Executive Summary

The Detroit Exposure and Aerosol Research Study

The goal of the Office of Research and Development's exposure program is to develop data and models that characterize and predict human exposure to particulate matter (PM) of ambient origin relative to that measured at central sites. Research was initiated in 1997 with a focus on susceptible sub-populations and PM mass to address these issues listed under the National Research Council's (NRC) Research Topic 1. Longitudinal PM exposure studies were conducted to characterize inter-personal and intra-personal variability in exposure to PM mass, and to describe the relationship between personal exposures and ambient exposure estimates based on central site monitoring. Results from these studies have verified that for fine PM mass and sulfate, the central monitoring site should serve as an adequate surrogate for exposure in community-based epidemiological studies. Differences between ambient levels and estimates of personal exposure should not change the conclusions regarding epidemiological-based health outcomes, although the strength of the association has been shown to vary by location, housing characteristics, and season. Since individuals are typically exposed to lower levels of ambient PM than would be predicted by central site monitors, the strength of the impact may be underestimated. In addition, since the ratio of personal exposure concentrations to central site concentrations (i.e., the attenuation factor) can change by city and season, a single nationwide PM standard may provide varying degrees of protection for different populations. Recent studies have not shown significant differences in personal exposure to ambient PM as a result of disease-state.

Evaluating exposure relationships for the causal agents of PM toxicity is addressed in the NRC Research Topic 2. Although substantial research has been conducted to understand the mechanisms of PM toxicity and to identify causal agents, specific toxic agents have not yet been identified. However, there is evidence that supports health effects associated with most of the originally hypothesized toxic agents. Concurrently, several epidemiological studies have shown health effects associated with PM from specific sources. In light of these findings, emphasis is now being placed on understanding both the exposure to and health effects from PM from specific sources. Source apportionment techniques are being incorporated into exposure research in order to evaluate the ambient-personal exposure relationship for PM from various sources as well as for individual PM species. Linking specific sources through central site concentrations and human exposures to health effects is likely to provide data that can be applied to regulatory policy more quickly, and can help support identification of biologically important characteristics and constituents as well.

The Detroit Exposure Aerosol Research Study (DEARS) is an important step in the U.S. EPA's National Exposure Research Laboratory's (NERL) Exposure Research Program. The study builds upon the results from previous longitudinal panel studies with several very important differences. The DEARS will examine the spatial variability of $PM_{2.5}$ and its components to determine the suitability of conducting health outcome studies using a central site monitor in an urban area like Detroit where there are many point

sources. Source apportionment techniques will be used to evaluate the relationship between PM and air toxics from specific sources. The DEARS is designed to look at and quantify the impact of local ambient sources on the relationship between central site monitors and exposures. Results from this study will be critical in providing exposure data for developing future standards.

Six objectives have been defined for this study.

(1) To determine the associations between concentrations measured at central site monitors and outdoor residential, indoor residential and personal exposures for selected air toxics, PM constituents, and PM from specific sources.
(2) To describe the physical and chemical factors that affect the relationship between central site monitors and outdoor residential and indoor residential concentrations, including those that affect ambient source impacts.
(3) To identify the human activity factors that influence personal exposures to selected PM constituents and air toxics.
(4) To improve and evaluate models used to characterize and estimate residential concentrations of and human exposures to selected air toxics, PM constituents, and PM from specific sources.
(5) To investigate and apply source apportionment models to evaluate the relationships for PM from specific sources and to determine the contribution of specific ambient sources to residential concentrations and personal exposures to PM constituents and air toxics.
(6) To determine the associations between ambient concentrations of criteria gases (O_3, NO_2, and SO_2) and personal exposures for these gases as well as personal exposures to air toxics, PM constituents, and PM from specific sources.

The DEARS is a three-year field monitoring study that will be conducted in Detroit, Michigan and is designed to measure exposure and describe exposure relationships for air toxics, PM components, PM from specific sources, and criteria pollutants. Detroit, Michigan was considered the best candidate for this study because of its current and projected future non-attainment status for $PM_{2.5}$, the number of point and mobile source influences present, its geographic location, meteorology, ambient monitoring networks, potential state and local collaborations, and community-based partnerships.

There are a large number of industrial point sources of PM and air toxics in the Detroit area, including coke ovens, iron/steel manufacturing, coal-fired power plants, sewage sludge incineration, automotive industry, refineries, and chemical plants. The border crossing between Windsor, Canada and Detroit via the Ambassador Bridge also provides a large diesel and automotive source from idling motor vehicles. There are 4 major interstates and many heavily traveled roadways, which will serve as line sources of vehicle emissions in Detroit and surrounding Wayne County.

Monitoring will focus primarily on the residence. Study participants and households will be identified through a step-wise approach involving identifying census blocks with and without impacts from local point and/or mobile sources based on prevailing wind

direction and then targeting individual households for recruitment into the study. Individual census tracts and blocks will be identified by evaluating available data on the location and emissions from various sources, ambient air concentrations and housing stock. Once census tracts/blocks are identified we will work through existing community action groups in Detroit and the surrounding area to assist with contacting individual households. Partnering with community groups will be important in making connections with residents and communicating the purpose of the study. Selection criteria for participants are: (1) non-smoker, (2) living in a non-smoking household, (3) ambulatory, (4) able to read and write English, (5) plan to be in the same dwelling for the next 9 months, (6) living in a detached home, and (7) age 18 or older.

Residences will be selected based on proximity to sources. Residences in seven ambient source-impacted areas (mobile sources, point sources, and a control) will be monitored for 5 days in each of 2 seasons (summer, winter). A total of 120 residences will be monitored over 3 years for a total of 1200 household-person/days. A combination of both weekday and weekend sampling will be conducted in order to evaluate expected variations in industrial source emissions, traffic volumes, and personal activities. A Speciation Trends Network site, Allen Park, has been selected as the central site monitor for this study. In addition, one residential outdoor location will be selected each week to serve as a secondary, or rotating, community site. These data will be used to determine how representative the primary and secondary community measures (Allen Park and the selected residential outdoor sites) are relative to all other outdoor locations. Monitoring is anticipated to start in the summer of 2004.

Measurements will include personal, residential indoor, residential outdoor, and central site monitoring for $PM_{2.5}$ (by integrated 24-hr filters and real-time portable nephelometers), volatile organic compounds (VOCs), and carbonyls. All $PM_{2.5}$ filters will be analyzed for mass, elemental carbon (EC), selected elements, and sulfate as sulfur. Since participants cannot carry a large number of personal monitors, some pollutants will only be measured indoors, outdoors, and at the central monitoring site. These include PM_{coarse}, nitrates, selected semi-volatile organic compounds (SVOCs), and EC/OC as collected on quartz filters. The criteria gases will only be measured in central site and personal exposure samples. Survey information will be collected on household characteristics, heating and air conditioning system operation, local ambient sources, indoor and personal sources, and time-activity patterns. The monitoring plan is summarized in Table 1.

Results from the DEARS will be used to determine if central site measurements for air toxics and PM species can be used as exposure surrogates in community-based epidemiological studies. We will be able to determine if proximity to mobile or stationary sources has an impact on these relationships. The DEARS data will be used to calculate infiltration factors, penetration rates and removal rates for different chemicals and different housing conditions. The impact of climate (summer vs. winter seasons) on these factors will also be evaluated. The time-activity and real-time $PM_{2.5}$ data will be used to determine the impact of spending time in non-residential locations and personal

activities on exposure. This will be critical in understanding the importance of commuting and work place activities on exposures.

The reliability of a central community monitor to predict the concentrations of PM, PM components, and air toxics is currently unknown. The DEARS data will be used to develop models which will provide the tools needed to predict exposures. The DEARS modeling analysis will answer many important questions relating to the feasibility of using a central site monitor to evaluate health outcomes in urban areas impacted by point and mobile sources. Results from this study may determine whether ambient monitoring data should be used in human health risk assessments and for setting future air quality standards.

Table 1. Summary of measurements to be performed in DEARS.

Parameter	Species	Personal	Indoor Res.	Outdoor Res.	Central Site
$PM_{2.5}$ (mass)	Elements: Ni, V, Mn, S, K, Fe, Zn, Si, Al	X	X	X	X
PM_{coarse} (mass)		--	X	X	X
EC-OC ($PM_{2.5}$)		--	X	X	X
EC ($PM_{2.5}$)		X	X	X	X
Nitrate		--	X	X	X
Gases	O_3, SO_2, NO_2	X	--	--	X
Carbonyls	acrolein, formaldehyde acetaldehyde	X	X	X	X
VOCs	MTBE, benzene, toluene, xylene,1,3 butadiene, ethyl benzene	X	X	X	X
SVOCs	norhopane, hopane, homohopane, bishomohopane, alkanes (C_{23} to C_{34}), levoglucosan, hexadecanoic acid, hexadecenoic acid, octadecanoic acid, octadecenoic acid	--	X	X	X
PAHs	pyrene, chrysene/triphenylenen, benzo[k]fluoranthene, benzo[b]fluoranthene, benzo[a]pyrene, indeno[1,2,3-cd]pyrene, benzo[ghi]perylene	--	X	X	X
Air Exchange Rate		--	X	--	--