

California Environmental Protection Agency



Air Resources Board

**PLANNED AIR POLLUTION
RESEARCH**

Fiscal Year 2004-2005

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Summary

This report presents the Air Resources Board's planned air pollution research for the fiscal year 2004-2005. Twenty-six projects are proposed. Twenty-two projects are recommended for funding and four are recommended if funding is available. This research portfolio is organized into five main areas of research: Environmental Justice, Health and Welfare Effects, Exposure Assessment, Technology Advancement and Pollution Prevention, and Global Air Pollution. This annual plan proposes research in these five areas, with a primary emphasis on particulate matter health effects, and exposure assessment and control of particulate matter. The proposed budget for the recommended projects is \$6,116,000.

Introduction

The Air Resources Board (ARB) sponsors a comprehensive program of research addressing the causes, effects, and possible solutions to air pollution problems in California, and provides support for establishing ambient air quality standards. The Board's research program was established by the Legislature in 1971 (Health and Safety Code Sections 39700 et seq.) to develop a better understanding of the various aspects of air pollution, including air pollution's effects on health and the environment, the atmospheric reactions and transport of pollutants, and the inventory and control of air polluting emissions. In recent years, several legislative mandates have expanded and further defined the scope of the program.

The ARB's mission to protect California's public health, welfare, and ecological resources is supported through a Strategic Plan for Research covering the years 2001-2010. The Strategic Plan is based on the ARB's regulatory priorities for the next several years and provides direction for the ARB's research program. The four main areas of research identified in the Strategic Plan are: Health and Welfare Effects, Exposure Assessment, Technology Advancement and Pollution Prevention, and Global Air Pollution. They are also the categories that guide this plan. These areas encompass the comprehensive mission of ARB's air pollution research. A copy of the Strategic Plan can be found at <http://www.arb.ca.gov/research/apr/apr.htm>.

An additional category of unique concern and included in this document is Environmental Justice. Senate Bill 115 (Solis, 1999) and the ARB's Environmental Justice Policies and Actions, adopted in December 2001, require all ARB programs, including research, to incorporate environmental justice to the extent possible. This plan has four specific projects that focus on the fair treatment and protection for all people regardless of race, color, national origin, or income with respect to the effects of air pollution.

The proposed research projects are not intended to be exhaustive or exclusive. Unanticipated opportunities, unique or innovative study approaches, or urgency may lead to consideration of other projects.

Objective of the Research Program. The goal of the research program is to provide the timely scientific and technical information that will allow the Board and local districts to make the public policy decisions necessary to implement an effective air pollution control program in California.

Process for Developing this Research Plan. The Board sends out a public solicitation inviting and encouraging the public to contribute ideas for project consideration. Members of the public, the academic community, and ARB staff submit research ideas. To aid in the evaluation, the Board's Executive Officer established internal committees to review research ideas. Proposed projects were examined for relevance to regulatory questions facing the Board and modified as necessary. Committee members then prioritized candidate projects in order of urgency and importance. The Board's scientific external

review committee, the Research Screening Committee (RSC), which was established by the Health and Safety Code, reviewed these candidate projects. The list of projects, along with comments from the RSC, were forwarded to the Executive Research Review Committee, whose members are the Executive Officer, her three deputies, and the Chief of the Research Division. The Executive Research Review Committee reviewed all of the proposed projects and established project priorities. Selected projects are then placed into two categories: 1) those that are recommended for funding, and 2) those that are recommended if funding is available. The Research Screening Committee reviewed the selected projects and recommended the Plan to the Board.

Implementation of the Plan. The next step for projects approved in the plan will be their development into full research projects. The submission and selection of an idea does not guarantee a resulting contract for the submitter. Rather, the ARB is required to consider public California universities for expertise to execute these projects. If the universities do not possess the expertise, then a public solicitation is issued or a sole source contract is awarded. There is a list serve that individuals can subscribe to for receiving updates on research activities. More information on the list serve can be found at <http://www.arb.ca.gov/listserv/research/research.htm>.

Research Budget. The 22 recommended projects total \$6,116,000. The allocations for the proposed recommended projects among research categories are as follows:

RESEARCH CATEGORY	BUDGET
Environmental Justice	\$1,186,000
Health and Welfare Effects	\$2,275,000
Exposure Assessment	\$1,195,000
Technology Advancement and Pollution Prevention	\$1,300,000
Global Air Pollution	\$ 160,000
TOTAL	\$6,116,000

Project Cosponsorships. The Research Division is continually looking for cofunding opportunities and other ways to leverage the state’s research dollars. This effort allows the ARB to be part of projects and studies that may otherwise be out of the state’s fiscal reach. ARB has had great success in working with other research organizations and has been part of multimillion dollar studies with nominal cash contributions. Several of the projects in this plan have either confirmed or have potential cofunding dollars included in the cost category.

Summaries of Past Research. Ongoing research projects and projects completed since the beginning of 1989 are summarized in the Research Division’s publication, Air Pollution Research, which is available on the World Wide Web at <http://www.arb.ca.gov/research/apr/past/past.htm>

Electronic copies of all of the Research Division’s final reports are available for downloading at the same web site.

Research Project Descriptions

Environmental Justice

Recommended

Air Pollution and Environmental Justice: Integrating Indicators of Cumulative Impact and Socioeconomic Vulnerability into Regulatory Decision Making 10

This project will provide new tools for analyzing the environmental-justice issues involved in permitting new sources of toxic air pollutants. Results will help detect excesses of air-quality burdens in some neighborhoods, explain the reasons for the excesses, characterize the populations that bear the excesses, provide information on the need to change siting and permitting rules to address total local exposure and sensitive populations, and provide an analytical tool that could be used if new rules were adopted. \$718,000

Characterization of Air Pollution Exposures in Economically Disadvantaged and High Traffic Density Neighborhoods in Los Angeles County, California..... 11

This project will monitor air pollution in Los Angeles County neighborhoods with varying levels of economic disadvantage and varying exposures to air pollution originating from vehicular sources. Results will be used to help validate a GIS-based, land-use regression model of air pollution exposure that could be used in subsequent epidemiological studies. \$350,000

Effects of Aircraft Ultrafine Particles on Local Air Pollution..... 12

This project will investigate ultrafine soot particles emitted from aircraft at and in the vicinity of LAX. Results will further the understanding of environmental impacts of aircraft ultrafine particles which will help to uncover the hidden social costs of operating a major airport in urban areas. \$118,000

Recommended if Funding Available

Mobile Monitoring of Community Ultrafine Particulate Matter and Copollutants in Community and Near-Roadway Environments..... 13

This project will extend the mobile monitoring platform approach to more fully characterize in-vehicle and near freeway ultrafine particulate matter as well as copollutant concentrations and ultrafine particle size distributions. Results will provide the first quantitative estimates of Californians' exposure to ultrafines particulate matter and other combustion-related pollutants. \$300,000

Health and Welfare Effects

Recommended

- Cardiovascular Health Effects of Ultrafine Particles During Freeway Travel 14
This project will determine if exposure to ambient air during travel on freeways changes heart rate variability and other noninvasive measures of cardiovascular health and will determine if such changes increase with increasing levels of exposure to ultrafine particles. Results will demonstrate the efficacy of a convenient tool to assess the short-term cardiovascular health impact of travel on freeways. \$665,000
- Effects of Wood Smoke Exposure on Cardiopulmonary Responses in Healthy and Susceptible Humans 15
This project will determine threshold levels of wood-smoke exposure inducing airway inflammation and heart rate variability (HRV) responses in humans and the influence of asthma status on wood smoke-induced changes in airway inflammation and HRV. This project will also identify the biological mechanisms controlling these responses. Results will determine the cardiopulmonary effects of wood smoke and will contribute to appropriate regulation of wood smoke levels in California. \$400,000
- Assessment of the Health Impacts of Particulate Matter from Indoor Sources 16
This project will identify and quantify the impacts of particulate matter (PM) of indoor origin on human health. Results would begin to provide insight regarding the potential type and extent of impacts of indoor PM sources on health and identify whether new epidemiology studies are needed to focus on the sources most responsible for PM impacts. \$400,000
- The Effects of Subchronic Exposures to Ambient Particulate Matter in Mice with Induced Genetic Susceptibility to Coronary Artery Disease 17
This project will determine whether cumulative daily exposures will cause progressive changes in cardiac function in an animal model for a susceptible human population. Results will address the mechanisms by which ambient particles contribute to the development of these diseases. \$300,000
- Effects of Ozone and Nitrogen Dioxide Exposure on Cardiovascular Responses in Healthy and Susceptible Humans 18
This project will determine the acute and subacute effects of ozone and nitrogen dioxide on heart rate variability, airway and systemic inflammation, the renin-angiotensin system, and blood coagulability in healthy and asthmatic humans. Results will determine whether these pollutants can induce systemic changes linked to cardiovascular morbidity and mortality in healthy or potentially susceptible populations. \$400,000

Particle Phase Peroxides: Concentration, Sources, Behavior and Health Effects 19
 This project will investigate a highly oxidizing component of particulate matter, hydrogen peroxide, to determine its sources, prevalence, levels and behavior. Results will provide an understanding of specific types of particulate matter toxicity which is key to devising cost effective control strategies that improve human health. \$110,000

Exposure Assessment

Recommended

Determination of the Spatial and Temporal Variability of Size-resolved PM2.5 Composition and Mixing State in Multiple Regions in California..... 20
 This project will perform particle characterization as well as measure other criteria pollutants in a number of regions of California impacted by PM2.5 including major cities, agricultural areas, and transport sites. Results will provide a better picture of the major sources impacting annual-average PM2.5 violations in California, allowing better control strategies to be established. \$600,000

Development and Demonstration of an Aerosol Tracer Technique Based on Neutron Activation Analysis for Studying Cyclical Deposition and Resuspension of Aerosol-Associated Toxic Compounds..... 21
 This project will develop and demonstrate the feasibility of a new tracer technique capable of detecting and quantifying the movement of surrogate aerosols undergoing cyclical deposition and resuspension. Results will validate a tracer technique of great general value to the study of aerosol and particle transport in both air and water, in particular the identification of sources of aerosol-associated toxic compounds and their fate in the environment. \$75,000

Characterization of Versatile Aerosol Concentration Enrichment System (VACES) 22
 This project will provide further tests to help determine the extent of possible artifacts from the use of VACES. The results will provide improved characterization of the output of the aerosol concentrator. \$80,000

Modeling Studies of Ozone and Particulate Matter Formation from Power Production and During the Ozone “Weekend Effect” 23
 This project will incorporate the state-of-the science for emissions, meteorology, and atmospheric chemistry in modeling studies of the relative impacts of central and distributed power generation and to test hypotheses of factors contributing to the ozone weekend effect. Results will incorporate for the first time heterogeneous chemical processes with updated meteorological and emission fields and will increase our understanding of the ozone and particulate

matter air quality dynamics associated with distributed power generation and the weekend effect in the South Coast Air Basin. \$150,000

- Assessment of Out-of-State Heavy-Duty Truck Activity Trends in California.....24
This project will provide information on out-of-state heavy-duty trucks such as: fueling patterns, quality of the fuel used, vehicle miles traveled, and amount of time spent in California. Results will identify the emission impacts of out-of-state heavy-duty trucks on the California inventory and allow for the development of potential control measures. \$65,000
- Refined Analysis of Activity Patterns Associated with Light-Duty Vehicles.....25
This project will improve activity estimates for light-duty motor vehicles. Results will improve the assumption used in emission models, help generate more accurate emission inventories, and improve modeling studies for assessing control necessary for meeting air quality standards. \$25,000
- Development of Exhaust Speciation Profiles for Commercial Jet Engines26
This project will develop accurate volatile organic compounds and particulate matter speciation profiles for a Boeing 737-type, or similar, modern commercial aviation engine, using modern, commonly used jet aviation fuel. Results will facilitate accurate modeling of commercial jet engine exhaust emissions for ozone precursors, particulate matter, and airborne toxics, as well as informed decision-making during the Environmental Impact Report process for airport expansion projects. \$200,000

Recommended if Funding Available

- Advanced Factor Analysis of Speciation Trends Network (STN) Data for Apportionment of Gasoline and Diesel Emission Contributions.....27
This project will use advanced factor analysis approaches to analyze the data obtained by the STN network and any other comparable data to resolve the sources of PM_{2.5} with a particular emphasis on the separation of gasoline and diesel fueled vehicle emissions. Results will provide an alternative means of resolution from the high cost sampling and analysis for molecular marker compounds. \$120,000
- Nighttime Chemistry: Observations of NO₃ and N₂O₅.....28
This project will document the atmospheric chemistry of NO₃ and N₂O₅ with field observations and provide useful data of immediate value for air quality attainment strategies. Analyses of the data can test the underlying chemical mechanisms that are the core elements of air quality assessment models. \$120,000

Measurement of Ozone Reactivity for Major Pesticide Volatile Organic Compounds (VOCs)	29
<p>This project will develop technically sound ozone reactivity factors for the most commonly used pesticide VOCs in California. Results will improve air quality modeling and assist in State Implementation Plan development. \$100,000</p>	

Technology Advancement and Pollution Prevention

Recommended

Development of In-Field Diesel Particulate Matter Compliance Method for Stationary and Portable Combustion Ignition Engines.....	30
<p>This project will conduct emissions source tests using both ARB Method 5 and the U.S. EPA dilution method on diesel engines at the certification loads. Results will provide a simplified and less expensive emissions test procedure for stationary diesel engines and would benefit the districts in determining compliance with prohibitory rules and to identify dirty engines. \$300,000</p>	

Determine the Population Mix of Off-Road Equipment by Applications and End Users; such as Agriculture, Warehousing, Automotive, Construction Etc.....	31
<p>This project will identify off-road equipment population by applications and end users. Results will provide a better understanding of the impact of preempt engines on California’s emission inventory. \$300,000</p>	

Development of an Improved Test Method for Architectural Coatings	32
<p>This project will develop a unified test method that can determine the Volatile Organic Compounds (VOCs) contents of all types of architectural coatings (including solvent-borne, water-borne, multi-component, and reactive diluent coatings). Results will provide an improved test method for determining the VOC contents of architectural coatings that will improve both the compliance with, and the enforcement of, districts’ coating’s rules. \$250,000</p>	

California Dairies – Evaluation of Covered Lagoons and Digesters for Emission Reductions.....	33
<p>This project will determine the control effectiveness of covered lagoons and digesters used for processing dairy waste and evaluate the cross-media effects of these processes, such as changes in water quality. Results will clarify the efficacy of digesters and covered lagoons in reducing emissions and possibly providing a source of clean electricity generation by burning the dairy waste gases. \$250,000</p>	

Methods to Reduce Fumigant Pesticide Emissions 34
This project will develop application techniques to reduce overall emissions of fumigants. Results will provide a technique to reduce fumigant emission that will significantly decrease Volatile Organic Compound (VOC) emissions in several nonattainment areas and will also reduce exposure to toxic air contaminants. \$200,000

Global Air Pollution

Recommended

Very Long Range Transport – Impacts of Background Ozone and Particulate Matter 35
This project will collect data to assess the current impact of intercontinental pollutant transport across California. Results will provide direct evidence of the spatial and temporal distributions of intercontinental pollutant impact in California and will assist in refining policy decisions regarding control strategies. \$160,000

TITLE: Air Pollution and Environmental Justice: Integrating Indicators of Cumulative Impact and Socioeconomic Vulnerability into Regulatory Decision Making

PROBLEM: The intersection of health disparities and differences in environmental exposures have led policy makers, researchers, and community advocates to exhibit growing concerns about environmental justice. This proposal will advance new methods to examine issues of environmental justice, in particular a framework that takes into account cumulative exposure, considers a fuller model of vulnerability, including both environmental and socioeconomic, and can be used to develop a screening tool by regulators and others to identify areas in need of special policy attention and community outreach.

PREVIOUS WORK: Previous research has established the plausibility of environmental inequity in the state of California and the likelihood that these patterns may play a role in disparate health and other outcomes. Previous work, however, generally does not account for both community-level socioeconomic and environmental vulnerability, deal seriously with issues of spatial clustering and scale, or lead to operational measures that can directly inform policy making.

OBJECTIVES: The objective, by integrating a wide range of databases from federal, state, and air district sources, as well as a micro-level case study, is to: (a) address methodological challenges in assessing cumulative exposure, (b) develop and test a dual model which accounts for environmental and socioeconomic conditions, (c) incorporate dimensions of spatial clustering (or "autocorrelation") to improve predictive power and also experiment with differing scales of analysis, and (d) incorporate both community meetings and community-based participatory research to gain community confidence in the process, and (e) develop screening measures that can be used to guide regulatory action and community outreach.

DESCRIPTION: A wide range of databases will be integrated to create a "riskscape" of California, examining how demographics and degree of segregation impact the statewide pattern. Advanced statistical techniques will be utilized to calculate the degree of spatial autocorrelation and test to see its impact on both estimated explanatory factors and the ability to predict patterns. Broad databases will be validated through a micro-scale study incorporating community-based researchers utilizing geo-positioning devices to incorporate local emitters and local perceptions. A screening tool will be developed to identify communities that may be vulnerable due to socioeconomic and environmental conditions. The tool will be applied to test the effects of scale, particularly buffer size, on the consequences of a hypothetical siting of a power plant, taking into account cumulative conditions and socioeconomics.

BENEFITS: The study will provide a more comprehensive view of environmental justice issues in the state and provide an approach for integrating cumulative impact/risk with measures of socioeconomic vulnerability. It will advance the general state of environmental justice research, particularly its spatial components, in ways that will solidify the base for science-based policy making in this field.

COST: \$718,000 (Under consideration by the California Energy Commission for cofunding)

TITLE: Characterization of Air Pollution Exposures in Economically Disadvantaged and High Traffic Density Neighborhoods in Los Angeles County, California

PROBLEM: There is currently a lack of neighborhood and individual level air pollution measurements for Californian children that live in high traffic density areas and who may be more susceptible to adverse health impacts from air pollution exposure due to economic disadvantage. Epidemiologic studies focused on assessing health impacts in such populations often have to rely on the existing network of air monitoring stations to assess exposures with all the attendant problems of exposure misclassification and limitation to the routinely measured criteria pollutants including particle mass measurements that focus mainly on larger particles. Although efforts have been and are being made to develop reliable models to assess exposures at a finer spatial scale, additional measurements in Los Angeles (LA) communities with varying amounts of major air pollution sources would help inform and validate these models.

PREVIOUS WORK: Previous studies that have focused on children's respiratory health have not specifically focused on economically disadvantaged areas and have not included communities throughout the entire county. Ralph Deflino at UCI performed extensive air pollutant monitoring of asthmatic children living in high traffic density areas of Los Angeles, however the studies were limited in size and geographic area covered.

OBJECTIVE: The objective is to conduct air pollution monitoring in LA County neighborhoods with varying levels of economic disadvantage and varying exposures to air pollution originating from vehicular sources. These monitoring data will be used in an epidemiologic study of outdoor air pollution and asthma in adults and children ages 0-17 years in conjunction with the L.A. FANS study.

DESCRIPTION: The selection of the communities to be monitored will be based on the Los Angeles Family and Neighborhood Survey (L.A.FANS). This NIH-funded study focuses on 65 neighborhoods throughout the county that were randomly selected from three strata of economic deprivation with oversampling for very poor and poor tracts and for families with children. In these communities various pollutants will be measured over one or two-week periods in each season for a one year period. Thus, there will be detailed, neighborhood-level monitoring data for the time period during which asthma outcomes are assessed in the LA FANS children which will be used in analyses of air pollution effects on asthma. The data will also be used in the development of regression models and by other collaborating researchers to inform the development of land use based models of air pollution exposure for use in subsequent epidemiologic studies.

BENEFITS: The findings from this study would help inform policy decisions makers on motor vehicle emissions control and asthma prevention, control and education in low socioeconomic status populations. It would also help in the development of air pollution exposure models that could be used in future epidemiologic studies in LA County focused on different age groups and different adverse health outcomes.

COST: \$350,000

TITLE: Effects of Aircraft Ultrafine Particles on Local Air Pollution

PROBLEM: The Los Angeles Basin has the worst air pollution of U.S. urban areas with approximately nine million motor vehicles traveled in 2000 generating more than 10 tons of PM10 per day. In addition to its roadway traffic, Los Angeles is also home to the third largest airport in the world, the Los Angeles International Airport (LAX). LAX handled more than 56 million passengers and 1.9 million tons of goods in 2002 via more than 1200 aircraft carriers per day. These aircraft carriers release large quantities of emissions, particularly ultrafine soot particles. There is little information available on the extent to which aircraft carriers at LAX contribute to the local air pollution of ultrafine particles.

PREVIOUS WORK: Aircraft emit a substantial amount of ultrafine black carbon (BC) particles. Petzold et al. found that particles from aircraft exhaust are primarily BC in a bimodal distribution emitted at rate of about 0.12 g BC / kg fuel. Romano et al. estimate that aircrafts consume 10 to 34 percent of the fuel carried by international (fuel capacity approximately 160,000 kg) and domestic (fuel capacity approximately 60,000 kg) carriers, respectively, at each cycle of landing and takeoff. This leads to about three tons of BC per day being emitted from aircraft landings and takeoffs at LAX in 2003. Compare that to the 10 tons PM10 per day emitted from motor vehicles across the basin and it is clear that aircraft emissions may play an important role in local air pollution. The aircraft emissions figure is a crude estimate; the issue is largely unstudied, even in recent studies of the air quality management district.

OBJECTIVE: The objective is to comprehensively investigate ultrafine soot particles emitted from aircraft at, and in the vicinity of, LAX. Specific aims include 1) characterizing the source of ultrafine soot particles at LAX; 2) monitoring the particles in the areas around the airport and those under aircraft landing pathways; and 3) differentiating the particles from those emitted from nearby roadways with those from aircraft.

DESCRIPTION: This study will consist of a series of field measurements performed upwind and downwind of the major aircraft operations areas at LAX. Sampling will also be performed in areas where vehicular traffic, both diesel-dominated airport support traffic and roadway traffic may be important. Special emphasis will be placed on time-resolved data collection for black carbon, ultrafine particle counts and size distribution, particle-phase PAH, and combustion gases.

BENEFITS: The significance of this study will contribute to our understanding of the scope of environmental impacts of aircraft ultrafine particles in the vicinity of LAX, which will help to uncover the hidden social costs of operating a major airport in urban areas.

COST: \$118,000 (under consideration by the California Energy Commission for cofunding)

TITLE: Mobile Monitoring of Ultrafine Particulate Matter and CoPollutants in Community and Near-Roadway Environments

PROBLEM: Ultrafine particulate matter (UFPM) is considered as potentially the most harmful component of particulate air pollution, but exposure data are lacking. Measurements near freeways have shown sharp concentration gradients, making fixed-site monitoring of limited value for UFPM. Spatially resolved exposure data is needed to evaluate the health consequence of UFPM.

PREVIOUS WORK: Animal exposure studies have found lung damage from UFPM and human studies have found that it enters the bloodstream. Monitoring studies have found high concentrations and sharp gradients near roads and freeways. A pilot study that used the Mobile Monitoring Platform (MMP) concept extended this work by outfitting an electric vehicle for similar field measurements. UFPM concentrations and size data, along with gaseous copollutants, were measured on roadways and in neighborhoods. UFPM concentrations on roadways were one to three orders of magnitude higher than most microenvironments, making in-vehicle time the route of most UFPM exposure for people who commute.

OBJECTIVE: The objective is to extend the MMP approach to more fully characterize in-vehicle and near-freeway UFPM as well as copollutant concentrations, and UFPM size distributions. These data will then be used in estimates of UFPM exposure in these important microenvironments.

DESCRIPTION: The MMP approach to measuring UFPM and other high-gradient pollutants will be based on an electric vehicle platform with extensive instrumentation. Enhancements to the previous MMP capabilities will include improved, rapid-response UFPM instrumentation with higher dynamic range, improved particle sizers, and a gas chromatograph to measure volatile organic compounds. Measurements will focus on high- and low-diesel traffic freeways, characterizing the effects of meteorology on impacts to downwind communities.

BENEFITS: The findings of this study should allow the first quantitative estimates of UFPM exposure for Californians to UFPM and other combustion-related pollutants. A better understanding of freeways and community-level concentration gradients will be gained, as well as the differences in impacts from truck traffic versus gasoline-powered vehicle traffic. This information will benefit air modelers who typically rely upon emission estimates when they calculate the impacts of traffic.

COST: \$300,000

TITLE: Cardiovascular Health Effects of Ultrafine Particles During Freeway Travel

PROBLEM: Significant cardiovascular health effects are associated with exposure to fine particles. Specific causative agents are not known, but one likely suspect is ultrafine (<0.1 µm) particles. In urban areas the highest exposure to ultrafine particles occurs on freeways. Currently no clinical data on cardiovascular stress associated with pollutant exposure during freeway travel exists.

PREVIOUS WORK: Many epidemiologic studies have shown that short-term increases in ambient particles are associated with excess cardiovascular illness and death. Ultrafine particles, a component of PM_{2.5}, show high toxicity in lab animals and enter the circulatory system when inhaled. Altered heart rate variability (HRV) is a known risk factor for cardiovascular morbidity, and has been observed in association with particle exposures. Ultrafine particles are found at high concentrations on and near freeways in Los Angeles.

OBJECTIVE: The objective is to determine if exposure to ambient air during travel on freeways changes HRV and other noninvasive measures of cardiovascular health and to determine if such changes increase with increasing levels of exposure to ultrafine particles.

DESCRIPTION: This is a clinical environmental study in which continuous measures of cardiovascular health and measures of fine and ultrafine particles would be performed, before, during and after a 2-hour exposure on a freeway. Twenty adult subjects will undergo continuous Holter electrocardiogram monitoring and periodic evaluation of cardiorespiratory symptoms and physiology (heart rate, blood pressure, arterial oxygen saturation), over a 26-hour period. Concentration and size distribution of fine and ultrafine particles, CO, and NO_x will be monitored in the subjects' personal environment. In a control experiment at least two weeks later or earlier, the air breathed will be HEPA-filtered to reduce fine and ultrafine particle concentrations by at least 90 percent. Statistical analyses will test relationships between measures of exposure/dose and response within and between subjects. Second and third years will evaluate the dose response characteristics of these measures.

BENEFITS: This research will establish whether adverse cardiovascular health effects occur with exposure to freeway contaminants. It will demonstrate the efficacy of a convenient tool to assess the short term cardiovascular health impact of travel on freeways. This methodology can be used for future studies to evaluate the health impact of gasoline versus diesel dominated freeways, summer versus winter conditions, gas phase versus particulate phase contaminants. It has the potential to answer the question, which subfraction of fine particles is responsible for observed cardiovascular health effects.

COST: \$665,000

TITLE: Effects of Wood Smoke Exposure on Cardiopulmonary Responses in Healthy and Susceptible Humans

PROBLEM: Wood smoke is a major air pollutant, particularly in some areas of California. In 2003, 750,000 acres of California wildland were burned. In 2000, 8,400,000 acres were burned in the USA, the worst year on record. In addition to wildfires, wood smoke is also produced by industrial and residential wood burning. Humans are exposed to wood smoke in outdoor, and indoor air, and in recreational, and occupational environments. Data on the cardiopulmonary effects of controlled exposure to wood smoke are not available.

PREVIOUS WORK: Epidemiologic data show an association between wood smoke exposure and adverse respiratory health effects, including asthma, as well as an association between particulate and gaseous air pollution and increased cardiovascular morbidity and mortality. Several studies have reported associations between particulate air pollution and reduced heart rate variability (HRV), which clinical data indicates is a risk factor for cardiovascular morbidity and mortality. Few controlled human studies exist on particulate matter, although one study utilizing rice straw smoke found some differences in markers of airway inflammation in healthy and asthmatic humans.

OBJECTIVE: The objective is to determine: 1) threshold levels of wood-smoke exposure inducing airway inflammation and HRV responses in humans; 2) the influence of asthma status on wood smoke-induced changes in airway inflammation and HRV; and 3) the biological mechanisms controlling these responses.

DESCRIPTION: The project will utilize an already extant unique smoke generation and exposure facility, and will consist of two experiments. Experiment One: 15 healthy subjects will be exposed for 2 hours with intermittent mild exercise, to single exposures of filtered air (control), 150 $\mu\text{g m}^{-3}$ wood smoke, 450 $\mu\text{g m}^{-3}$ wood smoke, and a three serial-day exposure to 150 $\mu\text{g m}^{-3}$ wood smoke. Experiment Two: 15 asthmatic subjects will complete the same exposure conditions as in Experiment One. Airway inflammation will be quantified using airway cell distribution, and gene and protein expression from airway fluid, cells, and tissue (from bronchoscopy). HRV will be measured using standard electrocardiographic techniques, and analyzed for both time-domain and frequency-domain variables. Blood samples will be analyzed for cardiovascular risk factors, including blood cell counts, platelets, angiotensin-converting enzyme, angiotensin II, C-reactive protein, fibrinogen, and endothelin-1.

BENEFITS: The results will contribute to appropriate regulation of wood smoke levels in California.

COST: \$400,000

TITLE: Assessment of the Health Impacts of Particulate Matter from Indoor Sources

PROBLEM: Ambient particulate matter (PM) levels in California have been estimated to result in thousands of excess premature deaths and serious adverse impacts such as bronchitis and asthma requiring emergency room visits and hospitalizations. Indoor sources of particles, such as smoking, cooking, burning candles and incense, woodburning, and dust resuspension, are only indirectly accounted for in ambient PM epidemiology studies. PM from indoor sources such as combustion appliances and products are comprised of a variety of components known to be very toxic, and can result in elevated indoor PM mass concentrations. Consequently, PM of indoor origin may cause additional impacts not quantified in outdoor PM epidemiology studies, and/or may account for a portion of the adverse effects quantified in the epidemiology studies. In either case, such impacts are likely to be large and would require key indoor sources to be addressed in order to most effectively reduce PM exposure and risk.

PREVIOUS WORK: In February 2004, ARB convened a panel of experts to identify what is known regarding the health impacts of indoor PM. Only a few studies have estimated the relative contributions of PM from indoor and outdoor sources to the indoor PM mix. Results have been highly variable, but some of those studies have shown that a substantial portion of indoor PM in some homes is emitted from indoor sources. Only one study to date has directly examined the relative toxicity of indoor and outdoor PM; indoor PM showed greater toxicity than outdoor PM, although some weaknesses in the study limit confidence in these results.

OBJECTIVE: The objective is to identify and quantify the impacts of PM of indoor origin on human health.

DESCRIPTION: Several types of projects could further our understanding of the impacts of indoor PM on health. Two suggested starting points for this research include:

1. Animal studies of the impacts of PM of indoor origin (other than ETS).
2. Oxidative assay type studies or similar laboratory approaches in which PM from indoor sources is assessed for its impacts on human or animal cellular activity and response.

BENEFITS: Results from these projects would begin to provide insight regarding the type and extent of impacts of indoor PM sources on health. The initial question addressed would be whether impacts comparable to those indicted with outdoor PM are seen in laboratory studies using indoor-generated PM. Ultimately, results may identify whether new epidemiology studies are needed and enable risk reduction approaches to focus on the sources most responsible for PM impacts.

COST: \$400,000

TITLE: Effects of Subchronic Exposures to Ambient Particulate Matter in Mice with Induced Genetic Susceptibility to Coronary Artery Disease

PROBLEM: Heart disease is the leading cause of death in the U.S. Recent data have indicated that exposure to air pollutants is a risk factor and may represent an important preventable cause of both morbidity and mortality among populations living in polluted environments. There are strong and relatively consistent associations between cardiovascular morbidity and mortality. However, most studies have focused on acute outcomes. The contribution of particulate matter (PM) to the development of cardiovascular disease after long-term ambient exposures has not been addressed directly and effects on susceptible populations need to be evaluated.

PREVIOUS WORK: Aged rats exposed to concentrated ambient particulate matter (CAPs) have shown changes in heart rate variability, heart rate, blood pressure and also increases in inflammatory cytokines. Genetically susceptible mice exposed to CAPs in a rural location in New York State showed evidence of atherosclerosis and premature mortality after exposures of 6 hr/d, 5d/week, for up to 6 months. The particle concentrations ranged from 25 to 500 $\mu\text{g}/\text{m}^3$. These mice also showed significantly decreased heart rate variability prior to death.

OBJECTIVE: The objective is to determine whether cumulative daily exposures will cause progressive changes in cardiac function in an animal model for a susceptible human population.

DESCRIPTION: These studies will use double knock-out transgenic mice lacking apolipoprotein E and the low density lipoprotein receptor (apoE^{-/-} LDLr^{-/-}). This makes them susceptible to the development of atherosclerosis and studies performed by Lippmann and associates at New York University (NYU) indicate that effects could be seen after exposures to non-urban PM. The NYU study used CAPs. However, the ambient concentrations regularly seen in polluted California communities such as Riverside during the summer high photochemical period are similar to the NYU rural CAPs concentrations. Therefore the exposures could be performed at Riverside, using the mobile exposure system developed with ARB support for the Southern California Particle Center and Supersite. Mice would be exposed to ambient PM (unconcentrated) and 2 concentrations of CAPs so that a dose-response could be evaluated. Gene array analyses will be conducted to determine whether activation or deactivation of specific genes could be associated with the development of coronary artery disease.

BENEFITS: Death and illness associated with heart disease is an escalating problem in California. This study will address mechanisms by which ambient particles contribute to the development of these diseases and the gene analyses that will be performed may provide directions for the development of possible therapeutic interventions that could reduce the impact of breathing polluted air.

COST: \$300,000

TITLE: Effects of Ozone and Nitrogen Dioxide Exposure on Cardiovascular Responses in Healthy and Susceptible Humans

PROBLEM: Both ozone (O₃) and nitrogen dioxide (NO₂) have been associated in epidemiological studies with increased cardiovascular morbidity and mortality, and with decreased heart rate variability (HRV), a risk factor for adverse cardiovascular outcomes. No controlled human studies have investigated the effect of O₃ or NO₂ on HRV. The biological mechanisms that mediate associations between air pollution and cardiovascular effects are largely unknown.

PREVIOUS WORK: Reduced HRV is a risk factor for adverse cardiovascular outcomes. Unpublished data show that controlled exposure to O₃ and particles combined, but not particles alone, decreases HRV in asthmatic humans, but the effect in other subject groups and with NO₂ exposure is unknown. Several studies also suggest that increased plasma viscosity, and/or increased plasma levels of fibrinogen, platelets, C-Reactive Protein (CRP), and endothelin-1 (ET-1) are possible mechanisms explaining associations between increased cardiovascular morbidity and mortality and exposure to O₃ and NO₂. Several factors in the renin-angiotensin system, including angiotensin-converting enzyme (ACE) and angiotensin II (AngII) can contribute to disruption of sympathovagal balance, which could also contribute to an increase in clinically significant heart arrhythmias. ET-1 has been associated with increased blood coagulability and increased risk of mortality after myocardial infarction.

OBJECTIVE: The objective is to determine the acute and subacute effects of O₃ and NO₂ on HRV, airway and systemic inflammation, the renin-angiotensin system, and blood coagulability in healthy and asthmatic humans.

DESCRIPTION: Twenty healthy and 20 asthmatic subjects, ages 18-55 years, will be exposed for four hours, with intermittent exercise, to O₃ (0.2 ppm), NO₂ (1.0 ppm) or filtered air in three separate exposure sessions. HRV will be evaluated from electrocardiogram (ECG) recordings with simultaneous continuous respiration, blood pressure and heart rate monitoring obtained prior to, during each exposure session, and following exposure using both time-domain and frequency-domain analysis. Blood will be drawn at each ECG recording, and will be analyzed for complete blood count, platelets, fibrinogen, CRP, ET-1, ACE activity, and AngII. Airway inflammation will be quantified using airway cell distribution, and gene and protein expression from airway fluid, cells, and tissue.

BENEFITS: Determination of whether O₃ and NO₂ can induce systemic changes linked to cardiovascular morbidity and mortality, in healthy or potentially susceptible populations, will yield important exposure and health risk endpoint information for regulation.

COST: \$400,000

TITLE: Particle Phase Peroxides: Concentrations, Sources, Behavior and Health Effects

PROBLEM: A class of biologically active species known collectively as reactive oxygen species (ROS) is a candidate for part of the adverse health effects caused by particle inhalation. In particles, the dominant ROS is hydrogen peroxide. In numerous *in vitro* studies, hydrogen peroxide at levels well below those expected for ambient samples has been shown to damage lung epithelial cells. Recently, an *in vivo* study showed that particulate hydrogen peroxide produced symptoms associated with respiratory distress, while gas-phase peroxides or ammonium sulfate particles alone did not, although particulate peroxide concentrations were not measured. A limited set of particulate peroxide concentrations have been measured in urban air, and show that peroxide levels are even higher than predicted by gas-particle partitioning.

PREVIOUS WORK: A technique to quantify peroxide levels in aerosols has been developed and has made limited measurements in urban air, finding that ROS levels are much higher than predicted by gas-particle partitioning. One other study in Taiwan found even higher levels, but were probably due to an analysis artifact.

OBJECTIVE: The objective is to measure aerosol-borne ROS concentrations at a variety of sites, investigating the relationship between these toxic compounds and location, source type, aerosol type, and photochemical activity. Additionally, laboratory studies on model systems and ambient samples will be carried out to determine the source and behavior of peroxides in aerosols, with particular attention to partitioning behavior on the time scales and humidities found in the lung environment.

DESCRIPTION: Size-segregated aerosols will be collected on filters and analyzed after extraction using high performance liquid chromatography/fluorescence. Aerosol water content will be measured with gas chromatography/thermal conductivity. Gas phase peroxides, particle mass, relative humidity, ozone, NO_x, and other parameters will be monitored. Samples will be collected from representative sources including diesel and gasoline powered engines, in photochemically processed air, and at a forest background site. Aerosols will also be generated in a smog chamber. It is anticipated that many samples will be collected at sites co-located with on-going or planned studies (e.g., conducted by CARB, SCAQMD, USC-Children's Health Study and UCLA Supersite/Particle Instrumentation Unit) to take advantage of additional aerosol chemical composition and related data.

BENEFITS: Airborne particulate matter is strongly associated with the increased mortality associated with air pollution events. This study will investigate a highly oxidizing component of particulate matter, hydrogen peroxide, to determine its sources, prevalence, levels and behavior. Understanding the specific types of particulate matter toxicity is key to devising cost-effective control strategies that improve human health.

COST: \$110,000

TITLE: Determination of the Spatial and Temporal Variability of Size-Resolved PM_{2.5} Composition and Mixing State in Multiple Regions in California

PROBLEM: In order to develop effective control strategies, one must further understand the major sources of particles in different regions of California. An understanding of the major sources contributing to PM_{2.5} in California is limited to several major areas over short time periods.

PREVIOUS WORK: Most of the research on PM_{2.5} composition has been limited to major field campaigns which focus on a relatively small period of time in a specific region. These studies have given us a much better idea of the particle composition in southern and central California. However, these represent extremely short snapshots in time of particle chemistry and the ability to apportion sources has been limited. Single particle analysis techniques have evolved to become quantitative and to include the ultrafine PM fraction. Data processing has become automated and allows one to unambiguously distinguish diesel and gasoline-derived particles.

OBJECTIVE: This objective is to perform particle characterization as well as measure other criteria pollutants in a number of regions of California impacted by PM_{2.5} including major cities, agricultural areas, and transport sites. Single particle fingerprints will be used to relate PM to various sources, especially sources producing the carbonaceous fraction such as biomass burning and vehicles. Seasonal dependence of the fraction of secondary PM at different locations will also be examined.

DESCRIPTION: Analysis of single particles by mass spectrometry produces size-resolved composition, providing information on sources as well as subsequent atmospheric processing leading to secondary organic aerosols. ATOFMS has been used to develop source fingerprints of diesel and gas vehicles, brake and tire wear, power plants, wood and other biomass burning aerosols, fine dust, and sea salt. By comparing these signatures with ambient particle mass spectra, the relative fractions of particles from different sources can be determined. New profiles will be developed for charbroiling operations and CNG buses. Sampling needs to be conducted in as many locations as feasible due to the high degree of spatial and temporal variability of PM_{2.5}. A mobile lab will be equipped with two ATOFMS and sizing (SMPS, APS), aethelometer, mass concentration, visibility, and trace gas (CO, ozone, and NO_x) instruments. Sampling at current California air quality stations will provide a historical basis for comparison and access to meteorological data. The mobile lab will provide the flexibility necessary to move to various locations, and allow for "target of opportunity" sampling during PM_{2.5} events.

BENEFITS: The proposed field studies will provide a long term picture of the temporal and spatial variability of particle composition in a number of major regions in California. The preliminary results should be available by early to mid 2007 for use in PM_{2.5} SIP development (2008). A more complete picture will be obtained of the major sources impacting annual-average PM_{2.5} violations in California, allowing better control strategies to be established. Furthermore, as current diesel PM and other regulations are being implemented, this long-term record will provide feedback on how these control programs are affecting air quality.

COST: \$600,000 (under consideration by the California Energy Commission for cofunding)

TITLE: Development and Demonstration of an Aerosol Tracer Technique Based on Neutron Activation Analysis for Studying Cyclical Deposition and Resuspension of Aerosol-Associated Toxic Contaminants

PROBLEM: Toxic inorganic (e.g. trace metals) and organic (e.g. PAHs, PCBs) contaminants, often associated with the solid phase of aerosols, have adverse effects on human health through inhalation, and, when deposited, on the health of aquatic and terrestrial ecosystems. It is well documented that resuspension of dust from paved and unpaved roads by traffic and from non-road surfaces by wind is a major source of these toxics to the atmosphere, particularly in urbanized areas. However, little is known about the actual pathways of this material from primary sources to sites of sequential deposition and resuspension.

PREVIOUS WORK: Recent research at UCLA and elsewhere has developed an effective suite of techniques for measuring the atmospheric concentration and deposition of aerosols and associated toxic contaminants over a wide range of aerosol sizes. This work has demonstrated that in many cases deposition is dominated by rapidly settling aerosols larger than 10 microns. Significant concentrations of these coarse aerosols are routinely found farther from sources than would be possible if resuspension were not present, leading to regional rather than local impacts of individual sources. This has led to the hypothesis that, where a mechanism for resuspension is present, there is a persistent layer of contaminant-laden aerosols constantly depositing and being resuspended.

OBJECTIVE: The objective is to develop and demonstrate the feasibility of a new tracer technique capable of detecting and quantifying the movement of surrogate aerosols undergoing cyclical deposition and resuspension.

DESCRIPTION: The tracer technique, which has been successfully tested in a pilot study at UCLA, consists of sorbing ions of a rare earth element to commercially available porous silica particles of known size, releasing these particles into the environment, and using Neutron Activation Analysis to detect the concentration of the rare earth element in aerosol and soil samples taken at appropriate locations. This technique uses a natural non-radioactive material with a low background concentration as a tracer and can detect this material with great sensitivity, making possible the study of aerosol transport over significant distances. By sorbing different rare earth elements to different size particles the effect of aerosol size on deposition and resuspension can be quantified directly. This project will demonstrate the feasibility of this technique in quantifying deposition and subsequent resuspension of dust-related aerosols generated by traffic on a major freeway.

BENEFITS: The results of this study will validate a tracer technique of great general value to the study of aerosol and particle transport in both air and water, in particular the identification of sources of aerosol-associated toxic compounds and their fate in the environment. The specific application to aerosol deposition and transport will help validate the hypothesis of a persistent near-surface layer of suspended coarse-fraction aerosols forced largely by vehicular traffic and provide the first systematic data on the spatial and temporal properties of this layer.

COST: \$75,000

TITLE: Characterization of Versatile Aerosol Concentration Enrichment System (VACES)

PROBLEM: VACES is a critical component of current ARB-funded research to determine how particulate matter (PM) causes adverse health effects. By providing increased concentrations of particles from ambient air, VACES enables real-time animal exposure studies. However, VACES uses water-condensation technology, which may generate artifacts in the concentrated aerosol. The ACES Project Plan from the Health Effects Institute recently stated that particle concentrators "would change the characteristics of the exhaust and/or the particles".

PREVIOUS WORK: The VACES developer, Professor Sioutas of the University of Southern California (USC), has co-authored papers that give reassuring basic results for VACES' operation. These papers provide performance-related measurements and some information on the chemical composition of the aerosol from VACES. Recent work by other researchers on VACES using aerosol mass spectrometers indicates that aqueous-phase fog processing and positive adsorption artifacts do occur. Independent evaluations that investigate the question of conservation of particle composition are necessary to help resolve these issues and establish a scientifically defensible position in the validation of VACES.

OBJECTIVE: This objective is to provide further tests to help determine the extent of possible artifacts from the use of VACES.

DESCRIPTION: Artifacts may be generated by the particle concentrator as the result of adsorption/absorption artifacts (both organic and inorganic), fast cloud chemistry (processing of inorganic and organic compounds), and kinetic growth limitations and/or coagulation of droplets for small particles in the saturator. Physical and chemical characteristics of the output aerosol from VACES need to be better characterized. Some aspects that need further exploration are:

- Whether gas-phase organic species in the input air influence the composition of the output aerosol from VACES.
- Whether the concentrator causes nitrate enrichment through a fog-processing cycle.
- The fate of particles under 30 nm, which exhibit a decrease in enrichment factor.
- Possible chemical effects, such as aqueous phase sulfur chemistry in particles from the concentrator.
- The ability of the diffusion dryer to function properly over long periods of time.

BENEFITS: The ARB needs a system that can accurately generate concentrated exposures to real-time PM found in California. The effort by the USC team has been very impressive, and toxicology studies based on VACES are providing major new PM health effects information. Understanding of the relative toxicity of size, site, and seasonal differences in ambient PM is vital to the development of future regulations to protect the public health. From the ARB's experience in developing health-protective regulations, we are aware of the need to validate the scientific basis for our regulations. Therefore, the performance of VACES should be characterized to the greatest extent feasible.

COST: \$80,000

TITLE: Modeling Studies of Ozone Formation from Power Production and during the Ozone “Weekend Effect”

PROBLEM: The transition from central to distributed power generation could affect ozone formation by redistributing NOX emissions from power production facilities. Similarly, the location and timing of traffic and other emission sources may explain the ozone weekend effect, the phenomena in some urban areas where ozone levels on Saturday and Sunday are higher, on average, than those on weekdays. Current air quality simulation modeling assessments are not definitive because they are missing critical physical and chemical processes that would tend to reduce their sensitivity to NOX species and potentially bias them against NOX control.

PREVIOUS WORK: The California Energy Commission funded a study with the University of California at Irvine in 2001-2003 to model the impact of distributed power generation on ozone and particle levels. In the early 2000s, ARB staff hypothesized several causes of the weekend effect that have been investigated by several university and private-sector modeling groups. However, potentially important recent discoveries in atmospheric processes (i.e., potential sources of renoxification, dynamics of chlorine in coastal areas, radiative transfer model improvement, meteorological fields based on radar wind profiler data, observations of ozone transport aloft, day-of-week emission activity data) have yet to be included in air quality simulation modeling of power production impacts and testing hypotheses of the weekend effect.

OBJECTIVES: The objective is to include the state-of-the science for emissions, meteorology, and atmospheric chemistry in modeling studies of the relative impacts of central and distributed power generation and to test hypotheses of factors contributing to the ozone weekend effect.

DESCRIPTION: A multi-day ozone episode in the South Coast Air Basin will be simulated using the California Institute of Technology (CIT) model. Wind fields that reproduce ozone recirculation processes observed aloft and an updated radiative transfer model will be provided by ARB staff. ARB staff will also provide a weekend emission inventory for input to the CIT model to compare with ozone predictions using the normal weekday inventory. Furthermore, to compare the ozone and particulate matter impacts of central and distributed power generation emission inventory from existing research sponsored by the California Energy Commission will be used. Predictions with and without heterogeneous reactions (renoxification, chlorine chemistry) will be compared.

BENEFITS: The weekend effect is an important issue in regulation as some interpretations suggest that controlling NOX would be counterproductive to reducing ozone. It is imperative that the models contain important atmospheric processes that have significant impact on the dynamics of air pollution. This work will incorporate for the first time heterogeneous processes with updated meteorological and emission fields and will perform a significant number of model runs to increase our understanding of the ozone and PM air quality dynamics associated with distributed power generation and the weekend effect in the South Coast Air Basin.

COST: \$150,000 (under consideration by California Energy Commission for co-funding)

TITLE: Assessment of Out-of-State Heavy-Duty Truck Activity Trends in California

PROBLEM: An increasing number of out-of-state heavy-duty trucks are operating in California each year. However, some data suggest that the average number of miles driven by each truck is decreasing. In addition, while some of these trucks appear to be transitory in nature, it appears that some trucks may be domiciled within California even though they are not registered within the state. As emissions from mobile sources become a larger portion of overall emission inventory, information is needed to accurately determine the impacts of these vehicles.

PREVIOUS WORK: Limited data is available on the activity trends of out-of-state trucks in California. In California, the Department of Transportation has collected some limited information on heavy-duty truck activity, and the Department of Motor Vehicles received some limited data on the number of out-of-state trucks entering California each year.

OBJECTIVE: The objective is to provide information necessary for staff to evaluate the emission impacts of out-of-state heavy-duty trucks on the California inventory. The information will allow staff to develop and/or coordinate programs that may reduce emissions from these vehicles.

DESCRIPTION: Under the proposed project, data would be collected on out-of-state heavy-duty trucks to determine:

- fueling patterns;
- quality of the fuel used;
- vehicle miles traveled, and
- amount of time spent in California.

BENEFITS: This project will benefit the citizens of the state by identifying the impacts out-of-state heavy-duty trucks have on California emissions, and allow for the development of potential control measures. These measures can reduce the impacts of both criteria pollutants as well as diesel particulate emissions.

COST: \$65,000

TITLE: Refined Analysis of Activity Patterns Associated with Light-Duty Vehicles

PROBLEM: Light-duty motor vehicles generate the majority of several criteria pollutant emissions but little work has been done to verify assumed activity patterns that generate actual emissions.

PREVIOUS WORK: The ARB has sponsored two projects investigating light-duty driving patterns with Global Positioning System technology. These projects, based on relatively small sample sizes, indicated significantly different activity numbers for trips and speeds.

OBJECTIVE: The objective is to improve activity estimates for light-duty motor vehicles.

DESCRIPTION: This project would take a closer look at the underlying raw data from previous activity studies, summarize the data in a consistent manner, characterize any different results, hypothesize causes for any differences, recommend further research to improve activity estimates, and recommend any appropriate changes to default values assumed in the FORTRAN computer model, EMFAC.

BENEFITS: Motor vehicles remain a major source of pollutant emissions adversely impacting public health and welfare. Refined activity factors would improve the assumptions used in emissions models, would help generate more accurate emission inventories, and would improve modeling performance assessing controls necessary for meeting air quality standards.

COST: \$25,000

TITLE: The Development of Exhaust Speciation Profiles for Commercial Jet Engines

PROBLEM: There are currently no commercial jet engine exhaust speciation profiles, using modern engines and modern fuels, available for either volatile organic compounds (VOCs) or particulate matter (PM). Current commercial jet exhaust modeling efforts, as well as Environmental Impact Report (EIR) efforts, rely on previous military aircraft testing results. This makes production of accurate ozone and toxic models, as well as EIR efforts in regions heavily impacted by commercial jet aircraft, impossible.

PREVIOUS WORK: Currently used jet engine exhaust speciation profiles were developed in the past using older fuels and engines, principally from military applications. They have limited applicability to modeling commercial aviation emissions. Recent programs have only begun to test engines and fuels that are somewhat similar to modern commercial engines and fuels. In addition, the specific compounds selected for testing, issues of limits of detection, needs for changes in overall methodology, and test equipment issues, currently limit the ability of previously-collected data to be applied to current commercial jet engine speciation profile needs.

OBJECTIVE: The objective is to develop accurate VOCs and PM speciation profiles for a modern, widely-used commercial aviation engine, using modern, commonly used jet aviation fuel.

DESCRIPTION: U.S. federal agencies, in conjunction with other interests, are currently working on projects to test and speciate exhaust from military jet engines in the 2004-2005 timeframe. Some of this previous testing has included an engine and fuel mix with similarities to current commercial engines and fuels. The currently proposed project could build on and extend these commercial-like tests to better characterize typical commercial jet engines and fuels. The same testing apparatus and methodology could be applied to the testing of a typical modern commercial aviation engine, using typical modern commercial jet aviation fuel, at a relatively low additional cost to these currently-planned projects.

BENEFITS: Successful completion of this project would facilitate accurate modeling of commercial jet engine exhaust emissions for ozone, PM and toxics, as well as aid informed decision-making during the EIR process for airport expansion projects.

COST: \$200,000

TITLE: Advanced Factor Analysis of STN Data for Apportionment of Gasoline and Diesel Emission Contributions

PROBLEM: The PM_{2.5} National Ambient Air Quality Standards are likely to be exceeded in a number of locations in California. Improved methods are needed to identify the important sources and then these methods can be applied to provide input to the state implementation planning process. Of particular interest is the resolution of traffic-related carbonaceous particle sources into the contributions from gasoline vehicles and diesel engines. Diesel exhaust is suggested to be more toxic and have more influence on adverse health effects. Currently there are samplers in the Speciation Trends Network (STN) in urban areas collecting chemical composition data for PM_{2.5} samples. However, it has been generally thought that it is necessary to obtain specific chemical components (molecular markers) in order to apportion diesel and gasoline engine emissions. It would be of great value both in terms of air quality strategy development and epidemiology, if such a resolution were possible based on the STN data.

PREVIOUS WORK: Improved source identification as well as separation of traffic-related carbonaceous particle sources into gasoline vehicles and diesel engines using temperature resolved carbon fractions has been demonstrated for Atlanta, Georgia, Washington, DC, and Brigantine, New Jersey. However, the STN network does not provide these fractions. The use of an expanded factor analysis model has been applied to a particulate matter data set from Atlanta and successfully separated diesel emissions from gasoline vehicle sources.

OBJECTIVE: The objective is to use advanced factor analysis approaches to analyze the data obtained by the STN network and any other comparable data to resolve the sources of PM_{2.5} with a particular emphasis on the separation of gasoline and diesel fueled vehicle emissions.

DESCRIPTION: In the expanded analysis, the bilinear model is augmented by an additional complex equation that contains modeling information. This expanded model can be applied to the variety of STN data from samples collected in California to identify the sources and apportion the mass to those sources with the expectation that gasoline and diesel sources can be accounted for separately.

BENEFITS: The project will yield several major benefits including providing a means to more fully utilize the STN data and to provide a resolution of motor vehicle emissions into gasoline and diesel without the need for high cost sampling and analysis for molecular marker compounds. These results will be helpful for both implementation planning and for future epidemiological studies.

COST: \$120,000

TITLE: Nighttime Chemistry: Observations of NO_3 and N_2O_5

PROBLEM: Chemistry involving the NO_3 radical is predicted to play an important role in removal of NOX and alkenes from the atmosphere. NO_3 oxidation of larger alkenes is also predicted to result in production secondary organic aerosol. However there is little direct experimental evidence constraining the importance of these processes.

PREVIOUS WORK: A suite of instruments have been developed for detection of all of the major nitrogen oxides: HNO_3 , alkyl nitrates, peroxy nitrates, and NO_2 . In late 2003, a paper was published describing a novel laser-induced fluorescence (LIF) approach to detection of NO_3 and N_2O_5 . The instrument described in that work was based on an inexpensive (\$50) diode laser and had a sensitivity of 75 ppt/min. This sensitivity is adequate for observing N_2O_5 in urban plumes. Since that time the technique was demonstrated in a short field study in Lafayette that developed new ideas for increasing the sensitivity to enable simultaneous measurements of NO_3 and N_2O_5 .

OBJECTIVE: The objective is to document the atmospheric chemistry of NO_3 and N_2O_5 with field observations. Development, demonstration and application of a new LIF approach to NO_3 and N_2O_5 detection would enable widespread observations of nighttime chemistry.

DESCRIPTION: The project will be a two year effort with the first year devoted to design, development and test of an improved technical approach to NO_3 measurement and the second devoted to two or three short (2-3 week) measurement intensives at sites to be determined through collaboration with ARB.

BENEFITS: This project will provide useful data of immediate value for air quality attainment strategies. Analyses of the data can test the underlying chemical mechanisms that are the core elements of air quality assessment models. The technology developed here will be inexpensive and could be easily developed for commercialization and then introduced throughout the ARB network.

COST: \$120,000

TITLE: Measurement of Ozone Reactivity for Major Pesticide Volatile Organic Compounds

PROBLEM: The ozone reactivity of many pesticide volatile organic compounds (VOCs) is not well known. Experimental measurements have been made for only a few of the pesticide VOCs most commonly used in California.

PREVIOUS WORK: UC Riverside has measured the ozone reactivity of several pesticide VOCs using environmental chamber experiments. Ozone reactivities have been measured for methyl bromide and chloropicrin, which collectively account for 34 percent of the total statewide pesticide VOC inventory. The analytical methods developed in these studies can be used to determine the ozone reactivities of other pesticide VOCs.

OBJECTIVE: Develop technically sound ozone reactivity factors for the most commonly used pesticide VOCs in California.

DESCRIPTION: Measure the ozone reactivity of five pesticide VOCs using environmental chamber irradiation experiments. Compounds most likely to be measured are methyl isothiocyanate, 1,3-dichloropropene, chlorpyrifos, thiobencarb, and EPTC. These five cumulatively account for approximately 30 percent of the total statewide VOC inventory and are all active ingredients. The list of compounds to be measured may change should new information become available.

BENEFITS: As ozone SIPs are developed for the San Joaquin Valley and other agricultural areas in California, a sound understanding of the impacts of pesticides on ozone formation is needed. Experimentally determined ozone reactivities will improve air quality modeling and assist in future SIP development.

COST: \$100,000

TITLE: Development of In-field Diesel Particulate Matter Compliance Method for Stationary and Portable Combustion Ignition Engines

PROBLEM: The current stationary source test methods used for measuring diesel particulate matter (PM) in the field are slow and very costly to conduct. The two accepted stationary source test methods for measuring diesel PM are ARB Method 5 and the ISO 8178 compliant mini-dilution system. The ARB Method 5 sampling (samples raw exhaust) of PM requires sampling the exhaust for 20 minutes to two hours to gather enough particulate on the sampling filter, depending on whether the engine is dirty or clean. Each sample has to be repeated at least three times over five engine loads. Also the laboratory requirements to separate and weigh the condensable fraction takes days or weeks to get results. The ISO 8178 compliant source test method is based on exhaust dilution and requires a mini-dilution tunnel. The mini-dilution tunnel correlates to the EPA certification emission source test method and requires weighing only a sampling filter with no condensable fraction and associated laboratory work. The sampling time is much shorter, even for clean engines, 15 minutes is adequate. The mini-dilution system can cost tens of thousands of dollars to purchase. We need an enforcement sampling system that can quickly screen for potentially dirty engines and use equipment available and/or inexpensive.

PREVIOUS WORK: While developing the stationary diesel engine air toxic control measure, ARB participated in a demonstration with the California Energy Commission to measure diesel PM from stationary back up generators. Part of the demonstration compared the EPA dilution method with the ARB Method 5 for measuring diesel PM. This demonstration source testing provides data that can be used to support the development of an alternative compliance test method. Further work is needed to develop an in-field test method.

OBJECTIVE: The objective is to statistically relate parts of the ARB Method 5 to the EPA certification dilution method as a way to quickly estimate the diesel PM emission rate and find a way to sample raw exhaust at a single load from stationary diesel engines and correlate to the certified PM emission rate. By knowing the approximate load and respective PM emission rate at which an ARB Method 5 test is conducted, the EPA certification PM emission rate can be calculated.

DESCRIPTION: Conduct emissions source tests using both ARB Method 5 and the EPA dilution method on diesel engines at the certification loads to better correlate the ARB Method 5 front-half filter to the EPA dilution method. Analyze this data to relate an ARB Method 5 front-half filter at various mid-range loads to the EPA certification level.

BENEFITS: Current diesel engine source testing is very expensive and time consuming. Development of a simplified and less expensive emissions test procedure for stationary diesel engines would be a benefit to the Districts determining compliance with prohibitory rules and in identifying dirty engines.

COST: \$300,000

TITLE: Determine the Population Mix of Off-Road Equipment by Applications and End Users; such as Agriculture, Warehousing, Automotive, Construction Etc.

PROBLEM: Our understanding of the contributions of various off-road mobile emission sources is critically dependent on knowing how much of the various equipment types are in service, and how much (and when) they are being used. Recent studies have updated this information for residential small off-road engines.

Unfortunately, the information gathered in these studies did not examine the question of whether some of these equipment types are properly categorized with respect to federal preemption, which exempts farm and construction equipment under 175 horsepower from California new engine control programs. The data supporting previous preemption decisions are now over 10 years old, and should be updated. We do not expect the study to have any impact on obviously preempt equipment like tractors, harvesters, graders, and loaders. However, it could impact (for example) equipment like compressors and aerial lifts, if it showed their use to be predominantly in nonpreempt applications. Note that before any change to the preemption lists would be made based on this study, it would be subject to extensive stakeholder review, paying particular attention to experts in the impacted industry.

PREVIOUS WORK: A list of farm and construction equipment was developed jointly by ARB and industry in the mid-1990's. It was developed with the limited data available at the time. A separate study funded by a natural gas association in the 1990's estimated the uses of forklifts by applications/end users.

OBJECTIVE: To identify off-road equipment population by applications and end users.

DESCRIPTION: Update the list of all the equipment types with off-road engines under 175 horsepower. Determine the population of each equipment type by application/end user.

BENEFITS: An updated list of all the equipment types of off-road engines under 175 horsepower would help clarify and provide a better understanding of the impact of preempt engines on California's emission inventory and provide a basis for dialogue with stakeholders on any changes needed.

COST: \$300,000

TITLE: Development of an Improved Test Method for Architectural Coatings

PROBLEM: Currently, the United States Environmental Protection Agency's (U.S. EPA) Method 24 is used to test the VOC content of coatings. However, as VOC contents of water-borne coatings get lower (approaching 50 grams/liter) in order to meet more stringent VOC limits, Method 24 becomes less reliable. An alternative or improved test method is urgently needed, since the VOC limits in some district rules are already in the 50 to 100 gram/liter range for some coating categories. This creates an enforceability challenge, with potential emission increases due to an inadequate sensitivity of Method 24.

PREVIOUS WORK: The U.S. EPA and the American Society for Testing and Materials have done extensive work developing and refining the current Method 24. The ARB's Method 310 incorporates Method 24 as well as other analytical procedures. As part of a 1996 ARB-contracted study by Censullo, et al., an alternative was developed to determine the water content of coatings, which is a source of uncertainty in the results of Method 24. In addition, the ARB's Method 310 is also used to determine percent VOC for aerosol paints.

OBJECTIVE: The objective is to develop a unified test method that: (1) can determine the VOC contents of all types of architectural coatings (including solvent-borne, water-borne, multi-component, and reactive diluent coatings); and (2) is more accurate than Method 24, especially with very low VOC coatings.

DESCRIPTION: The sources of error with Method 24, the status of any revisions to Method 24, and the types of coatings for which Method 24 has limitations will be described. Improvements to ARB Method 310 that address the existing limitations, or alternative test methods, if necessary, to address the limitations will also be identified. Improved or alternative test method using a range of architectural coatings, including consideration of gas chromatography/mass spectrometry, head space analysis, or further improvements to Methods 24 and 310 will be developed. If Method 310 proves to be the best method for determining the VOC content of architectural coatings, then the next step will be getting Method 310 approved by the U.S. EPA for architectural coatings.

BENEFITS: An improved test method for determining the VOC contents of architectural coatings will improve both the compliance with, and the enforcement of, districts' coatings rules, thereby better ensuring that the estimated emission reductions from such rules are achieved. This test method will also be used to improve the enforcement of district rules for other coating categories (e.g., automotive refinish coatings). By improving the ability to measure VOC content, the ability to check manufacturer claims and encourage the use of zero-and low-VOC coatings will be established.

COST: \$250,000

TITLE: California Dairies – Evaluation of Covered Lagoons and Digesters for Emissions Reductions

PROBLEM: Only limited information exists regarding the effectiveness of lagoon covers and digesters in reducing dairy waste emissions. Several jurisdictions within California are anxious to implement these technologies as control measures, but are somewhat limited due to incomplete information regarding their effectiveness.

PREVIOUS WORK: Several dairy lagoons have been covered and digesters developed. Unfortunately, none of this work had an air quality emphasis so information has not been collected regarding the net effect of these systems on air quality.

OBJECTIVE: The objective is to determine the control effectiveness of covered lagoons and digesters used for processing dairy waste. Evaluate the cross-media effects of these processes, such as changes in water quality.

DESCRIPTION: Perform a field test study over 18-24 months at a location with an existing covered lagoon and a location with a digester system. Fully evaluate the gases generated by each system. Fully evaluate the gases at the tail-end of each system, such as the internal combustion engine used for electricity generation. Evaluate the chemistry of the lagoon water or other effluents ultimately released to assess its environmental impacts.

BENEFITS: Questions regarding the efficacy of digesters and covered lagoons will be answered. If these technologies are shown to be effective in reducing emissions, there are substantial environmental benefits. Not only could they be an effective emission reduction measure, but digesters and covered lagoons could also provide a source of clean electricity generation by burning the dairy waste gases.

COST: \$250,000

TITLE: Methods to Reduce Fumigant Pesticide Emissions

PROBLEM: Fumigant pesticides are the largest contributors to the pesticide volatile organic compounds (VOC) inventory. Additionally, most of them are designated as toxic air contaminants. Using current application techniques, 40 to 90 percent of the amount applied is released to the air.

PREVIOUS WORK: Several academic, government, and industry researchers have developed application techniques to reduce peak emissions with limited success. Some of these techniques may just delay volatilization of fumigants. Many techniques have only been demonstrated in the laboratory or with small field plots.

OBJECTIVE: The objective is to develop application techniques to reduce overall emissions of fumigants.

DESCRIPTION: Many ideas have been proposed to reduce fumigant emissions, such as use of virtually impermeable films, irrigation techniques, soil amendments, and modified injection shanks. This study would select the best candidates and measure fumigant emissions using the new application techniques on commercial agricultural fields.

BENEFITS: Reduction of fumigant emissions will significantly decrease VOC emissions in several nonattainment areas (San Joaquin Valley, Ventura, Southeast Desert). This will also reduce exposure to toxic air contaminants.

COST: \$200,000

TITLE: Very Long Range Transport – Impacts on Background Ozone and PM

PROBLEM: International and intercontinental transport of both particulate and gaseous pollutants has been documented to impact California. The presence of these pollutants defines a “floor” which limits the potential air quality improvements possible from in-state pollution controls. This “floor” impacts the potential costs of air quality improvements and imposes constraints on State air quality policy, especially in regard to establishing ambient air quality standards. The problem is mirrored at the national level, with similar impacts on both control costs and flexibility to set ambient air quality standards. Detailed information on the spatial and temporal distributions of “global” pollutant effects in California is needed to deal with this problem, both in the technical and policy arenas.

PREVIOUS WORK: Recent research by ARB and others has shown that aerosols from Asia (both natural and anthropogenic) are a dominant component of “background” particulate matter (PM) at elevated sites in California. Ozone from Asian sources (urban areas and biomass fires) has been observed in Washington State and is inferred to be present over California.

OBJECTIVE: The objectives are to: 1) better assess the current impact of intercontinental pollutant transport across California, with direct application to refining policy decisions regarding both control strategies and standard setting, and 2) through the Coordinating Research Council (CRC) link to the global pollutant modeling community, develop a clearer understanding of the transport pathways impacting California and identify the major emission sources responsible.

DESCRIPTION: This project will establish a small set of remote air quality monitoring sites widely distributed in California, designed to detect very long range transport of PM and ozone. The project will operate in cooperation with CRC project A54, which will focus on modeling intercontinental pollutant transport. Instruments will be sited with cooperators (ideally, IMPROVE sites) to limit costs, and will employ equipment currently used in other remote-site global-scale pollution research that requires minimal operator attention.

BENEFITS: The data collected will both provide direct evidence of the spatial and temporal distributions of intercontinental pollutant impact in California and serve as a “test set” to evaluate the performance of the CRC-sponsored modeling. Validated model results will facilitate estimating long-term trends due to evolving emission patterns in the source regions (primarily East Asia).

COST: \$160,000