be focused on augmenting the State/local data by targeting measurements and activities not planned for in the State air monitoring network. While this workshop has had a good deal of focus on what data are missing, there are actually some redundancies between monitoring data collected for specific health studies and State/local air monitoring programs. Future research work should focus on maximizing the use of the State/local monitoring networks and identifying the most critical "missing" data to collect.

Some panel members commented on the wide variety of requests being made by the health community (e.g., lots of daily speciation, need for multiple speciation sites across a city, need for other measurements not currently being conducted such as ultrafines, etc.) and suggested that it would be useful to have a prioritized strategic plan of health research needs for ambient air monitoring data. Such a plan should include commentary on the usefulness of co-located measurements such as pollutant gases and meteorological measurements.

Recommendations/Actions for Consideration

Daily Speciation Sampling

Develop a protocol that utilizes a combination of semi-continuous and filter-based methods to characterize daily speciation. Ensure such a pilot has identified data users that can comment on the expected data quality so that if successful, these methods can be applied in other areas. Initially pilot this protocol in two or three major cities.

Specific actions to develop hybrid semi-continuous and filter-based daily speciation protocol:

- Inventory semi-continuous speciation methods operating across the country. Encourage entry of data into AQS where possible (OAQPS)
- Perform data analysis and determine data quality on available co-located semi-continuous and CSN data. (OAQPS)
- Evaluate intercomparability of Sunset carbon and Aethelometer data to CSN carbon data. Provide recommendations for relative value of each method to provide carbon data on days with no filter-based carbon sampling (ORD)
- Develop analytical protocol for XRF analysis on $PM_{2.5}$ FRM filters (ORD)
    - Test protocol by retrieving filters from a small number of monitoring agencies where there are co-located FRM and CSN data. Perhaps prioritize stations with collocated CSN sampler.
    - Analyze comparability of CSN and $PM_{2.5}$ FRM Teflon filters

- Provide recommendation on usefulness of XRF analysis on $PM_{2.5}$ FRM filter on days when the CSN Teflon channel has operated and already has elemental assay
- Develop laboratory protocol for additional carbon assay – Thermal Optical Reflectance - on $PM_{2.5}$ Teflon filter (ORD)
- Identify 2-3 test locations to pilot hybrid semi-continuous and filter-based daily speciation protocol. Prioritize based on both:
  - State/local partner(s) that will value daily speciation characterization for their program
  - Health research studies that are already underway, or soon to be underway, utilizing speciation data from an existing station

Other related actions

- Develop research action plan to address research questions from $PM_{10-2.5}$ chemical speciation Whitepaper (ORD)
- Analyze data from co-located hourly $PM_{10-2.5}$ by difference
- Analyze data from FDMS Dichotomous monitor; focus on volatile channel
- Evaluate potential for a urban PM-10 Sunset co-located with a PM-2.5 Sunset
- Demonstrate long-term (1-2 years) successful operation of the rotating drum sampler and Synchrotron XRF analyses, including loading elemental data to AQS and comparability to CSN data (ORD).

$PM_{2.5}$ Continuous mass data

The availability of over 600 $PM_{2.5}$ continuous monitors provides an opportunity to help health researchers utilize an important data set that might provide insights on the most important exposures of $PM_{2.5}$ by time of day and averaging period. EPA has already set up data storage protocols in AQS so that data can be retrieved according to the performance of the $PM_{2.5}$ continuous monitors and/or methods being utilized. EPA-OAQPS is actively working to store already reported $PM_{2.5}$ continuous data going back to 2004[21] under these new storage protocols.
Specific actions that may help facilitate better use of these data in health studies:

- Provide recommendations on storage of $PM_{2.5}$ continuous mass data from years 2004 through 2006 under the appropriate parameter code so that data users retrieve data as expected (OAQPS).
- Execute storage of $PM_{2.5}$ continuous mass data under new parameter codes in AQS from years 2004 through 2006 (OAQPS and State/local agencies).
- Develop long-term plan for including $PM_{2.5}$ continuous mass data in next iteration of national ambient air monitoring dataset used by health researchers (OAQPS and HEI).

Data Management

Availability of ambient air monitoring data to facilitate a two way communication of data can be improved by taking on the following actions:

- EPA should include a discussion of data reporting expectations in the solicitation of any new long-term health studies where speciation data are involved. (ORD)

[21] 2004 was the first full year of national $PM_{2.5}$ data reporting on AIRNow; the official launch date was October 1 of 2003. Prior to this date many agencies were just bringing their $PM_{2.5}$ continuous data on-line, including developing statistical adjustments to have their data more closely resemble the $PM_{2.5}$ FRM data.

    - In cases where the grant recipient will be utilizing methods consistent with the CSN network, the data will likely be highly valued, and provisions should be made to quality assure and report the data to AQS.
- Localized health effects studies should establish a contact with the State or local monitoring agency to facilitate access to data that may not necessarily be reported to AQS. (Health Researchers)
- Data leads on health effects research teams should be encouraged to contact State and local agencies for access to local data, even when the data are reported to AQS. (Health Researchers)

Communications

Many of the possible improvements to communication are already underway. For emphasis, the communication recommendations from the panel are provided here even if redundant or already underway:

- EPA will facilitate a continued dialogue between health effects researchers and routine ambient air monitoring programs (OAQPS and ORD)
    - Invite health effects researchers to share their work at monitoring conferences
    - Invite leaders in the ambient air monitoring community to attend health effects research meetings
    - Engage the National Association of Clean Air Agencies (NACAA) at the Air Director level to emphasize the importance of this work (OAQPS and ORD)
    - Continue dedicated meetings between health effects researchers and routine ambient air monitoring programs. (All)
    - Encourage (State or PQAO) Air Monitoring Staff representation on science advisory boards for health effects research programs that have significant monitoring data needs. (Health Researchers, State/local agencies)

- Facilitate input of health effects researchers into annual monitoring network plans[22] (EPA Regions, OAQPS, ORD, Health effects researchers)
    - Maintain AMTIC web site with links to each State/local agencies' annual monitoring network plan
    - In early 2008, EPA ORD's National Center for Environmental Research (NCER) conducted a preliminary survey of EPA-funded epidemiology studies to develop an initial list of monitoring sites that are being used in current or planned health studies[23]. ORD will consider options for expanding/updating this preliminary list and ways to make it available to State/local air agencies when they are considering changes to their monitoring networks.
    - Health effects researchers should engage monitoring program early in the process when they have specific needs for continued data availability.

[22] Annual Monitoring Network Plans are due to the applicable EPA Regional Office by July 1 of each year. These documents represent the plans for monitoring in the subsequent calendar year and are subject to EPA approval. Each agency is required to make their plan available for public inspection for at least 30 days prior to submittal to EPA. See 40 CFR §58.10. An internet link to plans is available at: http://www.epa.gov/ttn/amtic/plans.html

[23] See Appendix G.

- Develop strategic plan for health effects research ambient air monitoring data needs (ORD and HEI with input from OAQPS)
    - EPA and State/local agencies need to know the most valued data to help protect monitoring resources and guide future monitoring investments. Such a plan would be a guide for all monitoring investments including those by EPA-ORD, health effects researchers themselves and routine monitoring programs. Example topics to address include:
        - are Aethelometer BC data adequate?
        - is the UV channel useful?
        - are nitrate data necessary at all, or only in certain geographical areas?

BACKGROUND MATERIALS

Appendix A: Workshop Agenda and Participant List

Ambient Air Quality Monitoring and Health Research: Workshop to Discuss Key Issues April 16 and 17, 2008

US EPA Main Campus, Building C-Auditorium, Research Triangle Park, NC

EPA is interested in having an open dialogue with a small group of representative experts regarding health research priorities for ambient air quality monitoring data that could best advance our understanding of the impacts of air pollutant exposures on public health. In particular, we are interested in hearing comments and recommendations from experts on steps that could be taken to improve our understanding of the impact of fine particle components and other key air pollutants. These steps might include prioritization of monitoring sites and/or the designation of sites for more frequent monitoring.

This meeting is another step in a series of interactions to foster improved long-term communication between air quality experts and health researchers. This communication is critical for ensuring that the ambient air monitoring program offers, and health researchers use, the best and most appropriate data possible to support the health research that serves as a foundation for EPA's reviews of the national ambient air quality standards (NAAQS).

Primary Meeting Objectives

- To discuss specific recommendations for concrete steps that EPA and other organizations could take in the ambient air monitoring program to advance health research for the criteria air pollutants.

- To reexamine and assess progress to date on key issues identified at an earlier workshop sponsored by the Health Effects Institute (HEI) and EPA[24] and in follow-up discussions with the EPA-PM Center Directors, HEI National Particle Component Toxicity (NPACT) Directors, and other researchers.

- To provide constructive feedback on the following draft "white papers" developed to aid in a common understanding of the issues under discussion:
  - Chemical Speciation Network (CSN) - Carbon Issues
  - Access to EPA's Air Quality Data for Health Researchers
  - Air Quality Sampling: Benefits and Costs of Daily Health Targeted Monitors for Fine Particle Components

[24] HEI and EPA co-sponsored a meeting in late 2006 to discuss how the use of the accumulating data derived from nationwide monitoring of fine particulate matter (PM) components can facilitate current and future health effects studies and improve comparisons of risk estimates across studies. The workshop illuminated issues associated with accessing and analyzing monitoring data and identified needs of the health effects research community regarding monitoring of fine particle components. See http://www.healtheffects.org/AQDNov06/AQDWorkshop.html for more information.

- Long-term communication strategies for improving interactions between health researchers and air quality staff on changes in ambient air monitoring specifically:
    - Network Design and Site Selection Approval
    - Methods Implementation

Expectations for Meeting Participants

This workshop is designed to inform EPA staff plans for the criteria pollutant ambient air monitoring program to ensure that the most effective approaches for providing monitoring data to support health research studies are included. A large portion of the workshop agenda is devoted to discussion – the goal of which is to talk about recommendations for concrete steps that could be made to move the alliance between health and monitoring objectives forward. Thus, to maximize the effectiveness of the meeting, workshop participants will be expected to be familiar with background information distributed prior to the workshop, including draft white papers. The workshop discussions will need to be *forward* looking – to identify specific near- and long-term steps that EPA's health and monitoring staff, as well as external organizations and science communities, can take to improve the ambient air monitoring program to appropriately advance our understanding of the health impacts of criteria air pollutants. This workshop is designed to be an honest and objective endeavor to address health research needs, however, participants must also understand that EPA resources are, and will most likely continue to be, limited. Therefore, providing prioritization of recommendations for EPA and other organizations to consider is essential if we are to make some clear steps forward and, hopefully, build from anticipated initial successes.

Wednesday, April 16, 2008

8:30 – 9:45 Welcome/Introductory Remarks

8:30 – 8:45 **Purpose of the Meeting/Overview of Key Issues/Summary of Progress**
Dr. Daniel Costa, EPA National Program Director for Air Research/ORD

8:45 – 9:00 **EPA Program Office Perspective**
Ms. Lydia Wegman, Director, Health and Environmental Impacts Division/OAQPS
Mr. Richard Wayland, Director, Air Quality and Assessment Division/OAQPS

9:00 – 9:45 **Air Quality Experts and Health Researchers Working Together: Why Communication is Critical - Stories of Success**
Dr. Morton Lippmann, New York University

9:45 – 10:00 BREAK

10:00 – 2:45 Session I: Elemental and Organic Carbon Measurements

Background

In 2007, EPA made changes in the monitoring network to address inconsistencies in carbon sampling and analysis procedures used in urban CSN (STN/SLAMS) and rural IMPROVE programs. Health researchers have repeatedly raised concerns to EPA regarding this methodology change and potential interruptions in monitoring data used for time-series analyses. This session will include: (1) a brief overview of what measurements are currently being made; (2) highlights from a recent CSN/IMPROVE: Carbon PM monitoring workshop with emphasis on issues of most interest to the health research community[25]; (3) approaches that are being evaluated for relating different data sets and the potential impacts for on-going epidemiological studies, and (4) opportunities to discuss steps that are being taken or could be taken to identify and address information gaps, including continuous carbon measurements.

Background Information - Draft White Paper: "Chemical Speciation Network (CSN) - Carbon Issues"

10:00 – 10:20 **Overview and Introduction to Key Issues**
Dr. Venkatesh Rao, EPA/OAQPS
Dr. Barbara Turpin, Rutgers University

10:20 – 10:40 **A Health Researcher's Perspective: What's So Special About Carbon?**
Dr. Ed Avol, University of Southern California

10:40 – 11:00 **CSN Carbon Monitoring Changes and Issues**
Ms. Joann Rice, EPA/OAQPS

11:00 – 11:20 **Carbonaceous Aerosol Sampling Artifacts in the National Monitoring Networks**
Dr. John Watson, Desert Research Institute

11:20 - 11:40 **Transitions: Relating "Old" to "New" Methods**
Dr. Warren White, University of California-Davis

11:40 – 11:50 **Predicting Carbonaceous Species Concentrations with Partial Least Squares**
Dr. Philip Hopke, Clarkson University

11:50 – 12:10 **Impact of Method Transitions to Health Research**
Dr. Michael Hannigan, University of Colorado-Boulder

12:10 – 12:30 **Air Quality Monitoring: Perspectives from East and West**
Mr. Dirk Felton, NY Department of Environmental Conservation

[25] See http://vista.cira.colostate.edu/improve/Publications/Workshops/Carbon_Jan2008/CarbonMeeting2008.htm for more information.

12:30 – 1:30 LUNCH

Session I: Elemental and Organic Carbon Measurements (cont.)

1:30 – 2:45 Panel Discussion

Dr. Ed Avol, Univ. of Southern California
Dr. Michelle Bell, Yale University
Dr. Judith Chow, Desert Research Institute
Mr. Neil Frank, EPA/OAQPS
Dr. Philip Hopke, Clarkson University
Dr. Michael Kleeman, University of CA-Davis
Dr. Allen Robinson, Carnegie Mellon Univ.
Dr. Warren White, University of CA-Davis

Suggested Issues for Discussion:

- What types of measurement error are problematic for epidemiology?
- Knowing this, what is of most concern (to epidemiology) given the CSN changes?
    - Step changes in detection limits/precision?
    - Step changes in OC and EC (but not TC)?
    - Bias due to sampling artifacts?
    - Other?
- Are past and planned measurement comparisons adequate:
    - to aid epidemiology study analyses?
    - to "harmonize" results from old and new methods?
- How should blanks and sampling artifacts be handled?
- What other types of carbon measurements are good candidates for examination in large epidemiology studies?

2:45 - 3:00 BREAK

3:00 – 4:30 Session II: Accessing Ambient Air Monitoring Data

Background

EPA's Air Quality System (AQS) is designed to collect and store ambient air monitoring information. EPA recently introduced the AQS Data Mart to facilitate access to this monitoring information. The AQS Data Mart is a generic "retrieval" tool that provides the ability to query any information, but it does not provide significant data exploration or analytic capabilities. These capabilities are left to the "analytical" tools. Various analytical tools, or interfaces, are available including HEI's Air Quality Database, which focuses on levels of $PM_{2.5}$ components and gaseous pollutants at and near STN and SLAMS sites. This discussion will focus on data

access issues and how to help health researchers obtain monitoring data for fine particle components and other critical pollutants more easily.

Background Information - Draft White Paper: "Access to EPA's Air Quality Data for Health Researchers"

3:00 – 3:10	**Overview and Introduction to Key Issues** *Dr. Bryan Hubbell, EPA/OAQPS* *Dr. Michelle Bell, Yale University*
3:10 – 3:20	**Overview of Draft White Paper: "Access to EPA's Air Quality Data for Health Researchers"** *Mr. Nick Mangus, EPA/OAQPS*
3:20 – 3:30	**Summary of Recent Data Summit** *Mr. Rich Scheffe, EPA/OAQPS*
3:30 – 4:30	**Panel Discussion**

Dr. Sara Dubowsky Adar, Univ. of Washington
Dr. Kaz Ito, New York University
Mr. John Langstaff, EPA/OAQPS
Mr. Nick Mangus, EPA/OAQPS
Mr. Richard Poirot, Vermont DEC
Dr. Betty Pun, AER
Mr. Rich Scheffe, EPA/OAQPS

Suggested Issues for Discussion:

In general, we see that access to ambient air monitoring data needs to support health research/assessments falls into four general categories:

- epidemiological studies
- exposure/risk assessments
- public health surveillance
- health impact assessments

Keeping these broad categories in mind and understanding that the goal is to provide a framework for delivering consistent, well-documented monitoring data to users including the health research community, the issues discussed in this session will focus on data type/format, access, and context including:

- What key data and formats do health researchers need access to?
- How user-friendly are the data bases currently available to health researchers? What are the similarities/differences between the various data bases and how are they communicated?

- What potential changes could be made to improve access to ambient air monitoring data?
- What mechanisms are currently being used to communicate the limitations associated with the ambient air monitoring data? Are there specific recommendations for improving how the limitations are characterized?
- How can we improve the understanding of the limitations, quirks, and context of the ambient air monitoring data and assist end users in determining the subsequent appropriate use of the raw data?

4:30 ADJOURN

Thursday, April 17, 2008

8:00 – 8:30 Summaries of Day 1 Discussions and Comments on Draft White Papers/Next Steps

8:00 – 8:15 Session I: Elemental and Organic Carbon Measurements
Dr. Barbara Turpin, Rutgers University

8:15 – 8:30 Session II: Accessing Ambient Air Monitoring Data
Dr. Bryan Hubbell, EPA/OAQPS
Dr. Michelle Bell, Yale University

8:30 – 10:15 Session III: Ambient Air Monitoring for Health Research

Background

EPA has been measuring fine particle components in urban areas since 2001. The network consists of 54 sites intended to capture long-term trends (Speciation Trends Network or STN) and approximately 150 other State and local air monitoring stations (SLAMS). Collectively the urban locations are part of the EPA Chemical Speciation Network (CSN). Due to cost considerations the CSN was reduced in 2006 from its original size of approximately 240 stations to its present size. Currently, fine particle components are measured at each location every third or sixth day. The Interagency Monitoring of Protected Visual Environments (IMPROVE) network, covering background sites in national parks and wilderness sites in addition to Washington, DC and the South Bronx in New York City, provide additional data of great value to researchers. Health researchers have requested EPA implement *daily* fine particle speciation measurements, however resource constraints have impeded any real plans to this end. This session will explore opportunities to obtain these types of data in critical locations to make true inroads in improving our understanding of the temporal variability of fine particle components in ambient air. The monitoring issue presently is fine particles (and components), but looming ahead is the issue of thoracic coarse particles – what steps can we make to prepare for this new data-source?

Background Information - Draft White Paper: "Air Quality Sampling: Benefits and Costs of Daily Health Targeted Monitors for Fine Particle Components"

8:30–8:45 Overview and Introduction to Key Issues
Dr. Barbara Glenn, EPA/ORD/NCER
Dr. Joel Schwartz, Harvard School of Public Health

8:45–10:15 Panel Discussion
Dr. Robert Devlin, EPA/ORD/NHEERL
Dr. Patrick Kinney, Columbia University
Dr. Lucas Neas, EPA/ORD/NHEERL
Dr. Roger Peng, Johns Hopkins University
Dr. George Thurston, New York University
Dr. Jay Turner, Washington Univ. in St. Louis

Suggested Issues for Discussion:

- Sources of Error – which are the most limiting?
    - For time-series studies that rely on air monitoring data collected every third or sixth day from a single (or a few) central site monitors, which major sources of error are the most important? Why? Which is the most important?
        - Uncertainties in exposure assessment associated with:
            - Missing days.
            - Spatial variation.
            - Monitor location.
            - Instruments measurement error or analytic methods.
    - Could exposure modeling to "fill-in" missing days adequately address uncertainties associated with every third or sixth day monitoring data?
- If daily monitoring was going to commence in a few cities in the U.S., what is the best monitoring plan to study the relative health importance of PM components in the ambient mix of PM?
    - What are the best sites? Why? What site criteria are the most important?
    - What minimum number of locations for daily sampling is adequate to address a particular research area?
    - What components would you evaluate first?
- Integrating previous or ongoing data collection to obtain retrospective data.
    - In some locations, FRM filters may have been archived and could be analyzed to learn more about daily variation of fine particles and components.
    - In some areas, data from continuous monitors for previous years is available.
    - In previous years, special studies or grant-funded studies have collected data on PM species.
    - How could these data be integrated to provide daily data for time-series studies? If data from different instruments or methods were combined to obtain a set of daily ambient concentration data for a city, would this introduce a significant source of uncertainty/error?

- What components should be measured and what are the issues associated with their measurement and use in analyses?

10:15-10:30 BREAK

10:30–12:00 Session IV: Thoracic Coarse Particle Components and Potential Public Health Impacts

Background

On September 27, 2006, the U.S. Environmental Protection Agency (EPA) amended its national air quality monitoring requirements.[26] As part of these changes, EPA and the states will add measurements of "thoracic coarse particles" (i.e. $PM_{10-2.5}$) at 75 multi-pollutant monitoring sites (National Core or NCore sites). Some monitors will provide at least hourly measurements in near real-time (continuous mass concentration monitoring); while other monitors will sample the air over a 24-hour period and require laboratory processing of the sample (filter based sampling). Filter-based monitoring will enable development of $PM_{10-2.5}$ methods for chemical speciation of thoracic coarse particles. This session will explore criteria to consider as EPA adds speciation of thoracic coarse particles to the ambient air monitoring network.

10:30–11:00 **Overview and Introduction to Key Issues**
Dr. Timothy Larson, University of Washington
Mr. Timothy Watkins, EPA/ORD/NERL

11:00–12:00 **Panel Discussion**

Dr. David Diaz-Sanchez, EPA/ORD/NHEERL
Dr. Philip Fine, SCAQMD
Dr. Richard Flagan, CalTech
Dr. Terry Gordon, New York University
Dr. Michael Hannigan, Univ. of CO – Boulder
Dr. Thomas Peters, University of Iowa
Ms. Joann Rice, EPA/OAQPS
Dr. Jamie Schauer, Univ. of WI – Madison

Suggested Issues for Discussion :

- What is the relative value of coarse particle speciation at planned monitoring locations versus additional mass measurements?
- What is the relative value of understanding Intra-urban versus Inter-urban/rural variability in coarse particle composition and spatial and temporal distributions?
- What are your recommendations for coarse particle network design?

12:00 – 1:00 LUNCH

[26] See http://www.epa.gov/oar/particlepollution/actions.html for more information on amendments to EPA's National Air Quality Monitoring Requirements.

1:00 – 2:30 Session V: Ambient Air Monitoring Realities – EPA/State/Local Perspectives

Background

EPA works with State, local, and tribal air agencies to design and implement ambient air monitoring networks to meet several monitoring objectives including:

- Determining compliance with standards (i.e., the NAAQS)
- Providing air pollution data to the general public on a timely basis
- Supporting the development and tracking of the effectiveness of emission control programs
- Providing input data for health and welfare effects and exposure research studies
- Providing input data for health and welfare risk/exposure assessments conducted for NAAQS reviews
- Measuring overall progress of air pollution control programs

Opportunities are available for interested parties to provide comments on monitoring network plans to ensure input from health researchers and other interested users is considered in the design of these plans. Two draft white papers review the current processes for public comments on the monitoring network plans and changes to monitoring methodologies, respectively, as well as options for future efforts to improve communications with the health research community regarding ambient air monitoring networks.

This session is designed for EPA and State/local staff who manage monitoring programs to share their reactions (i.e., a reality check) to topics discussed in earlier sessions. This may include providing recommendations for addressing "low hanging fruit" as well as significant challenges that may need to be addressed in order to make considerable progress in the ambient air monitoring program to advance health research for the criteria air pollutants.

Background Information - Draft White Papers: "Ambient Air Monitoring Networks: Network Design and Site Selection Approval" and "Ambient Air Monitoring Method Implementation"

1:00 – 1:15 **Overview and Introduction to Key Issues**
Mr. Dirk Felton, NY DEC
Mr. Timothy Hanley, EPA/OAQPS

1:15 – 2:30 **Panel Discussion**

Dr. Philip Fine, SCAQMD
Mr. Michael Gilroy, Puget Sound CAA
Mr. Richard Payton, EPA/Region 8
Mr. Scott Reynolds, SCDHEC
Mr. Eric Stevenson, BAAQMD
Ms. Susan Zimmer-Dauphinee, GA DNR

2:30 – 2:45 BREAK

2:45 – 3:30 <u>Summaries of Day 2 Discussions and Comments on Draft White Papers/Next Steps</u>

2:45 – 3:00 Session III: Ambient Air Monitoring for Health Research
Dr. Barbara Glenn, EPA/ORD/NCER
Dr. Joel Schwartz, Harvard School of Public Health

3:00 – 3:15 Session IV: Thoracic Coarse Particle Components and Potential Public Health Impacts
Dr. Timothy Larson, University of Washington
Mr. Timothy Watkins, EPA/ORD/NERL

3:15 – 4:00 <u>Concluding Remarks/Emerging Issues/Next Steps</u>
Dr. Morton Lippmann, New York University
Ms. Lydia Wegman, EPA/OAQPS
Mr. Richard Wayland, EPA/OAQPS
Dr. Daniel Costa, National Program Director for Air Research, EPA/ORD

4:00 ADJOURN

Ambient Air Quality Monitoring and Health Research: Workshop to Discuss Key Issues - Participants

April 16-17, 2008

Last Name	First Name	Affiliation
Arnold	Jeff	EPA National Center for Environmental Assessment
Avol	Ed	University of Southern California
Baldauf	Rich	EPA NRMRL
Baxter	Lisa	EPA National Exposure Research Laboratory
Bell	Michelle	Yale University
Brook	Jeffrey	Environment Canada
Bucky	Barbra	EPA National Center for Environmental Assessment
Chow	Judy	Desert Research Institute
Costa	Dan	EPA Office of Research & Development
Devlin	Robert	EPA National Health & Environmental Effects Research Laboratory
Diaz-Sanchez	David	EPA National Health & Environmental Effects Research Laboratory
Dubowsky Adar	Sara	University of Washington
Felton	Dirk	New York State Department of Environmental Conservation
Fine	Phillip	South Coast Air Quality Management District
Flagan	Richard	California Institute of Technology
Foley	Kristen	EPA National Exposure Research Laboratory
Frank	Neil	EPA Office of Air Quality Planning & Standards
Garbe	Paul	Centers for Disease Control & Prevention
Garcia	Val	EPA National Exposure Research Laboratory
Gilliland	Alice	EPA National Exposure Research Laboratory
Gilroy	Mike	Puget Sound Clean Air Agency
Glenn	Barbara	EPA National Center for Environmental Research
Godleski	John	Harvard School of Public Health
Gordon	Terry	New York University
Hall	Eric S	EPA National Exposure Research Laboratory
Hanley	Tim	EPA Office of Air Quality Planning & Standards
Hannigan	Michael	University of Colorado at Boulder
Hansen	Craig	EPA National Center for Environmental Assessment
Hassett-Sipple	Beth	EPA Office of Air Quality Planning & Standards
Holland	David	EPA National Exposure Research Laboratory
Hopke	Phil	Clarkson University
Hubbell	Bryan	EPA Office of Air Quality Planning & Standards
Ito	Kaz	New York University
Jenkins	Scott	EPA Office of Air Quality Planning & Standards
Katz	Stacey	EPA National Center for Environmental Research
Kim	Jee-Young	EPA National Center for Environmental Assessment

Last Name	First Name	Affiliation
Kinney	Patrick	Columbia University
Kirrane	Ellen	EPA National Center for Environmental Assessment
Kleeman	Mike	University of California-Davis
Kryak	David	EPA National Exposure Research Laboratory
Lamason	Bill	EPA Office of Air Quality Planning & Standards
Langstaff	John	EPA Office of Air Quality Planning & Standards
Larson	Tim	University of Washington
Lippman	Morton	New York University
Long	Tom	EPA National Center for Environmental Assessment
Lorang	Phil	EPA Office of Air Quality Planning & Standards
Luben	Tom	EPA National Center for Environmental Assessment
Mangus	Nick	EPA Office of Air Quality Planning & Standards
Martin	Karen	EPA Office of Air Quality Planning & Standards
Mikel	Dennis	EPA Office of Air Quality Planning & Standards
Mintz	David	EPA Office of Air Quality Planning & Standards
Mukerjee	Shailbal	EPA National Exposure Research Laboratory
Neas	Lucas	EPA National Health & Environmental Effects Research Laboratory
Ozkaynak	Haluk	EPA National Exposure Research Laboratory
Payton	Richard	EPA Region 8
Peltier	Richard	New York University
Peng	Roger	Johns Hopkins University
Peters	Thomas	University of Iowa
Pierce	Tom	EPA National Center for Environmental Assessment
Pinto	Joe	EPA National Center for Environmental Assessment
Poirot	Rich	Vermont Department of Environmental Conservation
Pun	Betty	Atmospheric and Environmental Research, Inc.
Rao	Venkatesh	EPA Office of Air Quality Planning & Standards
Reynolds	Scott	South Carolina Department of Health and Environmental Control
Rice	Joann	EPA Office of Air Quality Planning & Standards
Richmond	Harvey	EPA Office of Air Quality Planning & Standards
Robarge	Gail	EPA National Center for Environmental Research
Robinson	Allen	Carnegie Mellon University
Ross	Zev	ZevRoss Spatial Analysis
Sacks	Jason	EPA National Center for Environmental Assessment
Schauer	Jamie	University of Wisconsin
Scheffe	Rich	EPA Office of Air Quality Planning & Standards
Schultz	Laurel	EPA Office of Research & Development
Schwartz	Joel	Harvard University
Sheldon	Linda	EPA National Exposure Research Laboratory

Last Name	First Name	Affiliation
Stanek	Lindsay	EPA National Center for Environmental Assessment
Stevenson	Eric	Bay Area Air Quality Management District
Stewart	Michael	EPA Office of Air Quality Planning & Standards
Stone	Susan	EPA Office of Air Quality Planning & Standards
Sunshine	Geoffrey	Health Effects Institute
Thurston	George	New York University
Tikvart	Joe	EPA Office of Air Quality Planning & Standards
Turner	Jay	Washington University in St. Louis
Turpin	Barbara	Rutgers University
Vandenberg	John	EPA National Center for Environmental Assessment
Vanderpool	Robert	EPA National Exposure Research Laboratory
Vette	Alan	EPA National Exposure Research Laboratory
Watkins	Tim	EPA National Exposure Research Laboratory
Watson	John	Desert Research Institute
Wayland	Richard (Chet)	EPA Office of Air Quality Planning & Standards
Wegman	Lydia	EPA Office of Air Quality Planning & Standards
Weinstock	Lewis	EPA Office of Air Quality Planning & Standards
White	Warren	University of California-Davis
Williams	Ron	EPA National Exposure Research Laboratory
Willis	Robert	EPA National Exposure Research Laboratory
Wilson	William	EPA National Center for Environmental Assessment
Winner	Darrell	EPA National Center for Environmental Research
Wyzga	Ronald	Electric Power Research Institute
Zimmer-Dauphinee	Susan	Georgia Department of Natural Resources

Appendix B: Session I: Elemental and Organic Carbon Measurements - Chemical Speciation Network (CSN) Carbon Issues

Questions on this draft white paper should be directed to Neil Frank, EPA/OAQPS, frank.neil@epa.gov, (919) 541-5560.

Introduction

The purpose of this draft white paper is to provide an overview of urban and rural carbon measurement protocols and to identify issues associated with data reporting and usage, particularly with respect to the CSN transition to IMPROVE-protocol for carbon measurements. This document will also serve as a discussion piece to gather input from the health research community on related issues and next steps.

Background

State and local air agencies, under EPA grants, have been measuring organic carbon (OC) and elemental carbon (EC) in urban areas since 2001. The network consists of 54 sites intended to capture long-term trends (speciation trends network or STN) and approximately 150 other State and local air monitoring stations (SLAMS). Collectively, the urban locations are part of the EPA Chemical Speciation Network (CSN). To support the regional haze and $PM_{2.5}$ programs, EPA also funds a largely rural network called IMPROVE. Together with support from NPS and other Federal agencies, the IMPROVE network provides carbon measurements at approximately 160 national park, wilderness, and other rural locations nationwide.

Two different thermal-optical analysis methods are currently used by the CSN and IMPROVE networks for the analysis of carbon. The IMPROVE method is based on the Desert Research Institute/Oregon Graduate Center (DRI/OGC) thermal-optical reflectance (TOR) method[27]. The CSN method has historically used a modified version of the National Institute for Occupational Safety and Health (NIOSH) 5040 thermal optical transmittance (TOT) method[28]. The latter CSN method is different from the NIOSH method in that it has a different thermal temperature profile. The CSN is transitioning to the IMPROVE sampling and analysis protocols for carbon. Currently 56 sites have changed. Additional sites will be changed in the future.

Research has shown that differences in the thermal profile, optical correction (transmittance versus reflectance), and specific analyzer used will result in differences in the OC and EC values obtained (Schmid et al, 2001; Currie, et al., 2002). In addition, sampling and sample handling differences also have an impact, especially for OC. Other carbon monitoring networks and measurement studies (e.g. SEARCH, Supersites) use variations of the CSN and IMPROVE protocols and are not discussed here.

For the first 6 years of CSN operation, urban and rural carbon have been collected with different samplers and analyzed by different thermal optical methods. For chemical analysis, CSN has used the NIOSH-type thermal optical transmittance (TOT) method for measures of OC

[27] The current IMPROVE_A method for Organic and Elemental carbon is described by the Standard Operating Procedure (SOP) provided at: http://vista.cira.colostate.edu/improve/Publications/SOPs/drisop2005.asp

[28] The CSN method for Organic and Elemental Carbon is described in the SOP provided at: http://epa.gov/ttn/amtic/files/ambient/pm25/spec/ocecsop.pdf

and EC. IMPROVE measurements are based on thermal optical reflectance (TOR) with a different thermal evolution temperature profile. Both measurement protocols provide operationally-defined measures of OC and EC. The IMPROVE protocol generally results in a lower OC/EC ratio and also provides 4 sub-fractions of OC (OC1, OC2, OC3, OC4), pyrolized organic carbon (OP), and 3 fractions of EC (EC1, EC2, EC3). These sub-fractions have been used in source attribution studies (Kim and Hopke, 2006). Starting in 2005, however, IMPROVE switched to an upgraded TOR analyzer with more accurate temperature settings. This change to "IMPROVE_A" results in approximately the same total OC and total EC but relatively different amounts of the sub-fractions (Chow et al., 2007). The new IMPROVE analyzer also provides TOT measurements which may have value in relating the two networks' data.

In addition, the two networks have their different approaches to address various sampling artifacts and public reporting of its carbon data. While CSN collects field and trip blanks (but with limited ambient exposure) at all sites as a measure of passively collected organic vapors (positive artifact), the IMPROVE program uses longer duration field blanks at all its sites, and additionally has deployed secondary carbon (sc), i.e. backup quartz filters, at 6 of their sites to provide a network-wide measure of sampling artifacts. IMPROVE data shows that sc is greater than field blank carbon (fbc) and IMPROVE uses the monthly median sc value (by carbon sub-fraction) to correct the entire network's organic and elemental carbon values. The adequacy of using 6 sites to represent the entire network is currently under review by IMRPOVE. IMPROVE reports publicly only the artifact adjusted data. EPA has been publicly reporting in AQS carbon data produced by the primary collection filters, and separately the carbon values for the field and trip blanks. [29] All field and trip blank data since 1999 are now available in AQS. Until CSN sites are transitioned to the new IMPROVE protocol, CSN sites are not measuring carbon on backup filters. To correct for urban sampling artifacts, CSN data users have used the CSN fbc data together with sampler specific flow rates to "blank correct" the reported CSN data and have also used material balance or statistical approaches (*Frank, Solomon, Kim*). These sampling artifact procedures have also considered the need to differentiate particulate carbon collected on quartz vs. Teflon filters. Some users have not made any adjustments in some work (*Pun*). The correction for sampling artifact can be as much as 30% of the organic carbon, as reported at the 2006 HEI meeting in Boston (www.healtheffects.org/AQDNov06/AQDWorkshop.html). The new CSN samplers whose quartz filters are analyzed with "IMPROVE_A" are deploying sc and 24-hr duration fbc filters. The potential use of those filters to adjust for sampling artifact is currently under study. EPA is also exploring what adjustments can/should be applied to old-protocol-CSN data to best correct for sampling artifacts and whether a single universally acceptable approach or multiple approaches for artifact corrected data exists. A question to pursue is: What is the impact of using CSN data that have not been corrected for sampling artifacts in epi studies (i.e., inclusion of a large and variable positive bias which may possibly have a seasonal component)?

To help understand the differences between CSN and IMPROVE carbon-protocol measurements, EPA has collocated CSN samplers with IMPROVE samplers in various urban and rural environments over a 1-3 year period (See Table 1). Because of the many separate influences on carbon measurements (e.g., sampler, specific analytical method, and artifact

[29] Arifact corrected CSN OC data, using network average fbc values, are available on http://www.epa.gov/airexplorer

correction), the only definitive data to show comparisons between CSN and IMPROVE are these data generated by the CSN and IMPROVE networks. From data analyzed to date, the results show that the IMPROVE-protocol EC is generally higher (+10 to +30%), except at 3 locations (Phoenix and Tonto, AZ and Rubidoux, CA) where the IMPROVE EC is lower (-2 to -8%). The average differences appear to vary by location and the difference may therefore be related to the type or composition of the carbon aerosol. On the other hand, OC concentration is greatly affected by sampling artifact, sampler flow rate and filter size, and therefore the inter-network differences are more difficult to characterize. Application of simple adjustments, say using field blanks, may not be sufficient to adjust CSN data to look like IMPROVE-protocol concentrations *(Flanagan).* Chow, Watson (at DRI) and White (at UC Davis) are also examining this issue for EPA and recommendations will be forthcoming.

National consistency in carbon measurements for source attribution, model evaluation and urban-rural comparisons is very important. Starting in calendar year 2007, EPA began transitioning the urban CSN to the IMPROVE analytical protocol, with an IMPROVE-like sampler (i.e. URG3000N sampler, with identical $PM_{2.5}$ particle size separator, filter size and flow rate, but with mass flow control) and will be employing secondary filters and 24-hr duration field blanks to help estimate carbon sampling artifacts. Fifty-six sites have been established and produced two months of collocated data during May-June 2007. Preliminary analysis of these collocated data show similar IMPROVE-CSN relationships as discussed above. The transition of CSN will continue in two additional phases. Phase 2 will begin early 2008 with the conversion of about 65 sites and Phase 3 (the last phase of about 65 sites) will begin late 2008-early 2009. See http://www.epa.gov/ttn/amtic/files/ambient/pm25/spec/faqcarbon.pdf for more information on the conversion. EPA has also reorganized the parameter codes and data field definitions in AQS to better differentiate current and future carbon measurement data according to collection sampler, analytical protocol and adjustments if any for sampling artifacts.

Closing the Gap in EC Monitoring to Support PM Health Effects Research

The association between ambient concentrations of EC in $PM_{2.5}$ and human health effects is a subject of considerable interest. This section describes a number of possible steps that could be taken towards minimizing the affects of CSN protocol changes on the ability of epidemiology projects to report useful results for consideration in planned periodic reviews of the $PM_{2.5}$ NAAQS. The purpose of this section is to facilitate communication about next steps along the lines of these steps or alternatives that are more promising. In addition, the OAQPS Air Quality Assessment Division (AQAD) convened an in-person workshop of CSN and IMPROVE monitoring program experts and selected atmospheric scientists in January 2008 to discuss outstanding issues related to EC and OC measurement in the two networks. The participants in this workshop are continuing the discussion by e-mail and conference calls to develop a 1-2 year research plan, possibly leading to changes in the operation of one or both monitoring networks and/or the post-processing of their monitoring data.

In order to improve the data usability of EC for epidemiological studies and subsequent PM NAAQS reviews, the following steps may be explored:

Possible Data Analysis Steps

1. **Relating Old CSN TOT and New CSN TOR Data:** Available data should be rigorously analyzed to determine if there is a reasonably good method for predicting the former from

the latter (including using sub-fraction information and possibly using site/day variables) or vice versa. Data that includes the effect of the sampler difference should also be analyzed. The purpose would be to determine whether double laboratory analysis of the sort described in Items 2 and 3 below is actually needed to close the time series discontinuity, versus relying on a mathematical conversion or algorithm.

a. There are some data sets available now that can be used to address this question.

Discussion Question: If new and old protocol CSN carbon data cannot be quantitatively related or adjusted so that a consistent time series is available for OC and EC, can epi studies use the unadjusted time series as long as it recognizes or accounts for the changes or intervention(s) in the measurement process?

2. **Epidemiological Sensitivity Analysis:** After some number (TBD) of months of doubly-analyzed samples are available from Items 5 and 6 below, epidemiologists should test whether the two physical measures of EC are similarly associated with health effects of interest. This would help determine the length of time and scope needed for items 4, 5 and 6 below.

Discussion Question: Can sensitivity testing of epi models be done to explore whether the change in carbon measurements has a significant impact on results?

Possible Pilot/Investigative Studies

3. **Sampling Effects on EC measurements:** Test the hypothesis that sampler model, artifact correction (subtraction of field blank or backup filter blank values), and quartz filter brand (Whatman QMA vs. Pallflex) have a small enough effect on measured EC, such that epidemiology studies can span discontinuities in these aspects provided there is consistency in the EC thermal analysis, by taking second punches from relevant filters already in cold storage. There are 517 filter pairs available from 56 sites in May and June 2007, each pair consisting of an old-CSN filter and a new-CSN filter. The two kinds of filters have already been tested for EC once each, with the old and new laboratory method respectively. Of these, 53 sites used the old CSN method with the MetOne sampler, which has the flow rate most different from the new URG3000N sampler (~6.7 vs. ~22.7 L/min). The sensitivity of EC to sampler type (independent of lab analysis) can be tested by taking a second punch from the old CSN filters and analyzing them with IMPROVE_A, and comparing the results to the IMPROVE_A result on the new CSN filter. Alternatively or in addition, the comparison can be done the other way by taking the extra punch from the new CSN filter. This comparison may not be indicative of sensitivities during other seasons.

4. There are about 250 site-months of collocation data between old CSN TOT and IMPROVE TOR (up until January 2005) and IMPROVE_A TOR (after January 2005), spanning all seasons, in selected urban areas.[30] Some of these filters could be analyzed a second time, as described immediately above to evaluate sampling effects on EC measurements.

Discussion Questions: What are the most important data assessment attributes or metrics for the comparison to satisfy the needs for health studies? Can sensitivity testing of

[30] Sites are in Atlanta, Birmingham, Allen Park, MI, Fresno, New York City, and Pittsburgh.

epidemiologic models be done to explore whether the change in carbon measurements has a significant impact on results?

Possible Gap-Filling Data Collection (Short and Long-term) to Extend the Continuity of the OC/EC time series

5. At some number (TBD) of converted CSN sites of most importance to ongoing epidemiology studies, analyze some number (TBD) of quartz filters from the new URG3000N sampler with the old CSN-TOT method, in addition to the IMPROVE_A measurements. Double analysis is possible because a single filter can usually allow three separate analyses using three separate punches from the filter. This would give a continuous time series using the old CSN-TOT lab method. There would be a discontinuity in sampling method.
    a. Same-time, double analysis would be implemented for newly collected filters as they are received.[31]
    b. Filters collected since conversion that have completed analysis would be retrieved from cold storage and re-analyzed also.

6. (Additionally or Alternatively to Item 2 above) At some number (TBD) of converted CSN sites of most importance to ongoing epidemiology studies, retrieve pre-conversion filters from cold storage and perform a second analysis for EC using IMPROVE_A. This would give a continuous time series using the new IMPROVE_A lab method. There would be a discontinuity in sampling method.

7. Depending on the outcomes of steps 3 and 4, the number of sites subject to double analysis could be reduced (because no important differences are discerned) or increased to include more sites of interest (because it becomes clear that only consistent physical measurements are useful.)

8. Presently, EPA has no plan for long term operation of any sites at which the old CSN method (using the dominant old sampler type and the old TOT analysis protocol) and the new CSN method (URG300N and IMPROVE_A) are collocated. A possible step is to establish some such sites and commit to their operation until these EC (and related OC) issues are well settled. Depending on logistics and monitoring agency agreement, these could be the same 6 sites where IMPROVE and one CSN samplers already operated on a collocation basis.[32]

Discussion Questions: What are the number and location of sites that are of most interest or importance to ongoing epidemiological studies? If long-term comparisons of old and new CSN are needed, where should collocated measurements be obtained, and at what frequency, and for how long? What are the most important data attributes or metrics for the comparison of new vs. old CSN protocol measurements to satisfy the needs for epi studies (e.g. sufficiently high correlation; consistent day-day and seasonal variability)? What is judged to be sufficiently high correlation; what is "consistent" temporal behavior?

[31] It is not urgent to begin this same-time double analysis because any filters tested only with IMPROVE_A can be retrieved from cold storage later if necessary.
[32] Sites are in Atlanta, Birmingham, Allen Park, MI, Fresno, New York City, and Pittsburgh.

9. As presented by Frank at the 2006 meeting in Boston, carbon by material balance between non-carbon species and FRM mass ("SANDWICH" technique) may have value in providing a consistent and independently derived time series of carbonaceous mass as measured on Teflon filters. This alternative indicator can minimally assist with quality control of newly derived procedures. To help isolate the OC and EC portions of the mass balance estimates, new measurements from archived Teflon filters may be needed to compensate for network changes in the thermal optical procedures used on collocated CSN measurements (e.g., optical measures of black carbon in combination with statistical procedures to establish site specific correction factor for "EC").

What About Daily EC?

EPA ORD is investigating the feasibility of limited speciation on daily FRM collected Teflon filters, where available. This may involve performing XRF analyses and possibly an additional optical measure of black carbon in combination with statistical procedures to establish a site-specific correction factor for "EC". This work has not started and is not expected to be available by April 2008.

Table 1. List of EPA CSN/IMPROVE Collocated Study Sites

Site Name	AQS Site ID	Urban/ Rural	CSN Sampler	Start Date	End Date
Atlanta (Decatur), GA	13-089-0002	Urban	Andersen RAAS until 1/2006 then MetOne SASS	4/2004	Ongoing *
Birmingham, AL	01-073-0023	Urban	MetOne SASS (URG3000N for carbon May 2007)	4/2004	Ongoing
Detroit (Allen Park), MI	26-163-0001	Urban	MetOne SASS	11/2003	Ongoing *
Fresno, CA	06-019-0008	Urban	MetOne SASS	9/2004	Ongoing
New York (IS52), NY	36-005-0110	Urban	R&P2300 until 1/2006 then MetOne SASS (URG3000N for carbon May 2007)	8/2004	Ongoing
Pittsburgh, PA	42-003-0008	Urban	MetOne SASS	4/2004	Ongoing *
Houston, TX	48-201-1039	Urban	URG MASS	5/2004	9/2005
Chicago, IL	17-01-0076	Urban	URG MASS	11/2003	9/2005
Rubidoux (Riverside), CA	06-065-8001	Urban	MetOne SASS	9/2004	9/2005
Phoenix, AZ	04-013-9997	Urban	MetOne SASS	10/2001	12/2003
Tonto NP, AZ	04-007-0010	Rural	MetOne SASS	10/2001	12/2003
Seattle, WA	53-033-0080	Urban	URG MASS	10/2001	12/2003
Mt. Ranier, WA	53-053-0014	Rural	URG MASS	10/2001	12/2002
Washington DC	11-001-0042	Urban	Andersen RAAS	10/2001	12/2003
Dolly Sods, WV	54-093-9000	Rural	Andersen RAAS	10/2001	12/2003

* Continuing with IMPROVE carbon aerosol measurements starting July 2005. Full IMPROVE speciation at other sites.

References

Chow, J. C., Watson, J.G., Chen, L-W., Chang, M.C.O., Robinson, N.F., Trimble, D., Kohl, S., (2007) The IMPROVE_A Temperature Protocol for Thermal/Optical Carbon Analysis: Maintaining Consistency with a Long-Term Database, *J. Air & Waste Management Association*; 57: 1014-1023.

Currie, L. A., B.A. Benner, Jr., J.D. Kessler, D.B. Klinedinst, G.A. Klouda, J.V. Maroif, J.F. Slater, S.A. Wise, H. Cachier, R. Cary, J.C. Chow, J. Watson, E.R.M. Druffel, C.A. Masiello, T.I. Eglinton, A. Pearson, C.M. Reddy, O. Gustafsson, J.G. Quinn, P.C. Hartmann, J.I. Hedges, K.M. Prentice, T.W. Kirchstetter, T. Novakov, H. Puxbaum, H. Schmid. (2002). A critical evaluation of interlaboratory data on total, elemental, and isotopic carbon in the carbonaceous particle reference material, NIST SRM 1649a. *J. Res. Natl. Inst. Stand. Technol.*, 107: 279-298.

Flanagan, James B., Max R. Peterson, R.K.M. Jayanty, and Ed E. Rickman. Analysis of PM2.5 Speciation Network Carbon Blank Data, Research Triangle Institute, Research Triangle Park, North Carolina 27709 (2003). http://www.rti.org/pubs/OCEC_flanagan_2003.pdf

Frank, N. H., Retained Nitrate, Hydrated Sulfates, and Carbonaceous Mass in Federal Reference Method Fine Particulate Matter for Six Eastern U.S. Cities, *J. Air & Waste Manage. Assoc.* 2006, *56*, 500-511.

Frank, N. H., Carbon Measurements and Adjustments. Presented at HEI/EPA Workshop on Air Quality Data in Health Effects Research , Newton Marriott Hotel, Newton, MA, November 30-December 1, 2006 http://www.healtheffects.org/AQDNov06/AQD_Frank.pdf

Kim, E. , P.K. Hopke and Y. Qin (2005). Estimation of Organic Carbon Blank Values and Error Structures of the Speciation Trends Network Data for Source Apportionment. *J. Air & Waste Manage. Assoc.* 55:1190–1199.

Kim, E. and P.K. Hopke (2006). Characterization of fine particle sources in the Great Smoky Mountains area; Science of the Total Environment: 368: 781–794.

Pun, B. HEI Air Quality Database. http://hei.aer.com/aboutDatabase.php

Schmid, Heidrun, Lothar Laskus, Hans Jürgen Abraham, Urs Baltensperger, Vincent Lavanchy, Mirko Bizjak, Peter Burba, Helene Cachier, Dale Crow, Judith Chow, et al. (2001). Results of the "carbon conference" international aerosol carbon round robin test stage I. *Atmos. Environ.* 35: 2111-2121.

Solomon, Paul. Organic Carbon Artifacts. Presented at Mid-Atlantic Regional Air Management Assoc., June 29, 2004. http://oaqpswww.epa.gov/tom/wiki/pmteam/files/MARAMA_OC_Artifacts_6-29-04_Conf_Call.ppt

Appendix C: Session II: Accessing Ambient Air Monitoring Data - Access to EPA's Air Quality Data for Health Researchers

Questions on this draft white paper should be directed to Nick Mangus, EPA/OAQPS, mangus.nick@epa.gov, (919) 541-5549.

Introduction

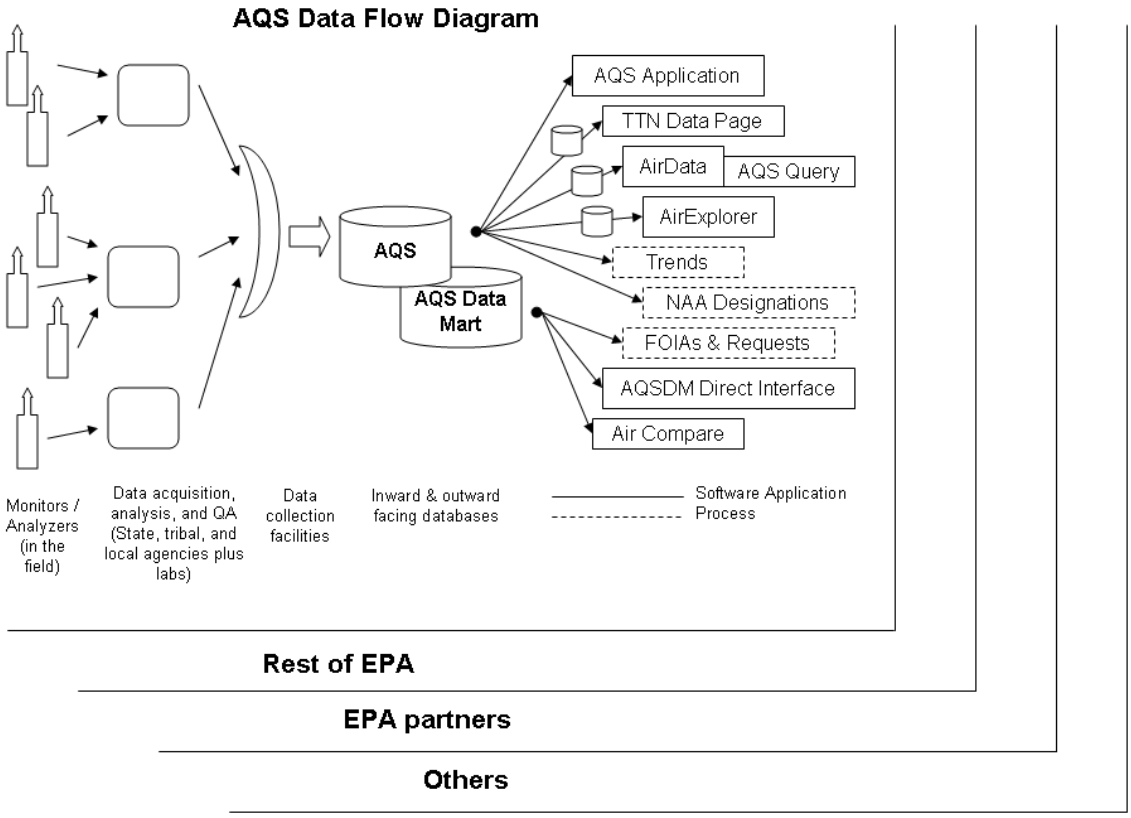
A common refrain from policymakers, analysts, and scientists is that obtaining the air quality data which they need is a challenge. This paper outlines the current collection and dissemination framework for air quality data and poses "charge questions" to the health-research/ epidemiology community. The answers to these questions will help us at the EPA improve our offerings.

To frame the charge questions, this document describes a relatively new EPA system, the AQS Data Mart, and contrasts it with the HEI Air Quality Database, which was put in place to provide access to PM components and other data for health researchers. Finally, the charge questions are presented.

Background

The collection, storage, and dissemination of air quality data is a complex process achieved by a series of separate groups of hardware, software, and people. As technology has advanced and the number of distinct sets of user groups (those with different data or analytical needs) have proliferated, the problem for any individual finding precisely what they need has only gotten more complex. Adding to this complexity are intermediate "value-added" providers who may integrate, visualize, or otherwise post-process data from various sources. Thus, users can invest in their own data gathering and processing or they can rely on an array of intermediary providers. We also have data from special studies. The quality is (probably) high, but the data may not be readily available to others. So, EPA will always be the provider of certain base data, but we may not have it in the desired form, integrated with other desirable data (emissions or population), or presented in the desired manner. There will always be the possibility for a value-added provider to enhance the EPA data or integrate it with other data.

The following diagram is a simplified view of the components that accomplish the collection and dissemination tasks at the EPA. It will be used to explain how data are collected, stored, and provided by EPA and how the HEI acts as a value-added post-processor.



The main part of the diagram shows the major components of the EPA's Air Quality System (AQS). Beginning from the left hand side, samples are collected in the field by monitors. Some of these samples are analyzed *in situ*, others are collected by the State, tribal, or local agency responsible for the monitor and analyzed at laboratories. Either way, the agency responsible for the monitor is also responsible for ensuring the measurements are reported to AQS. It should be noted that only monitors within the EPA national ambient air quality monitoring network must have their data reported to AQS, for other monitoring networks or special studies (e.g., The Texas $PM_{2.5}$ Sampling and Analysis Study) it is optional and the information may be stored in another system (e.g., NARSTO).

AQS is the EPA system designed to collect and store the monitored information. When users are allowed unlimited access to download information from such collection systems, the demands put on the system by voluminous requests can compromise the ability of the system to fulfill its collection function. To alleviate this problem, software engineers developed the AQS Data Mart which stores a copy of the information from the AQS and allows users to download data. It is a generic "retrieval" tool that provides the ability to query any information, but it does not provide significant data exploration or analysis capabilities. These capabilities are left to downstream "value-added" tools.

EPA is in the process of transitioning our user applications designed for downloading information from the AQS database to the AQS Data Mart database. The right hand side of the diagram represents the several places to query or download air quality information that EPA

provides. Each has been targeted to a specific audience: the general public, data analysts, or researchers. The diagram indicates which ones are still connected to AQS and the ones that have been transitioned to the AQS Data Mart. Note that the small cylinders by three of the systems still getting their data from AQS indicate that they must copy data and store it separately so as not to impose large loads on AQS. One of the advantages of using a data mart is to alleviate the need to store these data again.

As an example, raw $PM_{2.5}$ data collected by EPA is available to external users in three of these EPA "front-ends". Large text files can be downloaded from our website (The TTN Data Page at http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm). The AirExplorer site can be used to query, plot, and map these data. Finally, the Data Mart Direct Interface can be used to query the data. Each of these tools has advantages and disadvantages depending on the needs of the user. For more information about all of the front-ends listed in the diagram, please see Appendix A.

Beyond AQS and the related EPA systems, there are many other stakeholders involved in the collection and dissemination of air quality data, each with their own activities and possibly systems. AQS is likely the largest repository, but there may be additional information of interest to health researchers stored in other places. These additional stakeholders are represented by the other "layers" in the diagram. Elsewhere in EPA there are data collection and dissemination systems (CASTNET and AirNow in the Office of Air and Radiation; RSIG and PHASE in the Office of Research and Development; and Environmental Geoweb in the Office of Environmental Information). Additionally, EPA has other systems that present public and management views of air quality data.

The next layer out represents EPA partners, those who operate in cooperation with EPA, like the Health Effects Institute, Colorado State University, etc. who maintain data dissemination systems (many that integrate data from outside of AQS). Also in this layer are special studies (DEARS, NMMAPS, etc.) that manage the full lifecycle of air quality data management from collection to dissemination. Generally these non-governmental partners and EPA communicate with each other and the action that one takes may influence the other. Considering again the $PM_{2.5}$ example, the HEI Air Quality Database uses the EPA provided data for PM and the nearest gas phase monitors, and integrates EPA emissions and non-EPA population and meteorological information. This is a value-added service to provide a custom-tailored solution to a specific community. Finally, there is the layer entitled "Others," which represents those stakeholders who operate independently. These are the "unknown unknowns" in terms of additional data that may be collected or made available.

Each of these groups brings with them a different list of what they can do easily, what they can do with difficulty, and what they cannot do. That is, each provides a degree of flexibility or constancy that makes them the best at providing a particular product or service. Collaboration, building on the strengths of each organization, is critical and one organization may have to take up the role of integrator and communicator so the research community knows where to get vital information. That is, if a clearinghouse listing all available databases, datasets, and access systems is needed, someone will have to manage its creation and maintenance.

The remainder of this paper discusses only one EPA access mechanism, the AQS Data Mart Direct Interface, which was designed specifically to address the needs of the research community. EPA perceived these needs as primarily the ability to locate and extract large sets of data. The Data Mart was made available for internal EPA use in mid-2006 and for external use, along with the Direct Interface, in early 2007. Use has been growing steadily since then. Overall, it has been well received by most of those who have accessed and used it. Initially a pilot project, the reaction from users has been positive enough that EPA management has committed to ongoing support for the system. Most of the negative reaction falls into two categories: the user friendliness of the system and the documentation of the data. To address the first, we continue to add features and improve usability to make the Data Mart as friendly as possible to the research community. Documentation of the data is not a problem inherent to the Data Mart, but we realize it is much needed, so we are also addressing this as we can.

The remainder of this paper will introduce the Data Mart Direct Interface, compare it to the HEI Air Quality Database, and place "charge" questions to the research user community to help us continue to improve these systems to meet your needs.

Contents of the Data Mart

The Data Mart contains every measured ("raw") and aggregated ("daily and annual summary") value reported to AQS from January 01, 1980 to the present. It also contains all of the same site and monitor descriptive data and measurement metadata in AQS. We have converted most data-entry codes to plain English words to help with the interpretation of downloaded data.

There are no additional quality assurance steps performed on the data in the Data Mart, as the data in AQS are generally considered to be of the highest quality. Data must undergo many quality control steps as part of the loading process before it is saved in the AQS database. Likewise, submitters are required to assure that the monitor is operating properly and has passed precision and bias checks before loading the data. Finally, each year, EPA and the submitter review the data for completeness and correctness before the data are "certified" for regulatory use.

It should be noted that IMPROVE (visibility network) and SANDWICH (modeled $PM_{2.5}$ species) data are not generally reported to AQS. However, EPA staff has recently loaded the IMPROVE data for 1988-2005 into AQS and the loading of SANDWICH data is planned. As of January 14, 2008, there were 1.67 billion raw measurements for 885 different parameters in the database (there is a profiling spreadsheet under the documentation section of the web page).

The Data Mart is refreshed from AQS each weekday night, so it always has the latest available information. However, since data up to 4 years old can be submitted to AQS at any time, and there are special windows for "historical" data updates, any of the contents can change at any time. That is, there is no freezing or snapshotting of data into a static version in the database.

Accessing the AQS Data Mart

The AQS Data Mart can be accessed by visiting the webpage, http://www.epa.gov/ttn/airs/aqsdatamart, and following the "Access" link. Registration is required, and a user ID and password needed for access. You may sign up for your own account or use a guest account with user = aqsdatamart@epa.gov and password = AQSdatamart1 (case sensitive). Access is provided by an application that you can either run in your web browser or download and run on a PC. The application is used to submit a query. A query lets the user select the geography, substance (parameter), time, metric, and optional data to return. The Data Mart currently has five queries, summarized below.

Query	Description
Values	Recommended, returns any single raw, daily, or annual variable with metadata and is very efficient
Monitor	Returns descriptions of the monitoring site and equipment
Annual Summary	Returns all annual summary aggregate statistics for the monitors selected
Raw Data	Returns raw data in the AQS transaction format - recommended only for AQS users
Sites by Threshold	Returns a list of sites that meet a specific data-related threshold that you specify

When the query is complete, results can be downloaded using the application or by following a link in an email message sent to the user. All output is in XML format, but with embedded links to stylesheets for user-friendly display.

The Data Mart is intended as an extraction system only and EPA does not plan to provide analytic or graphical capabilities with the Data Mart. However, some of the other tools that EPA provides do have these capabilities (see Appendix A for details).

Contents of the HEI Air Quality Database

In September 2005, a group funded by the Health Effects Institute (HEI) and led by Christian Seigneur and Betty Pun at Atmospheric and Environmental Research (AER) launched a website/database to facilitate health effects studies that require detailed knowledge of air pollutant levels and other relevant information at selected sites across the US. The HEI Air Quality Database combines information on $PM_{2.5}$ components collected at monitoring sites in the Chemical Speciation Network (CSN); meteorological variables; and levels of gaseous pollutants (SO_2, O_3, NOx, and CO) from monitoring sites at or near each CSN site. Metadata are provided for each monitoring site, such as its geographic coordinates, state, as well as county, city location information, population, and emissions data for nearby point, area, and mobile sources. AER updates information in the HEI Database every few months and is currently funded to do this through 2008.

Accessing the HEI Air Quality Database

The HEI Air Quality Database can be accessed by visiting the webpage, http://hei.aer.com. Once you obtain an account by following the instructions on this page, you can access the site browser and list building, database queries, and users' guides. The general

data retrieval process consists of four steps: browsing sites, defining and saving a list of sites, extracting data for the sites in a saved site list, and, downloading the extracted air quality data.

Comparison of AQS Data Mart and the HEI Air Quality Database

The HEI Air Quality Database represents a value-added service over what EPA provides for a scientist looking for specific speciated $PM_{2.5}$ data to evaluate in health research studies. So, a natural starting point for such a user would be the more tailored HEI system. If, however, that system does not have some particular information that the user needs, they can revert to using the EPA system. The EPA system is broader, but less refined; the closer the user gets to the source, the more raw material they must process to get a finished product. The following table compares some of the features of the HEI Air Quality Database and the AQS Data Mart to illustrate some of these trade-offs.

Feature	HEI Air Quality Database	AQS Data Mart
Site browser	Yes, with maps to help	No
Site finder	Yes, with multiple-variable filter	Yes, via a single-variable "sites by threshold" query
Query from saved list	Yes. Station lists may be saved and re-used	No. Query based on geography and parameter or single site
Query by any geography	Yes	Yes
Air quality data for $PM_{2.5}$, O_3, CO, NOx, NO_2, & SO_2	Yes	Yes
Air quality data for all other parameters	No	Yes
AQS met data	Yes	Yes
Integrated non-EPA met data	Yes	No
Emissions data	Yes	No
Census data	Yes	No
On-line help	Yes	No
Off-line help	Yes	Yes
File format	CSV	XML (CSV planned)
Data returned in one file	No	Yes
Update frequency (versions)	Quarterly	Daily
Build your own query	Yes	No

To summarize the key differences:

- The HEI interface is more tailored to the $PM_{2.5}$ analyst.
- The HEI interface contains emissions, census, or NCDC meteorology data, the Data Mart does not.
- The Data Mart contains all ambient data reported to AQS (not just PM, meteorological, and NAAQS gases).

- The Data Mart only contains special studies data (e.g., supersites) if it has been loaded into AQS.

Interpreting the Data

Between data element names, report headings, and data transfer formats, there are almost 2000 named data elements relating to air quality that EPA makes available. In addition, some of the values in those fields need individual documentation to properly describe them (for example, what is the difference between a SLAMS and a NAMS monitor type). To help the user identify and perhaps understand the data they have, the EPA created an annotated, cross-referenced index called the "Field Guide to Air Quality Data". It is available in the documentation section of the Data Mart web page. There is also a list server that can be used to ask questions or monitored for system status.

Charge Questions - Introduction

To help prioritize and define future activities so that we can better meet the needs of the members of the research community, EPA has compiled a list of "charge questions" for invitees to this conference to consider. The overarching issue is connecting the data users to the data providers. For EPA and our partners to improve on this, we need to fully understand the data needs of the health research community. The more specifically the needs can be elucidated, the more concrete actions that can be taken to improve the situation. We are interested in feedback from users and potential users of air quality data and retrieval tools. This paper is concerned only with access to existing data; possible new data collection activities are covered elsewhere.

Standout Charge Questions

In previous interactions with data users and the health research community, three questions repeatedly come to the forefront as seemingly ubiquitous and critical. These issues are also at a high level and decisions on them will potentially impact decisions on the other charge questions. To complicate matters, there is not a single unifying idea that all agree is progress in the right direction on these issues. Thus, these questions are presented in more detail and with possible solutions to initiate discussions.

1. **Data versioning/snapshotting**: How often should EPA release data and how should we indicate that it has changed? The EPA, HEI, and others currently provide data via many applications. The data in those applications are generally updated on a schedule or as new data become available. For example, the AQS Data Mart is updated every day with new submissions and changes to AQS. However, new data or changes coming into AQS may be 10 years old. So a value in the AQS Data Mart representing a sample taken in the late 1990s may change today. Likewise, the HEI Air Quality Database is generally updated as the EPA makes new AQS "flat file" data extracts available on our web sites. This is usually done quarterly and without notice, thus the HEI database changes about quarterly; and the same 10 year rule applies. The key difference is that if you get data from the AQS Data Mart and your colleague gets the "same" data the next day, the data may have changed. If you are using the HEI database, the data may also have changed in one day, but the odds are less and the data vintage is clear in the "about" pages of the website. The stability of data for verifying and comparing research is essential, so the charge question is this: ***How often should EPA release data and how should we indicate that it has changed?*** One solution to this issue is to only make new data

available outside EPA once per year. These data would be released on Independence Day and would be up-to-date through the prior year. This option provides greater stability to the data but may not be timely enough for particular studies or NAAQS revisions. A second solution is for EPA to continue to release data as it is received. Each value would be date-stamped with the date it last changed along with the date it represents. This allows for comparisons of data sets but requires more data to be downloaded and analyzed by the user. There are many intermediate options that could be implemented.

2. **Topic-focused portals**: Are topic focused portals needed for air quality data? If so, what should those portals be and what should they contain? A strength of the HEI Air Quality Database is that it is geared towards health researchers evaluating speciated $PM_{2.5}$ data and the user interface provides tools and information specifically targeted to this user. The AQS Data Mart, on the other hand, is generic and targeted at anyone wishing to download air quality data. An annotated map of the $PM_{2.5}$ speciation sites on the HEI page helps the user understand and find the data they need. An analogous map of all 5,000 sites represented in the AQS Data Mart would only overwhelm and confuse users. Custom tailored "portals" into data, like HEI's, are very helpful to the user, especially when they have an interest limited to less than everything available. The EPA is reasonably good at providing data but is often constrained in the technology we can use to provide descriptive and analytical tools. Likewise, we are sometimes not able to quickly secure funding to add tools to respond to developing areas of interest. This may be a place where the flexibility of external organizations can be used to provide a more custom, and therefore useful, experience. ***Are topic-focused portals needed for air quality data? If so, what should those portals be and what should they contain?*** For example, there could be portals specific to $PM_{2.5}$ speciation, ozone and precursors, toxics, organic compounds, etc. Given the new technologies, a portal that resides outside of the EPA can have live access to a single, consistent, stable database within EPA.

3. **Accessibility of non-AQS data**: The AQS Data Mart stores data from the national ambient air quality monitoring network(s) and, as previously mentioned, has recently begun to add some data from other networks and "special studies." ***Is it important to have access to data from local, short-term, air quality special studies?*** Examples include MESA-Air, DEARS, Supersites, and ultrafine particle projects. If these data should be included, how should it be done? For example, to be loaded into the AQS Data Mart the data must match the monitor paradigm (no remote sensing or mobile monitors), it must meet format and quality requirements, and it must have associated descriptive data (e.g., method used, sampling schedule). Getting new data to match EPA's data standards are often labor-intensive activities – are they worth it? Would EPA have to correct and load these data into the AQS database (or a "research" copy of the AQS database)? Would EPA be able to commit the resources to doing this? As an alternative, EPA can provide information to managers of new studies about the data format and content standards we have so that the data can be collected in a way that could be more easily shared and compared with AQS data or other new data collected using the standards. If this special study data remains outside of EPA systems, is there a role for a clearinghouse? The clearinghouse could keep an up-to-date list of monitoring efforts,

databases, contents, and appropriate uses. Issues to be considered include: how resource intensive would this effort be and who would develop and maintain this clearinghouse?

Other Charge Questions

The remaining charge questions are more straight-forward than the standout charge questions. They are related to how individuals gather and use data rather than community-wide concerns.

4. **What are the key data that you need? Is any of this currently collected but not available?**
5. **Is there a particular way that you need data organized, grouped, or formatted?**
6. **What data elements other than measurements do you need?**
7. **What is the typical domain of the data you need (time, space, and parameter selections; for example, 3 years, several cities, and 4 parameters; or 1 year, national, 44 parameters)?**
8. **Are there "profiling" reports – descriptions of which sites collect which data, how complete the data are, etc. – that you need?**
9. **Would you rather query a database or have a large list of files that you can select from to download (like http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm but with more geographic resolution)?**
10. **What would your ideal query builder/interface look like?**
11. **Are there pieces of data that we provide or questions that we ask that confuse you?**

Appendix C.1 – Other Data Access Mechanisms

EPA has many places to access air quality data. Each of these websites or applications was designed for a specific target audience, for example, the general public concerned with acute health issues, the general public concerned with long-term air quality where they live, the general public interested in air quality comparisons between multiple locations (for living, vacationing, etc.), data analysts concerned with regulatory compliances, data analysts contributing to policy decisions, and health researchers. We consider a researcher to be someone who is looking to download raw data; either in large volume or in small, discrete sets that are difficult to tease out of large published datasets. Each of these websites or applications presents a unique front end for queries, charts, or maps that are geared toward their target audience.

EPA is developing a "portal" to list all of the sources of air quality (and emissions) data that are available and link directly to their access pages. This portal is at the following web address: http://www.epa.gov/oar/airpolldata.html. Below is a table comparing key information about each of the available EPA-maintained systems for air quality data (including AirNow and CASTNET which contain data not in AQS). The systems are described at the link above. (Key: a filled circle means "yes" and an empty circle means "some".)

System	Level of Detail				Time	Substances						Outputs			Audience		
	Raw (samples & NAAQS)	Daily sums & avgs	Annual sums & avgs	QA	Time range of most detailed data	Ozone + PM2.5	Other Criteria	Toxics	PM2.5 Adj. Spec	PM2.5 Unadj. Spec	Other	Canned queries: tabular	Canned queries: maps	Ad hoc	Public	SLT Analysts	Researchers
AQS	●	●	●	●	1994 – Present	●	●	●		●	●	●		●		●	
AirNow (Tech)	●	●			1999 – Present	●	○					●	●			●	
AirData			●		1996 - 2006	●	●					●	●		●		
AirExplorer		●	●		1996 – 2006	●	●	○	●	●		●	●			●	
AirCompare		●	●		2000 – Present	●	●					●	●		●		
AQS Data Page	●				1994 – 2006	●	●			●		●					●
NATA (modeled)			●		1996 & 1999			●				●	●			●	
Air Trends			●		1990 – 2005	●	●					●	●			●	
AQS Data Mart	●	●	●		1980 – Present	●	●	●		●	●	●					●
CASTNET	●		●		*1987 - 2005*	○					●	●				●	

Appendix D: Session III: Ambient Air Monitoring for Health Research - Air Quality Sampling: Benefits and Costs of Daily Health Targeted Monitors for Fine Particle Components

Questions on this draft white paper should be directed to Dr. Barbara Glenn, EPA/NCER, glenn.barbara@epa.gov; (202) 343-9721.

INTRODUCTION

EPA's air quality datasets are generally recognized and valued primarily for their use in ascertaining compliance with the National Ambient Air Quality Standards (NAAQS), developing State Implementation Plans for the improvement in air quality, and providing timely air quality data to the public. EPA's air quality datasets also are essential to extramural and intramural health research addressing scientific uncertainty related to the current NAAQS and to the assessment of the possible health benefits of any new air quality standard. These health-related uses of EPA's air quality datasets are an important consideration in the design and conduct of the national air quality monitoring network. As specialized monitoring networks have begun providing information on the composition of particulate matter, epidemiologic researchers are striving to address a major research priority defined by the National Academy of Sciences National Research Council (NRC)—assessing the health effects of PM components and sources.

The NRC reports on "Research Priorities for Airborne Particulate Matter" repeatedly emphasize the importance of research to assess the relationships between particle composition and health responses. According to the fourth report, "Progress on assessment of hazardous PM components is central to the national research portfolio and to any refinement of the current mass-based NAAQS for PM….A better understanding of characteristics that modulate toxicity could lead to targeted control strategies specifically addressing those sources having the most significant adverse effects on public health." (NRC 2004)

On November 30, 2006, the Health Effects Institute (HEI) and EPA, in conjunction with the annual EPA PM Centers meeting, convened a meeting of the research and air quality management communities to discuss the use of EPA's air quality datasets for health research on particulate matter (PM). Participants raised several issues that complicate the design and interpretation of epidemiologic research on $PM_{2.5}$ mass, components, and sources. Participants emphasized that the lack of daily concentration measurements for fine particle mass and components in key locations was severely affecting their ability to design and conduct epidemiologic studies that would address issues of scientific uncertainties highlighted in air quality standard setting at Federal and state levels. This paper summarizes these issues, proposing a range of options to address the need for daily data based on the November 2006 meeting and subsequent information exchange with EPA grantees, state/local air quality monitoring representatives, HEI and EPA staff. These challenges would not exist if resources to collect daily, speciated monitoring data were readily available. The pressing needs for these data are increasing at a time when resources are decreasing and monitoring costs are generally increasing. This draft white paper provides background information to facilitate a broad discussion on the benefits of obtaining daily fine particle speciation measurements and to

encourage health researchers and air quality experts to work together to creatively identify solutions that address the need for daily data while understanding the resource constraints and competing needs for monitoring data.

The goal of this discussion paper is to draw attention to the importance of specific monitoring data needs in planning health research studies, specifically related to evaluating potential public health impacts of fine particles. Epidemiologic studies relating daily variation in ambient air pollutant concentrations with disease-specific mortality or morbidity have been very important for providing the scientific basis for recent standard-setting for PM. Some of the key policy relevant issues considered in evaluating the PM NAAQS include:

- What are the potential public health impacts associated with exposures to specific size fractions, chemical components, sources and/or environments (e.g., urban and non-urban areas) of PM?
- What is the relationship between various health endpoints and different lag periods (e.g., less than one day, single day, and multi-day distributed lags)?
- How does spatial and/or temporal heterogeneity of PM exposures vary with different size fractions and/or components?

Providing daily ambient air monitoring data for fine particle components from several cities to health researchers would reduce exposure misclassification, allow the use of all health events in statistical analyses, and thereby increase the precision of risk estimates. In addition, the availability of these data would significantly decrease the length of time necessary to produce study results.

BACKGROUND

Epidemiologic studies of the adverse human health effects of short-term exposures to air pollutants have generally relied upon air quality monitoring systems established to ensure compliance with ambient air quality standards. These epidemiologic studies contributed to decisions in 1987 to change the indicator for the PM NAAQS from total suspended particles (TSP) to PM_{10} and to decisions in 1997 to add new standards to consider fine and coarse fractions of PM_{10} separately, using $PM_{2.5}$ as the indicator for fine particles and using PM_{10} as the indicator for purposes of regulating thoracic coarse particles.. As regulatory efforts have increasingly focused on reducing the mass of fine particles from combustion sources, the air quality monitoring network has successfully responded, at considerable cost and human effort, to the monitoring challenges. Since promulgation of the fine particle NAAQS in 1997, subsequent epidemiologic and toxicologic research has confirmed the earlier scientific findings and validated the substantial investment in ambient air monitoring.

The 2004 Air Quality Criteria Document (CD) for PM highlighted the importance of epidemiologic studies in its evaluation of the scientific evidence. In particular, the CD emphasized new multi-city studies that investigated the effects of short-term human exposures to PM on mortality and morbidity using data from multiple locations with varying climate and air pollution mixes. These epidemiologic studies were valued because they provided information about areas not previously studied, reported risk estimates for all study locations, and used the

same analytical approach at each location allowing comparisons. In addition, multi-city studies contributed to an increased understanding of the role of various potential confounders, including gaseous co-pollutants, on observed associations. These studies, which combined risk estimates across all locations, provided more precise estimates of the magnitude of an effect of exposure to PM than most smaller-scale individual city studies because of their larger sample size. Because model results were reported for all study locations regardless of the magnitude of the observed risk estimate, these studies also avoided the potential for publication bias.

The National Mortality and Morbidity Air Pollution Study (NMMAPS) was the first multi-city time-series study of air pollution and health and serves to illustrate the data-availability issues highlighted in this discussion paper. NMMAPS, funded by HEI, evaluated associations between daily mortality rates in 90 U.S. cities with the largest population and the daily level of PM_{10} reported for that locality in the EPA Air Quality System (Samet et al, 2000, Dominici et al, 2003). Mortality data from 1987 to 1994 was obtained from CDC's National Center for Health Statistics. While location-specific risks were reported, the objective was to construct precise national and regional estimates of mortality risk from daily changes in ambient PM and other criteria pollutants, thus increasing confidence in the values of the disease-specific risk estimates, and that these estimates were representative of those experienced by the U.S. population as a whole. In 14 cities with daily monitoring on at least 50% of study days, NMMAPS also evaluated the association of hospital admissions with PM_{10} (Samet et al., 2000; Schwartz et al., 2003).

Despite its national scope, NMMAPS was limited by the amount of air quality data available for analysis. The 90-city mortality analyses were based on air quality data in the AQS primarily collected using 1-in-6 day sampling schedules. The 8-year mortality dataset was necessarily restricted to only those days where PM_{10} data were available between 1987 and 1994 in each county. County-specific mean PM_{10} concentrations were calculated for each day with PM_{10} measurements contributed by one or more monitors. Almost half (43) of the 90 cities had data from only one or two monitors and only 28 cities had the equivalent of two or more years (730 days) of monitoring days available. The dataset for the 20 city analysis of PM_{10} adjusting for other pollutants was further restricted for multi-pollutant models because data on all pollutants had to be available on the same day. Consequently, these adjusted risk estimates were less precise. Even with these limitations, the risk estimates were determined to be robust in several sensitivity analyses to investigate residual confounding and exposure misclassification.

An NMMAPS sub-study of ten cities with PM_{10} monitoring on a daily schedule (New Haven, Birmingham, Pittsburgh, Detroit, Canton, Chicago, Minneapolis/St. Paul, Colorado Springs, Spokane, and Seattle) systematically evaluated the potential bias associated with the use of a single day PM concentration (Samet et al., 2000, Appendix B, pp. 54-61). Mortality data was fit using a generalized additive Poisson regression model and polynomial constrained and unconstrained lag models for ambient PM. Risk estimates from these models were compared to those obtained using 1 or 2 day means. Overall effects estimated using the distributed lag models were larger compared to effects estimated using the single or two-day mean lags. These analyses showed that the mortality effects of an increase in pollution levels on a single day are spread over several succeeding days, or conversely, that deaths on a single day are the result of pollution over several preceding days. For the 90-cities, the NMMAPS mortality analyses estimated

increased mortality per each 10 $\mu g/m^3$ increase in daily PM_{10} using a specified lag structure (0, 1 or 2 days prior to the day deaths occurred). The 10 city sub-study using distributed lags demonstrated that the larger multi-city study underestimated the risk associated with PM_{10}. In addition, consistent with previous reports, the NMMAPS results for morbidity in 14 cities demonstrated that use of PM_{10} concentrations on a single day (a one day lag) resulted in an underestimation of the cumulative PM_{10} effect on hospitalizations. Therefore, the flexibility to analyze effects in relation to PM concentrations over several days is key to a complete understanding of the magnitude of risk and the relevant time period for exposure to PM components.

Many of the other times-series studies reviewed in the CD also relied on 1-in-6 day PM measurements including the Canadian eight cities study (Burnett et al., 2000; Burnett and Goldberg, 2003). The 2004 CD was able to cite very few studies that relied on daily ambient concentrations for PM indicators. As a consequence, the CD discussed in depth the trade-offs of increased representativeness and precision provided by the larger, multi-site studies with the increased uncertainties in the reported risk estimates due to exposure misclassification.

MISSING AMBIENT CONCENTRATION DATA AND STATISTICAL POWER

Data collection frequency is a key component of statistical power for time-series studies, and missing data results in increased uncertainty in study results (discussed in PM Staff Paper, Dec. 2005, p. 3-39 and CD, p. 9-41). The Staff Paper concluded that, "consistent with the CD's observation that uncertainty is increased in studies using infrequently collected PM data, staff judges that greater weight should be placed on those studies with daily or near-daily PM data collection in drawing quantitative conclusions." Daily PM measurements in locations where enough health events occur will support future health studies that reduce uncertainties and thereby improve our understanding of the public health impacts of PM. Such studies will provide important information on specific components within the ambient mix of particles to inform the review of the PM NAAQS and strategies to implement these standards.

Statistical Power and Potential Bias

The statistical power of any proposed study is the probability that the completed study will correctly reject the null hypothesis with a specified confidence level, usually 95% confidence or a p-value of less than 0.05. In the calculation of statistical power, one must specify the expected magnitude of the exposure-health association, the expected exposure gradient, the sample size, the variability of the health outcome measure, and the specified confidence level. The minimum desired statistical power is usually 80%, and the formula may be inverted to calculate the necessary minimum sample size for a specified statistical power. Generally, increased exposure variability is associated with an increased exposure gradient and with increased statistical power. However, exposure variability due to measurement error and unmeasured exposure variability does not increase statistical power. For many epidemiologic study designs, sample size is directly related to the person-time of observation. For time-series studies of air pollution in a large metropolitan area, the usable sample size is largely determined by the number of days with complete exposure information. The variability of the health outcome measure depends on the type of measure (e.g., mortality counts or continuous biological indicators) and on the precision with which the outcome is measured. For time-series studies of

the daily variation in mortality for large urban areas, the variability of the outcome measure is largely determined by the average number of daily deaths. Everything else held constant, statistical power for a time series study increases relative to the square root of the average number of daily deaths. Hence, the weights in tables 1 and 2 are the square root of the estimated number of daily deaths, or 1% of the population (In the US, about 1% of the population dies each year) / 365.

For air pollution time-series studies, when air quality measurements are missing, the deaths or heart attacks that would be studied for those days must be excluded. Therefore, the sample size (number of mortality-days) available to analyze in a locality is reduced because the exposure data may not exist for the desired lag days. For example, if one wants to evaluate deaths in relation to ambient pollution levels on the same day, the day before, and the day before that (lags 0, 1 and 2), then air pollution concentrations must be available at that location for three consecutive days. Statistical power has implications for the selection of cities in epidemiologic studies. The cities that can be analyzed become restricted to locations with a high number of daily events (e.g., deaths, hospital admissions, etc.) so that the required sample size will be obtained in a reasonable time period.

Dr. Kazuhito Ito, NYU, presented a slide at the November 2006 meeting that showed statistical power curves for hypothetical time-series studies by the number of daily deaths in a location and study duration (see Figure 1). These curves indicate statistical power achieved to evaluate a hypothesized increase in daily total (non-accidental) deaths of 2.5% per 25 $\mu g/m^3$ increase in $PM_{2.5}$. The hypothesized increase in mortality rate was derived from city-specific relative risks reported in the PM literature. With 1-in-3 day monitors, six years of monitoring data would be required to achieve 80% statistical power to evaluate non-accidental mortality in cities with 100 mean daily deaths (6 years x 365 days/year x ⅓ monitoring days = 730 days). For example, a study in New York City, with 180 to 200 deaths per day, would achieve 80% power to evaluate the effect of $PM_{2.5}$ on nonaccidental mortality in about three years (3 years x 365 days/year x ⅓ monitoring days = 365 days). Conversely, a study conducted in a city the size of Seattle, with about 30 deaths per day would not achieve 50% power even if the study were extended beyond six years! Furthermore, study power decreases when the focus of study is cause-specific mortality or the identification of susceptible subgroups.

For many fine particle components, temporal and spatial variation within and between localities may be different than the variation for $PM_{2.5}$ mass. With greater temporal exposure variation and spatial variation between cities, the statistical power to study specific fine particle components is likely higher than for $PM_{2.5}$ mass. Statistical power is also enhanced if the mortality risk associated with a specific component is higher than for $PM_{2.5}$ mass.

However, exposure error caused by uncertainties in a study's exposure assessment can result in an attenuation of risk estimates and an inability to reject the null hypothesis. Exposure error also may lead to biased risk estimates. Within a metropolitan area, some PM ambient air measurements, such as total $PM_{2.5}$ mass or sulfates, show less spatial variability and a metropolitan area may be well characterized by a single central-site monitor. Other $PM_{2.5}$ components, such as elemental carbon, show considerable spatial variability and a metropolitan area may not be well characterized by a single central-site monitor. However, this uncertainty in

exposure assessment related to the unmeasured spatial variability will be differential with respect to $PM_{2.5}$ component; and $PM_{2.5}$ components with less spatial variability would have less exposure uncertainty. For a multi-city study focused on regional air pollution gradients, city-to-city differences in exposure uncertainty related to monitor location could affect city-to-city differences in the observed associations with health outcomes and hence could be misinterpreted as related to city-to-city differences in PM components.

Within the $PM_{2.5}$ ambient air monitoring network, there are approximately 900 Federal Reference Method (FRM) filter-based samplers that provide 24-hour $PM_{2.5}$ mass concentration data and about 600 continuous $PM_{2.5}$ mass monitors that provide hourly data on a near real-time basis. Due to the complex nature of fine particles, EPA implemented the Chemical Speciation Network (CSN) to better understand the components of fine particle mass at selected locations. Chemical speciation measurements are made at 54 ‘‘Speciation Trends Network (STN)’’ sites that are intended to remain in operation indefinitely and about 150 other, potentially less permanent sites used to support State Implementation Plan (SIP) development and other monitoring objectives.[33] Specific components of fine particles also are measured through the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring program which supports regional haze characterization and tracks changes in visibility in Class I areas as well as many other rural and some urban areas. Together, the CSN and IMPROVE data provide chemical species information for fine particles that are critical for use in health and epidemiologic studies to help inform reviews of the PM NAAQS.

The cities where the CSN monitoring sites are located are very important for studying health effects associated with fine particle exposures. There are more than 200 sites in the CSN. Table 1 (see associated pdf file) lists the Primary Metropolitan Statistical Areas (PMSAs) and Metropolitan Statistical Areas (MSAs) ordered by population size and a weight determined by the contribution to precision that area would make to a statistical analysis of risk. The site locations for CSN monitors are listed within the relevant PMSA where they operate. It is encouraging that more than 50% of the U.S. population resides in census areas with at least one CSN monitor. There also are some large population centers where PM components are not measured such as Orange County and Oakland in California, northern New Jersey, and Long Island, New York (PMSAs and MSAs where no speciation monitors are located are highlighted in red on Table 2). Currently, the CSN sites measure fine particle mass and components every third day or every sixth day. A change to daily sampling would increase the statistical power for time-series studies.

In evaluating criteria for identifying potential locations for increased monitoring, consideration could be given to CSN locations representing varied fine particle sources in the eastern, western, mid-western and southern parts of the U.S. Future epidemiologic studies that examine PM exposures at or below the current level of the $PM_{2.5}$ NAAQS will contribute significantly to reducing scientific uncertainty concerning health effects. Most major US metropolitan areas are below or close to the current PM NAAQS and can contribute useful information on the public health impact of PM exposures. The collection of daily measurements for $PM_{2.5}$ mass and key $PM_{2.5}$ components in metropolitan areas with high numbers of deaths and

[33] See http://www.epa.gov/ttn/amtic/speciepg.html for more information on the $PM_{2.5}$ speciation monitoring program.

in locations with variation in ambient concentrations near the current standard and in the mix of $PM_{2.5}$ components would inform our understanding of the relative health significance of specific $PM_{2.5}$ constituents and sources of $PM_{2.5}$.

MISSING DAYS: IMPACT ON VALUE OF RISK ESTIMATES

Missing days of sampling data presents problems for epidemiology studies of health effects associated with PM exposures over and above a decrease in statistical power and the problems are compounded for studies of fine particle components. $PM_{2.5}$ components are likely to present a large degree of variation involving associations with different health endpoints and time from exposure to response. This requires flexibility in constructing statistical models and lag structures. In addition, variation between localities presents complexities in the interpretation of the results of multi-site time series studies. Different components predominate in different regions of the U.S. and the correlation between PM components in each area will vary. Finally, the temporal and spatial variability of each PM component of interest within a city will vary and, if not adequately captured in sampling data, will result in exposure misclassification and an effect on the value of risk estimates.

The NMMAPS study and other time-series studies of mortality and morbidity indicate that risk estimates may vary between metropolitan areas or regions. There are multiple explanations for these observations including, random variation (chance), residual confounding, exposure misclassification, and the existence of real source-specific differences in risk. The differences in the precision of city-specific estimates of mortality risk associated with daily change in PM concentration complicate the interpretation of heterogeneity in risk reported by multi-city time-series studies or when single-city estimates show differences between localities.

Some authors have used interpolation approaches to fill in the missing days of ambient concentration data in order to avoid excluding cases for days with no air quality measurements. These imputation methods are often based on hourly or daily air quality measurements of PM mass or gaseous co-pollutants. Unfortunately, imputed values never carry as much information about population exposures as measured values and any evaluation of the improved health associations with speciated PM would be diluted by the high proportion of imputed values. Moreover, the error in imputation is not likely to be constant for each specific PM component; some components will be imputed with more error than other components. For example, filling in missing data with imputed values may be associated with more error in studies of coarse particle mass and fine particle components which are associated with larger spatial and day-to-day variation than fine PM mass. Along with the simple imprecision of the imputed values, any use of the gaseous co-pollutants in an imputation algorithm will necessarily increase the co-linearity between the measured values for the gaseous co-pollutants and the imputed values for various PM components. Thus, imputation methods will generally tend to bias any epidemiologic studies of the differential associations of PM components with human health outcomes.

The 2004 CD discussed results from a study conducted in Chicago, IL, which illustrates the impact on risk estimates caused by the use of 1-in-6 day ambient concentration data. In this study, a significant association was reported between daily change in PM_{10} concentration and

mortality between 1985 – 1990 using data from one monitor collected on a daily basis (Ito et al., 1995). However, when the data set was divided into 6 subsets representing a 1-in-6 day monitoring frequency, the effect estimates for the PM_{10}-mortality association were quite variable. Moreover, the confidence intervals were wider and analysis of only one of the subsets indicated a statistically significant association. This analysis indicates reduced precision due to the markedly decreased number of events available for analysis, but also indicates that risk estimates may be affected by exposure misclassification, chance, or selection bias. Selection bias could occur if the analyzed group associated with any particular sampling schedule were different from the unanalyzed group in a way that was systematically associated with exposure estimates. However, selection bias is not as prevalent a concern for time-series studies as is exposure misclassification due to inadequate characterization of the spatial variation of the PM exposure measure within a locality.

Exposure Misclassification and Spatial Variability

Exposure misclassification can occur when ambient concentration from one or only a few monitors in a geographic area is assigned to estimate the PM exposure of the individuals who died in that area. If the ambient concentration that is calculated for a particular day is higher than what some of those who died actually experienced, but lower than what others who died experienced, the resulting "noise" in the PM indicator makes it harder to distinguish a statistical association with mortality. If the calculated ambient concentration is not consistently higher or lower than the concentration experienced by those who died on that day (that is, nondifferential misclassification), the size of the relative risk may be attenuated. The importance of the attenuation depends on the degree of spatial variability characteristic of the pollutant under analysis and the resulting amount of exposure misclassification. While the impact of spatial variability on estimates of exposure is of less concern for studies of fine PM mass, a PM exposure with relatively homogenous local distribution, this is an important issue for epidemiology studies of $PM_{2.5}$ components or thoracic coarse particle mass and components. The NCER STAR program is funding five studies beginning in early 2008 that will provide information about spatial variability in coarse particle mass and components and effects on health. Additional studies, to be awarded in 2008, will address strategies to incorporate data on spatial and temporal variability of PM components in atmospheric and exposure models.

Evaluation of Cumulative Effects of Air Quality on Health

Studies using distributed lag models indicate that risk estimates using zero or one-day lags may underestimate the magnitude of mortality associations with air quality. Distributed lag models allow the examination of the combined effect of air pollution across a range of prior days on mortality for one particular day, e.g. today's mortality with today's air quality (lag 0), yesterday's air quality (lag 1), and day before yesterday's air quality (lag 2). The lagged effects of air quality over multiple previous days are compared with each day's mortality throughout the study period. With 1-in-3 or 1-in-6 day monitors, the relationship with the health measurements is disordered; the lagged effects of air quality on a single day must be compared with mortality on different days. For example, today's air quality is compared to today's mortality at lag 0, with tomorrow's mortality at lag 1, and with the day after tomorrow's mortality at lag 2. Distributed lag models using daily monitors are advantageous because a specific lag structure for

modeling the association of a pollutant with health does not have to be selected in advance. This modeling flexibility will be especially important for the study of PM components, which may have differing lags between exposure and health outcome.

SUMMARY

The purpose of the preceding discussion has been to highlight the importance of time-series studies using air quality data obtained from EPA's Air Quality System to identify health risks associated with ambient PM mass concentration and the limitations of the national monitoring networks for similar studies of fine particle components as indicators of PM sources. This issue was raised by the health research community at the HEI/EPA workshop in Boston November, 2006 and in subsequent discussions. The lack of daily speciation monitoring for $PM_{2.5}$ components is an important research need identified by the epidemiology community. This issue has been highlighted because the number of $PM_{2.5}$ speciation monitors per location is much smaller and variability (temporal and spatial) for many fine particle components is much greater than for $PM_{2.5}$ mass. Obtaining daily $PM_{2.5}$ speciation monitoring in a set of key locations will enhance our understanding of the health effects associated with fine particles by:

- providing improved statistical power for epidemiologic studies of PM components within a reasonable time period,
- providing analytical flexibility to examine distributed lags, and
- reducing exposure misclassification to improve the validity and precision of health effect estimates.

In addition, targeted studies in some metropolitan areas will help to characterize the spatial variability of $PM_{2.5}$ components and quantitative impact on risk estimates.

POTENTIAL OPTIONS FOR OBTAINING DAILY $PM_{2.5}$ SPECIATION MEASUREMENTS

A: Retrospectively fill in the missing data

Actions could be taken to construct a dataset containing daily values for $PM_{2.5}$ mass, metals, elements, sulfate, nitrate, and carbon for previous years. Options could include analyzing archived daily $PM_{2.5}$ mass (Teflon) filters collected at CSN or nearby sites, using data collected at nearby continuous (hourly) monitors. These efforts most likely could be done at most at a limited number of sites due to resource constraints and the limited historical use of the relevant samplers.

1. ***Analyze archived filters to obtain daily measurements of metals and elements (XRF)***

The 54 STN monitors operate on a 1-in-3 day sampling schedule. Some non-STN monitors in the CSN network may also operate on this schedule. There are some things that could be done to achieve daily measures at some of these sites retrospectively (back to 1999) for $PM_{2.5}$ and some components that are key source indicators. XRF analysis of archived daily $PM_{2.5}$ mass (Teflon) filters collected from an adequate number of locations of daily FRM monitors (primarily ones co-located with some of the 1-in-3 day CSN monitors) would provide critical

information about daily concentrations of metals and elements. There are alternative methods to measure particle mass, EC, and XRF-elements that may address the data needs for epidemiology studies and be cost-effective. For example, Joel Schwartz and George Thurston recommended using reflectance, a measure of black carbon, at the CSN sites to obtain estimates of daily EC (where daily samples for $PM_{2.5}$ mass are available). Reflectance or other optical analyses of the same filters may provide an indicator of EC. It must be noted that the existence of all historical, Teflon filters of interest remains to be determined and gaining access to those filters that have been archived will require a collaborative effort with State and local agencies.

2. Evaluate continuous measurement data to obtain daily organic carbon (OC)/elemental carbon (EC) at TRENDS sites.

Continuous (hourly) data for sulfate, nitrate, EC, and OC are available in some cities including, Chicago, IL, Indianapolis, IN, Davenport, IA, Bar Harbor, ME, Cedar Rapids, IA, Raleigh, NC, New York City, Seven Oaks, SC, Greenville, SC, Rockwell, NC, Seattle, WA, and Detroit, MI. However, all components are not measured at all cities. Daily measures for sulfate, nitrate, EC, and OC could be obtained over multiple years for Chicago (2002-2007), Bar Harbor (2004-2007 for sulfate, 2004 –? for OC, EC, & TC), New York City (2001 – 2007 for sulfate & nitrate, 2005 - 2007 for OC & EC), and Raleigh (2003 – 2006 for OC, 2003 - ? for sulfate, 2003 – 2007 for nitrate, and 2003 – 2006 for total carbon). These data could be used to construct a data set containing daily concentrations. Of these sites, STN monitors are located in the vicinity of the continuous monitors at Chicago, New York City, and Raleigh. OAQPS notes that continuous speciation monitors have their own measurement uncertainties, which may include systematic biases that are not well characterized; data from them cannot simply be merged with CSN data to fill in missing days. However, the continuous data could be used on a site-by-site basis if a relationship between the continuous analyzer and the filter-based monitor was established.

B: Expand current monitoring schedules at selected locations in order to conduct daily speciation measures in selected metropolitan areas.

1. Locations

Population size and the number of health events that occur each day are location attributes that contribute the greatest amount to the power of a time-series study to detect an association with exposure to an air pollutant if one exists. The top 22 PMSAs or MSAs with the highest weight were selected from Table 1 and are listed in Table 2 along with any CSN monitors currently operating in that location. It should be noted that there are three PMSAs (highlighted in red) in this group where there is no CSN monitor located. All of the other locations, except for Los Angeles, have an STN monitoring site. In addition to population size and mortality and the opportunity to take advantage of an existing CSN monitor, there are a number of factors that are important to consider for site selection for daily speciation monitoring. Important information might include:

- What are the major sources in an area? – Are components of interest present in measureable concentrations?

- Regional representation of study locations under consideration
- Area characteristics – topography, which influences spatial variability
- Existing data collection at a location -
- Are data available on a daily timescale for components of interest retrospectively?
- Are multiple speciation monitors operating in the location?
- Are special studies (government or grant-supported) being conducted in the location?

Participants at the April 2008 workshop will be asked to provide feedback about the importance of daily monitoring for fine particle components for advancing our understanding of the impacts of air pollutant exposures on public health and criteria to consider for prioritizing locations for daily $PM_{2.5}$ speciation monitoring. For discussion purposes, three columns have been added to Table 2 indicating significant area characteristics, notes on predominant PM components, and any special studies known to be conducted in the location that may contribute information on temporal or spatial variability.

2. Components

For what PM species would it be beneficial to have daily ambient measurements? For discussion purposes, Ito (HEI/EPA workshop, 2006) suggested the following components: OC, EC, nitrate, sulfate, Se, As, Si, Fe, Mn, Cr, Zn, Pb, V, Ni based upon information from toxicology and source apportionment studies. Some of these components may have more homogenous distributions in certain regions but others are likely to have a high degree of spatial variability. **CSN and IMPROVE currently analyze for these components and EPA plans are to continue to do so.**

3. Costs

The estimated annual cost for shipping and lab analysis to add daily $PM_{2.5}$ mass and speciation monitoring at one CSN site that is currently operating on a 1-in-3 day sampling schedule would be $100,000 based on current EPA contracts. The State/local monitoring agency would incur additional labor and equipment costs to operate the monitors as well.

OTHER MONITORING ISSUES

Two additional issues should be mentioned in this discussion of the use of air quality monitoring data in time-series studies.

A: Spatial Variability: Set up additional monitoring sites within certain cities to increase understanding of spatial variability of specific components.

Several components of research interest will be associated with a high degree of spatial variability across a location. A small number of monitors (4 – 6) distributed to capture concentrations throughout an area could give enough information to conclude whether or not a specified component has a uniform distribution in that area. If the distribution appeared uniform for a certain component, multi-site time-series analyses could be conducted using data from one or more centrally located monitors per location. If not, a more detailed exposure analysis would

be necessary in certain locations to obtain a finer spatial resolution and develop exposure models. Such a detailed, nonroutine study could potentially involve a research grant. Based on current EPA contracts, the estimated annual cost to establish a CSN-like site operating on a daily schedule in a new location but probably where other monitors are located is $150,000 for shipping and lab analysis.

B. Alternative Measurement Methodologies

There are alternative methods to measure particle mass, EC, and XRF-elements that may address the data needs for epidemiology studies and be cost-effective. For example, Joel Schwartz and George Thurston recommended using reflectance, a measure of black carbon, at the CSN sites to obtain estimates of daily EC. In addition, the use of a rotating drum sampler which measures various size classes of PM mass and PM components with a finer time resolution (six hours) could be considered. At a meeting with State/local monitoring managers, reservations were expressed about whether this sampler has demonstrated adequate repeatabililty.

BENEFITS OF OBTAINING DAILY $PM_{2.5}$ SPECIATION DATA

If resources can be secured or re-programmed to support daily $PM_{2.5}$ monitoring at a well prioritized set of monitoring sites of most value in health studies, the following benefits would be obtained:

1. Time-series studies will have enough statistical power to determine which particles are more toxic than others without having to wait ten or more years for results.
2. We will develop more accurate estimates of health effects that fully address lag issues due to the availability of daily health and monitoring data. Studies have shown that the use of distributed lag models evaluating several consecutive days prior to the occurrence of death result in a higher estimated relative risk. Studies of PM components need more flexibility in choice of lag models because not all components are predicted to have the same lag structure for effects. This has obvious implications for RIA, accountability studies, and basis for NAAQS decisions.
3. With multiple daily speciation monitoring sites in some of the larger cities, especially those with more complicated geologic features, it would become possible to improve our understanding of the impact of spatial variability on exposure estimates for PM components. Studies of within-city spatial variability will allow assessment of whether the "noise" in exposure estimates is so large for some components that no excess risk is observed.
4. Researchers could base their analyses on actual data, rather than using creative approaches to get around the fundamental issue of missing data. These methods are helpful, but introduce more uncertainty into the exposure estimates by increasing the co-linearity with co-pollutants.
5. The primary recommendation in the final NRC report was the need for EPA to systematically examine which PM components and sources are most important for public health. Since PM components may exert their adverse influences over different lags between exposure and outcome, the ability to correctly evaluate lagged effects may be

crucial to the correct assessment of the relative toxicity of PM components. The availability of daily air quality information would enable the differential assessment of PM components and PM sources, and eliminate a potential bias in favor of the assessment of those components with very immediate effects.

6. EPA is investing heavily in studies of key components and sources of PM (e.g., Hopkins PM Center studies, HEI's NPACT study, recent STAR RFAs). The return on this investment would be increased significantly if daily $PM_{2.5}$ data are available to increase confidence in the findings and reduce uncertainties in the estimates as explained above.
7. Accountability: Assessing the health improvements attributable to reduced air pollution is already a difficult challenge. Without daily data, such research will be even more difficult and take many years to demonstrate benefits.

REFERENCES

Burnett RT, Brook J, Dan T, Celocla C, Philips O, Cakmak S, Vincent R, Goldberg MS, Krewski D. 2000. Association between particulate- and gas-phase components of urban air pollution and daily mortality in eight Canadian cities. Inhalation Toxicol 12 (Suppl4):15-39.

Burnett RT and MS Goldberg. 2003. Size-fractionated particulate mass and daily mortality in eight Canadian cities. In: Revised Analyses of Time-Series Studies of Air Pollution and Health. Special Report. Health Effects Institute, Boston, MA.

Dominici F, McDermott A, Daniels M, Zeger SL, Samet JM. 2003. Mortality among residents of 90 cities. In: Revised Analyses of Time-Series Studies of Air Pollution and Health. Special Report. Health Effects Institute, Boston, MA.

Ito K, Kinney PL, and Thurston GD. 1995. Variations in PM-10 concentrations within two metropolitan areas and their implications for health effects analyses. Inhalation Toxicol 7:735-745.

National Research Council (NRC). 2004. Research Priorities for Airbourne Particulate Matter IV: Continuing Research Progress. The National Academies Press, Washington D.C.

Samet JM, Zeger SL, Dominici F, Curriero F, Coursac I, Dockery DW, Schwartz J, Zanobetti A. 2000. The National Morbidity, Mortality, and Air Pollution Study, Part II: Morbidity and Mortality from Air Pollution in the United States. Research Report 94. Health Effects Institute, Cambridge MA.

Schwartz J, Zanobetti A, Bateson T. 2003. Morbidity and Mortality Among Elderly Residents of Cities with Daily PM Measurements. In: Revised Analyses of Time-Series Studies of Air Pollution and Health. Special Report. Health Effects Institute, Boston, MA.

Figure 1. Implication of every-6th-day and every-3rd-day data: Statistical power for time-series studies.
Slide provided by Dr. Kazuhito Ito, presented at HEI/EPA Workshop on Air Quality Data, Newton, MA, November 2006. Adapted slightly for this discussion paper.

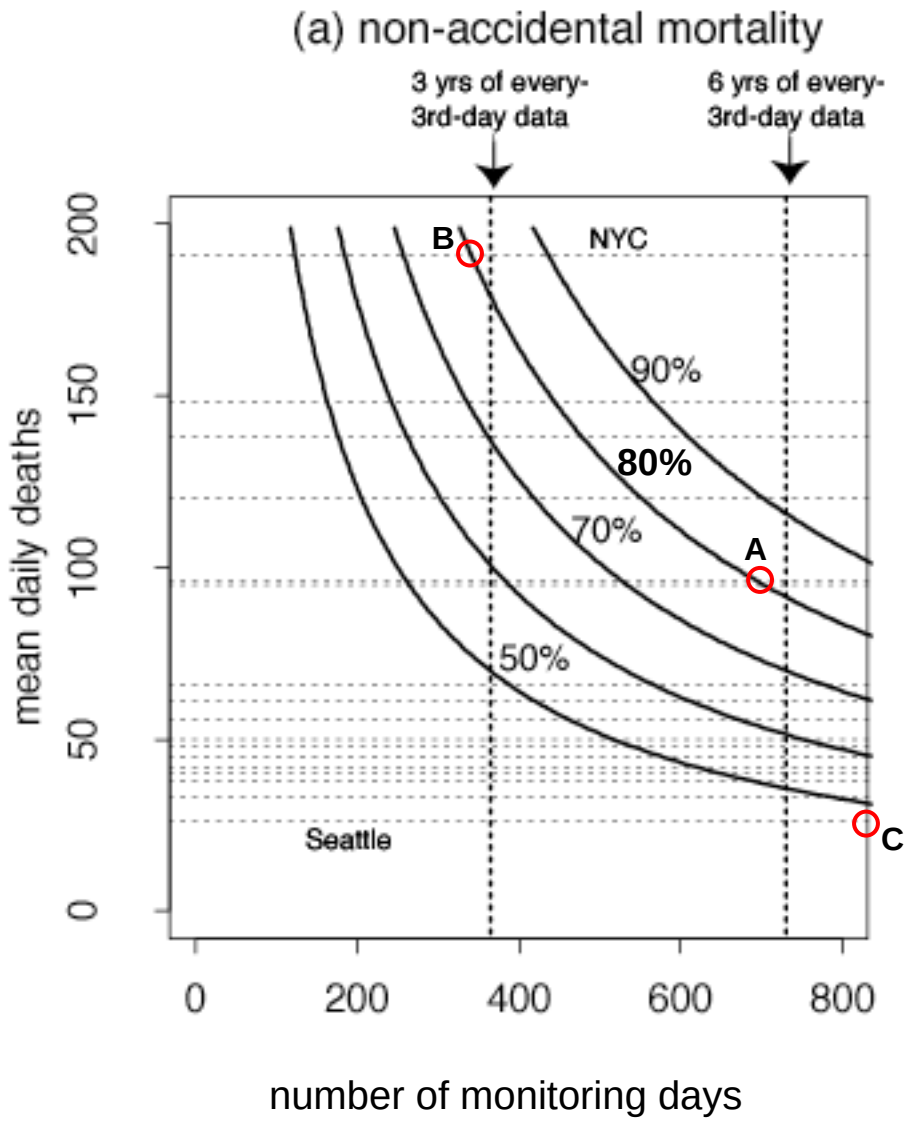


Table 2. Twenty-two MSAs with largest population and associated speciation monitors.

#	2000 Pop	Wgt[34]	MSA	Local Site Name	City Name	State	Site ID	Sample Collection	County Name	STN?	Area characteristics	Components	Special Studies
1	9,314,235	16.0	**New York, NY PMSA; New York--Northern New Jersey--Long Island, NY--NJ--CT--PA CMSA**								Large urban increment plus NE background	High sulfate and organics, low nitrates	NYDOC, MESA-AIR, Supersite
				IS 52	New York	NY	0110	Met One SASS Teflon	Bronx	STN			
				DIVISION STREET	New York	NY	0134	Met One SASS Teflon	New York				
				QUEENS COLLEGE 2	New York	NY	0124	R&P MDL2300 PM2.5 SEQ SPEC	Queens				
2	9,519,338	16.1	**Los Angeles--Long Beach, CA PMSA; Los Angeles--Riverside--Orange County, CA CMSA**								Complex coastal and mountain topography, extreme traffic, ozone. and sun	Extremely high nitrate and organics, low sulfate	CARB, PM Center, CHS, MESA-Air, Supersite
				NULL	Los Angeles	CA	1103	Met One SASS Teflon	Los Angeles				
3	8,272,768	15.1	**Chicago, IL PMSA; Chicago--Gary--Kenosha, IL--IN--WI CMSA**								Industrial center with lake influences, windy	High sulfate and organics, low nitrates	
				SPRINGFIELD PUMP STATION	Chicago	IL	0057	Met One SASS Teflon	Cook				MESA-Air
				COM ED MAINTENANCE BLDG	Chicago	IL	0076	Met One SASS Teflon	Cook	STN			
				NORTHBROOK WATER PLANT	Northbrook	IL	4201	Met One SASS Teflon	Cook				
				CITY HALL	Naperville	IL	4002	Met One SASS Teflon	DuPage				
4	5,100,931	11.8	**Philadelphia, PA--NJ PMSA; Philadelphia--Wilmington--Atlantic City, PA--NJ--DE--MD CMSA**								Industry plus NE background	High sulfate and organics, low nitrates	
				CAMDEN LAB	Camden	NJ	0003	Met One SASS Teflon	Camden				
				AMS Laboratory	Philadelphia	PA	0004	Met One SASS Teflon	Philadelphia	STN			
				ON AMTRAK RIGHT OF WAY - NEAR AIRPORT HI SPEED LINE (ELECTRIFIED)	Philadelphia	PA	0136	Met One SASS Teflon	Philadelphia				
				A420450002LAT/LON POINT IS OF CORNER OF TRAILER	Chester	PA	0002	Met One SASS Teflon	Delaware				

[34] Weights (Wgt) are proportional to expected inverse-variance regression weights: sqrt((population * 0.01) / 365)

#	2000 Pop	Wgt	MSA	Local Site Name	City Name	State	Site ID	Sample Collection	County Name	STN?	Area characteristics	Components	Special Studies
				CHESTER COUNTY TRANSPORT SITE INTO PHILADELPHIA	Not in a city	PA	0100	Met One SASS Teflon	Chester				
				CORNER OF MLK BLVD AND JUSTISON ST, NO TRAFFIC DATA AVAILABLE	Wilmington	DE	2004	Met One SASS Teflon	New Castle				
5	4,923,153	11.6	**Washington, DC--MD--VA--WV PMSA; Washington--Baltimore, DC--MD--VA--WV CMSA**								NE background plus traffic	High sulfate and organics, low nitrates	Supersite
				MCMILLAN PAMS	Washington	DC	0043	Andersen RAAS Teflon	District of Columbia	STN			
				HOWARD UNIVERSITY	Beltsville	MD	0030	Andersen RAAS Teflon	Prince George's				
6	4,441,551	11.0	**Detroit, MI PMSA; Detroit--Ann Arbor--Flint, MI CMSA**								Industry and high traffic	High sulfate and organics, low nitrates	EPA
				NULL	Allen Park	MI	0001	Met One SASS Teflon	Wayne	STN			
				PROPERTY OWNED BY DEARBORN PUBLIC SCHOOLS	Dearborn	MI	0033	Met One SASS Teflon	Wayne				
				DEAN ROAD DEAD-ENDS AT SITE, 200 FT WEST	Luna Pier	MI	0005	Met One SASS Teflon	Monroe				
7	4,177,646	10.7	**Houston, TX PMSA; Houston--Galveston--Brazoria, TX CMSA**								Extreme chemical industry and ozone, coastal sunny	Medium (if interesting) organics, sulfate?	
				SOUTH OF DETERMINED & ALDINE MAIL RD INTERSECTION	Not in a city	TX	0024	R & P Model 2025 PM-2.5 Sequential Air Sampler w/VSCC	Harris				
				NW OF W. LAMBUTH & DURANT INTERSECTION	Deer Park	TX	1039	URG MASS400 Teflon WINS	Harris	STN			
8	4,112,198	10.6	**Atlanta, GA MSA**								Extreme biogenics, high traffic, sunny	High sulfate and organics, low nitrates	EPRI, Supersite
				2390-B WILDCAT ROAD, DECATUR, GA	Decatur	GA	0002	Met One SASS Teflon	DeKalb	STN			
9	3,519,176	9.8	**Dallas, TX PMSA; Dallas--Fort Worth, TX CMSA**								Traffic and cattle, sunny	high ammonia?	
				WEST OF S. AKARD & CANTON STREETS INTERSECTION	Dallas	TX	0050	R & P Model 2025 PM-2.5 Sequential Air Sampler w/VSCC	Dallas				

#	2000 Pop	Wgt	MSA	Local Site Name	City Name	State	Site ID	Sample Collection	County Name	STN?	Area characteristics	Components	Special Studies
				DALLAS HINTON	Dallas	TX	0069	URG MASS400 Teflon WINS	Dallas	STN			
				THIS SITE WILL MONITOR THE SAME AREA AS SITE 1390015	Midlothian	TX	0016	R & P Model 2025 PM-2.5 Sequential Air Sampler w/VSCC	Ellis				
10	3,406,829	9.7	**Boston, MA--NH PMSA; Boston--Worcester--Lawrence, MA--NH--ME--CT CMSA**								NE background plus traffic	High sulfate and organics, low nitrates	Harvard
				DUDLEY SQUARE ROXBURY	Boston	MA	0042	Met One SASS Teflon	Suffolk	STN			
11	3,254,821	9.4	**Riverside--San Bernardino, CA PMSA; Los Angeles--Riverside--Orange County, CA CMSA**								Complex coastal and mountain topography, extreme traffic, ozone. and sun	Extremely high nitrate and organics, low sulfate	MESA-Air
				NULL	Rubidoux (West Riverside)	CA	8001	Met One SASS Teflon	Riverside	STN			
12	3,251,876	9.4	**Phoenix--Mesa, AZ MSA**								Extreme traffic, ozone. and sun	High nitrate and organics, low sulfate	
				PHOENIX SUPERSITE	Phoenix	AZ	9997	Met One SASS Teflon	Maricopa	STN			
13	2,968,806	9.0	**Minneapolis--St. Paul, MN--WI MSA**								Continental urban	Medium	MESA-Air
				ANDERSON SCHOOL - PHILLIPS NEIGHBORHOOD	Minneapolis	MN	0963	Met One SASS Teflon	Hennepin	STN			
14	2,846,289	8.8	**Orange County, CA PMSA; Los Angeles--Riverside--Orange County, CA CMSA** **No speciation monitors?**								Complex coastal and mountain topography, traffic, ozone. and sun	High nitrate and organics, low sulfate	
15	2,813,833	8.8	**San Diego, CA MSA**								Complex coastal and mountain topography, traffic, ozone. and sun	Medium nitrate and organics, low sulfate	
				NULL	El Cajon	CA	0003	Met One SASS Teflon	San Diego	STN			
				NULL	Escondido	Ca	1002	Met One SASS Teflon	San Diego				
16	2,753,913	8.7	**Nassau--Suffolk, NY PMSA; New York--Northern New Jersey--Long Island, NY--NJ--CT--PA CMSA** **No speciation monitors?**								Large urban increment plus NE background	High sulfate and organics, low nitrates	
17	2,603,607	8.4	**St. Louis, MO--IL MSA**								Industry and traffic	High sulfate and organics, low nitrates	Supersite

#	2000 Pop	Wgt	MSA	Local Site Name	City Name	State	Site ID	Sample Collection	County Name	STN?	Area characteristics	Components	Special Studies
				SIU DENTAL CLINIC	Alton	IL	2009	Met One SASS Teflon	Madison				
				NULL	Not in a city	MO	0012	Met One SASS Teflon	Jefferson				
				BLAIR STREET CATEGORY A CORE SLAM PM2.5.	St. Louis	MO	0085	Met One SASS Teflon	St. Louis City	STN			
18	2,552,994	8.4	**Baltimore, MD PMSA; Washington--Baltimore, DC--MD--VA--WV CMSA**								NE background plus traffic	High sulfate and organics, low nitrates	MESA-Air, Supersite
				ESSEX	Essex	MD	3001	Met One SASS Teflon	Baltimore	STN			
19	2,414,616	8.1	**Seattle--Bellevue--Everett, WA PMSA; Seattle--Tacoma--Bremerton, WA CMSA**								Coastal urban, high wood burning	Medium organics?, nitrate?, low sulfate?	
				SEATTLE DUWAMISH	Seattle	WA	0057	Andersen RAAS Teflon	King				
				BEACON HILL	Seattle	WA	0080	Met One SASS Teflon	King	STN			
				OLIVE STREET	Seattle	WA	0048	Met One SASS Teflon	King				
20	2,395,997	8.1	**Tampa--St. Petersburg--Clearwater, FL MSA**								Coastal with some SE and power plant influence	Medium sulfate and organics	
				SYDNEY	Plant City	FL	3002	Met One SASS Teflon	Hillsborough	STN			
				NULL	Pinellas Park	FL	0026	Met One SASS Teflon	Pinellas				
21	2,392,557	8.1	**Oakland, CA PMSA; San Francisco--Oakland--San Jose, CA CMSA** **No speciation monitors?**								Coastal urban, high wood burning	Medium organics?, nitrate?, low sulfate?	
22	2,358,695	8.0	**Pittsburgh, PA MSA**								Industry & traffic plus eastern background	High sulfate & organics, low nitrates	
				NULL	Pittsburgh	PA	0008	Met One SASS Teflon	Allegheny	STN			Supersite
				NULL	Not in a city	PA	5001	Met One SASS Teflon	Washington				
				S ALLEGHENY HS DOWN WIND FROM USS CLAIRTON COKE WORKS	Liberty	PA	0064	Met One SASS Teflon	Allegheny				
				LAT/LON POINT IS TRAILER	Greensburg	PA	0008	Met One SASS Teflon	Westmoreland				

Appendix E: Session V: Ambient Air Monitoring Realities – EPA/State/Local Perspectives - Ambient Air Monitoring Network: Network Design and Site Selection Approval

Questions on this draft white paper should be directed to Tim Hanley, EPA/OAQPS, hanley.tim@epa.gov; (919) 541-4417.

Introduction

The purpose of this white paper is to briefly describe the process for designing major ambient air monitoring networks including:

- the roles of EPA and State, local, and Tribal monitoring agencies in selecting and approving monitoring stations;
- the ways that health and other researchers can provide input currently to State/local/Tribal monitoring agencies and EPA on the usefulness and approval of monitoring stations; and
- suggestions to improve facilitation of soliciting input on monitoring station selection from health and other researchers.

Background

The measurement of ambient air pollution in the United States is provided through a number of ambient air monitoring networks operated almost exclusively by State, local, and Tribal air monitoring programs. The EPA identifies key parameters to measure such as criteria pollutants[35], pollutant precursors, chemical composition of particles, and air toxics. Ambient air monitoring networks are implemented through a combination of Federal requirements and voluntary programs.[36] EPA provides required siting criteria and network deployment strategies for measurement of pollutants as one of several key components to implementing air monitoring networks. Monitors are categorized as State and local Air Monitoring Stations (SLAMS) when they are approved as part of the long-term operating network or Special Purpose Monitors (SPMs) when they are being used for short-term investigations (i.e., less than two years). Air toxic monitoring stations are not required by regulation, and do not carry the SLAMS distinction.

Additional, Federally run networks provide monitoring coverage in primarily rural areas to meet specialized objectives. The Interagency Monitoring of Protected Visual Environments (IMPROVE) network, a cooperative measurement effort guided by a steering committee composed of representatives from Federal and regional-state organizations, provides important data for implementing both regional haze and $PM_{2.5}$ attainment programs. The Clean Air Status and Trends Network (CASTNET), managed by EPA's Clean Air Markets Division, provides atmospheric data on the dry deposition component of total acid deposition, ground-level ozone and other forms of atmospheric pollution. The National Atmospheric Deposition Program (NADP), another cooperative program involving several governmental agencies, provides measurements of pollutants in precipitation, including sulfate, nitrate and ammonium.

[35] The Clean Air Act requires EPA to set National Ambient Air Quality Standards (NAAQS) for six common air pollutants. They are particle pollution (often referred to as particulate matter), ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead.

[36] All Tribal monitoring programs are provided for cooperatively as compliance with Federal rules cannot be required of Tribes.

EPA designs and implements ambient air monitoring networks to meet several monitoring objectives:

- Determining compliance with health- and welfare-based standards (i.e., the NAAQS);
- Providing air pollution data to the general public on a timely basis; and
- Supporting the development and tracking of emission control programs.

In addition to the monitoring objectives above, EPA recognizes important additional objectives that need to be factored into designing ambient monitoring networks such as:

- Supporting health and welfare effects and exposure research studies
- Providing air pollution data for human health risk/exposure assessments and NAAQS reviews;
- Providing air pollution data for welfare effects assessments; and
- Supporting atmospheric research studies.

EPA recently made changes to the NAAQS-related monitoring regulations. Specifically, the general monitoring network design requirements for the minimum number of ambient air monitors were modified to focus more on populated areas with air quality problems and to significantly reduce the requirements for criteria pollutant monitors that have measured ambient air concentrations well below the applicable NAAQS. A number of the changes related to the monitoring of $PM_{2.5}$ include revisions to the requirements for reference and equivalent method determinations (including specifications and test procedures). These regulations also added a requirement for a new multi-pollutant monitoring network called National Core (NCore) and revised certain provisions regarding monitoring network descriptions and periodic assessments, quality assurance, and data certifications (71 FR 61236, October 17, 2006)[37].

Design criteria for required ambient air monitoring networks are provided in Appendix D to 40 CFR Part 58. Network design criteria include monitoring objectives, scale of representation, and specifications for locating monitors (e.g., a requirement to be in the area of expected maximum concentration). In many cases, there are multiple monitoring objectives for a site with the highest concentration of a pollutant. For instance, a neighborhood scale site in the area of maximum fine particle exposure could be thought of as a central monitoring station. These central monitoring stations might have several PM measurement samplers such as a $PM_{2.5}$ FRM for comparison to the NAAQS, a $PM_{2.5}$ continuous mass monitor for reporting the Air Quality Index (AQI), and a fine particle speciation sampler to develop and track emission control strategies. All of these data could be useful in health studies depending on the purpose and availability of health endpoint data. Requirements for the minimum number of monitors to operate are identified for PM, ozone, Photochemical Air Monitoring Stations (PAMS), and NCore (which include several measurements); however, monitoring agencies are encouraged to operate additional stations to adequately characterize pollutants. Siting criteria are provided in Appendix E to Part 58. Siting criteria include the specifications for probe and inlet height, distance from obstructions, and traffic.

[37] See also http://www.epa.gov/ttn/amtic/ for more information on the Ambient Monitoring Technology Information Center (AMTIC) operated by EPA's Ambient Air Monitoring Group (AAMG). AMTIC contains information and files on ambient air quality monitoring programs, details on monitoring methods, relevant documents and articles, information on air quality trends and nonattainment areas, and Federal regulations related to ambient air quality monitoring.

Roles of EPA and Monitoring Agencies in selecting and approving changes to a monitoring network:

The EPA requires each State monitoring agency to develop and submit an Annual Monitoring Network Plan to the applicable EPA Regional Office by July 1 of each year. States may delegate portions of the Annual Monitoring Network Plan to applicable local agencies (e.g., in California there are several plans, while in New York there is one plan for the whole State). The annual monitoring network plan must be made available for public inspection for at least 30 days prior to submission to EPA. Any annual monitoring network plan that proposes SLAMS network modifications including new monitoring sites is subject to the approval of the EPA Regional Administrator. Air Toxic monitoring stations are encouraged to be included in annual monitoring network plans, but are not formally required. Modifications to PAMS, the Speciation Trends Network (STN), and the NCore network are to be approved by EPA's Office of Air Quality Planning and Standards. The EPA Regional Office will provide an opportunity for public comment and approve or disapprove the plan and schedule within 120 days of submission. If the State or local agency has already provided a public comment opportunity on its plan and has made no changes subsequent to that comment opportunity, the Regional Administrator is not required to provide a separate opportunity for comment.

The annual monitoring network plan must contain the following information for each existing and proposed site:

1. The AQS site identification number.
2. The location, including street address and geographical coordinates.
3. The sampling and analysis method(s) for each measured parameter.
4. The operating schedules for each monitor.
5. Any proposals to remove or move a monitoring station within a period of 18 months following plan submittal.
6. The monitoring objective and spatial scale of representation for each monitor as defined in appendix D to this part.
7. The identification of any sites that are suitable and sites that are not suitable for comparison against the annual $PM_{2.5}$ NAAQS as described in §58.30.
8. The metropolitan area (e.g., MSA, CBSA, CSA) or other area represented by the monitor.

The annual monitoring network plan must document how State and local agencies provide for the review of changes to a $PM_{2.5}$ monitoring network that impact the location of a violating $PM_{2.5}$ monitor or the creation/change to a community monitoring zone. The affected State or local agency must document the process for obtaining public comment and include any comments received through the public notification process within their submitted plan.

What factors are critical in decisions to change the location of a monitoring station?

In most cases, monitoring stations are located for many years in the same location; however, from time to time a monitoring station is moved or shut down due to either planned or unforeseen reasons. The following list provides a summary of the most common reasons why monitoring stations are moved or shut down:

Logistical reasons:

- The lease for the land or building where the monitoring station is located cannot be extended due to redevelopment or other reasons.

- Construction adjacent to a monitoring station renders the site inappropriate to use during construction and in some cases unable to meet siting criteria after construction is complete.

Failure to meet probe and siting criteria:

- Growth of trees around a monitoring station renders the site no longer able to meet siting criteria and the owner of the trees is unwilling to have them cut or trimmed.
- Increases in motor vehicles traffic, including the addition of new traffic lanes lead to re-categorizing the scale of representation or failure to meet set-back requirements; which no longer meets the network design criteria.
- Site inspections reveal that some aspect of the siting criteria is no longer acceptable (e.g., a new HVAC system or emission source is located too close to an inlet).

Changes in responses to emission and/or ambient monitoring trends:

- Changes to existing point, area, or mobile source emission inventories (e.g., establishment of new beltways, shut-down of manufacturing facilities) that alter the original premise for site placement.
- Long-term trends analysis demonstrates monitor's objective has been fulfilled (taking into account future alterations of the NAAQS). For example, steep declines in ambient carbon monoxide levels at micro-scale compliance sites led to discontinuation of a large number of CO monitors.
- Network assessment indicates that monitoring resources should be devoted to other issues (e.g., air toxics measurement) or conserved to preserve high priority objectives (e.g., ozone, $PM_{2.5}$)

What feeds into the decision-making process for moving or shutting down a monitoring station?

With any number of reasons why a monitoring station may need to be moved or shut down, monitoring agencies must plan for network changes. For situations where it may be possible to stay at the existing site, if barriers can be overcome, an agency would likely make the necessary efforts to maintain the site if the monitoring objective were critical and no other suitable location were available. Knowing that data from a monitoring station were being used in an important health or epidemiological study would provide a persuasive argument to keep the station in the same place if the agency knew the data were being used. For example, an agency may be willing to petition a land owner to trim a tree or move an obstruction given the more compelling use of the data in a health research study.

If a monitoring station has to be moved, how is a new location picked and approved?

Although usually not possible, the best way to handle moving a monitoring station is to identify a new site location within the same general area such that:

- the scale of representation and impacts from emission sources is the same as the original site (so long as this is what is intended to be measured at the monitor);
- the old and new monitoring stations can be both operated simultaneously for one year or, at minimum, during the season(s) of maximum expected concentrations; and
- the statistical analyses of the data from the old and new monitoring stations are deemed to be sufficiently comparable.

In many cases, the decision to move a monitoring station does not allow enough time to provide for simultaneous operation, so careful selection of the new station and analysis of its data can only be compared to historical levels and other operating monitors. Use of emission inventories, traffic counts, pictures, and satellite imagery can help document site characteristics for comparability of old and new sites.

Monitoring station removals or relocations that are anticipated for the next 18 months must be identified in the annual monitoring network plan that is required to be made available for public inspection and is due to the EPA Regional Office by July 1 of each year. Although not required, ideally the applicable EPA Regional Office will visit and perform a site inspection to assure the new station meets siting criteria and is acceptable. In recognition of uncontrollable circumstances (e.g., a natural disaster such as Hurricane Katrina), the EPA provides for moving an air monitoring station outside the window of an annual monitoring plan by review and approval of the applicable EPA Regional Office.

In what ways can communication with the health research community be improved concerning possible changes in the ambient air monitoring networks?

Improved outreach concerning currently available tools:

- EPA has developed a web site that provides a link to each available State and local agency annual monitoring network plan (see: http://www.epa.gov/ttn/amtic/plans.html).

- EPA will continue to update the website as plans are revised. EPA is seeking input regarding recommendations for how often a reminder should goes out when plans are updated.
    - State/local/Tribal monitoring agencies can be encouraged to summarize their anticipated monitoring network changes in one place within the annual monitoring network plans, or in a companion summary document, that could be easily scanned by interested parties without wading through an extensive plan.
    - Although not currently available, there is recognition that a mechanism allowing for quick review of all anticipated network changes across the nation in one place would be beneficial to the health research community. Note: this is not available as all network plans are currently summarized by the appropriate State, local, and/or Tribal agency.

- EPA has developed a web site dedicated to documenting the site characteristics, including photos, and links to satellite imagery of candidate NCore monitoring stations (http://www.epa.gov/ttn/amtic/ncore/). At the bottom of each individual NCore station web page, there is an opportunity to provide comments on the candidate station. EPA encourages health researchers to offer comments on the usefulness of candidate NCore stations.

- EPA maintains a relatively easy to use public web site that can be used to generate maps and lists of active ambient air monitors (http://www.epa.gov/air/data/).
    - An agency contact list is maintained as part of this web site so that data users can reach State and local contacts concerning monitors of interest (http://www.epa.gov/air/data/contsl.html).
    - A contact list for EPA Regional Office monitoring staff is available at: http://www.epa.gov/ttn/amtic/namscon.html.

- EPA's Office of Air Quality Planning and Standards (OAQPS) has recently developed a list serve that is used as a communication tool for ambient air monitoring and health researchers can be added to our distribution list. Sign-up instructions are available at: http://www.epa.gov/ttn/amtic/airlist.html.

Increased participation in health-focused gatherings:

- Monitoring experts from OAQPS can participate in key, annual national health research conferences to present information on ambient air monitoring networks and plans for method improvements or changes. This would also improve monitoring experts' knowledge of health research needs, improve communication, and build a bridge between these two communities.
    - OAQPS can also work with key State and local agency monitoring and network leads by inviting them to participate in annual national health research conferences to present information on ambient air monitoring networks for which they are responsible.

- EPA will continue to engage CASAC's Ambient Air Monitoring and Methods Subcommittee, and in doing so can specifically engage or address health research interests.

Communication initiatives:

- Health researchers are encouraged to communicate with the ambient air monitoring community on the key monitoring sites that provide data to their research. Communications should be at multiple levels to ensure an understanding of the importance of the work; however, the most important communication needs to be directly with the State and/or local air monitoring agency responsible for operating ambient air monitoring stations.
- EPA will facilitate and encourage the participation of health researchers at national air monitoring conferences to provide presentations on how their research is using ambient data. This will serve to educate and sensitize monitoring staff to the importance of the ambient air monitoring program to health researchers especially if the issue of relocation or termination of long-term monitoring sites is being considered.
- Health researchers and EPA should work collectively to establish the requirements for a website or other publicly available forum to serve as an inventory of all on-going and planned health studies utilizing ambient air monitoring data, the monitoring sites and key ambient monitoring data being used, and the time period of the study. This would be extremely beneficial so that monitoring agencies can make contacts with researchers who are using the information from their networks.

Appendix F: Session V: Ambient Air Monitoring Realities – EPA/State/Local Perspectives - Ambient Air Monitoring Method Implementation

Questions on this draft white paper should be directed to Joann Rice, EPA/OAQPS, rice.joann@epa.gov, (919) 541-3372.

Introduction

The purpose of this draft white paper is to describe the current process and communication strategy used by the EPA to implement monitoring methods and method improvements in support of National Ambient Air Quality Standards (NAAQS) criteria pollutants, criteria pollutant precursors, and air toxics and to encourage discussion on how to improve communications with the health research community.

Background

The Office of Air Quality Planning and Standards (OAQPS) is responsible for identifying ambient monitoring needs based on the NAAQS review process and other air quality data requirements. OAQPS implements the nation's ambient air monitoring networks to ensure that they meet critical air program needs by leading and collaborating on the development of data quality objectives (DQOs), monitoring methods, and a quality assurance (QA) program for achievement of monitoring objectives. The best approach is utilized to optimize the value of the monitoring networks to meet multiple program objectives and regularly assesses the network's effectiveness in continuing to meet those objectives. This is done in collaboration with other key partners, including EPA Headquarters and Regional Offices, the Office of Research and Development (ORD), other Federal agencies, the Ambient Air Monitoring Steering Committee (AAMSC), State/local/Tribal agencies, the National Association of Clean Air Agencies (NACAA), Multi-State Organizations, the National Academy of Sciences (NAS), the Clean Air Scientific Advisory Committee (CASAC), and private entities such as instrument manufacturers.

The EPA requires approved methods for measuring criteria pollutants. The monitoring staff participates in the NAAQS review process to help identify monitoring network issues and new monitoring technology needs. Once these needs are identified and articulated, the staff works with ORD to develop new monitoring technologies and Federal Reference Methods (FRMs) to support these needs. EPA also engages the CASAC, and their subcommittee on ambient air monitoring and methods, in review of the methods developed. Once EPA develops and specifies the FRM requirements, the instrument manufacturers are involved to develop candidate FRM and Federal Equivalent Methods (FEMs). ORD is responsible for testing and approval of equivalent and reference methods. A method has several components: sample collection, analysis, handling, archival, and data processing and reporting, etc. Once FRM/FEMs are approved, they are implemented in the national ambient air monitoring network to support the NAAQS. As the NAAQS review cycle repeats, EPA reviews the monitoring networks and monitoring method needs in consultation with monitoring agencies at the State, Local and Tribal level. If adjustments to the FRM/FEMs are needed, the AAMG works with ORD to develop new methods, or make adjustments or improvements to methods to meet the data needs in support of the NAAQS. Then the method development, review, consultation, approval, and implementation cycles repeat as described above.

In the case of criteria pollutant precursors, like $PM_{2.5}$ chemical species or air toxics, there are no requirements for FRM development and approval. EPA rules or method plans may specify the species or components and methods needed. In this case, OAQPS works with ORD to identify the best methods and technologies available to meet the data use objectives. Once these methods/technologies are identified, OAQPS/ORD consults with Regional Offices, State/local/Tribal agencies, Multi-State Organizations, and CASAC to obtain feedback on the appropriateness of the methods chosen. Once recommendations are provided on the method/technological approach, the monitoring methods are implemented with the help of the Regions and State/local agencies. Method plans are documented in the monitoring agency's quality assurance project plan (QAPP). States and local agencies often adopt the methods employed in the national monitoring programs for additional monitoring in their networks. As EPA regularly reviews and assesses the monitoring networks to confirm that they are meeting the data quality objectives and data use needs, revisions to the monitoring methods may be recommended or warranted.

What factors are critical in decisions to change – why make changes or improvements?

Changes to the FRM/FEM are done in support of the NAAQS review process and any resulting changes in the form or level of the standards, as well as to address needed operational efficiencies. Changes for non-criteria pollutants or precursor species are largely made to improve consistency and data usability across our monitoring networks, and to support multiple monitoring objectives such as:

- Supporting the development of modeling tools and the application of source apportionment modeling for control strategy development in support of the NAAQS;
- Assessing the effectiveness of emission reductions strategies through the characterization of air quality trends;
- Supporting health effects and exposure research studies; and
- Supporting programs aimed at improving environmental welfare (e.g., the regional haze program).

What feeds into the decision-making process?

Some changes are intentionally made and others inadvertently or unknowingly happen as a result of changes at the sample collection or analysis stages (e.g., changes in field or laboratory instrument operation). In the case of intentional plans for change, EPA may invoke special field or monitoring studies and data analysis efforts to assess the need for, and the impact of change. Plans for change are then vetted within EPA, and the monitoring, expert, and academic community (disciplines covered include monitoring, modeling and data analysis researchers, as well as health scientists) in a variety of ways and forums to obtain feedback from key partners. These forums include participation in and presentation or communication of plans for change at conferences, meetings, workshops, and Regional/State/Local and NACAA conference calls. In addition, OAQPS holds a tri-annual monitoring conference specific to monitoring issues (the last one was held November 2006). OAQPS may also issue letters, memorandums, program Newsletters, and other forms of written communication through our list serve (link to sign up instructions provided below). The list serve sends an email notification to all parties on the distribution about posting of information on our Ambient Monitoring Technology Information Center (AMTIC) website. In addition, special consultation with the AAMSC and CASAC is held if appropriate.

How do we communicate plans for change?

Several opportunities exist along the way for interested parties and key partners to provide feedback. EPA begins to consider possible changes well in advance of implementation. It takes several months if not years to perform any special studies, analyze the data, consult with ORD, the academic and expert community and other groups before change can occur. The EPA has (and continually develops) a variety of mechanisms to communicate plans for method improvements and changes. These mechanisms have already been mentioned above (e.g., participation in conferences, meetings and conference calls, newsletters, consultations, etc.).

In what new ways can we engage health researchers and improve communication?

Communications between OAQPS and the health research community can be improved by the following:

- OAQPS can participate in key, annual national health research conferences to present information on ambient air monitoring networks and plans for method improvements or changes. This would also improve OAQPS's knowledge of health research needs, improve communication, and build a bridge between these two communities.
  - Important conferences and dates need to be identified.

- EPA will continue to engage CASAC, and in doing so can specifically engage or address health research interests.
  - If the monitoring subcommittee is restored, make sure "right" health person(s) involved

- OAQPS has recently developed a list serve that is used as a communication tool and health researchers can be added to our distribution list. Sign-up instructions are available at: http://www.epa.gov/ttn/amtic/airlist.html.
  - NCER can help OAQPS focus what health researchers need to pay attention to or focus the distribution versus "mass mailing" (see below).

- EPA can improve internal communications by instituting regular forms of communication between ORD and OAQPS' divisions.
  - Need regular process of communication across EPA on changes/plans, etc.
  - Need to "institutional" process to formalize communications between OAQPS and health researchers through NCER.
  - Build additional relationships and channels for communication.

- OAQPS is involved in ORD's air research implementation planning process where OAQPS research needs are identified and conveyed across ORD laboratories. This forum can also be used to communicate plans for change across ORD.
  - OAQPS can communicate plans to ORD and ORD can help to convey messages and information across ORD labs and centers.

- ORD can participate in the AAMSC to improve communication with health researchers regarding monitoring method issues and to monitoring agencies regarding ongoing and planned research efforts.

Appendix G: Preliminary Survey of Ambient Air Monitoring Sites Currently Being Considered in EPA-funded Epidemiology Studies Feb 2008

Preliminary Survey of Ambient Air Monitoring Sites Currently Being Considered in EPA-funded Epidemiology Studies Feb 2008

for more information, contact Sascha Lodge, lodge.sascha@epa.gov; (202) 343-9769

PLEASE NOTE: Colors signify that a given monitor is being used by multiple researchers. There is no distinction between blue and orange. For example, four researchers are using the Bakersfield (CA) monitor, three researchers are using the El Cajon (CA) monitor, and only one researcher is using the Phoenix (AZ) monitor.

State	City	County	Site Name	State Code	County Code	Site ID	Priority	Address	Mon Objective1	Mon Objective2	Latitude	Longitude	Parameters Measured	Researcher Name	Organization/Affiliation	Duration of Study
STN Sites																
Alabama	Birmingham	Jefferson	NULL	01	73	0023	Medium				33.553056	-86.815000		Kaz Ito	NYU	
Arizona	Phoenix	Maricopa	PHOENIX SUPERSITE	04	013	9997	High				33.503643	-112.095001		Kaz Ito	NYU	
California	Bakersfield	Kern	FLAT TERRAIN,OIL REFINERY 1.3 MI NNW,TRAIN 1.4 MI N,FREEWAY 1.3 MI E	06	029	0014	Medium	5558 California Ave; Bakersfield	Population Exposure		35.356111	-119.040278	if available NO2 OZ PM10 PM25 PM25species	Bart Ostro	CA OEHHA	For time-series and case-crossover, the longer into the future, the better the analyses.
California	Bakersfield	Kern	FLAT TERRAIN,OIL REFINERY 1.3 MI NNW,TRAIN 1.4 MI N,FREEWAY 1.3 MI E	06	029	0014	High				35.356111	-119.040278		Antonella Zanobetti	Harvard University	2000-2003
California	Bakersfield	Kern	FLAT TERRAIN,OIL REFINERY 1.3 MI NNW,TRAIN 1.4 MI N,FREEWAY 1.3 MI E	06	029	0014	High				35.356111	-119.040278		Kaz Ito	NYU	
California	Bakersfield	Kern	FLAT TERRAIN,OIL REFINERY 1.3 MI NNW,TRAIN 1.4 MI N,FREEWAY 1.3 MI E	06	029	0014	High				35.356111	-119.040278		Kaz Ito	NYU	

California	El Cajon	San Diego	NULL	06	073	0003	Medium	1155 Redwood Ave.; El Cajon	Population Exposure		32.791389	-116.941667	if available NO2 OZ PM10 PM25 PM25species	Bart Ostro	CA OEHHA	For time-series and case-crossover, the longer into the future, the better the analyses.
California	El Cajon	San Diego	NULL	06	073	0003	High				32.791389	-116.941667		Antonella Zanobetti	Harvard University	2000-2003
California	El Cajon	San Diego	NULL	06	073	0003	High				32.791389	-116.941667		Kaz Ito	NYU	
California	Riverside	Riverside	Mira Loma	06	065	8005	High	5130 Poinsettia Place	Other		33.995638	-117.493304	PM2.5, PM10	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
California	Rubidoux (West Riverside)	Riverside	NULL	06	065	8001	Medium	5888 Mission Blvd.; Rubidoux	Population Exposure		33.999580	-117.416010	if available NO2 OZ PM10 PM25 PM25species	Bart Ostro	CA OEHHA	For time-series and case-crossover, the longer into the future, the better the analyses.
California	Rubidoux (West Riverside)	Riverside	Riverside-Rubidoux	06	065	8001	High	5888 Mission Blvd., Rubidoux	Population Exposure (Riverside-San Bernardino, CA)		33.99958	-117.41601	PM2.5, PM10, SO2, NO2, Oz, CO	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
California	Rubidoux (West Riverside)	Riverside	NULL	06	065	8001	High				33.999580	-117.416010		Antonella Zanobetti	Harvard University	2000-2003
California	Rubidoux (West Riverside)	Riverside	NULL	06	065	8001	High				33.999580	-117.416010		Kaz Ito	NYU	
California	Rubidoux (West Riverside)	Riverside	NULL	06	065	8001	High				33.999580	-117.416010		Kaz Ito	NYU	
California	Sacramento	Sacramento	NULL	06	067	0006	Medium	Del Paso-2701 Avalon Dr; Sacramento	Population Exposure		38.614167	-121.366944	if available NO2 OZ PM10 PM25 PM25species	Bart Ostro	CA OEHHA	For time-series and case-crossover, the longer into the future, the better the analyses.
California	Sacramento	Sacramento	NULL	06	067	0006	High				38.614167	-121.366944		Antonella Zanobetti	Harvard University	2000-2003
California	Sacramento	Sacramento	NULL	06	067	0006	High				38.614167	-121.366944		Kaz Ito	NYU	

California	San Jose	Santa Clara	SAN JOSE JACKSON ST	06	085	0005	Medium	156B Jackson Street; San Jose	Population Exposure		37.348500	-121.895000	if available NO2 OZ PM10 PM25 PM25species	Bart Ostro	CA OEHHA	For time-series and case-crossover, the longer into the future, the better the analyses.
California	San Jose	Santa Clara	SAN JOSE JACKSON ST	06	085	0005	High				37.348500	-121.895000		Kaz Ito	NYU	
California	Simi Valley	Ventura	NULL	06	111	2002	High				34.277500	-118.684722		Kaz Ito	NYU	
Colorado	Commerce City	Adams	ALSUP ELEMENTARY SCHOOL-COMMERCE CITY	08	001	0006	High				39.825739	-104.936987		Kaz Ito	NYU	
Connecticut	New Haven	New Haven	NULL	09	009	0027	High				41.301111	-72.902778		Kaz Ito	NYU	
District Of Columbia	Washington	District of Columbia	MCMILLAN PAMS	11	001	0043	High				38.918889	-77.012500		Kaz Ito	NYU	
Florida	Davie	Broward	NULL	12	011	1002	High				26.082778	-80.237778		Kaz Ito	NYU	
Florida	Plant City	Hillsborough	SYDNEY	12	057	3002	High				27.965650	-82.230400		Kaz Ito	NYU	
Georgia	Decatur	DeKalb	2390-B WILDCAT ROAD, DECATUR, GA	13	089	0002	High				33.688007	-84.290325		Kaz Ito	NYU	
Idaho	Meridian	Ada	NULL	16	001	0010	Medium				43.607568	-116.348434		Kaz Ito	NYU	
Illinois	Chicago	Cook	Lawndale Comm-Ed	17	031	0076	High	7801 Lawndale	Population Exposure (Chicago, IL Northwestern Indiana)		41.751369	-87.713745	PM2.5, SO2, NO2, Oz	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
Illinois	Chicago	Cook	COM ED MAINTENANCE BLDG	17	031	0076	High				41.751369	-87.713745		Kaz Ito	NYU	
Illinois	Chicago	Cook	COM ED MAINTENANCE BLDG	17	031	0076	High				41.751369	-87.713745		Antonella Zanobetti	Harvard University	2000-2003
Indiana	Indianapolis	Marion	IN PARKING LOT NEXT TO POLICE STATION	18	097	0078	High				39.811097	-86.114469		Kaz Ito	NYU	

Kansas	Kansas City	Wyandotte	JFK	20	209	0021	Medium				39.117500	-94.635556		Kaz Ito	NYU	
Kansas	Kansas City	Wyandotte	JFK	20	209	0021	High				39.117500	-94.635556		Antonella Zanobetti	Harvard University	2000-2003
Louisiana	Baton Rouge	East Baton Rouge	NULL	22	033	0009	Medium				30.461111	-91.176944		Kaz Ito	NYU	
Maryland	Essex	Baltimore	Essex	24	005	3001	High	Woodward And Franklin Roads Essex	Population Exposure (Baltimore, MD)		39.310833	-76.474444	PM2.5, SO2, NO2, Oz, CO	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
Maryland	Essex	Baltimore	ESSEX	24	005	3001	High				39.310833	-76.474444		Kaz Ito	NYU	
Massachusetts	Boston	Suffolk	DUDLEY SQUARE ROXBURY	25	025	0042	High				42.329444	-71.082778		Kaz Ito	NYU	
Massachusetts	Boston	Suffolk	DUDLEY SQUARE ROXBURY	25	025	0042	High				42.329444	-71.082778		Antonella Zanobetti	Harvard University	2000-2003
Massachusetts	Chicopee	Hampden	NULL	25	013	0008	High				42.194460	-72.555711		Kaz Ito	NYU	
Michigan	Allen Park	Wayne	NULL	26	163	0001	High				42.228611	-83.208333		Kaz Ito	NYU	
Michigan	Detroit	Wayne		26	163	0001	High				42.228333	-83.209167		Antonella Zanobetti	Harvard University	2000-2003
Minnesota	Minneapolis	Hennepin	Phillips	27	053	0963	High	2727 10th St. Minneapolis	Population Exposure (Minneapolis-St. Paul, MN)		44.955396	-93.25827	PM2.5	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
Minnesota	Minneapolis	Hennepin	ANDERSON SCHOOL - PHILLIPS NEIGHBORHOOD	27	053	0963	High				44.955396	-93.258270		Kaz Ito	NYU	
Minnesota	Minneapolis	Hennepin	ANDERSON SCHOOL - PHILLIPS NEIGHBORHOOD	27	053	0963	High				44.955396	-93.258270		Antonella Zanobetti	Harvard University	2000-2003

Mississippi	Gulfport	Harrison	BEHIND HARRISON COUNTY YOUTH COURT	28	047	0008	High				30.390139	-89.049722		Kaz Ito	NYU	
Missouri	St. Louis	St Louis (City)	BLAIR STREET CATEGORY A CORE SLAM PM2.5.	29	510	0085	High				38.656300	-90.198100		Antonella Zanobetti	Harvard University	2000-2003
Missouri	St. Louis	St. Louis City	BLAIR STREET CATEGORY A CORE SLAM PM2.5.	29	510	0085	High				38.656300	-90.198100		Kaz Ito	NYU	
Montana	Missoula	Missoula	NULL	30	063	0031	Medium				46.874912	-113.995253		Kaz Ito	NYU	
Nebraska	Omaha	Douglas	NULL	31	055	0019	High				41.247222	-95.975556		Kaz Ito	NYU	
Nevada	Reno	Washoe	NULL	32	031	0016	Medium				39.525083	-119.807717		Kaz Ito	NYU	
New Jersey	Elizabeth	Union	ELIZABETH LAB	34	039	0004	High				40.641440	-74.208360		Kaz Ito	NYU	
New Jersey	North Brunswick (Township of)	Middlesex	NEW BRUNSWICK	34	023	0006	High				40.472790	-74.422510		Kaz Ito	NYU	
New York	New York	Bronx	I.S. 52	36	005	0110	High	E 156th St Bet Dawson And Kelly	Population Exposure (New York, NY-Northeastern New Jersey)		40.81616	-73.90207	PM2.5, SO2, NO2, Oz	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
New York	New York	Bronx	IS 52	36	005	0110	High				40.816160	-73.902070		Kaz Ito	NYU	
North Carolina	Charlotte	Mecklenburg	Garinger High School	37	119	0041	High				35.240278	-80.785556	NO2 OZ PM10 CO	Adel Hanna	University Of Noth Carolina	01/01/06 - 12/21/2008
North Carolina	Charlotte	Mecklenburg	Garinger High School	37	119	0041	High				35.240278	-80.785556		Kaz Ito	NYU	
North Dakota	Fargo	Cass	FARGO NW	38	017	1004	High				46.933754	-96.855350		Kaz Ito	NYU	
Ohio	Cleveland	Cuyahoga	GT CRAIG	39	035	0060	High				41.493955	-81.678542		Kaz Ito	NYU	

Ohio	Cleveland	Cuyahoga	GT CRAIG	39	035	0060	High				41.493955	-81.678542		Antonella Zanobetti	Harvard University	2000-2003
Oklahoma	Tulsa	Tulsa	NORTH TULSA - FIRE STATION#24 AT 36TH AND PEORIANR	40	143	1127	High				36.204902	-95.976537		Kaz Ito	NYU	
Oregon	Portland	Multnomah	NULL	41	051	0080	High				45.496667	-122.602222		Kaz Ito	NYU	
Pennsylvania	Philadelphia	Philadelphia	AMS Laboratory	42	101	0004	High				40.008889	-75.097778		Kaz Ito	NYU	
Pennsylvania	Philadelphia	Philadelphia	AMS Laboratory	42	101	0004	High				40.008889	-75.097778		Antonella Zanobetti	Harvard University	2000-2003
Pennsylvania	Pittsburgh	Allegheny	NULL	42	003	0008	High				40.465556	-79.961111		Kaz Ito	NYU	
Pennsylvania	Pittsburgh	Allegheny	NULL	42	003	0008	High				40.465556	-79.961111		Antonella Zanobetti	Harvard University	2000-2003
Rhode Island	Providence	Providence	BUILDING ROOFTOP	44	007	0022	High				41.807949	-71.415000		Kaz Ito	NYU	
South Carolina	Charleston	Charleston	CHARLESTON PUBLIC WORKS	45	019	0049	High				32.790984	-79.958694		Kaz Ito	NYU	
Tennessee	Knoxville	Knox	NULL	47	093	1020	Medium				36.019440	-83.873610		Kaz Ito	NYU	
Texas	Dallas	Dallas	DALLAS HINTON	48	113	0069	High				32.819952	-96.860082		Kaz Ito	NYU	
Texas	Dallas	Dallas	DALLAS HINTON	48	113	0069	High				32.819952	-96.860082		Antonella Zanobetti	Harvard University	2000-2003
Texas	Deer Park	Harris	NW OF W. LAMBUTH & DURANT INTERSECTION	48	201	1039	High				29.670046	-95.128485		Kaz Ito	NYU	
Texas	Deer Park	Harris	NW OF W. LAMBUTH & DURANT INTERSECTION	48	201	1039	High				29.670046	-95.128485		Antonella Zanobetti	Harvard University	2000-2003
Texas	El Paso	El Paso	CHAMIZAL	48	141	0044	High				31.765673	-106.455225		Kaz Ito	NYU	
Texas	El Paso	El Paso	CHAMIZAL	48	141	0044	High				31.765673	-106.455225		Antonella Zanobetti	Harvard University	2000-2003

Utah	Salt Lake City	Salt Lake	UTM COORDINATES = PROBE LOCATION	49	035	3006	High				40.736389	-111.872222		Kaz Ito	NYU	
Vermont	Burlington	Chittenden	ZAMPIERI STATE OFFICE BUILDING, CORNER OF CHERRY STREET	50	007	0012	Medium				44.480278	-73.214444		Kaz Ito	NYU	
Virginia	Not in a city	Henrico	NULL	51	087	0014	High				37.558333	-77.400278		Kaz Ito	NYU	
Washington	Seattle	King	BEACON HILL	53	033	0080	High				47.570273	-122.308596		Kaz Ito	NYU	
Washington	Seattle	King	BEACON HILL	53	033	0080	High				47.570273	-122.308596		Antonella Zanobetti	Harvard University	2000-2003
Washington	Seattle	King	Beacon Hill	53	033	0080	High	4103 Beacon Ave. S.	Population Exposure (Seattle-Tacoma-Bellevue, WA)		47.570273	-122.308596	PM2.5, SO2, NO2, Oz, CO	Tim Larson	Univ. of Wash.	7/1/2008 - 6/30/2009
West Virginia	Not in a city	Kanawha	NULL	54	039	0011	Medium				38.448611	-81.683889		Kaz Ito	NYU	
Wisconsin	Milwaukee	Milwaukee	DNR SER HQRS SITE	55	079	0026	High				43.061111	-87.912500		Kaz Ito	NYU	
SLAMS																
California	Escondido	San Diego	NULL	06	073	1002	Medium	600 E. Valley Pkwy.; Escondido	Population Exposure		33.127778	-117.074167	if available NO2 OZ PM10 PM25 PM25species	Bart Ostro	CA OEHHA	For time-series and case-crossover, the longer into the future, the better the analyses.
California	Fresno	Fresno	NULL	06	019	0008	Medium	3425 N First St; Fresno	Population Exposure		36.781389	-119.772222	if available NO2 OZ PM10 PM25 PM25species	Bart Ostro	CA OEHHA	For time-series and case-crossover, the longer into the future, the better the analyses.
California	Fresno	Fresno		06	019	0008	High				36.781389	-119.772222		Antonella Zanobetti	Harvard University	2000-2003

California	Los Angeles	Los Angeles	NULL	06	037	1103	Medium	1630 N Main St; Los Angeles	Population Exposure		34.066590	-118.226880	if available NO2 OZ PM10 PM25 PM25species	Bart Ostro	CA OEHHA	For time-series and case-crossover, the longer into the future, the better the analyses.
California	Los Angeles	Los Angeles		06	037	1103	High				34.06659	-118.22688		Antonella Zanobetti	Harvard University	2000-2003
California	Los Angeles	Los Angeles	Los Angeles-North Main Street	06	037	1103	High	1630 N Main St, Los Angeles	Population Exposure (Los Angeles-Long Beach,CA MSA)		34.06659	-118.22688	PM2.5, PM10, SO2, NO2, Oz, CO	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
California	Sacramento	Sacramento	NULL	06	067	0010	Medium	1309 T St.; Sacramento	Population Exposure		38.558333	-121.491944	if available NO2 OZ PM10 PM25 PM25species	Bart Ostro	CA OEHHA	For time-series and case-crossover, the longer into the future, the better the analyses.
Illinois	Chicago	Cook	Springfield Pump Station	17	031	0057	Medium	1745 N. Springfield	Population Exposure (Chicago, IL Northwestern Indiana)		41.914733	-87.722725	PM2.5	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
Illinois	Northbrook	Cook	Northbrook Water Plant	17	031	4201	High	750 Dundee Road	Population Exposure (Chicago, IL Northwestern Indiana)		42.14	-87.799167	PM2.5, PM10, SO2, NO2, Oz, CO	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
Missouri	Not in a city	Clay		29	047	0005	High				39.303056	-94.376389		Antonella Zanobetti	Harvard University	2000-2003
New York	Rochester	Monroe	Rochester 2	36	055	1007	High	Yarmouth Rd (RG&E Substation)	Population exposure		43.146198	-77.54813	PM2.5, SO2, CO, O3	Philip Hopke	Clarkson University	6/2006 to 12/2009

North Carolina	Asheville	Buncombe	BOARD OF ED BLDG NW CORNER PARKING LOT	37	021	0034	Medium				35.609722	-82.350833	NO2 OZ PM10 CO	Adel Hanna	University of North Caroliana	01/01/06 - 12/21/2008
North Carolina	Raleigh	Wake	NULL	37	183	0014	High				35.856111	-78.574167	NO2 OZ PM10 CO	Adel Hanna	University of North Caroliana	01/01/06 - 12/21/2008
North Carolina	Winston-Salem	Forsyth	Hattie Avenue	37	067	0022	High	1300 Blk. Hattie Avenue	Population Exposure (Winston-Salem, NC)		36.110556	-80.226667	PM2.5, PM10, SO2, NO2, Oz	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
Ohio	Akron	Summit		39	153	0023	High				41.088056	-81.541667		Antonella Zanobetti	Harvard University	2000-2003
Ohio	Columbus	Franklin		39	049	0081	High				40.087778	-82.959722		Antonella Zanobetti	Harvard University	2000-2003
Ohio	Toledo	Lucas		39	095	0026	High				41.620556	-83.641389		Antonella Zanobetti	Harvard University	2000-2003
Pennsylvania	Erie	Erie		42	049	0003	High				42.14175	-80.038611		Antonella Zanobetti	Harvard University	2000-2003
Pennsylvania	Harrisburg	Dauphin		42	043	0401	High				40.245	-76.844722		Antonella Zanobetti	Harvard University	2000-2003
Washington	Seattle	King		53	033	0057	High				47.563333	-122.338333		Antonella Zanobetti	Harvard University	2000-2003
Other network sites																
CA	Azusa	Los Angeles	Azusa	06	037	0002	Low	803 N. Loren Ave., Azusa	HIGHEST CO	OTHER	34.1365	-117.923	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA		Los Angeles		06	037	0016	Low				34.1443	-117.85	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014

CA		Los Angeles		06	037	0031	Low		OTHER	POPULATION	33.7861	-118.246	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA		Los Angeles		06	037	0113	Low				34.0511	-118.456	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Burbank	Los Angeles	Burbank	06	037	1002	Low	228 W. Palm Ave., Burbank	GENERAL/ BA	OTHER	34.176	-118.317	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Los Angeles	Los Angeles		06	037	1103	Low		HIGHEST CO	OTHER	34.0665	-118.226	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Reseda	Los Angeles	Reseda	06	037	1201	Low	18330 Gault St., Reseda	OTHER	POPULATION	34.1992	-118.532	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Lynwood	Los Angeles	Lynwood	06	037	1301	High	11220 Long Beach Blvd., Lynwood	Population Exposure (Los Angeles, CA)		33.92899	-118.21071	PM2.5, NO2, Oz, CO	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Pico Rivera	Los Angeles	Pico Rivera #1	06	037	1601	Low		HIGHEST CO	MAX PRECUR	34.014	-118.06	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Pico Rivera	Los Angeles	Pico Rivera #2	06	037	1602	High	4144 San Gabriel River Pkwy, Pico Rivera	Population Exposure (Los Angeles, CA)		34.01407	-118.06995	PM2.5, NO2, Oz, CO	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA		Los Angeles		06	037	1701	Low				34.067	-117.751	NOx	Joel Kaufman	Univ. of Wash. project	8/1/2004 - 7/31/2014

CA	Pasadena	Los Angeles	Pasadena	06	037	2005	High	752 S. Wilson Ave., Pasadena	Population Exposure (Los Angeles, CA)		34.1326	-118.1272	PM2.5, NO2, Oz, CO	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Long Beach	Los Angeles	North Long Beach (Long Beach)	06	037	4002	Low	3648 N. Long Beach Blvd., Long Beach	HIGHEST CO	OTHER	33.8237	-118.189	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Long Beach	Los Angeles	South Long Beach	06	037	4004	Low	1305 E. Pacific Coast Hwy., Long Beach	OTHER		33.7923	-118.175	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA		Los Angeles		06	037	5001	Low		MAX OZONE	POPULATION	33.9228	-118.37	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA		Los Angeles		06	037	5005	Low		UPWIND BAC		33.9508	-118.43	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA		Los Angeles		06	037	6012	Low		OTHER	POPULATION	34.3834	-118.528	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA		Los Angeles		06	037	9002	Low		POPULATION		34.69	-118.131	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Lancaster	Los Angeles		06	037	9033	Low	43301 Division St., Lancaster, Ca	POPULATION		34.6713	-118.13	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA		Orange		06	059	0001	Low		OTHER	POPULATION	33.8306	-117.938	PM, NOx	Joel Kaufman	Univ. of Wash. project	8/1/2004 - 7/31/2014

CA	Anaheim	Orange	Anaheim-Loara School	06	059	0007	Low	1630 W. Pampas Lane	POPULATION		33.8306	-117.938	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Riverside	Orange	Riverside-Magnolia	06	059	1003	Low	7002 Magnolia Ave., Riverside			33.6746	-117.925	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Mission Viejo	Orange	Mission Viejo	06	059	2022	Low	26081 Via Pera, Mission Viejo, Ca 92691	OTHER	POPULATION	33.63	-117.675	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Palm Springs	Orange		06	059	5001	Low	Fs-590 Racquet Club Ave, Palm Springs	POPULATION		33.9251	-117.952	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA		Riverside		06	065	0012	Low		POPULATION	UPWIND BAC	33.9208	-116.858	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Riverside	Riverside	Riverside-Magnolia	06	065	1003	Low	7002 Magnolia Ave., Riverside	HIGHEST CO	OTHER	33.946	-117.4	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Indio	Riverside		06	065	2002	Low	46-990 Jackson St., Indio	OTHER	POPULATION	33.7085	-116.215	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Palm Springs	Riverside		06	065	5001	Low	Fs-590 Racquet Club Ave, Palm Springs	OTHER	POPULATION	33.8527	-116.541	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Rubidoux (West Riverside)	Riverside	Big Bear	06	065	8001	Low	501 W. Valley Blvd., Big Bear City	HIGHEST CO	OTHER	33.9995	-117.416	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA		Riverside		06	065	9001	Low		POPULATION		33.6764	-117.33	NOx	Joel Kaufman	Univ. of Wash. project	8/1/2004 - 7/31/2014

CA		San Bernardino		06	071	0001	Low		POPULATION	REGIONAL T	34.895	-117.023	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Ontario	San Bernardino	Ontario-Fire Station	06	071	0025	Low	1408 Francis St.	OTHER	POPULATION	34.0372	-117.69	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Victorville	San Bernardino		06	071	0306	Low	14306 Park Ave., Victorville, Ca	POPULATION	REGIONAL T	34.51	-117.33	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA		San Bernardino		06	071	1004	Low		GENERAL/ BA	HIGHEST CO	34.1037	-117.629	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Fontana	San Bernardino	Fontana-Arrow Highway	06	071	2002	Low	14360 Arrow Blvd., Fontana	HIGHEST CO	OTHER	34.1	-117.492	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	San Bernardino	San Bernardino	San Bernardino	06	071	9004	Low	24302 4th St., San Bernardino, Ca	HIGHEST CO	OTHER	34.1068	-117.274	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Thousand Oaks	Ventura		06	111	0007	Low	2323 Moorpark Road, Thousand Oaks	OTHER	POPULATION	34.21	-118.869	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Piru	Ventura		06	111	0009	Low	3301 Pacific Avenue, Piru, Ca 93040	OTHER	POPULATION	34.4046	-118.81	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA		Ventura		06	111	1004	Low		OTHER	POPULATION	34.4483	-119.23	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	Simi Valley	Ventura		06	111	2002	Low	5400 Cochran Street, Simi Valley	HIGHEST CO	OTHER	34.2775	-118.684	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014

CA		Ventura		06	111	2003	Low		GENERAL/ BA	POPULATIO N	34.2804	-119.313	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CA	El Rio	Ventura		06	111	3001	Low	Rio Mesa School, El Rio	GENERAL/ BA	HIGHEST CO	34.255	-119.142	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		Fairfield		09	001	0010	Low		GENERAL/ BA	HIGHEST CO	41.1708	-73.1947	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		Fairfield		09	001	0113	Low		HIGHEST CO	OTHER	41.1836	-73.1902	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		Fairfield		09	001	1123	Low		POPULATI ON		41.3991	-73.443	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		Fairfield		09	001	2124	Low		HIGHEST CO	POPULATIO N	41.063	-73.5288	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		Fairfield		09	001	3005	Low		HIGHEST CO	POPULATIO N	41.1125	-73.4072	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		Fairfield		09	001	9003	Low		GENERAL/ BA	POPULATIO N	41.1183	-73.3366	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		Hartford		09	003	1003	Low		GENERAL/ BA	HIGHEST CO	41.7847	-72.6316	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		New Haven		09	009	0018	Low		HIGHEST CO	OTHER	41.2938	-72.9013	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		New Haven		09	009	0026	Low		POPULATI ON		41.2911	-72.8941	PM	Joel Kaufman	Univ. of Wash. project	8/1/2004 - 7/31/2014

CT		New Haven		09	009	0027	Low		GENERAL/ BA	HIGHEST CO	41.3011	-72.9027	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		New Haven		09	009	1123	Low		HIGHEST CO	OTHER	41.3108	-72.9169	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		New Haven		09	009	2008	Low		POPULATION		41.3313	-72.9197	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		New Haven		09	009	2123	Low		HIGHEST CO	OTHER	41.5505	-73.0436	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
CT		New Haven		09	009	9005	Low		HIGHEST CO	MAX PRECUR	41.3411	-72.9213	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
DE		Kent		10	001	0002	Low	State Road 384, Killens Pond Rd	GENERAL/ BA	OTHER	38.9847	-75.5555	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
DE	Dover	Kent		10	001	0003	Low	Water St. Dover	POPULATION		39.155	-75.518	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
DE	Bellefonte	New Castle		10	003	1003	Low	River Road Park	HIGHEST CO	POPULATION	39.7611	-75.4919	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
DE		New Castle		10	003	1007	Low	Lums Pond State Park	OTHER	POPULATION	39.5511	-75.7308	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
DE	Newark	New Castle		10	003	1012	Low	Univ. Del. North Campus	OTHER	POPULATION	39.6919	-75.7616	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
DE	Wilmington	New Castle		10	003	2004	Low	Mlk Blvd And	HIGHEST	OTHER	39.7394	-75.558	PM, NOx	Joel	Univ. of project	8/1/2004 - 7/31/2014

DE	Seaford	Sussex		10	005	1002	Low	350 Virginia Ave Seaford	OTHER	POPULATION	38.6444	-75.613	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
DC		District of Columbia		11	001	0025	Low		POPULATION		38.9752	-77.0227	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
DC		District of Columbia		11	001	0041	Low		HIGHEST CO	POPULATION	38.8972	-76.9527	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
DC		District of Columbia		11	001	0042	Low		GENERAL/ BA	HIGHEST CO	38.8808	-77.0325	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
DC		District of Columbia		11	001	0043	Low		HIGHEST CO	MAX OZONE	38.9188	-77.0125	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Chicago	Cook	Farr Dormitory	17	031	0014	Low	3300 S Michigan Ave	POPULATION		41.8342	-87.6238	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Chicago	Cook	Washington	17	031	0022	Medium	3535 E. 114th St.	Population Exposure (Chicago, IL Northwestern Indiana)		41.689195	-87.539318	PM2.5	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014

IL	Chicago	Cook	S.E. Chicago	17	031	0050	Medium	103rd And Luella	Source Oriented (Chicago, IL Northwestern Indiana), Population Exposure (Chicago, IL Northwestern Indiana)		41.709561	-87.568576	PM2.5, SO2	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Chicago	Cook	Mayfair Pumping Stn.	17	031	0052	Medium	4850 Wilson Ave.	Population Exposure (Chicago, IL Northwestern Indiana), Highest Concentration (Chicago, IL Northwestern Indiana)		41.967429	-87.749819	PM2.5, PM10	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Chicago	Cook	Springfield Pump Station	17	031	0057	Low	1745 N. Springfield	POPULATION		41.9147	-87.7227	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL		Cook		17	031	0063	Low		HIGHEST CO	POPULATION	41.8772	-87.6344	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL		Cook		17	031	0075	Low		POPULATI		41.9641	-87.6586	NOx	Joel	Univ. of project	8/1/2004 - 7/31/2014

IL	Chicago	Cook	Lawndale Comm-Ed	17	031	0076	Low	7801 Lawndale	GENERAL/ BA	HIGHEST CO	41.7513	-87.7137	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Mccook	Cook		17	031	1016	Low	50th St. And Glencoe	HIGHEST CO	POPULATIO N	41.8011	-87.8319	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Blue Island	Cook		17	031	2001	Medium	12700 Sacramento	Population Exposure (Chicago, IL Northwester n Indiana)		41.663997	-87.696468	PM2.5, PM10	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Schiller Park	Cook		17	031	3103	Low	4743 Mannheim Rd.	HIGHEST CO	POPULATIO N	41.9652	-87.8763	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Summit	Cook		17	031	3301	Low	60th St. & 74th Ave.	POPULATI ON		41.7827	-87.8052	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL		Cook		17	031	4002	Low		HIGHEST CO	POPULATIO N	41.8552	-87.7524	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Des Plaines	Cook		17	031	4007	High	9511 W. Harrison St	Population Exposure (Chicago, IL Northwester n Indiana)		42.060278	-87.863333	PM2.5, Oz	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Northbrook	Cook	Northbrook Water Plant	17	031	4201	Low	750 Dundee Road	MAX OZONE	POPULATIO N	42.14	-87.7991	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Cicero	Cook		17	031	6005	Low	13th St. &	POPULATI		41.8642	-87.7488	PM	Joel	Univ. of project	8/1/2004 - 7/31/2014

IL		Cook		17	031	8003	Low		POPULATION		41.6313	-87.568	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Naperville	DuPage	City Hall	17	043	4002	Low	400 S. Eagle St.	POPULATION		41.7711	-88.1525	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL	Elgin	Kane		17	089	0003	Low	258 Lovell St.	POPULATION		42.0502	-88.2802	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL		Lake		17	097	1007	Low	Illinois Beach State Park	EXTREME DO	HIGHEST CO	42.4675	-87.81	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL		McHenry		17	111	0001	Low		POPULATION		42.2214	-88.242	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL		Will		17	197	1002	Low		HIGHEST CO	POPULATION	41.5266	-88.1163	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IL		Will		17	197	1011	Low		GENERAL/ BA	POPULATION	41.2215	-88.1909	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN		Gibson		18	051	0010	Low				38.2762	-87.5529	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN		Hendricks		18	063	0001	Low	Cr 800 N And Cr 275 E	HIGHEST CO	OTHER	39.8769	-86.4738	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN		Hendricks		18	063	0002	Low	206 N. Meridian St.	HIGHEST CO	OTHER	39.8633	-86.4707	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN	Pittsboro	Hendricks		18	063	0003	Low	High School,	HIGHEST	OTHER	39.8808	-86.5421	NOx	Joel	Univ. of project	8/1/2004 - 7/31/2014

IN	East Chicago	Lake		18	089	0006	High	Franklin School Alder & 142nd St	HIGHEST CO	POPULATION	41.6361	-87.4408	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN	Gary	Lake		18	089	0022	High	201 Mississippi St., Iitri Bunker	HIGHEST CO	POPULATION	41.6066	-87.3047	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN	Gary	Lake		18	089	0026	High	25th And Burr Street	HIGHEST CO	POPULATION	41.573	-87.4058	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN	Griffith	Lake		18	089	0027	High	Ready Eldon School, 1345 N. Broad St.	POPULATION		41.5466	-87.4263	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN	Gary	Lake		18	089	1003	High	Ivanhoe School 15th & Gerry Sts	POPULATION		41.5888	-87.4077	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN		Lake		18	089	1016	High		HIGHEST CO	POPULATION	41.6002	-87.3347	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN	Hammond	Lake		18	089	2004	High	Purdue Univ Calumet-Powers Building 6937	POPULATION		41.5852	-87.4744	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN	Hammond	Lake		18	089	2010	High	1921 Davis St., Robertsdale, Clark H.S.	POPULATION		41.6783	-87.5083	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN	Indianapolis	Marion		18	097	0073	Low	Naval Avionics Center, 6125 E. 16th St.	HIGHEST CO	OTHER	39.7891	-86.0608	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
															project	

IN	Ogden Dunes (Wickliffe)	Porter		18	127	0024	Low	84 Diana Rd/ Water Treatment Plant	HIGHEST CO	POPULATION	41.6175	-87.1991	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN		St. Joseph		18	141	1008	Low		OTHER	POPULATION	41.6936	-86.2366	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN		Spencer		18	147	0008	Low				37.9811	-87.0325	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IN	Evansville	Vanderburgh		18	163	0012	Low	425 West Mill Road/ Fire Station #17	HIGHEST CO	OTHER	38.0216	-87.5694	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA	Waterloo	Black Hawk		19	013	0008	Low		HIGHEST CO	POPULATION	42.493	-92.3438	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA		Cerro Gordo		19	033	0019	Low		OTHER	POPULATION	43.1616	-93.2083	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA	Clinton	Clinton		19	045	0021	Low	Roosevelt St.	OTHER	POPULATION	41.8749	-90.1774	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA		Emmet		19	063	0003	Low		GENERAL/ BA	POPULATION	43.3975	-94.8172	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA	Iowa City	Johnson		19	103	2001	Low	2200 East Court	POPULATION		41.6573	-91.5034	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA	Cedar Rapids	Linn		19	113	0033	Low	408 E. Linn St. Coggon, Iowa	POPULATION		42.2805	-91.5269	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
															project	

IA	Cedar Rapids	Linn		19	113	0037	Low	1599 Wenig Rd Ne	POPULATION		42.0083	-91.6786	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA	Muscatine	Muscatine		19	139	0015	Low	1409 Wisconsin	POPULATION		41.4008	-91.0677	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA	Emmetsburg	Palo Alto		19	147	1002	Low	Iowa Lakes Community College	GENERAL/BA	POPULATION	43.1233	-94.6933	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA	Des Moines	Polk		19	153	0030	Low	1907 Carpenter, Des Moines Iowa	OTHER	POPULATION	41.603	-93.643	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA		Polk		19	153	0058	Low		POPULATION		41.6077	-93.5719	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA	Des Moines	Polk		19	153	0059	Low	Se 18th And Scott, National By-Products	HIGHEST CO	OTHER	41.5833	-93.5838	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA	Clive	Polk		19	153	2510	Low	9401 Indian Hills Drive, Clive 50325	OTHER	POPULATION	41.6027	-93.7477	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA		Polk		19	153	2520	Low		OTHER	POPULATION	41.6647	-93.6141	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA	Davenport	Scott		19	163	0014	Medium	Scott County Park	GENERAL/BA	POPULATION	41.6991	-90.5219	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
															project	

IA	Davenport	Scott		19	163	0018	Medium	3029 N Division St. Davenport	POPULATION		41.55	-90.6	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA	Davenport	Scott		19	163	0019	Medium	300 Wellman St. Davenport	POPULATION	SOURCE ORI	41.5177	-90.6186	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA		Story		19	169	2530	Low		OTHER	POPULATION	42.0413	-93.6138	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
IA	Clarion	Wright		19	197	0004	Low	2446 Quincy Ave. Clarion	GENERAL/BA	POPULATION	42.6953	-93.6559	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD		Anne Arundel	Davidsonville Family Recreation Center	24	003	0014	High	Queen Anne And Wayson Roads	POPULATION		38.9025	-76.653	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Fort Meade (U.S. Army)	Anne Arundel		24	003	0019	Low	9001 'Y'Street,Ft.Meade	GENERAL/BA	POPULATION	39.1011	-76.7294	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Glen Burnie	Anne Arundel		24	003	1003	High	7409 Balto And Annapolis Blvd	POPULATION		39.1695	-76.6279	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Riviera Beach	Anne Arundel		24	003	2002	Low	8515 Jenkins Rd Riviera Beach	GENERAL/BA	POPULATION	39.1597	-76.5116	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Cockeysville	Baltimore		24	005	1007	High	Padonia E.S. 9834 Greenside Dr. Cockeysv	GENERAL/BA	HIGHEST CO	39.4608	-76.6311	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Essex	Baltimore		24	005	3001	High	600 Dorsey Avenue,	HIGHEST CO	MAX PRECUR	39.3108	-76.4744	PM, NOx	Joel Kaufman	Univ. of Wash. Air	8/1/2004 - 7/31/2014

MD		Cecil		24	015	0003	Low	4600 Telegraph Road, Fairhill, Cecil Co.	POPULATION		39.7011	-75.86	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Edgewood	Harford		24	025	1001	High	Edgewood Army Chem Center, Waehli Road	HIGHEST CO	POPULATION	39.41	-76.2966	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Rockville	Montgomery		24	031	3001	Medium	Lathrop E. Smith Env.Ed Center , 5110 Me	POPULATION		39.1144	-77.1069	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Beltsville	Prince George's		24	033	0030	Medium	Howard University'S Beltsville Laborator	GENERAL/BA	HIGHEST CO	39.0552	-76.8783	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Greater Upper Marlboro	Prince George's		24	033	8003	Medium	P.G. Co. Equestrian Cntr, 14900 Pennsylv	POPULATION		38.8119	-76.7441	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Hagerstown	Washington		24	043	0009	Low	18530 Roxbury Road, Hagerstown	POPULATION		39.5655	-77.7219	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Baltimore	Baltimore	NEPS	24	510	0006	Medium	N E Police Sta, 1900 Argonne Dr, Balto	Population Exposure (Baltimore, MD)		39.340556	-76.582222	PM2.5	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Baltimore	Baltimore	NWPS	24	510	0007	Medium	N W Police Station 5700 Reistertown Rd.	Population Exposure (Baltimore, MD)		39.344444	-76.685278	PM2.5	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Baltimore	Baltimore	SEPS	24	510	0008	Medium	S E Police	Population		39.28768	-76.547616	PM2.5	Joel	Univ. of Air	8/1/2004 - 7/31/2014

MD	Baltimore	Baltimore (City)		24	510	0035	High	Fmc Corp. 1701 E Patapsco Avenue	GENERAL/ BA	HIGHEST CO	39.2327	-76.5797	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Baltimore	Baltimore	Oldtown	24	510	0040	Medium	Old Town Fire Station 1100 Hillen Street	Population Exposure (Baltimore, MD)		39.298056	-76.604722	PM2.5	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MD	Baltimore	Baltimore (City)		24	510	0049	High		POPULATION		39.2616	-76.6375	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	Blaine	Anoka		27	003	1002	High	Anoka County Airport 2289 Co. Rd. J	GENERAL/ BA	POPULATION	45.1397	-93.2076	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	Cloquet	Carlton		27	017	7416	Low	175 University Rd	GENERAL/ BA	POPULATION	46.7052	-92.5236	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN		Dakota		27	037	0020	High	12821 Pine Bend Trail	POPULATION	SOURCE ORI	44.7653	-93.0324	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	Rosemount	Dakota		27	037	0423	High	2142 120th Street East	POPULATION	SOURCE ORI	44.775	-93.0627	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	Apple Valley	Dakota		27	037	0470	High	225 Garden View Drive	HIGHEST CO	OTHER	44.7407	-93.2372	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN		Dakota		27	037	6018	Low		POPULATION	REGIONAL T	44.75	-92.8877	PM	Joel Kaufman	Univ. of Wash. MESA Air	8/1/2004 - 7/31/2014
															project	

MN	Minneapolis	Hennepin	Richfield	27	053	0961	High	7020 12th Ave S, Minneapolis, Mn	POPULATION		44.8775	-93.2588	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	Minneapolis	Hennepin	Phillips	27	053	0963	High	2727 10th St. Mpls	POPULATION	WELFARE RE	44.9553	-93.2582	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	Minneapolis	Hennepin		27	053	1007	High	4646 Humboldt Ave. N.	POPULATION	SOURCE ORI	45.0418	-93.2987	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	St. Louis Park	Hennepin	St. Louis Park	27	053	2006	High	5005 Minnetonka Blvd.	POPULATION		44.95	-93.3428	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN		Mille Lacs		27	095	3051	Low	Hcr 67 Box 194	POPULATION	REGIONAL T	46.207	-93.7594	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	Rochester	Olmsted		27	109	5008	Medium	1801 9th Ave S. E. Rochester, Mn 55904	GENERAL/ BA	HIGHEST CO	43.9969	-92.4503	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN		Ramsey		27	123	0864	Low		POPULATION		44.9919	-93.183	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	St. Paul	Ramsey	Red Rock Road	27	123	0866	Medium	1450 Red Rock Road, St. Paul, Mn	Highest Concentration (Minneapolis-St. Paul, MN)		44.899379	-93.017155	PM2.5, PM10	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	St. Paul	Ramsey	St Paul Health Centre	27	123	0868	Medium	555 Cedar Street	Population Exposure		44.952442	-93.098475	PM2.5, PM10	Joel Kaufman	Univ. of Wash. Air	8/1/2004 - 7/31/2014

MN	St. Paul	Ramsey	Harding High School	27	123	0871	Medium	1540 East 6th Street	Population Exposure (Minneapolis-St. Paul, MN)		44.961451	-93.035894	PM2.5	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN		Ramsey		27	123	0872	Low		POPULATION		44.9311	-93.156	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	Virginia	Saint Louis		27	137	7001	Low	City Hall Roof	POPULATION		47.5233	-92.5363	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	Duluth	Saint Louis		27	137	7550	Low	1202 East University Circle	POPULATION		46.8201	-92.0894	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	Duluth	Saint Louis		27	137	7551	Low	2424 W 5th St	HIGHEST CO	POPULATION	46.7666	-92.133	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	Shakopee	Scott		27	139	0505	High	917 Dakota St., Shakopee, Mn 55379	POPULATION		44.7914	-93.5125	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MN	St. Cloud	Stearns		27	145	3052	Low	1321 Michigan Ave, St. Cloud Mn 56304	POPULATION		45.5498	-94.1334	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
MO		Mercer		29	129	0001	Low		OTHER	SOURCE ORI	40.56	-93.4183	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ	Fort Lee	Bergen	Fort Lee Library	34	003	0003	High	Fort Lee Library,Center Avenue	POPULATION		40.8516	-73.9733	PM	Joel Kaufman	Univ. of Wash. MESA Air	8/1/2004 - 7/31/2014
															project	

NJ	Pennsauken (Pensauken)	Camden		34	007	1007	Low	Pennsauken Twp; Morris-Delair Wtp	HIGHEST CO	POPULATION	39.9888	-75.0491	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ	Newark	Essex		34	013	0015	High	Mary Willis Cultural Ctr, 18th Av,Newark	POPULATION		40.7319	-74.2052	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ	Jersey City	Hudson		34	017	1003	High	355 Newark Ave,Consolidated Fire House	HIGHEST CO	POPULATION	40.7254	-74.0522	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ	Lawrence (Township Of)	Mercer		34	021	0005	Low	Rider College;Lawrence Township	HIGHEST CO	MAX OZONE	40.283	-74.7426	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ	Trenton	Mercer		34	021	0008	Low	120 Academy Street, Trenton Public Libr.	HIGHEST CO	POPULATION	40.2222	-74.7636	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ		Mercer		34	021	8001	Low	Washington Crossing State Park	POPULATION	REGIONAL T	40.3124	-74.8726	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ	North Brunswick (Township Of)	Middlesex		34	023	0006	Medium	Cook College, Log Cabin Road	HIGHEST CO	POPULATION	40.4727	-74.4225	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ	East Brunswick (Township Of)	Middlesex		34	023	0011	Medium	R.U. Veg Research Farm 3,Ryders Ln, Newb	GENERAL/ BA	POPULATION	40.4621	-74.4294	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ	Morristown	Morris		34	027	0004	High	16 Early St, Morristown	POPULATION		40.803	-74.4833	PM	Joel Kaufman	Univ. of Wash. MESA Air	8/1/2004 - 7/31/2014
															project	

NJ	Paterson	Passaic		34	031	0005	High	Health Department 176 Broadway	POPULATION		40.9186	-74.1677	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ	Elizabeth	Union		34	039	0004	High	New Jersey Turnpike Interchange 13	HIGHEST CO	POPULATION	40.6414	-74.2083	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ	Elizabeth	Union		34	039	0006	High	Mitchell Building,600 North Broad Street	HIGHEST CO	POPULATION	40.673	-74.2136	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ	Rahway	Union		34	039	2003	High	Rahway Fire Dept, 1300 Main Street	POPULATION		40.606	-74.2749	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NJ	Phillipsburg	Warren		34	041	0006	High	Pburg Municipal Bldg, 675 Corliss Ave	POPULATION		40.6872	-75.1813	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY	New York	Bronx	Morrisania	36	005	0080	Medium	Morrisania Center, 1225-57 Gerard Ave.	Population Exposure (New York, NY-Northeastern New Jersey)		40.83608	-73.92021	PM2.5	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY	New York	Bronx	NY Botanical Gardens	36	005	0083	Medium	200th Street And Southern Blvd	Population Exposure (New York, NY-Northeastern New Jersey)		40.86586	-73.88075	PM2.5, SO2, NO2, CO	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
															project	

NY		Dutchess		36	027	1004	Low		OTHER	POPULATION	41.6948	-73.9144	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY		Kings		36	047	0052	Low		HIGHEST CO	OTHER	40.6415	-74.0183	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY		Kings		36	047	0076	Low		OTHER	POPULATION	40.6718	-73.9782	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY	New York	Kings		36	047	0122	High	Jhs 126 424 Leonard St	POPULATION		40.7198	-73.9478	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY	East Meadow	Nassau		36	059	0005	Low	Eisenhower Park,Merrick Av&Old Country R	GENERAL/BA	HIGHEST CO	40.7432	-73.5854	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY	Cedarhurst	Nassau		36	059	0008	Low	Lawrence High School,Arlington Place	POPULATION		40.631	-73.7347	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY		Nassau		36	059	0012	Low		OTHER	POPULATION	40.789	-73.6364	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY		Nassau		36	059	0013	Low		OTHER	POPULATION	40.7607	-73.4906	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY		New York		36	061	0010	High		HIGHEST CO	OTHER	40.7394	-73.9861	PM	Joel Kaufman	Univ. of Wash. MESA Air	8/1/2004 - 7/31/2014
															project	

NY	New York	New York		36	061	0062	High	Post Office,350 Canal Street	GENERAL/ BA	HIGHEST CO	40.7205	-74.004	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY	New York	New York	JHS 45	36	061	0079	Medium	School Is 45, 2351 1st Avenue	Population Exposure (New York, NY-Northeastern New Jersey)		40.79937	-73.93334	PM2.5	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY	New York	New York		36	061	0128	High	Ps 19 185 1st Avenue	POPULATION		40.73	-73.9844	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY	Newburgh	Orange		36	071	0002	Low	55 Broadway	GENERAL/ BA	POPULATION	41.4994	-74.0097	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY		Queens		36	081	0094	Low		OTHER	POPULATION	40.7779	-73.8431	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY		Queens		36	081	0096	Low		OTHER	POPULATION	40.7703	-73.8284	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY		Queens		36	081	0097	Low		GENERAL/ BA	OTHER	40.7552	-73.7586	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY		Queens		36	081	0098	Low		GENERAL/ BA	SOURCE ORI	40.7842	-73.8475	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY	New York	Queens	Queens College 2	36	081	0124	High	14439 Gravett Road	GENERAL/ BA	OTHER	40.7362	-73.8231	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air	8/1/2004 - 7/31/2014
															Air	

NY	New York	Richmond		36	085	0067	High	Susan Wagner Hs, Brielle Ave.& Manor Rd,	GENERAL/ BA	POPULATIO N	40.5973	-74.1261	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY		Suffolk		36	103	0001	Low		POPULATI ON		40.7458	-73.4202	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NY	Mamaronec k	Westcheste r		36	119	1002	High	5th Avenue & Madison, Thruway Exit 9	POPULATI ON		40.93	-73.7692	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Burlington	Alamance		37	001	0002	High	827 S Graham & Hopedale Rd	EXTREME DO	POPULATIO N	36.089	-79.4078	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Black Mountain	Buncombe		37	021	0034	Medium	175 Bingham Road Asheville Nc	POPULATI ON		35.6097	-82.3508	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC		Caswell		37	033	0001	Low	7074 Cherry Grove Rd, Reidsville	GENERAL/ BA	POPULATIO N	36.307	-79.4674	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC		Chatham		37	037	0004	Medium	Rt 4 Box 62	GENERAL/ BA	POPULATIO N	35.7572	-79.1597	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Fayetteville	Cumberlan d		37	051	0009	Medium	4533 Raeford Rd	POPULATI ON		35.0414	-78.9531	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Durham	Durham		37	063	0001	Medium	Health Dept, 300 E Main	HIGHEST CO	POPULATIO N	35.9919	-78.8963	PM	Joel Kaufman	Univ. of Wash.	8/1/2004 - 7/31/2014
															project	

NC	Rocky Mount	Edgecombe		37	065	0004	Medium	900 Springfield Road	GENERAL/BA	POPULATION	35.9335	-77.75	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Winston-Salem	Forsyth	North Forsyth H.S.	37	067	0024	Low	North Forsyth High School	POPULATION		36.1713	-80.2819	{shut down Jan. '06}	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Winston-Salem	Forsyth	Clemmons	37	067	0030	High	Fraternity Church Road	Population Exposure (Winston-Salem, NC)		36.026	-80.342	PM2.5, Oz	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC		Guilford		37	081	0009	Low		POPULATION		36.0758	-79.7944	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Greensboro	Guilford	Mendenhall	37	081	0013	Low	205 Wiloughby Blvd	Population Exposure (Greensboro, NC), General/Background (Greensboro, NC)		36.109167	-79.801111	PM2.5, PM10, Oz	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Charlotte	Mecklenburg		37	119	0041	Medium	1130 Eastway Drive	OTHER	POPULATION	35.2402	-80.7855	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Spruce Pine	Mitchell		37	121	0001	Low	City Hall Summit St	GENERAL/BA	POPULATION	35.9152	-82.0733	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Candor	Montgomery		37	123	0001	Low	112 Perry Drive,	GENERAL/BA	POPULATION	35.26	-79.84	PM	Joel Kaufman	Univ. of Wash.	8/1/2004 - 7/31/2014
															project	

NC	Lumberton	Robeson		37	155	0005	Low	1170 Linkhaw Road	GENERAL/ BA	POPULATIO N	34.6425	-78.9902	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Raleigh	Wake		37	183	0014	Medium	3801 Spring Forest Rd.	GENERAL/ BA	MAX OZONE	35.8561	-78.5741	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC		Wake		37	183	0015	Low		POPULATI ON		35.79	-78.6197	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Boone	Watauga		37	189	0003	Low	361 Jefferson Road, Boone	EXTREME DO	GENERAL/B A	36.2219	-81.663	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
NC	Goldsboro	Wayne		37	191	0005	Medium	Dillard Middle School, Devereau St	POPULATI ON		35.3692	-77.9938	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
Ohio	Dayton	Montgomer y		39	113	0031	High				39.759444	-84.144444		Antonella Zanobetti	Harvard University	2000-2003
PA		Adams		42	001	0001	Low		EXTREME DO	POPULATIO N	39.92	-77.31	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Berks		42	011	0009	Low		HIGHEST CO	OTHER	40.3202	-75.9266	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Bucks		42	017	0012	Low		OTHER	POPULATIO N	40.1072	-74.8822	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Chester		42	029	0100	Low		POPULATI ON	REGIONAL T	39.8344	-75.7686	PM	Joel Kaufman	Univ. of Wash.	8/1/2004 - 7/31/2014
															project	

PA		Dauphin		42	043	0401	Low		HIGHEST CO	OTHER	40.245	-76.8447	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Delaware		42	045	0002	Low		HIGHEST CO	OTHER	39.8355	-75.3725	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Lackawanna		42	069	2006	Low		HIGHEST CO	OTHER	41.4427	-75.623	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Lancaster		42	071	0007	Low		HIGHEST CO	OTHER	40.0466	-76.2833	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Lehigh		42	077	0004	Low		OTHER	POPULATION	40.6119	-75.4325	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Luzerne		42	079	1101	Low		OTHER	POPULATION	41.2655	-75.8463	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Montgomery		42	091	0013	Low		OTHER	POPULATION	40.1122	-75.3091	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Northampton		42	095	0025	Low		OTHER	POPULATION	40.628	-75.3411	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Perry		42	099	0301	Low		GENERAL/BA	POPULATION	40.4569	-77.1655	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Philadelphia		42	101	0004	Low		HIGHEST CO	POPULATION	40.0088	-75.0977	PM	Joel Kaufman	Univ. of Wash.	8/1/2004 - 7/31/2014
															project	

PA		Philadelphia		42	101	0024	Low		POPULATION		40.0763	-75.0119	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Philadelphia		42	101	0047	Low		HIGHEST CO	POPULATION	39.9447	-75.1661	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		Philadelphia		42	101	0136	Low		HIGHEST CO	POPULATION	39.9275	-75.2227	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
PA		York		42	133	0008	Low		HIGHEST CO	OTHER	39.9652	-76.6994	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
SC		Chesterfield		45	025	0001	Low		GENERAL/ BA	POPULATION	34.6171	-80.1987	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
SC		Florence		45	041	0002	Low		OTHER	POPULATION	34.1676	-79.8504	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
SC		Greenville		45	045	0008	Low		OTHER	POPULATION	34.8404	-82.4029	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
SC		Greenville		45	045	0009	Low		GENERAL/ BA	OTHER	34.901	-82.313	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
SC		Greenwood		45	047	0003	Low		OTHER	POPULATION	34.2145	-82.1731	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
SC		Lexington		45	063	0008	Low		GENERAL/	OTHER	34.0528	-81.1549	PM	Joel	Univ. of	8/1/2004 - 7/31/2014
															project	

SC		Richland		45	079	0019	Low		OTHER	POPULATION	33.9932	-81.0241	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
SC		Spartanburg		45	083	0010	Low		OTHER	POPULATION	34.9268	-82.0052	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
Texas	Port Arthur	Jefferson		48	245	0022	High				29.863889	-94.317778		Antonella Zanobetti	Harvard University	2000-2003
VA		Arlington		51	013	0020	Low		POPULATION		38.8575	-77.0591	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
VA		Fairfax		51	059	0030	Low		GENERAL/BA	HIGHEST CO	38.7727	-77.1055	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
VA		Fairfax		51	059	1005	Low		POPULATION		38.8375	-77.1632	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
VA		Fairfax		51	059	5001	Low		POPULATION		38.9319	-77.1988	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
VA		Loudoun		51	107	1005	Low		POPULATION		39.0244	-77.49	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI		Dane		55	025	0025	Low		HIGHEST CO	POPULATION	43.0819	-89.3766	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI	Madison	Dane		55	025	0047	Low	City Well #6, 2557	HIGHEST CO	POPULATION	43.0733	-89.4358	PM	Joel Kaufman	Univ. of Wash.	8/1/2004 - 7/31/2014
															Air	

WI		Douglas		55	031	0025	Low		HIGHEST CO		46.7302	-92.0797	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI		Grant		55	043	0009	Low	128 Hwy 61, Potosi Township	POPULATION	REGIONAL T	42.6921	-90.6863	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI		Jefferson		55	055	0008	Low		HIGHEST CO		43.1838	-88.9941	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI	Pleasant Prairie	Kenosha		55	059	0019	High	Chiwaukee Prairie, 11838 First Court	GENERAL/ BA	HIGHEST CO	42.5047	-87.8093	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI	Milwaukee	Milwaukee		55	079	0010	Medium	Health Center, 1337 So 16th St	OTHER	POPULATIO N	43.0166	-87.9333	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI	Milwaukee	Milwaukee		55	079	0026	Medium	Dnr Ser Hdqrts, 2300 N M. L. King Jr Dr	HIGHEST CO	MAX PRECUR	43.0611	-87.9125	PM, NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI	Milwaukee	Milwaukee		55	079	0041	Medium	Uwm North Campus, 2114 E Kenwood Blvd	HIGHEST CO	MAX PRECUR	43.0752	-87.8844	NOx	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI	Milwaukee	Milwaukee		55	079	0043	Medium	Virginia Fire Station, 100 W Virginia St	POPULATION	SOURCE ORI	43.0264	-87.9111	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI		Milwaukee		55	079	0050	Low		POPULATI		43.0977	-88.0077	PM	Joel	Univ. of	8/1/2004 - 7/31/2014
															project	

WI	Milwaukee	Milwaukee		55	079	0059	Medium	Federal Aviation Adm, 4942 S 16th St	GENERAL/ BA	HIGHEST CO	42.955	-87.9341	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI	Milwaukee	Milwaukee		55	079	0099	Medium	Milw Fire Dept Hq, 711 W Wells St	HIGHEST CO	POPULATIO N	43.0397	-87.9205	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI	Grafton	Ozaukee		55	089	0008	Medium	Grafton, Hwy32 And I43	HIGHEST CO	POPULATIO N	43.343	-87.9208	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI		Ozaukee		55	089	0009	Medium	Harrington Beach State Park, 531 Hwy D	GENERAL/ BA	HIGHEST CO	43.498	-87.81	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI	Somerset	St. Croix		55	109	1002	High	Hwy 64, Somerset Town Hall	POPULATI ON	REGIONAL T	45.1244	-92.6625	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI		Sauk		55	111	0007	Low	Devils Lake State Park, E12886 Tower Rd	GENERAL/ BA	OTHER	43.4355	-89.6802	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI		Taylor		55	119	8001	Low	1 Mi E. Perkinstown On Sr.M	GENERAL/ BA	POPULATIO N	45.2038	-90.6	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI	Waukesha	Waukesha		55	133	0027	Medium	1310 Cleveland Ave	HIGHEST CO	OTHER	43.0202	-88.215	PM	Joel Kaufman	Univ. of Wash. MESA Air project	8/1/2004 - 7/31/2014
WI		Waukesha		55	133	0034	Low		POPULATI ON		43.0072	-88.2297	PM	Joel Kaufman	Univ. of Wash.	8/1/2004 - 7/31/2014
															project	

United States Environmental Protection Agency

Office of Air Quality Planning and Standards
Health and Environmental Impacts Division
Research Triangle Park, NC

Publication No. EPA 452/S-08-001
December 2008