ARB 1998
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CALIFORNIA AIR RESOURCES BOARD

RESEARCH DIVISION

AIR POLLUTION RESEARCH

Short Summaries of Research Studies
Funded by the Air Resources Board

1989-Present

June 1998

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Air Pollution Research

June 1988

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Introduction

The California Air Resources Board (ARB) sponsors a comprehensive program of research into the causes, effects, and possible solutions to the air pollution problem in California. This publication summarizes the results of projects carried out under the program over the past nine years. Information given in the title line of each summary includes the title of the final report, the ARB contract number, and the name of the contractor. For some reports, Research Notes (see below) have been written. In such cases, the Research Note number is cited.

The research program, established by the Legislature in 1970, is based on the need to develop a better understanding of emission and transport of air pollutants, related atmospheric reactions, the effects of air pollution on health and the environment, and control of air pollution. Since that time, several legislative mandates have expanded and further defined the scope of the ARB's research program. These mandates are embodied in the California Clean Air Act (1988), the Toxic Air Contaminant Identification and Control Act (1983), the Air Toxics "Hot Spots" Information and Assessment Act (1987), and the Alternative Fuels Act (1988).

The goal of the research program is to provide the timely scientific and technical information needed to develop and support the public policy decisions required for an effective air pollution control program in California. In planning the research program, the ARB works to develop short- and long-range goals and objectives that address present and future issues related to air pollution. The relevant scientific and technical problems are identified by the Legislature, the Board, ARB staff, local air pollution control districts, the academic community, and two research advisory committees. The advisory committees are legislatively mandated to provide peer review and guidance in planning research direction for specific programs and are composed of experts from a number of disciplines.

The Research Division manages the ARB's research programs in close coordination with other air pollution research organizations. We contract with private entities, universities, and other governmental agencies to perform the research for these projects. Research Division staff responsible for research planning and oversight have a high level of expertise in a wide range of disciplines.

The ARB's core research efforts are conducted through its extramural research program, which focuses on the following areas: Motor Vehicles and Fuels, Toxic Air Contaminants, California Clean Air Act mandates, and Air Quality Standards. Research topics included in these categories cover mobile sources, toxic air contaminants, stationary source emissions,

regional air quality, economic studies, health effects, and ecological effects. The annual extramural research budget is subject to approval by the Legislature and the Governor.

The Research Division also administers research under other programs for which the Legislature has provided more narrowly defined objectives. These programs, funded separately, include the Atmospheric Acidity Protection Program, the Air Pollution Health Effects Epidemiologic Research Program, the Indoor Air Quality Program, and Particulate Matter Studies. These activities are fully coordinated with the extramural research program.

On the World Wide Web, more information can be found on the Research Division at <www.arb.ca.gov/rd/rd.htm> and on the ARB in general at <www.arb.ca.gov>.

This publication is available on the Web, updated continuously, at <www.arb.ca.gov/rd/apr/intro.htm>.

The Research Division publishes two- to four-page synopses (Research Notes) of some of the projects described in this book. The title lines of those projects for which Research Notes have been published include a notation "Research Note _____". To order copies of Research Notes, or an index of these synopses, contact:

EJ Joiner (916) 445-0753
Research Division, California Air Resources Board
PO Box 2815
Sacramento CA 95812
e-mail: <research@arb.ca.gov>

Please provide the Research Note title, the contract number, and the Research Note number. Research Notes from 1993 through the present are available on the Web at <www.arb.ca.gov/rd/resnotes/resnotes.htm>

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Emma Plasencia
Assistant Contracts Administrator
(916) 323-1067
e-mail: <eplasenc@arb.ca.gov>

Motor Vehicles and Fuels

Motor Vehicles and Fuels:

Mobile Sources

Mobile Sources of Air Pollution

Projects in Progress

EVALUATION OF FUEL-CELL REFORMER EMISSIONS. 95-313: Acurex Environmental.

Objectives: To evaluate fuel-cell reformer technology (the fuel-cell reformer changes the fuel in such a way that hydrogen is released for use by the fuel cell) and to characterize and quantify the emissions that may result from fuel-cell vehicles.

Importance to ARB's Program: Results from this project will help the ARB assess the role of fuel-cell technology in reducing emissions from vehicles.

THREE-WAY CATALYST TECHNOLOGY FOR OFF-ROAD EQUIPMENT POWERED BY GASOLINE AND LPG ENGINES. 95-340: Southwest Research Institute.

Objectives: To develop and evaluate two emission control technologies for off-road gasoline and liquefied petroleum gas (LPG) industrial equipment engines of 25 to 175 horsepower. Use of these new emission control technologies by industry will assist the ARB in reducing total hydrocarbons, nonmethane hydrocarbons, carbon monoxide, and oxides of nitrogen from off-road engines. Existing off-road engine test procedures and cycles will be further developed and the investigators will suggest emission standards for off-road gasoline and LPG engines.

Importance to ARB's Program: The development of these emission control technologies will assist the ARB in adopting emission standards, and a test procedure upon which the standards can be based, for controlling the emissions from industrial equipment and to meet the emission reductions projected by California's implementation plan for reaching Federal ozone standards.

HEAVY-DUTY VEHICLE FLEET CHARACTERIZATION FOR REDUCTION OF NO_x AND PARTICULATE MATTER EMISSIONS IN THE SOUTH COAST AIR BASIN. 96-317: Jack Faucett Associates.

Objectives: To obtain activity and usage data for all heavy-duty vehicles (HDVs) operating in the South Coast Air Basin (SoCAB), and, based on these data, develop emission estimates and implementation strategies to accelerate the introduction of low-emitting engines and/or vehicles in the SoCAB.

Importance to ARB's Program: This study will provide information that is necessary for fulfilling California's plan for implementing Federal ozone standards as they apply to HDVs.

AUTOMOTIVE CHARGING SYSTEM FOR ELECTRIC VEHICLES: DEMONSTRATION PROJECT. 96-321: Bevilacqua-Knight, Inc. Co-sponsored with the Southern California Air Quality Management District.

Objectives: To design, fabricate, test, and demonstrate a reasonably priced electric vehicle (EV) automatic charging system that will require the EV driver only to provide an actuation signal in order to charge the vehicle batteries.

Importance to ARB's Program: This technology will help reduce emissions from vehicles by improving the market appeal of EVs and speeding the introduction of EVs into California's automobile population.

DEVELOPMENT OF MODELING TOOLS FOR MICROSCALE EMISSION MODELING. 96-316: California State Polytechnic University at San Luis Obispo.

Objectives: To develop equipment and modeling techniques for measuring vehicle activity (e.g. individual vehicle type and its average speed and acceleration) so that emissions can be simulated for a specific roadway type (e.g. freeway).

Importance to ARB's Program: The equipment and techniques developed during this study are intended to form the basis for a new generation of emission models that are designed to calculate emissions for conformity analyses. (Conformity analyses are required by Federal law to ensure that Federally funded infrastructure improvement projects not have an adverse environmental impact.) The emissions that must be estimated are generally for very small regions, thus the term "microscale".

INCORPORATION OF RADIO TRANSPONDERS INTO VEHICULAR ON-BOARD DIAGNOSTIC SYSTEMS. 96-332: Sierra Research.

Objectives: To develop an on-board transponder system for reporting of emission system failure.

Importance to ARB's Program: Successful development and application of this technique would reduce vehicle inspection costs for drivers and would also ensure detection of vehicles with emission system failures. The results and options presented in the final report for this study will provide ARB policymakers with a selection of measures and/or programs that could be used to improve the effectiveness of the Smog Check program.

DEMONSTRATION OF DIESEL-FUEL-BORNE CATALYST SYSTEM AND LOW- NO_x CONTROL TECHNOLOGY FOR PARTICULATE EMISSIONS. 96-334: Acurex Environmental. Co-sponsored with the Southern California Air Quality Management District.

Objectives: To demonstrate a system that consists of a cerium-based diesel fuel additive and particulate filter, combined with low-NO_x engine emission control technology such as cooled exhaust gas recirculation. Addition of this advanced prototype technology to diesel exhaust systems could assist in the regeneration (restoration and reusability) of particulate filters and in particulate matter (PM) reduction, and would also reduce NO_x emissions from heavy-duty diesel engines.

Importance to ARB's Program: The emergence of new, advanced emission control technology has been a key factor in reducing emissions from motor vehicles over the past 30 years. Heavy-duty diesel (HDD) engines emit significant quantities of PM and NO_x. A major challenge exists in controlling NO_x and PM emissions from HDD engines simultaneously: When NO_x emissions are reduced, PM emissions tend to increase and vice versa. This system has the potential to reduce both PM and NO_x emissions from HDD engines.

CHARACTERIZATION OF PARTICULATE EMISSIONS FROM GASOLINE-FUELED VEHICLES. 94-319: University of California, Riverside.

Objectives: To provide current inventory data for particulate emissions from gasoline-powered vehicles. Emissions from light-duty automobiles will be analyzed for mass and particle size distribution, and chemical speciation will be performed on samples of total particulate matter.

Importance to ARB's Program: The data from this study will be made available for improving the ARB's particulate matter emissions inventory and for use in future state implementation plans for attainment of the national ambient air quality standard for particulate matter.

Completed Projects

1998

HEAVY-DUTY TRUCK POPULATION ACTIVITY AND USAGE PATTERNS. 93-306: Jack Faucett Associates.

Objectives: To develop contemporary population, activity, and usage pattern data for heavy-duty trucks (HDTs) that operate in California. Activity data include vehicle miles traveled (VMT), numbers of trips and engine starts, and average speed. "Usage pattern" refers to range of operation (0-50 miles, 50-200 miles, etc.) and type of use (e.g., delivery, for-hire, construction). The data were obtained by analyzing existing databases such as California's DMV registration records and national Truck Inventory and Usage Survey data, and by the collection of data by means of on-board dataloggers.

Findings: The total 1995 population of California-registered HDTs was 661,287. Fifty-nine percent were gasoline-powered and 41% diesel-powered. The total HDT VMT estimate for calendar year 1992 was 12.3 billion miles, with about 25% attributed to out-of-state HDTs. The datalogger data for the small fleet of instrumented vehicles indicates that the HDTs in that fleet averaged about 17 trips and 18 starts per day and their average speed was about 30 mph.

Importance to ARB's Program: The emissions inventory is used for planning and regulatory purposes and must be as up to date as possible. The data collected in this study will be used for developing current activity data for HDTs, leading to improvements in this portion of the inventory. The activity data gathered in this study will be used for short-term inventory improvements, such as better characterization of trips, starts, and other activities, and for longer term improvements such as the development of chassis dynamometer driving cycles for HDTs. Whereas the new analysis is an improvement over previous ones, HDTs are much more difficult to characterize than light-duty vehicles, and the datasets in existence during the study made the task somewhat problematic. The ARB and DMV are working to reconcile methods and registration datasets for HDTs, and use of data from the International Registration Plan should improve out-of-state HDT characterization for future analyses. Use of on-board dataloggers should also ease the characterization problem considerably.

DEMONSTRATION OF A HEAVY-DUTY VEHICLE CHASSIS SCREENING TEST FOR COMPLIANCE TESTING HEAVY-DUTY ENGINES. 94-347: West Virginia University.

Objectives: To develop and demonstrate a chassis dynamometer screening test that could be used to test heavy-duty engines (HDEs) for compliance with applicable HDE exhaust emissions standards. A chassis dynamometer test, which is performed upon the vehicle itself, would be less costly than an engine dynamometer test, which requires removal of the engine from the vehicle.

Findings: Two heavy-duty truck and engine combinations were tested using a single gear over the entire driving cycle where the vehicle engine speed-versus-time trace is very similar to the engine speed-versus-time trace used in the HDE certification test. For the test, NO_x and particulate matter (PM) emissions were predicted and measured. The NO_x emissions correlated well with those predicted, but only gross PM emitters could be detected with the procedure. The limited number of test situations means that the viability of the chassis dynamometer screening test as a large-scale compliance tool cannot be assessed until the procedure is applied to a larger number of engine/vehicle combinations.

Importance to ARB's Program: More diesel and gasoline heavy-duty engines and vehicles are being fitted with electronic controls and aftertreatment devices (e.g., exhaust gas recirculation or catalytic converters) to control exhaust emissions, and there is now a need to be able to detect system failures that occur in in-use vehicles. The test developed in this study will be able to act as a screening test for emission certification compliance, and will also have the potential to detect in-use engine/vehicle problems such as failed vehicle speed sensors and low coolant level indicators. Because chassis emission testing is less expensive than engine dynamometer emission testing, this test offers the potential for screening a greater number of engines. Engines failing the chassis dynamometer test would be considered for further testing using the heavy-duty vehicle Federal Test Procedure, the official engine certification test (an engine dynamometer test).

1997

STUDY TO REDEFINE COLD- AND HOT-START EMISSIONS. 93-322: GM Powertrain Division, General Motors Corp.

Objectives: To collect data to better characterize start emissions for light-duty autos to be used later to investigate the emissions impacts of vehicle engine starts as a function of "soak" time (the amount of time the engine has had to cool after being fully warmed up), ambient temperature, type of gasoline, and vehicle technology type.

Findings: Comprehensive analysis of the data from this study and the integration of these data with other start emissions data are currently being performed by the ARB's Mobile Source Control Division.

Importance to ARB's Program: The ARB's motor vehicle emission factors and inventories, which are the state's responsibility, are used to support a variety of critical ARB functions and programs. Uses include air quality attainment plans, local air pollution control district analysis, conformity analysis, and pollution source problem definition. Results from this study will be used to support improvement of the ARB's on-road motor vehicle emission factors model EMFAC.

1996

DETERMINATION OF THE EFFECTS OF SPEED, TEMPERATURE, AND FUEL FACTORS ON EXHAUST EMISSIONS. 92-323: Automotive Testing and Development Services, Inc.

Objectives: To determine synergistic effects that may occur as cycle speed, ambient temperature, and vehicle fuel (gasoline) are simultaneously varied. In the typical procedure, only one of these parameters is varied at a time.

Findings: Vehicle technology type and vehicle average speed were identified as the factors that most heavily influence exhaust emissions. Analysis of emissions dependent on fuel type (Phase 1 gasoline vs. Phase 2) revealed statistically significant reductions of 17, 13, and 11 percent respectively for hydrocarbons, carbon monoxide, and NO_x. While temperature had minimal effects on hot stabilized emissions, cold start

emissions were higher than hot start emissions. Interactions among fuel, speed, and temperature were found to be statistically insignificant. ARB staff are continuing to analyze the data for second-by-second changes in emissions.

Importance to ARB's Program: The data from this project will be used to update the emission factors in the ARB's short-term emissions inventory. In addition, the relationships uncovered will be reflected in improvements to the longer-term model.

1995

DEMONSTRATION OF A NON-ADDITIVE LEAN- NO_x CATALYTIC CONVERTER FOR HEAVY-DUTY DIESEL VEHICLES. 92-310: Southwest Research Institute. Research Note 1997-2.

Objectives: To develop and demonstrate a heavy-duty diesel catalytic converter that is capable of reducing NO_x emissions without using additives and which will operate in an oxygen-rich ("lean") environment.

Findings: The lean NO_x catalyst technology investigated was found to be promising, achieving NO_x emission reductions of 10 to 20 percent in the laboratory. However, the technology is not yet ready for installation on a heavy-duty truck.

Importance to ARB's Program: The results from this project will be used as part of a demonstration of the technological feasibility of a lower NO_x emission standard for heavy-duty diesel engines.

EFFECT OF PHASE 1 AND PHASE 2 GASOLINE BLENDS ON EVAPORATIVE AND EXHAUST EMISSIONS FROM LIGHT-DUTY VEHICLES. A132-183: Automotive Testing Laboratories, Inc.

Objectives: To collect and analyze emission data that reflect both the adoption of Phase 2 reformulated gasoline regulations and the extended high-temperature evaporative emissions test procedure.

Findings: The data from this study indicate that reduction of hydrocarbon (HC) and carbon monoxide (CO) emissions can be achieved through the use of oxygenated gasolines. The ethanol blend tested was found to increase evaporative emissions.

Importance to ARB's Program: The data collected will be used to develop correction factors to adjust motor vehicle emission models to reflect use of reformulated gasoline and its emission benefits. The data obtained from the extended evaporative emissions tests will be used to adjust the current diurnal emission factors in the model to conditions more closely representing those of the real world.

MONITORING OF PERSONAL DRIVING HABITS AND VEHICLE ACTIVITY. A132-175: Automotive Testing and Development Services, Inc. Research Note 1996-10.

Objectives: To collect activity data (for example, vehicle speeds, numbers and durations of trips, catalyst temperatures) for light-duty vehicles loaned by private citizens to the ARB for in-use surveillance testing.

Findings: The results of this study indicate that light-duty autos make significantly more trips per day than had been estimated before the study was undertaken: about 7 trips versus the estimated 3. Additional data gathered showed the average trip length to be 7.4 miles and about 14 minutes in length. The vehicles in this study traveled an average of 49 miles per day.

Importance to ARB's Program: The data will be used to improve the vehicle activity estimates used in the ARB's EMFAC/BURDEN emissions inventory models.

DEVELOPMENT OF AN OFF-HIGHWAY MOBILE SOURCE EMISSIONS MODEL. A132-164: Energy and Environmental Analysis, Inc. Research Note 1997-8.

Objectives: To develop an off-road mobile source emission model similar to the EMFAC/BURDEN on-road motor vehicle inventory models.

Findings: The off-road model developed will be able to calculate emissions inventories for 12 different classes of off-road equipment, including construction and mining equipment, agricultural equipment, and lawn and garden equipment. The model will ultimately replace the current piecemeal methods used to calculate off-road emissions inventories.

Importance to ARB's Program: This model is designed to complement and supplement the categories in the ARB's Emission Data System.

DEVELOPMENT OF AN IMPROVED INVENTORY OF EMISSIONS FROM PLEASURE CRAFT IN CALIFORNIA. A132-184: Systems Applications International. Research Note 1995-21.

Objectives: To develop an improved emissions inventory for pleasure craft operations in California. The existing inventory was based on incomplete and now outdated data from a 1973 study. The investigators for this study conducted a survey of pleasure craft owners statewide. The results were combined with emission estimates for Coast Guard-documented vessels and emissions estimated for rental vessels.

Findings: Nearly all boating activity in California occurs on Saturdays and Sundays during the period April through September. The heaviest time of use is around noon. Average annual fuel consumption in this study was 77.5 gallons, about half that of an earlier ARB estimate. NO_x, total organic gases (TOG), and sulfur oxides SO_x emissions had decreased by about 45, 18, and 85 percent, respectively, compared to the 1973 inventory. CO had increased by about 3 percent and PM 100 percent. One of the reasons for the changes in values was that emission factors have been updated since the earlier inventory. Other causes may include overestimation of fuel consumption in the earlier estimate and the relatively low level of California's water reservoirs during the period 1993-1994, when hours of pleasure craft operation were reduced.

Importance to ARB's Program: The ARB is required by the Health and Safety Code to inventory sources of air pollution. The inventory completed in this study will provide updated data for use by the ARB in estimating emissions from pleasure craft. The procedures for calculating pleasure craft emissions will be reviewed and improved as necessary.

1994

FEASIBILITY AND DEMONSTRATION OF NETWORK SIMULATION TECHNIQUES FOR ESTIMATION OF EMISSIONS IN A LARGE URBAN AREA. A132-166: Deakin, Harvey, Skabardonis.

Objectives: To use roadway network simulation techniques to develop modal (second-by-second) vehicle activity data (for example, numbers of accelerations, decelerations, cruises, and time at idle).

Findings: The contractor determined that the network simulation techniques investigated in this study were feasible. An integrated modeling framework was developed, and the integrated model was applied to

the entire 1,120-zone Metropolitan Planning Commission San Francisco Bay Area network to obtain time spent in each driving mode. The analysis of the results demonstrated the applicability of the model in predicting vehicle activity in regional studies.

Importance to ARB's Program: The activity data may be used with concomitant modal emission factors in the calculation of an emissions inventory.

ON-ROAD MOTOR VEHICLE ACTIVITY DATA. A132-182: Valley Research Corporation. Research Note 1995-9.

Objectives: To update and upgrade several segments of the database used to calculate the ARB's on-road motor vehicle emissions inventory.

Findings: Several segments of the database used to calculate the Air Resources Board's mobile source emissions inventory were improved: (1) vehicle registration by model and year, by county; (2) mileage accumulation rates for vehicles; and (3) urban bus vehicle miles traveled, by speed.

Importance to ARB's Program: The ARB is required by the Health and Safety Code to inventory sources of air pollution. The results of this study will be used to develop and maintain more current motor vehicle emissions inventories.

1993

CONTROLLING LOCOMOTIVE EMISSIONS IN CALIFORNIA. A032-169: Engine, Fuel, and Emissions Engineering, Inc. Research Note 1997-4.

Objectives: To identify feasible and cost-effective measures to reduce locomotive emissions, develop and recommend a regulatory strategy and implementation schedule for controlling locomotive emissions, and identify and recommend areas for further research, development, and demonstration.

Findings: The following methods of reducing locomotive emissions were identified: diesel engine and diesel fuel modifications, selective catalytic reduction (SCR) of diesel emissions, use of alternative fuels such as liquefied natural gas, and locomotive electrification. A regulatory strategy that focuses on oxides of nitrogen and particulate matter emissions was proposed. Research was recommended to develop a suitable short, in-the-field emission test procedure, and a demonstration project is recommended for SCR technology.

Importance to ARB's Program: This report currently forms the basis for ongoing locomotive regulatory development by ARB staff. These regulations are expected to be presented to the Board in 1994.

METHANOL FUEL ADDITIVE DEMONSTRATION. A832-123: Southwest Research Institute. Research Note 1997-3.

Objectives: To perform a literature search and laboratory testing of chemicals added to methanol fuels to increase performance. To develop and test for emissions two additive packages for use in methanol-fueled motor vehicles.

Findings: The additive packages increased the fuel's luminosity, flammability, and lubricity, as had been desired. In a comparison against "industry average" gasoline, M100 (100 percent methanol), and M85 (85

percent methanol, 15 percent gasoline), methanol with the additive packages were found to produce exhaust emissions similar to those produced by M85.

Importance to ARB's Program: These findings permit additional research to develop additives to address concerns regarding performance of methanol fuels, while retaining methanol's reduced ozone-forming potential.

FORMALDEHYDE EMISSION CONTROL TECHNOLOGY FOR METHANOL FUELED VEHICLES. A732-148: Southwest Research Institute. Research Note 1997-6.

Objectives: To identify and demonstrate durable emission control systems capable of reducing formaldehyde emissions from methanol-fueled vehicles to levels comparable to those from gasoline-fueled vehicles while not adversely affecting other criteria pollutant levels.

Findings: Eighteen catalyst systems were evaluated. Of these, one was selected and installed on each of four vehicles for a 4,000-mile durability test. The test fleet generally exhibited low emission levels (including those for formaldehyde), but the investigator cautioned that it should be remembered that a vehicle with only 4,000 miles of use is essentially a new vehicle and would be expected to exhibit low emission levels.

Importance to ARB's Program: These findings will be used to demonstrate that formaldehyde emissions from methanol-fueled vehicles can be reduced to about the same level as those for gasoline-fueled vehicles; thus use of methanol has the potential for achieving substantial air quality benefits.

FEASIBILITY OF REDUCING NITROGEN OXIDE EMISSIONS FROM HEAVY DUTY VEHICLES. A132-085: Acurex Environmental Corp.

Objectives: To investigate various means of reducing emissions of NO_x and PM from heavy-duty vehicles. These included diesel and gasoline engine modifications, use of alternative fuels such as alcohols (methanol and ethanol) and gaseous fuels (liquefied petroleum gas and natural gas), and electric and hybrid-electric technologies.

Findings: The investigator determined that a NO_x emission standard equal to one-half the 1994 standard is feasible for diesel engines by 2002. For PM emissions the investigator proposed a reduction of approximately 50 percent by 2002 for diesel fueled trucks, and beginning in 1997 for alternatively fueled trucks.

Importance to ARB's Program: The results will be used to support low-emission vehicle regulations currently being developed by ARB staff.

CHARACTERIZATION OF DRIVING PATTERNS AND EMISSIONS FROM LIGHT-DUTY VEHICLES IN CALIFORNIA. A932-185: Sierra Research. Research Note 1996-11.

Objectives: To develop a model to estimate vehicle emissions based on a given driving cycle and to develop a driving cycle more representative of current California driving conditions.

Findings: Using models developed by the contractor, the new driving cycle reveals that light-duty vehicles produce double the emissions of CO and NO_x than expected from the Federal Test Procedure (FTP). HC emissions remained nearly the same.

Importance to ARB's Program: This cycle is undergoing testing and analysis to determine its suitability as a possible supplement to the FTP.

EFFECTS OF THE USE OF LOW-OXYGENATE GASOLINE BLENDS UPON EMISSIONS FROM CALIFORNIA VEHICLES. A932-159: Automotive Testing Laboratories, Inc. Research Note 1995-28.

Objectives: To measure the impact that Phase 1 oxygenated gasoline has had upon emissions of a small sample of California-certified vehicles tested over three driving cycles -- the FTP, the New York City Cycle (NYCC), and the Highway Fuel Economy Test (HFET) -- and for four fuels: base fuel and three oxygenated fuels (methyl tertiary butyl ether [MTBE], ethyl tertiary butyl ether [ETBE], and ethanol blends).

Findings: The emission results showed that hydrocarbons and carbon monoxide emissions were generally reduced for the oxygenate blends. For some vehicles NO_x emissions were also reduced, while for other vehicles NO_x emissions remained about the same, or increased slightly.

Importance to ARB's Program: These findings will be reflected in the ARB's emission factor model.

1992

CHEMICAL ANALYSIS OF AROMATICS IN DIESEL FUELS. A932-125: Southwest Research Institute. Research Note 1992-6.

Objectives: To develop a simple, reliable method of analysis that can be used to determine the total aromatic hydrocarbon content of diesel fuel and to quantify the relative amounts of various types of aromatics. Standard American Society for Testing and Materials (ASTM) tests for aromatics require complicated, expensive procedures and clear samples.

Findings: A successful infrared spectral method for determining total aromatic content of diesel fuel was developed. The method requires no sample preparation, and is effective with opaque samples. An ultraviolet spectral technique was developed to measure the percentage of the fuel made up of the different aromatic species.

Importance to ARB's Program: The new methods for characterizing and quantifying the aromatic hydrocarbon components of diesel fuel will enhance the ARB's ability to regulate both fuel quality and exhaust emissions, in support of the ARB's diesel fuel composition regulations.

1991

QUANTIFICATION OF EVAPORATIVE RUNNING LOSS EMISSIONS FROM GASOLINE-POWERED PASSENGER CARS IN CALIFORNIA. A832-153: Automotive Testing Laboratories.

Objectives: To gather data on evaporative running loss emissions from passenger cars.

Findings: The test results typically showed relatively low emissions, but some vehicle/temperature/fuel-volatility conditions produced substantially higher running loss emissions. Slow-speed driving conditions produced increased emissions from most vehicles.

Importance to ARB's Program: These findings have been used to update and improve the on-road motor vehicle emissions inventory. This study also contributed to the recognition of the need to include running losses in the ARB's evaporative emissions test procedure, which has subsequently been updated.

1989

QUANTITATIVE ESTIMATES OF THE AIR QUALITY IMPACTS OF METHANOL FUEL USE. A6-048-32: Carnegie-Mellon University. Research Note 1989-2.

Objectives: To use the Airshed model to study the air quality impacts of methanol fuel use in the South Coast Air Basin.

Findings: The results indicate that while the South Coast Air Basin would not achieve attainment with the National Ambient Air Quality Standards by complete conversion to methanol, methanol can help reduce ozone concentrations. M100 fuel was found to be twice as effective as M85 when results are compared to baseline ozone concentrations formed when gasoline fuel is used in advanced conventional vehicles.

Importance to ARB's Program: These Findings have been used by the air quality planning community when comparing various alternative fuels.

RUNNING LOSS EVAPORATIVE EMISSIONS DETERMINATION BY THE POINT SOURCE METHOD. A732-151: National Institute for Petroleum and Energy Research. Research Note 1990-4.

Objectives: To quantify evaporative running losses from two light-duty vehicles -- a carbureted 1987 Chevrolet, and a fuel-injected 1985 Buick -- by measuring evaporative emissions at specific locations on the vehicles.

Findings: The test results showed that the charcoal canister of the evaporative emission control system is the major source of evaporative running losses and that, for the carbureted vehicle, evaporative running loss emissions are as high as tailpipe hydrocarbon emissions. The carbureted vehicle showed significantly greater running loss emissions than did the fuel-injected vehicle.

Importance to ARB's Program: The findings contributed to an ARB study to develop an emissions database and emission factors for evaporative running losses.

Toxic Air Contaminants

Toxic Air Contaminants

Projects in Progress

REFINEMENT OF SELECTED FUEL-CYCLE EMISSIONS ANALYSES. 97-308: California State Polytechnic University at Pomona.

Objectives: Fuel-cycle emissions are emissions produced over the entire life cycle of a fuel, from fuel production and distribution through consumption. Liquefied petroleum gas, diesel fuel, and methanol (for fuel cell) have fuel cycle emissions closest to those of electric vehicles. The investigator will estimate the overall emissions impact associated with the fuels for 1996 (as the base year) and projections to the year 2010.

Importance to ARB's Program: The ARB has promulgated low-emission vehicle and clean fuels regulations, focused on the relative ozone-forming potential of non-methane organic gas emissions from various fuels. Because of the interest in providing partial zero-emission vehicle credits for fuels that are relatively non-polluting, the ARB needs to clarify the fuel-cycle emissions estimates of the above three fuels, as well as electricity generation for electric vehicles.

VAPOR RECOVERY SYSTEMS AT GASOLINE DISPENSING FACILITIES: IMPACTS OF ON-BOARD REFUELING VAPOR RECOVERY SYSTEMS. 95-342: AeroVironment Environmental Services.

Objectives: To determine the impacts of vehicle on-board vapor recovery systems on the effectiveness of vapor recovery systems at gasoline dispensing facilities.

Importance to ARB's Program: Beginning in 1998, Federal law will require a portion of new motor vehicles to have an on-board vapor recovery system, with compliance required in 40% (1998), 80% (1999), and 100% (2000) of new vehicles. This study will provide information that can be used by vapor recovery manufacturers to prevent interference with the effectiveness of facility vapor recovery systems.

VAPOR RECOVERY SYSTEMS AT GASOLINE DISPENSING FACILITIES: SEASONAL IMPACTS. 95-343: AeroVironment Environmental Services.

Objectives: To determine the impacts of seasonal factors such as temperature and atmospheric pressure on emission of hydrocarbons from gasoline service station holding tanks.

Importance to ARB's Program: The results of this study will be used to improve the ARB's certification and test procedures that are used to evaluate various vapor recovery equipment technologies.

PERFORMANCE SPECIFICATION TESTS FOR VAPOR RECOVERY SYSTEMS AT GASOLINE DISPENSING FACILITIES. 95-344: Bay Area Air Quality Management District.

Objectives: To provide performance specification testing and advisory services for the two contracts above, 95-342 and 95-343.

Importance to ARB's Program: These tests will ensure that the vapor recovery equipment at the gasoline dispensing facilities chosen for testing are in good working order.

DEVELOPMENT OF TOXICS EMISSION FACTORS FROM SOURCE TEST DATA COLLECTED UNDER THE AIR TOXICS HOT SPOTS PROGRAM, PART II. 96-333: Energy and Environmental Research Corporation.

Objectives: To incorporate enhancements to the emission factor database developed in Part I of this study (92-338, see 1996) and to develop additional emission factors from new data.

Importance to ARB's Program: The emission factors resulting from this project can be used by small facilities for reporting purposes, eliminating the need for these facilities to conduct costly source tests themselves. The factors will also be used to evaluate cost-effective control measures for the ARB's Toxic Air Contaminant Identification and Control Program.

CHARACTERIZATION OF EMISSIONS FROM NICKEL PLATING. 95-328: Sierra Research.

Objectives: To characterize the emissions from nickel plating operations in terms of their magnitude and in terms of the impact of nickel plating process variables on emissions.

Importance to ARB's Program: The ARB will use the emission factors developed from this study to assess the need for a nickel plating airborne toxics control measure, as required by the Health and Safety Code.

BIOFILTER TECHNOLOGY FOR NO_x REMOVAL FROM AIRSTREAMS. 96-304. University of California, Davis.

Objectives: To determine whether biofiltration systems are a feasible technology for controlling NO_x emission. Specifically, to determine whether destruction of NO_x can be carried out in biofilters using microbial nitrification and de-nitrification, and to determine the extent of NO_x emissions from biofilters through experimental measurements of emissions under controlled laboratory conditions.

Importance to ARB's Program: This technology, if successful, could help California attain ozone standards by providing a low-cost method of removing nitrogen oxides from emissions.

AN ASSESSMENT OF THE EFFECTIVENESS OF ROOM ENCLOSURES WITH VENTILATION SYSTEMS IN REDUCING RISK AT DRY CLEANING FACILITIES USING PERCHLOROETHYLENE. 96-324: AeroVironment Environmental Services, Inc.

Objectives: To document the effectiveness of room enclosures with ventilation systems in reducing risk to the public at dry cleaning facilities that use perchloroethylene (perc), and to develop guidelines for the dry cleaning industry on room enclosure design, installation, operation, and risk reduction potential.

Importance to ARB's Program: California's Health and Safety Code requires that a facility identified as posing a "significant risk" to the public must develop and implement a plan to reduce its risk below the significant risk level as set by the district the facility resides in. Demonstration that room enclosures with ventilation systems reduce the public risk to below significant levels will provide dry cleaning facilities with information for reducing their perc emissions.

RECLAMATION OF AUTOMOTIVE BATTERIES: ASSESSMENT OF HEALTH IMPACTS AND RECYCLING TECHNOLOGY. 93-323: Acurex Environmental Corporation.

Objectives: To assess the feasibility of current and prospective battery recycling technologies and to evaluate health and hazard impacts of recycling and disposal of spent batteries. The battery types investigated include lead-acid, nickel-cadmium, nickel-iron, lithium-iron disulfide, lithium-ion, lithium polymer, and zinc. The project will result in two ranked lists of battery technologies, one ranking for recycling prospects, and one for health and hazard impacts of the recycling process.

Importance to ARB's Program: The ARB expects that all zero-emissions vehicles will initially be battery-powered electric vehicles (EVs). The great majority of batteries contain substances that are toxic and may pose a health hazard to humans and the environment. It is important to identify these potential hazards and ensure that a robust recycling chain is established in order to accommodate the increased number of batteries, thereby minimizing any potential health and environmental effects. Thus, it is important to identify and assess the potential fate of spent batteries prior to market penetration, especially with respect to those new battery technologies that contain materials known to be toxic and hazardous. This project is jointly funded by CALSTART and the Air Resources Board.

DEVELOPMENT OF LASER DESORPTION LASER PHOTOIONIZATION MASS SPECTROMETRY METHOD FOR THE SCREENING OF NITRO-SUBSTITUTED POLYCYCLIC AROMATIC HYDROCARBONS, CHLORINATED DIOXINS, AND CHLORINATED FURANS. 97-305: University of California, Davis.

Objectives: To modify an existing analytical instrument -- the laser desorption laser photoionization mass spectrometer (LDLPMS) -- to allow for relatively rapid and inexpensive examination of a selection of polycyclic aromatic hydrocarbons (PAHs) as well as certain other carcinogens: nitro-PAHs (an especially toxic subgroup of PAHs) and chlorinated dioxins and chlorinated furans (collectively called dioxins, several of which are extremely carcinogenic).

Importance to ARB's Program: Current methods for determining the presence and concentrations of certain toxic air contaminants are very expensive and time-consuming. This technique will allow for relatively rapid and inexpensive examination of a selection of PAHs of current interest for ARB test method development as well as a number of other carcinogens: nitro-PAHs (an especially toxic subgroup of PAHs), chlorinated dioxins, and chlorinated furans (these last two collectively called dioxins, several of which are extremely carcinogenic). Development of less costly methods will aid the ARB in fulfilling its requirements under the Air Toxics Hot Spots Program to perform chemical analyses for toxic air contaminants emitted by sources in California.

Completed Projects

1998

EVALUATION OF FACTORS THAT AFFECT DIESEL EXHAUST TOXICITY. 94-312: UCR.

Objectives: To perform a preliminary assessment of the potential impact of diesel fuel formulation on the speciation and toxic components of diesel exhaust. A heavy-duty diesel engine was operated over a standard test cycle using three fuels: a pre-1993 diesel fuel, a low aromatic diesel fuel, and a post-1993 fuel with higher aromatic content.

Findings: A major part of this study involved analysis for polycyclic aromatic hydrocarbons (PAHs) and their derivatives. For volatile PAHs, the concentrations in the exhaust appear to be derived mainly from the PAH initially present in the fuel. In contrast, the emission levels of most of the less volatile PAHs were similar for all fuel types, suggesting that these PAHs are mainly formed during combustion. Levels of particle-associated nitro-PAHs were similar for all fuels.

Importance to ARB's Program: The ARB is evaluating diesel exhaust for possible identification as a toxic air contaminant. Diesel exhaust is a complex mixture of many individual chemicals, and its composition has probably changed since the ARB's 1993 diesel fuel reformulation regulation. Although differences were found, in general, the exhaust does not show substantial compositional changes.

1997

DEVELOPMENT OF METHODS AND ANALYSIS FOR THREE PESTICIDE SAMPLES FROM THE AIR. 93-309: University of California, Davis.

Objectives: To develop sampling and analytical methods and perform the analysis on ambient air samples for three pesticides and two breakdown products. These compounds are carbofuran, naled and its breakdown product dichlorvos, and oxydemeton-methyl and its breakdown product dioxydemeton-methyl.

Findings: Methods for air sampling and analysis were developed for the three pesticides and two breakdown products. Airborne concentrations of the pesticides and their breakdown products were determined using the methods developed. These data will be used by the Department of Pesticide Regulation (DPR).

Importance to ARB's Program: In accordance with California Food and Agriculture Code Section 14022, the ARB documents ambient levels of pesticides to provide the DPR with data for the evaluation of the persistence of airborne pesticides and the degree of public exposure.

LIFETIMES AND FATES OF TOXIC AIR CONTAMINANTS IN CALIFORNIA'S ATMOSPHERE. 93-307: University of California, Riverside. Research Note 1997-13.

Objectives: The objectives of this study were to provide the ARB with data concerning the atmospheric fate of about 200 compounds and to determine atmospheric concentrations of polycyclic aromatic hydrocarbons (PAHs) for which the State has established cancer risk factors.

Findings: In general, the PAH concentrations measured were significantly below those measured in the 1986-1987 study. However, some nitro-PAHs (formed as the result of reactions in the atmosphere) had levels similar to those previously observed. The final report for this project also reviews the sources of nitro-PAHs and includes data on ambient levels in California and suggested routes of formation. Several nitro-PAHs of unknown cancer risk are found at relatively high levels compared to those that have been assigned cancer risk factors.

Importance to ARB's Program: Atmospheric persistence is an important factor for the ARB to consider to ensure that airborne toxic control efforts will focus on those compounds that represent the greatest public health threat. With the results of this study, the ARB now has information on the levels of all the PAHs and nitro-PAHs for which the State has determined cancer risk factors, so that the overall public health risk due to exposure to these compounds can be calculated.

ALTERNATIVES TO PERCHLOROETHYLENE-BASED GARMENT CARE: ASSESSING THE VIABILITY OF PROFESSIONAL WET CLEANING. 94-315: University of California, Los Angeles. Research Note 1997-14.

Objectives: To measure, in a market context, the effectiveness of wet cleaning for garments as an alternative to dry cleaning. Consumer acceptance of wet cleaning and the financial characteristics of a wet-cleaning establishment will also be determined. As part of this project, the local dry cleaning industry will be informed about wet cleaning methods and encouraged to use them.

Findings: In general, the wet cleaning establishment successfully cleaned both the volume and mix of garments typically encountered by a dry cleaner. Ninety percent of the wet-cleaning customers rated the results good or excellent; this rate is similar to that for customers who regularly use a particular dry cleaner.

Importance to ARB's Program: The solvent most often used in dry cleaning is perchloroethylene (perc), which is regulated as a toxic air contaminant. In 1993, the ARB adopted a measure to reduce perc emissions from dry cleaning establishments. Adoption of wet cleaning could lead to a significant reduction in public exposure to perc.

BIOASSAY AND CHEMICAL METHODS DEVELOPMENT FOR CHARACTERIZATION OF HEAVY-DUTY DIESEL EXHAUST USING REFORMULATED FUEL. 92-342 and 94-335: University of California, Davis.

Objectives: To develop methods for analyzing diesel exhaust, which is under consideration for identification as a toxic air contaminant.

Findings: The diesel exhaust showed significant levels of polycyclic aromatic hydrocarbons. No substantial differences were found between the engine exhaust compositions that resulted from combustion of the two fuels used.

Importance to ARB's Program: The techniques developed for this study are being used in another contract (94-312, above), which is a more definitive study on the effects of different diesel fuels on diesel exhaust toxicity.

1996

DEVELOPMENT OF PREDICTIVE CAPABILITIES FOR INTERMEDIA TRANSFER FACTORS FOR TOXIC AIR POLLUTANTS. 92-344: University of California, Los Angeles. Research Note 1997-11.

Objectives: To develop an integrated system of tools for the prediction of intermedia transfer factors for toxic air contaminants. Literature data for most of these substances is lacking, and obtaining experimental data for such a large number of substances is not feasible.

Findings: The researchers developed algorithms to allow the estimation of region-specific and chemical-specific intermedia transfer factors, which can be used according to the State's published guidelines. The project's product is a user-friendly software package with an integrated predictor of intermedia transfer factors and a physicochemical properties database.

Importance to ARB's Program: The results of this study will be used to support the State's multipathway exposure assessment methodology, which is used to assess the public health risk posed by emissions from a facility.

DEVELOPMENT OF TOXICS EMISSION FACTORS FROM SOURCE TEST DATA COLLECTED UNDER THE AIR TOXICS HOT SPOTS PROGRAM. 92-338: Energy and Environmental Research Corporation. Research Note 1997-10.

Objectives: To develop air toxics emission factors from source test data collected as a result of the Air Toxics "Hot Spots" Information and Assessment Act of 1987 to support the emissions inventory processes. (An example of an air toxics emission factor is number of pounds of a toxic gas that a specified volume of a material emits.)

Findings: Data from 200 source test reports were validated and analyzed to produce approximately 1,600 emission factors. Emission factors were calculated for trace metals, including hexavalent chromium, polychlorinated dibenzodioxin/furan; polycyclic aromatic hydrocarbons and other semivolatile organic compounds; benzene, toluene, and other volatile organic compounds; aldehydes; and hydrogen chloride. The database is available on diskette as well as paper. The diskette database features a graphical user interface.

Importance to ARB's Program: Development of these test-based emission factors will greatly assist small businesses and other small facilities that would otherwise be required to conduct costly source tests to comply with the Air Toxics "Hot Spots" Information and Assessment Act of 1987.

1995

PESTICIDES IN AIR. PART I: ANALYSIS OF AIR SAMPLES FOR TWO FUNGICIDES. PART II: DEVELOPMENT OF PREDICTIVE MODELS FOR ESTIMATING PESTICIDE FLUX TO AIR. 92-313: University of California, Davis.

Objectives: To determine airborne concentrations of the fungicides ziram and mancozeb. To develop the ability to predict the pesticides that are likely to be found in the ambient air, and at what levels.

Findings: For Part I of this study, airborne concentrations of ziram and mancozeb were determined. These data will be used by the Department of Pesticide Regulation (DPR). For Part II of the study, methods were developed for predicting estimates of pesticide flux to air, depending on mode of pesticide application. For five pesticides, downwind concentrations calculated by these methods were found to correlate well with reported downwind concentrations.

Importance to ARB's Program: The ARB will present the fungicide analytical results to the DPR. The DPR has asked ARB to document airborne levels of these fungicides, and will use the results pursuant to the Food and Agriculture Code. The predictive part of the study will provide information that will allow for the setting of priorities for future ambient pesticide monitoring.

DEMONSTRATION OF BIODEGRADATION TECHNOLOGY, PHASE II. 92-304: University of California, Davis.

Objectives: To establish operational parameters that would allow commercial development of a biofilter for the removal of air pollutants from dilute emission streams. Under a previous study, a pilot-scale biofilter facility successfully removed air pollutants from a sewage treatment plant by using microbes present in compost derived from sewage sludge.

Findings: Biofilters were found to be effective in degrading low-concentration emissions of aromatic and aliphatic hydrocarbons and biodegradable chlorinated solvents. A model was developed that accurately

described pollutant concentrations in a compost biofilter. An important finding for commercial purposes was that biofilter composts may function more effectively if nitrogen is added as a nutrient.

Importance to ARB's Program: The findings may lead to the commercial development of emission control devices for sewage treatment plants and landfills. Although these sources emit significant quantities of air pollutants, the pollutants are emitted at relatively low concentrations, making their control difficult.

1994

DEVELOPMENT OF INTERMEDIA TRANSFER FACTORS FOR TOXIC AIR POLLUTANTS. A032-170: University of California, Los Angeles. Research Note 1995-5.

Objectives: To develop information on the transfer of toxic air pollutants between any two of: air, water, soil, and the biosphere. The pollutants to be investigated are TCD-dioxin, chromium (VI), benzene, benzo[a]pyrene, mercury, methylene chloride, and formaldehyde. These are all either already listed as toxic air contaminants or are candidates for listing.

Findings: These were some of the interesting findings of this study: (1) Inhalation is the most important exposure route for chromium(VI). (2) Resuspension of particle-bound TCD-dioxin may be a significant exposure route. (3) The most significant pathway of exposure to mercury is by ingestion of fish contaminated with methyl mercury.

Importance to ARB's Program: Under regulations pursuant to the Air Toxics "Hot Spots" Act, the ARB needs this information to refine the multipathway exposure components of health risk assessments for these compounds.

INVESTIGATION OF THE USE OF SOLVENTS BY CALIFORNIA INDUSTRIES IN THREE SOURCE CATEGORIES. A132-086: Battelle Memorial Institute. Research Note 1995-15.

Objectives: To perform a comprehensive survey of recent solvent use in coatings and aerosols. Some of the solvents used in these products have been identified as toxic air contaminants, while others are being phased out because they contribute to the depletion of stratospheric ozone.

Findings: Data from the architectural coatings survey showed that 36,250 tons of VOCs were emitted in 1990. Although water-borne coatings constituted about three-fourths of the sales, solvent-borne VOC emissions represented more than two-thirds of the emissions. 6,750 tons of VOCs were emitted from aerosol paints in 1992. Less than 10 percent of aerosol paint sales were from water-based paints.

Importance to ARB's Program: Emissions of these compounds need to be reduced to comply with the Health and Safety Code. This research will fill data gaps on the use of solvents in these categories, on control equipment effectiveness, and on substitute processes or compounds. Improved data will facilitate ARB's development of control measures for processes using these solvents.

UPDATING THE MULTI-PATHWAY EXPOSURE ASSESSMENT COMPUTER PROGRAM. 92-318: University of California, Davis.

Objectives: To improve and update the ARB's Health Risk Assessment computer program, which is used to assess public health risks from facilities subject to the State's air toxics "Hot Spots" legislation.

Findings: A multi-pathway exposure assessment computer program is now available that is very easy to use. The manual provides a lucid description of the procedures that should be followed in order to operate the program. The program can be operated without reference to the manual by those who have some familiarity with risk assessment methodology. State agencies will be able to easily add or delete inputs (such as unit risk factors) as circumstances may warrant.

Importance to ARB's Program: Pursuant to regulations implementing the Air Toxics "Hot Spots" Act, industry is required to submit, and air districts are required to evaluate, health risk assessments for facilities. The ARB will make this computer program, which is easier to use and gives more accurate results than the current program, available to industry and air districts.

DEVELOPMENT OF PARTICLE SIZE TEST METHODS FOR SAMPLING HIGH-TEMPERATURE AND HIGH-MOISTURE SOURCE EFFLUENTS. A132-084: Southern Research Institute. Research Note 1995-6.

Objectives: To develop particle size test methods for pollutant sources having exhaust temperatures greater than 1300°F, and those with wet scrubber effluents. Both conditions have caused problems with source testing, and have led to unreliable results.

Findings: Appropriate equipment for such special purpose source testing can be constructed. Equipment is being developed that can be used for routine determination of particle sizes for these special sources.

Importance to ARB's Program: Under the Health and Safety Code, ARB staff conduct emissions testing at several facilities. The results will enable the ARB to test several important emission sources that cannot currently be tested and evaluate them in terms of health risk.

ASSESSMENT OF AIRBORNE EMISSIONS FROM BIOREMEDIATION PROCESSES. A132-083: University of California, Davis. Research Note 1994-17.

Objectives: To perform a literature review on the airborne emissions from bioremediation processes, and to determine experimentally the nature of emissions from these systems. Bioremediation involves removal of pollutants through microbial action, and is used to reclaim polluted soils and groundwaters.

Findings: Well designed and operated bioremediation operations are not likely to give rise to significant levels of toxic air contaminants, but that may be less true for some field operations. In addition, bioremediation operations produce significant emissions of volatile organic compounds under some conditions.

Importance to ARB's Program: As a result of this research, it is now easier to estimate the extent of airborne emissions likely to result from increased use of bioremediation as a hazardous waste cleanup option. As a result, the ARB will be able to determine whether regulatory controls should be pursued, based upon the Health and Safety Code.

MONITORING OF TWO PESTICIDES IN AIR: ANALYSIS OF AIR SAMPLES FOR CARBOFURAN AND CAPTAN. 92-314: University of California, Davis.

Objectives: To provide data on airborne concentrations of the pesticides carbofuran and captan, in response to a request by the Department of Pesticide Regulation (DPR). As part of this effort, analytical method development was necessary.

Findings: Carbofuran monitoring showed that most of the samples contained detectable levels of the pesticide. Only some of the samples monitored for captan showed detectable levels of that compound.

Importance to ARB's Program: DPR was provided with the monitoring results. It will use the data to evaluate possible regulatory controls on these pesticides pursuant to the Food and Agriculture Code.

FORMATION OF MUTAGENS FROM THE ATMOSPHERIC PHOTO-OXIDATIONS OF PAHs AND THEIR OCCURRENCE IN AMBIENT AIR. A132-075: University of California, Riverside. Research Note 1994-22.

Objectives: To chemically identify the compounds that are responsible for much of the cell mutation capability (mutagenicity) of ambient air in smoggy areas. Previous research suggested that a particular class of compounds formed from atmospheric reactions of directly emitted polycyclic aromatic hydrocarbons (PAHs) may be responsible for a large portion of this mutagenicity.

Findings: This study has determined the distribution of mutagenicity that results from the atmospheric reactions of PAH compounds that are abundant in California's air.

Importance to ARB's Program: The ARB plans to identify PAHs as a toxic air contaminant category, pursuant to the Health and Safety Code. Data from this study will provide a basis for determining the effects of various PAH control options on the mutagenicity of ambient air.

1993

LIFETIMES AND FATES OF TOXIC AIR CONTAMINANTS IN CALIFORNIA'S ATMOSPHERE. A032-055: University of California, Riverside. Research Note 1995-2.

Objectives: To review the atmospheric lifetimes of several potential toxic air contaminants (TACs), to provide possible atmospheric formation routes and atmospheric breakdown routes and products for these pollutants, and to investigate the mutagenicity of products of simulated atmospheric reactions of gasoline and of terpenes (terpenes are emitted from vegetation).

Findings: The atmospheric lifetimes, fates, and formation routes of three TACs, N-nitrosomorpholine, di(2-ethylhexyl)phthalate (DEHP), and dialkylnitrosamines, were reviewed in detail. Eleven of 23 additional TACs reviewed were found to have lifetimes exceeding a day. For several TACs, atmospheric levels are determined more by their formation in the atmosphere than by their direct emission. Finally, gasoline and terpenes were determined to not be significant sources of the mutagenicity found in ambient air.

Importance to ARB's Program: California's Health and Safety Code requires the ARB to prepare a report that addresses the stability, persistence, transformation products, and dispersion potential of each toxic air contaminant in ambient air. This study provides needed information in these areas for several TACs. The finding that many TACs are formed in the atmosphere will help the ARB develop appropriate control strategies. Knowing which TACs persist will help guide appropriate ambient air monitoring methods development.

AIRBORNE CONCENTRATIONS OF PESTICIDES IN CALIFORNIA. A032-094: California State University, Fresno.

Objectives: To document the airborne levels of several pesticides and their breakdown products, as requested by the Department of Pesticide Regulation (DPR).

Findings: Airborne concentrations of the following pesticides and their breakdown products was determined: naled and dichlorvos; methidathion and methidaoxon; and oxydemeton-methyl and dioxydemeton-methyl.

Importance to ARB's Program: Pursuant to the Food and Agriculture Code, the Department of Pesticide Regulation uses monitoring data to assess whether a pesticide should be identified as a toxic air contaminant. The ARB responds to requests from DPR as part of the toxic air contaminant regulatory program.

MEASUREMENT OF AMBIENT CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS AND CHLORINATED DIOXINS AND FURANS. A932-093: ENSR Consulting and Engineering Corporation. Research Note 1994-7.

Objectives: To measure ambient concentrations of chlorinated dioxins and polycyclic aromatic hydrocarbons at three locations: in an industrial area of Richmond, in Fresno during a period of heavy wood burning, and in rice growing areas while rice straw was burned nearby.

Findings: In general, the highest concentrations of dioxins and PAHs were found in those samples impacted by wood burning, and the lowest concentrations were found in those samples impacted by rice straw burning.

Importance to ARB's Program: Although the dioxins and PAHs are considered serious toxic air pollutants, only limited information was available on ambient levels of these compounds in California. The results provide a basis for assessing the public health risk from exposure to ambient levels of dioxins and PAHs, as required by the Health and Safety Code.

MEASUREMENT AND CHEMICAL CHARACTERIZATION OF VAPOR-PHASE MUTAGENS IN DIESEL EXHAUST. A032-095: University of California, Davis. Research Note 1995-3.

Objectives: To use microbial tests (bioassays) to help direct chemical analyses of diesel exhaust, a complex emissions mixture, in order to chemically identify vapor-phase mutagenic air contaminants.

Findings: Methods were developed to collect and concentrate vapor-phase organic compounds. The methods were then integrated with a modified bioassay for vapor-phase mutagens. The mutagenic activity of the vapor phase was found to be comparable to that of the particle phase.

Importance to ARB's Program: Diesel exhaust is a candidate toxic air contaminant. As a result of this research, ARB now has important information regarding the health benefits that may result from regulatory controls on diesel engine exhaust such as may be implemented under the TAC control program.

MEASUREMENT OF PARTICULATE EXPOSURES DURING RICE FARMING OPERATIONS. A032-177: University of California, Davis.

Objectives: To establish a monitoring method for amorphous silica fibers generated from the burning of rice straw after harvest. Attention has recently been focused on adverse public health effects that may result from exposure to these fibers.

Findings: A method was developed to collect and analyze breathable amorphous silica fibers in ambient air. The fibers were found to be released to ambient air during rice harvesting, rice straw burning, and field preparations after burning. However, concentrations of these fibers was low.

Importance to ARB's Program: The Health and Safety Code requires the ARB to identify toxic air contaminants (TACs). The information obtained is useful in determining the relative priority of identifying various forms of silica as TACs.

1992

DEVELOPMENT OF A TECHNIQUE TO ESTIMATE AMBIENT ASBESTOS CONCENTRATIONS DOWNWIND FROM SERPENTINE-COVERED ROADWAYS. A032-147: Valley Research Corporation. Research Note 1993-4.

Objectives: To gather data to assist in determining whether asbestos emissions from unpaved road surfaces containing serpentine rock should be mitigated. Asbestos is classified as a toxic air contaminant.

Findings: A model was developed to enhance the ARB's and local air districts' ability to predict public exposure to asbestos from unpaved road surfaces containing crushed serpentine rock.

Importance to ARB's Program: In response to State statutes for control of toxic air contaminants, the results may be used as a relatively inexpensive technique for identifying and prioritizing unpaved roads, in terms of potential to expose the public to ambient asbestos fibers.

DEVELOPMENT OF AN IMPROVED SOURCE SAMPLING METHOD FOR POLYCYCLIC AROMATIC COMPOUNDS AND OTHER SEMI-VOLATILE ORGANIC SPECIES. A932-098: California Department of Health Services.

Objectives: To develop an improved sampling system to detect polycyclic aromatic compounds in stack emissions for use by the ARB in testing and evaluating emission sources. The current sampling method is known to produce artifacts that alter the composition and physical characteristics of the collected material.

Findings: A promising integrated approach to determining PAH emissions from stationary combustion sources was developed that includes a system to collect both vapor-phase and particulate-phase PAHs. The new approach allows filtration of particulate matter under cool rather than artificially hot conditions, thereby reducing artifacts.

Importance to ARB's Program: As part of the ARB's effort to identify and control PAHs as toxic air contaminants (pursuant to the Health and Safety Code), many source tests will be needed. The more accurate collection, extraction, and analysis of this sampling system will allow better assessments of stationary combustion sources that emit PAHs.

BIODEGRADATION TECHNOLOGY FOR REMOVAL OF VOLATILE ORGANIC COMPOUNDS FROM AIRSTREAMS, PHASE I: PERFORMANCE VERIFICATION. A032-127: University of California, Davis. June 1992. Research Note 1992-9.

Objectives: To determine whether microbial packed-bed systems (biofilters) could be applied in the removal of volatile organic compounds (VOCs) from gases resulting from sewage treatment. VOCs and toxic air pollutants are emitted in significant quantities from sewage treatment plants. Because the concentrations are low, emission control has been difficult.

Findings: This study verified the potential application of microbial packed-bed systems for removal of VOCs from gases resulting from wastewater treatment. In the field, removal of benzene, toluene, and hydrogen sulfide was generally over 90 percent. Removal of chlorinated compounds was somewhat lower.

Importance to ARB's Program: Sewage treatment plants had been found to be significant emission sources of both VOCs and toxic air pollutants, requiring control pursuant to the Health and Safety Code. The results indicate the feasibility of developing a cost-effective emission control device for sewage treatment plants.

CONTROL OF PCDD/PCDF EMISSIONS FROM MEDICAL WASTE INCINERATORS. A832-155: Energy and Environmental Research Corporation.

Objectives: To summarize information needed to evaluate medical waste incinerators for their emission of PCDD/PCDF (dioxin and furan), and to provide information on the operation and capability of various flue gas cleaning systems to control emissions of these toxic air contaminants.

Findings: PCDD/PCDF emissions can be controlled through the use of devices such as wet and dry scrubbers, electrostatic precipitators, and fabric filters. Use of two or more of these devices is usually needed to provide satisfactory emission reductions.

Importance to ARB's Program: Pursuant to the Health and Safety Code, the ARB adopted a regulation to control toxic emissions from medical waste incinerators. This information has been used to guide the design and retrofit of emission control systems for these incinerators.

DEVELOPMENT OF LASER DIAGNOSTIC METHODS TO SCREEN FOR POLYCYCLIC AROMATIC HYDROCARBONS IN SOOT AND FLY ASH. A933-099. University of California, Davis. May 1992. Research Note 1995-23.

Objectives: To develop a method to screen for polycyclic aromatic hydrocarbons (PAHs) in soot and airborne (fly) ash samples.

Findings: A technique using laser-desorption/laser-photoionization mass spectrometry was developed to detect PAHs in rice smoke soot samples. The level of detection for PAHs was well within ARB's desired detection limit, indicating that this technique could be used as a replacement for the current ARB method.

Importance to ARB's Program: The ARB and industry incur considerable expense in monitoring facilities for emissions of PAHs. We anticipate an increased need to monitor facilities for PAHs. The technique developed in this project has the potential for use at far less cost and employs faster analytical methods to determine the extent of emissions of these toxic air contaminants.

1991

ASSESSMENT OF COMBUSTION SOURCES THAT EMIT POLYCHLORINATED DIOXINS AND FURANS, POLYCYCLIC AROMATIC HYDROCARBONS, AND OTHER TOXIC COMPOUNDS. A832-124: Midwest Research Institute. Research Note 1994-1.

Objectives: To determine the emission levels of polychlorinated dioxins and furans, polycyclic aromatic hydrocarbons, and other toxic compounds from recycled waste-oil burners and drum reconditioners.

Findings: The drum reconditioning facilities emitted higher levels of dioxins than did the waste oil burners, while the two source categories had roughly comparable metals emissions. PAH emissions levels from both source categories were relatively low.

Importance to ARB's Program: Pursuant to the Health and Safety Code, these results have helped the ARB determine the need for airborne toxic control measures for these source categories.

HYDROXYNITRO-PAHs AND OTHER DERIVATIVES IN CALIFORNIA'S ATMOSPHERE AND THEIR CONTRIBUTION TO AMBIENT MUTAGENICITY. A732-154: University of California, Riverside. Research Note 1991-8.

Objectives: To identify airborne derivatives of polycyclic aromatic hydrocarbons (PAHs) that contribute to mutagenicity. PAHs are emitted from combustion sources and are transformed to various other chemical compounds by photochemical processes. The resulting derivatives are believed to be responsible for much of the mutagenicity of ambient air.

Findings: A hitherto unsuspected class of PAH derivatives, nitro-lactones, was found to be responsible for most of the mutagenicity of the products formed from irradiation of simple PAHs in a smog chamber. Much of the mutagenicity of ambient air appears to be due to this class of compounds.

Importance to ARB's Program: PAHs and their atmospheric reaction products have been associated with significant health risks. ARB's strategy to control PAH emissions as toxic air contaminants is being redefined as a result of these findings.

1990

LIFETIMES AND FATES OF TOXIC AIR CONTAMINANTS IN CALIFORNIA'S ATMOSPHERE. A732-107: University of California, Riverside.

Objectives: To review the atmospheric chemistry of eight candidate toxic air contaminants (TACs), and to pursue an experimental investigation of the atmospheric chemistry of four candidate TACs.

Findings: The atmospheric lifetimes and fates of a dozen candidate toxic air contaminants were determined.

Importance to ARB's Program: Before proposing emission controls for TACs, the ARB must prepare a report that addresses the stability, persistence, and transformation products of toxic air contaminants in the atmosphere. The results of this work are being incorporated into staff reports for the identification and control of these TACs.

EMISSIONS OF VOLATILE AND POTENTIALLY TOXIC ORGANIC COMPOUNDS FROM WASTEWATER TREATMENT PLANTS AND COLLECTION SYSTEMS, PHASE II. A732-085: University of California, Davis.

Objectives: To quantify airborne pollutant emissions from various treatment processes at sewage plants, to quantify the total strength of emissions from a major sewage plant, and to identify possible emission controls.

Findings: Five main emission control options for sewage plants were identified: upstream source control, reduction of in-plant toxics formation, covering of treatment units, collection of off-gases followed by

treatment, and modification of facilities, such as by elimination of aeration that occurs during some of the treatment processes.

Importance to ARB's Program: The results were used to advise air districts and sewage plant operators on the extent of airborne emissions from their facilities, as well to suggest possible approaches for controlling these emissions. Several sewage plant operators have been using the results to devise control systems for their facilities. This will help them meet various State air pollution control regulations.

METHODS DEVELOPMENT FOR ASSESSMENT OF VAPOR-PHASE MUTAGENS AND CARCINOGENS IN AMBIENT AIR. A6-174-32: University of California, Davis.

Objectives: To develop methods of identifying potentially toxic and mutagenic compounds in the gaseous (vapor) phase of ambient air.

Findings: The feasibility of a new system to chemically characterize a complex volatile mixture was demonstrated and applied to diesel bus exhaust. Results indicated that mutagenic activity in vapor-phase exhaust gases was greater than that in particulate phase exhaust.

Importance to ARB's Program: The Health and Safety Code requires the ARB to identify toxic air contaminants. The methods developed in this project will help the ARB determine which vapor-phase compounds are the most important candidate toxic air contaminants.

SOUTHERN CALIFORNIA AIR QUALITY STUDY: TOXIC AIR CONTAMINANTS, TASK 1. A832-152: Daniel Grosjean and Associates.

Objectives: To determine the ambient concentrations and trends of two chlorinated hydrocarbons -- CH_3CCl_3 (trichloroethane) and C_2Cl_4 (perchloroethylene) -- from data obtained during the 1987 Southern California Air Quality Study (SCAQS). These compounds are generally used as solvents for dry cleaning and inert fillers for pesticides and are recognized as toxic air contaminants in California.

Findings: Ambient concentrations were lowest at the background site on San Nicolas Island. Concentrations measured at other sites compared to those at San Nicolas Island showed that there are urban emissions of these compounds. Diurnal variations were more pronounced in the summer than in the fall.

Importance to ARB's Program: This database can be used by the ARB to better understand spatial and temporal variations in these compounds, and to develop control measures for these TACs. This database is useful for monitoring compliance toward California standards for these TACs.

1989

AMBIENT CONCENTRATIONS OF CHLORINATED DIBENZODIOXINS AND DIBENZOFURANS IN THE SOUTH COAST AIR BASIN. A6-100-32: ENSR Consulting and Engineering Corporation. Research Note 1990-9.

Objectives: To collect ambient air samples at several sites in the Los Angeles area and analyze them to determine concentrations of fifteen compounds in the dioxin family. The sites represented industrial, commercial, residential, and background locations, some near known emission sources.

Findings: The highest concentrations were noted during a period of land-to-sea air flows in winter, suggesting a regional air mass and transport phenomenon. Dioxin compound distribution profiles suggest the influence of combustion sources in most cases.

Importance to ARB's Program: The results have been used by ARB staff to clarify impacts of known emission sources, and to establish a baseline for assessing the risks of proposed dioxin emission sources.

CHLORINATED DIBENZO-*p*-DIOXIN (PCDD) AND CHLORINATED DIBENZOFURAN (PCDF) RESIDUE LEVELS IN FOOD. A6-197-3: Midwest Research Institute, Inc.

Objectives: To measure the levels of chlorinated dioxins and furans (PCDD and PCDF) in foods consumed by California residents. Samples of fish, hamburger, chicken, bacon, milk, and eggs were collected from retail markets in San Francisco and Los Angeles and analyzed for PCDD and PCDF residues.

Findings: Detectable levels were identified in all but the egg samples, with those in freshwater fish highest.

Importance to ARB's Program: Results of the study were used to evaluate the overall public exposure to PCDD and PCDF and to determine the need for regulation of airborne emissions of these toxic air contaminants.

California Clean Air Act

California Clean Air Act:

Stationary Source Emissions

Stationary Sources of Air Pollution

Projects in Progress

EMISSIONS TESTING OF TWO-STROKE UTILITY ENGINES. 97-313: University of California, Riverside.

Objectives: To obtain exhaust emissions data from two-stroke hand-held utility engines, including a low-emitting two-stroke hand-held utility engine that is being developed with the assistance of ARB funding. The engine, called the "Clean Air Two-Stroke" or "CATS", is being developed with the goal of meeting the ARB's 1999 emission standards for hand-held utility engines. It features electronically controlled, direct-injection of gasoline fuel and a redesigned oiling system. The investigator will emissions test the prototype and, for comparison, five other hand-held engines, including one made by the same company. Emissions measured will include total hydrocarbons, CO, NO_x, CO_2, and particulate matter.

Importance to ARB's Program: The ARB is committed to supporting the advancement of innovative clean air technologies to the commercial stage. Emissions testing of this promising engine is one way in which the ARB can provide this support.

ENERGY EFFICIENT, ULTRA-LOW-NO_x INDUSTRIAL GAS BURNERS: 95-310: University of California, Irvine.

Objectives: To develop technologies necessary to attain and maintain the energy-efficient operation of natural gas burners with ultra-low emissions of NO_x.

Importance to ARB's Program: The resulting burner design information will be provided to cooperating burner manufacturers for the development and demonstration of boiler burner and high-temperature process burner technologies for the majority of industrial and commercial applications. This project will help reduce NO_x emissions from industrial gas burners by demonstrating a technology that reduces the energy penalty for reducing emissions.

IMPROVEMENTS OF SPECIATION PROFILES FOR AEROSOL COATINGS. 95-336: California State Polytechnic University at San Luis Obispo.

Objectives: To determine the identity and amount of the organic gases in about 50 aerosol paint and coating products that are representative of the many consumer products sold in California.

Importance to ARB's Program: The results of this study will be used to improve consumer product control measure development and emissions inventories for organic species and air toxics.

Completed Projects

1998

TEMPORAL, SPATIAL, AND AMBIENT TEMPERATURE EMISSION EFFECTS IN THE SACRAMENTO MODELING REGION. 94-333: University of California, Davis.

Objectives: To investigate important temporal and spatial variations in emissions in the Sacramento modeling region, specifically from non-road mobile sources and industrial surface coatings and related process solvents, and to assess the effect of ambient temperature on emissions from those sources.

Findings: A GIS-based approach was developed by the investigators to spatially allocate regional or county-level emissions to units such as the grid cells that are used in photochemical air quality simulation models. They also developed statistical models by which the values of spatial surrogates can be estimated and updated using widely available data on land use and population and the U.S. Census Bureau's topographically integrated geographic encoding and referencing files. The effects of ambient temperature and weather on the source activities were estimated based on the investigators' survey data and emissions estimates made by the ARB.

Importance to ARB's Program: Information on temporal and spatial distributions of emissions is important to air quality monitoring, emissions inventory development, and air quality simulation and modeling. The results of this study will allow the emissions inventory for the Sacramento area to better reflect these variations and provide insights into ways to improve emissions inventories for other areas of the state. This is of importance for air pollution control districts and the U.S. EPA. The results of this study will be also of use in industries that use coatings, businesses or farms that use light- or heavy-duty equipment, and businesses that use pleasure craft or locomotives.

IDENTIFICATION OF POINT SOURCE EMISSION CONTROLS AND DETERMINATION OF THEIR EFFICIENCIES AND COSTS. 96-325: E.H. Pechan & Associates, Inc.

Objectives: To provide up-to-date data on controls for emissions of air pollutants from point sources, and to identify existing controls, along with their costs and efficiencies.

Findings: The investigators identified the controls currently used by point sources to control emissions of total organic gases, reactive organic gases, oxides of nitrogen, sulfur oxides, carbon monoxide, total particulate matter, PM10 (particulate matter having an aerodynamic diameter less than 10 micrometers), and PM2.5. Toxic air contaminants were also included, grouped as volatile organic toxics, particulate organic toxics, and particulate inorganic toxics. The costs and efficiencies of the controls were determined. The controls were grouped by type: add-on control, control process, and integrated control. Control efficiencies were identified as a range, from low to high.

Importance to ARB's Program: The data from this study will be included in California's emissions inventory to provide the ARB, air quality districts, and the air pollution control planning and rule development community with better and more complete information about the emission controls of air polluting processes than is now available. This information will help determine the point source processes that are most likely to provide cost-effective controls and the processes that are currently fully controlled.

1997

INDUSTRIAL SURFACE COATINGS: WOOD FURNITURE AND FIXTURES EMISSIONS INVENTORY DEVELOPMENT. 93-343: University of California, Davis.

Objectives: Over the years, air pollution district rules have resulted in changes in coating formulations and in coating solvents. The purpose of this study was to provide data for the State's emissions inventory to account for these changes in this emission source.

Findings: Data obtained in this study include amounts of coatings used in industrial surface coating of wood furniture and fixtures in California by district for one year for various coating application categories; emission and activity factors for each coating application category; estimates of variabilities in coating usage and emission factors; and sources of information for annual updates for emission activity factors.

Importance to ARB's Program: An important source of organic gases in California's air may be evaporation of organic solvents associated with the coating of wood furniture and fixtures. This project is part of efforts to attain Federal and California ambient air quality standards for ozone. The resulting data will be used by the ARB to revise and update the emissions inventory methodology for industrial surface coating of wood furniture and fixtures and to assist in the development of control measures. Results of the study will be of use to the districts for determining the effectiveness of rules for the use of low-VOC coatings in this industry. The wood furniture business community will also benefit from this report.

1996

DEMONSTRATION OF A LOW-EMITTING TWO-STROKE UTILITY ENGINE. 93-324: Engine, Fuel, and Emissions Engineering.

Objectives: To demonstrate the technological feasibility of the ARB's 1999 exhaust emission standards for utility engines of less than 25 horsepower. Chainsaw application is considered to be the most demanding in the context of designing effective and durable emission controls for utility engines of this size. The ARB has proposed emission standards, to be implemented in 1999, for this class of engine.

Findings: This study found that manufacturers of two-stroke engines should be able to meet the ARB's 1999 emission standards for utility engines of less than 25 horsepower. This could be accomplished by using fuel injection technology and catalytic converters, or by conversion to four-stroke engine designs.

Importance to ARB's Program: This report presents evidence that the 1999 emission standards for utility engines of less than 25 horsepower are technologically feasible. The report will be used in review of the standards.

SOLVENT CLEANING/DEGREASING SOURCE-CATEGORY EMISSIONS INVENTORY. 93-341: E.H. Pechan and Associates.

Objectives: To develop a comprehensive emissions inventory of total organic gases for the solvent cleaning category of stationary emission sources.

Findings: An emissions inventory of total organic gases was developed for solvent cleaning. The amount of solvent used in solvent cleaning and degreasing operations in California was determined by district and by county for 1993 for various equipment groups. Specified sources of information were provided for future annual updates of California's emissions inventory.

Importance to ARB's Program: Emissions from solvent cleaning and degreasing operations have been determined by the ARB to be an important source of smog-forming organic gases and of toxic air contaminants. Changes in ARB and air district rules over the years have led to the reformulation of solvent cleaners and degreasers. The data collected in this study were used to revise and update the solvent cleaning and degreasing emissions inventory methodology and to support the development of control measures for ozone, in compliance with the Clean Air Act. The results of the study will be of use to local government entities faced with control of VOC emissions. The results will also enable chemical manufacturers, solvent distributors, end-users, and toxic waste disposal companies to better understand solvent usage and emissions from solvent cleaning operations.

COATING OPERATIONS TEST METHOD AND METHOD DEVELOPMENT SURVEY. 93-344: University of California, Davis.

Objectives: To document the existing regulatory requirements for control of volatile organic compound (VOC) emissions from coatings and coating operations. Included are those operations involving paints, inks, coatings, adhesives, and polyester resin materials, and the solvent cleaning associated with these operations. Test methods specified in the regulations were analyzed to identify problem areas and methods development needs.

Findings: The physical characteristics to be tested and existing test methods were identified. Problems with test methods were identified and ranked in order of importance or urgency.

Importance to ARB's Program: Information obtained from this study is being used to guide and prioritize the development of test methods for or related to emission of volatile organic compounds from coatings applications and associated operations. Results of this project will improve the enforceability of VOC control rules. The results will also be used by local air districts' testing programs, by other governmental coatings testing laboratories, and by private industry laboratories and coatings manufacturers.

DETERMINATION OF EMISSIONS FROM OPEN BURNING OF AGRICULTURAL AND FORESTRY WASTES: PHASE II. A932-126: University of California, Davis.

Objectives: To assess the combustion characteristics of the waste-burning test facility located at the University of California, Davis, and to use the facility to develop emission factors for the simulated open burning of different types of agricultural and forestry wastes.

Findings: The report from this study gives results of laboratory test burns conducted in a combustion wind tunnel with eight different fuel types: barley straw, corn stover, rice straw, wheat straw, almond prunings, walnut prunings, Ponderosa pine slash, and Douglas fir slash. The repeatability of the data obtained from the tests was good, and the values obtained for the emission factors were consistent with data obtained by other researchers.

Importance to ARB's Program: This information is needed to develop emission offsets for waste materials in accordance with the non-vehicular air pollution control regulations for basinwide mitigation for cogeneration and resource recovery projects. The results are of use to business proponents of energy projects and of alternatives to agricultural burning.

IMPROVEMENT OF SPECIATION PROFILES FOR ARCHITECTURAL AND INDUSTRIAL COATING OPERATIONS. 93-319: California Polytechnic State University Foundation.

Objectives: To develop and improve speciation profiles for organic gas emissions from selected architectural and industrial maintenance coating processes and associated solvent use.

Findings: Emission profiles were obtained for 52 water-based and 56 solvent-based coatings by averaging the results of at least two analyses. Typical agreement for replicates was good, with standard deviations on the order of three of four percent, relative to the mean. Up to 15 components were found in the water-based coatings and 100 to 300 components in the solvent-based coatings. Coatings were separated into eleven categories based on similarity of emissions, carrier technology, and market size of a given category. Group profiles reflect a composite of profiles from all coatings analyzed in a given category.

Importance to ARB's Program: Information from this study will be used to improve emissions inventories that are used in modeling analyses for the development of cost-effective ozone control strategies.

1995

DETERMINATION OF VARIABILITY IN LEAF BIOMASS DENSITIES OF CONIFERS AND MIXED CONIFERS UNDER DIFFERENT ENVIRONMENTAL CONDITIONS IN CALIFORNIA'S SAN JOAQUIN VALLEY AIR BASIN. 92-303: University of California, Riverside.

Objectives: To update the ARB's San Joaquin Valley Air Basin emissions inventory to include emission of organic gases from conifer forests on the western slopes of the Sierra Nevada.

Findings: This field study produced a wealth of raw data on foliar biomass estimates and environmental conditions. Elevation was found to be the most useful parameter for predicting foliar biomass of conifer-dominated plots. The relation between biomass of conifer-dominated plots and elevation was used to construct a GIS-based map and lookup table of the distribution of conifer foliar biomass for 2 x 2 km grid cells across elevational gradients in the area studied. Oak biomass displayed low variability across plots. The best predictor of oak foliar biomass may be the mean biomass of the plots studied.

Importance to ARB's Program: The ARB and other entities used the results of this project, along with emission factors obtained by other investigators, to estimate biogenic hydrocarbon emissions. This information will be employed in the production of a good emissions inventory (for the two major vegetation types found in this valley) for use in Clean Air Act implementation plans.

TESTING OF ARCHITECTURAL AND INDUSTRIAL MAINTENANCE COATINGS. 92-339: Harlan Associates, Inc.

Objectives: To measure the key chemical, physical, performance, and application properties of commercially available and recently developed architectural and industrial maintenance (AIM) coatings. The samples were tested for volatile organic compounds (VOC) and water content and numerous performance properties, including (where applicable) viscosity, stability, dry time, freeze-thaw resistance, adhesion, impact resistance, gloss, salt spray resistance, abrasion resistance, appearance, sanding properties, chemical resistance, yellowness index, and fungus resistance.

Findings: Analyses were confirmed to be within American Society for Testing and Materials (ASTM) precision test limits. The compilation of data is available for use in regulatory decisionmaking. The data may be used to analyze to what extent producers of coatings for California markets have achieved reductions of VOCs, and to what extent new coatings perform their protective or decorative functions.

Importance to ARB's Program: The California Clean Air Act of 1988 required the implementation of reasonably available control technology (RACT) for areas projecting attainment of the ozone standard by 1994, and best available retrofit control technology (BARCT) for areas projecting attainment by 1997 or beyond. An integral step in the development of RACT/BARCT determination guidance is the analysis of current AIM coatings technology.

1994

DEVELOPMENT OF SPECIES PROFILES FOR EMISSIONS FROM SELECTED COMBUSTION SOURCES. A132-104: Energy and Environmental Research Corporation.

Objectives: To develop speciation profiles (identification and relative amounts) for emissions of organic gases and oxides of nitrogen from natural gas combustion and oil refinery combustion sources that burn other gaseous fuels.

Findings: Preliminary draft species profiles have been developed for several natural and refinery gas-fired sources.

Importance to ARB's Program: Information from this study is being used to improve emissions inventories that are used by the ARB in modeling analyses for the development of ozone control strategies in response to the Clean Air Act.

AIR QUALITY MITIGATION MEASURES FOR AIRPORTS. A132-168: Energy & Environmental Analysis, Inc.

Objectives: To identify and quantify the effectiveness of air quality mitigation measures designed to minimize emissions of hydrocarbons, carbon monoxide, nitrogen oxides, and particulate matter generated by all aspects of airport activity, especially construction and expansion.

Findings: This study produced a draft list of air quality mitigation measures designed to minimize emissions generated by aircraft ground and flight operations, and land use developments associated with the construction of airports.

Importance to ARB's Program: The ARB is the State agency responsible for certifying under the Airport and Airway Safety and Capacity Expansion Act of 1987 that airport projects will comply with applicable air quality standards. With the information from this study, we are better able to evaluate airport projects to minimize the impact of emissions.

1993

EVALUATION OF A METHOD FOR DETERMINING VAPOR PRESSURES OF PETROLEUM MIXTURES BY HEADSPACE GAS CHROMATOGRAPHY. A6-178-32: University of California, Davis.

Objectives: To develop and demonstrate a method in which headspace gas chromatography could be used for measuring the vapor pressure of complex petroleum mixtures such as crude oil. Vapor pressure is one determinant of the rate of production of atmospheric pollutants by volatile substances.

Findings: The investigators developed, demonstrated, and validated a headspace vapor pressure measurement method. Precision was good when used on medium and light crude oils; there was some variability in response for the heavy crude oils.

Importance to ARB's Program: Data resulting from application of this method were used, along with other data, by ARB staff and others to assess hydrocarbon emissions from crude oil storage and processing facilities for planning attainment of the ambient air quality standards for ozone.

1992

DEVELOPMENT OF EMISSIONS FROM OPEN BURNING OF AGRICULTURAL AND FORESTRY WASTES. PHASE II: FLAME CHARACTERIZATION. A932-161: University of California, Davis.

Objectives: To characterize flame propagation at an agricultural waste burn test facility. Combustion emissions are critically affected by differences in temperature, time, and oxygen concentration in the fire zone.

Findings: This study documented the combustion characteristics of a wind tunnel facility during experiments conducted on rice straw under a range of conditions. Pollutant emissions from the tunnel, especially for particulate matter, were found to be dependent on tunnel wind speed.

Importance to ARB's Program: A detailed characterization of flame behavior was used to better understand how the test system may influence emissions relative to fire conditions in the field. Ongoing ARB work at UC Davis will use these results for determination of emission factors as they apply to emission credits under the non-vehicular air pollution control regulations for basinwide mitigation for cogeneration and resource recovery projects program.

1991

DEVELOPMENT OF A UNIVERSALLY ACCEPTED TEST METHOD FOR DETERMINATION OF VOLATILE ORGANIC CONTENT OF PAINTS AND RELATED COATINGS. A832-126: Calcoast Analytical and ITL. Research Note 1992-1.

Objectives: To develop new or refine currently used methods to test for volatile organic compounds (VOCs) in architectural and industrial coatings to achieve a method acceptable to ARB and air pollution control districts.

Findings: Several of the current ASTM test methods were found acceptable, while others were not. Changes were recommended for two of the methods for determination of water content and organic solvent content of coatings.

Importance to ARB's Program: This study is part of ARB's comprehensive investigation of emissions reduction measures for VOCs from consumer products, as required by the Health and Safety Code. Adoption of the modified test method by regulatory agencies could ease the burden of compliance for paint and coatings producers and for enforcement agencies.

EVALUATION OF LOW-SOLVENT AUTOMOTIVE REFINISHING COATINGS. A832-115: Calcoast Analytical Labs. Research Note 1992-2.

Objectives: To compare the performance and application properties of low-solvent automotive refinishing coatings with those of conventional coatings.

Findings: There is no apparent relationship between the VOC content and the performance properties of automotive refinishing coatings. High quality coatings were identified with low-solvent, medium-solvent, and high-solvent content.

Importance to ARB's Program: This study demonstrated to industry, consumers, and government agencies that coatings manufacturers and formulators have succeeded in developing reliable low-solvent automotive refinishing coatings. This study is part of the ARB's comprehensive investigation of emission reduction measures for VOCs from consumer products, as required in the Health and Safety Code.

DEVELOPMENT OF SPECIES PROFILES FOR SELECTED ORGANIC EMISSION SOURCES. A832-059: California Polytechnic State University, San Luis Obispo.

Objectives: To develop lists and descriptions (speciation profiles) for emission of organic compounds from selected source categories that contribute to violation of ambient air quality standards for ozone. The sources investigated were: oil field fugitive hydrocarbon emissions, such as those from leaks and open sources; utility engine exhaust; and farm and heavy-duty equipment exhaust.

Findings: Over fifty hydrocarbon species were quantified in the oil field fugitive emissions work. The engine test results showed that twelve compounds accounted for at least half of the total hydrocarbon emissions from every engine tested. In addition, formaldehyde accounted for about one percent of the emissions from the engines.

Importance to ARB's Program: Information from this study was used to improve the ARB's emissions inventories for organic gases and to improve modeling analyses used for the development of ozone control strategies for attainment of the ambient air quality standard for ozone.

1990

HYDROCARBON EMISSIONS FROM VEGETATION FOUND IN CALIFORNIA'S CENTRAL VALLEY. A732-155: University of California, Riverside. Research Note 1990-12.

Objectives: To determine the emission rates and chemical composition of organic gases emitted by prominent vegetative species in California's central valley. The new data fill a critical gap in the reactive organic gases emissions inventory.

Findings: Hydrocarbon compounds emitted by more than 30 of the most common agricultural and natural plants found in California's Central Valley were separated and measured. All of the plant species tested emitted some of these hydrocarbons at rates suggesting a possible effect upon air quality.

Importance to ARB's Program: These data together with data on land use and biomass density were employed by ARB staff to develop a hydrocarbon emissions inventory for agriculturally important and naturally occurring vegetation sources. This places biogenic sources in perspective for development of ozone attainment plans for the Clean Air Act.

1989

TEST AND EVALUATION OF A POLYMER MEMBRANE PRECONCENTRATOR. A732-153: Radian Corporation. Research Note 1990-8.

Objectives: To evaluate a membrane system for use as a preconcentration step for hydrocarbon emissions control devices. The project was co-managed by the U.S. EPA.

Findings: The system generated a stream about three times as concentrated as the original feed stream. However, membrane-augmented technology does not appear to be a cost-effective alternative to conventional carbon adsorption or other classical control options for low-concentration vapor streams.

Importance to ARB's Program: As a result of this study, data on efficiency and costs for this control measure are now available for this innovative volatile organic compound control technology for use in compliance with the Clean Air Act.

California Clean Air Act:

Regional Air Quality

Regional Air Quality Studies

Projects in Progress

I. SCOS97-NARSTO Studies

MANAGEMENT OF DATA FROM THE UPPER-AIR METEOROLOGICAL NETWORK FOR THE 1997 SOUTHERN CALIFORNIA OZONE STUDY. 96-323: National Oceanic and Atmospheric Administration.

Objectives: To provide uniform quality control and management of the data collected from the upper-air meteorological network in the Southern California Ozone (SCOS97-NARSTO) Study, and to manage and validate the data in near-real time to support efforts for forecasting the intensive operational periods of the study and for detecting operational problems promptly.

Importance to ARB's Program: The meteorological data collected in the SCOS97-NARSTO study will be used to characterize the meteorological processes in the lower troposphere. The data must be uniform and of high quality to enable proper performance by ozone air quality models.

AUDIT OF THE RADAR WIND PROFILER NETWORK AND SELECTED SURFACE METEOROLOGICAL SITES FOR THE 1997 SOUTHERN CALIFORNIA OZONE STUDY. 96-320: Aerovironment.

Objectives: To assure the quality of a subset of the meteorological observations made at the SCOS97-NARSTO upper-air sites.

Importance to ARB's Program: The ARB is one of several organizations carrying out the 1997 Southern California Ozone Study, the purpose of which is to develop tools for better air quality simulation for southern California.

ENHANCEMENT OF THE EXISTING RADAR WIND PROFILER NETWORK FOR THE 1997 SOUTHERN CALIFORNIA OZONE STUDY. 96-318: Radian International LLC and Sonoma Technology, Inc.

Objectives: To install and operate five radio wind profiler/radio acoustic sounding system (RWP/RASS) sites as part of the SCOS97-NARSTO study.

Importance to ARB's Program: The data collected will be used in combination with other meteorological and air-quality data to investigate the processes and mechanisms that must be understood and adequately treated in the SCOS97-NARSTO air quality modeling.

ENHANCEMENT OF THE EXISTING RADAR WIND PROFILER NETWORK FOR THE 1997 SOUTHERN CALIFORNIA OZONE STUDY. 95-345: National Oceanic and Atmospheric Administration - Environmental Technology Laboratory.

Objectives: To install and operate 11 RWP/RASS sites and three SODAR sites to supplement the existing meteorological monitoring network (particularly aloft) to provide the three-dimensional data necessary for

developing and validating meteorological models. To refine our understanding of the formation and transport of high ozone concentrations aloft.

Importance to ARB's Program: Plans to attain Federal and State ambient air quality standards rely on the application of ozone models. Models based on the 1987 Southern California Air Quality Study underestimated ozone concentrations in the urban core and aloft. A major factor contributing to this less-than-desirable performance was the limited amount of data about conditions aloft. The data collected in this project will be used to investigate the processes and mechanisms that must be understood and adequately treated in the SCOS97/NARSTO air quality modeling.

MEASUREMENT OF OZONE CONCENTRATIONS ALOFT BY LIDAR DURING THE EPISODIC MONITORING PERIODS OF THE 1997 SOUTHERN CALIFORNIA OZONE STUDY. 95-337: National Oceanic and Atmospheric Administration - Environmental Technology Laboratory.

Objectives: To monitor the vertical distribution of ozone concentrations during the 15-day intensive monitoring periods of the SCOS97-NARSTO study.

Importance to ARB's Program: These and other data collected during the SCOS97-NARSTO study will be used to validate the performance of photochemical air quality models, to estimate horizontal ozone flux in the San Gabriel Valley, and to refine our understanding of the formation and transport of high ozone concentrations aloft. This information is necessary for the development of cost-effective ozone control strategies.

AIRCRAFT MEASUREMENTS IN SUPPORT OF THE 1997 SOUTHERN CALIFORNIA OZONE STUDY. 95-332: University of California, Davis.

Objectives: To increase understanding of the processes that lead to high ozone and NO_x concentrations above-ground and how they affect air pollution at ground level. To characterize the 3-dimensional distribution of ozone, NO_y, and meteorological variables within the south coast air basin during the 15-day intensive monitoring period.

Importance to ARB's Program: This project is part of the SCOS97-NARSTO study, whose resources will be used to gather data for regional modeling of ozone. With new and extensive upper air data for the south coast air basin, subsequent air quality simulations can be validated and will contribute to the determination of the most cost-effective path to attainment of the national ambient air quality standard for ozone in southern California.

INVESTIGATION OF PROCESSES LEADING TO THE FORMATION OF HIGH OZONE CONCENTRATIONS ALOFT IN SOUTHERN CALIFORNIA. 96-309: Sonoma Technology.

Objectives: To support the SCOS97-NARSTO study by providing an aircraft instrumented to monitor ozone, oxides of nitrogen, volatile organic compounds, and meteorological conditions during the intensive 15-day monitoring period.

Importance to ARB's Program: These data will subsequently be combined with other air quality and meteorological data collected during SCOS97-NARSTO to refine ideas of how ozone layers are formed aloft and to improve the ability of airshed air quality models to predict the magnitude, timing, and altitude(s) of ozone concentrations aloft.

SURFACE AND UPPER-AIR VOC SAMPLING AND ANALYSIS DURING THE 1997 SOUTHERN CALIFORNIA OZONE STUDY. 96-322: University of California, Riverside.

Objectives: To conduct sampling and analysis of certain compounds associated with the production of ozone: speciated C_2-C_{12} hydrocarbons, C_1-benzaldehyde carbonyl compounds, methane, carbon monoxide, carbon dioxide, and methyl tertiary butyl ether.

Importance to ARB's Program: The results of this study, which is part of the SCOS97-NARSTO study, will contribute to the improvement of airshed models that are used to develop control strategies and verify control plans, and will improve our understanding of ozone formation and the extent of transport of emissions between air basins.

AIR MONITORING PROGRAM FOR DETERMINATION OF THE IMPACTS OF INTRODUCTION OF CALIFORNIA'S PHASE 2 REFORMULATED GASOLINE ON AIR QUALITY IN THE SoCAB. 94-332: Desert Research Institute.

Objectives: To collect data in the south coast air basin to be used to determine the immediate air quality impact of the introduction of cleaner burning gasoline and to support the SCOS97-NARSTO program.

Importance to ARB's Program: The results from this air monitoring effort and complementary studies of emission sources will be analyzed to determine the impact of this important ARB regulatory program on atmospheric levels of ozone precursors and toxic air contaminants. The results of the SCOS97-NARSTO program will be used to improve air quality models used to design air quality control plans and strategies.

II. Other Studies

ATMOSPHERIC CHEMISTRY OF SELECTED LINEAR, BRANCHED, AND CYCLIC C_{10} ALKANE COMPONENTS OF MINERAL SPIRITS. 97-312: University of California, Riverside.

Objectives: Recent laboratory experiments have found that existing chemical models overestimate the ozone-forming potential of mineral spirits (products of petroleum distillation widely used as cleaning solvents) by about a factor of two. In this study the investigators will analyze the primary products formed from the reactions of the OH radical with three C_{10} alkanes that will serve as models for the three types of alkanes found in mineral spirits and develop methods for identifying and quantifying secondary products of atmospheric reactions of these alkanes that lead to both ozone and PM2.5 (very fine particle) formation. The model alkanes to be studied are *n*-decane, 3,4-diethylhexane, and *n*-butylcyclohexane.

Importance to ARB's Program: This study will provide an understanding of the relative ozone-forming potential of the types of alkanes found in mineral spirits. This will allow the ARB and other organizations concerned with air quality to develop more effective consumer product regulations.

DEVELOPMENT AND APPLICATION OF IMPROVED METHODS FOR MEASUREMENT OF OZONE FORMATION POTENTIALS OF VOLATILE ORGANIC COMPOUNDS. 97-314: University of California, Riverside.

Objectives: To modify existing methods for measuring and estimating the ozone forming potentials of VOCs to be more sensitive, consistent, and cost-effective, and to not require specialized knowledge or expertise in atmospheric chemistry. The improved techniques will be evaluated for VOCs with well studied

reactivity characteristics and applied to compounds that are important components in various consumer product categories.

Importance to ARB's Program: VOC reactivity has become an important component in the development of ozone control strategies. Until recently a VOC was defined as either reactive or not. The techniques developed in this study will be more technically sound than this binary approach and therefore more effective. They should also be less costly.

THE FORMATION OF GASEOUS NITROUS ACID (HONO): A KEY DETERMINATION OF TROPOSPHERIC OZONE AND FINE PARTICLES. 97-311: University of California, Irvine.

Objectives: To determine the basic chemistry of the formation of nitrous acid (HONO) from atmospheric NO_2-water reactions and to determine the effect of particles on HONO formation.

Importance to ARB's Program: A better understanding of atmospheric HONO formation will result in more technically accurate chemical mechanisms used in airshed models that are used for air pollution control strategies and plans.

REVIEW AND IMPROVEMENT OF METHODS FOR ESTIMATING RATES OF PHOTOLYSIS IN PHOTOCHEMICAL MODELS. 96-335: University of California, Berkeley.

Objectives: Improvement of estimates of the rates of photolysis that are used in air quality models. This involves determination of the state of the science in radiative transfer modeling, identification of the uncertainties in existing models, development or adaptation of a state-of-the-science radiative transfer model and methods for preparing input data, assessment with atmospheric observations, and incorporation of the radiative transfer model into selected air quality models.

Importance to ARB's Program: Results from this study will be used to improve the ARB's estimates of changes in ozone concentrations resulting from changes in emissions of ozone precursors. Accurate estimates are needed for development of California's implementation plan for meeting Federal emission and air quality requirements for ozone.

IMPROVING THE ACCURACY OF MIXING DEPTH PREDICTIONS FROM THE MESOSCALE METEOROLOGICAL MODEL MM5. 96-319: MCNC-Environmental Programs.

Objectives: To improve the accuracy of estimates of the mixing depth (the depth in the atmosphere through which pollutants emitted near the surface are mixed and diluted) predicted by a meteorological model that simulates the physical processes occurring in the atmosphere and assimilates information from meteorological measurements. The model -- the Pennsylvania State University/National Center for Atmospheric Research Mesoscale Meteorological Model -- is known as MM5.

Importance to ARB's Program: Accurate meteorological information is needed to support air quality modeling, which is applied for the purpose of predicting future air quality, determining the effects from control of emissions, and formulating California's plans for implementation of Federal emission and air quality requirements for ozone and particulate matter.

IMPROVEMENT AND EVALUATION OF THE MESOSCALE METEOROLOGICAL MODEL MM5 FOR AIR QUALITY APPLICATIONS IN SOUTHERN CALIFORNIA AND THE SAN JOAQUIN VALLEY. 97-310: California State University at San Jose and Pennsylvania State University.

Objectives: To improve the performance characteristics and range of application of the meteorological model MM5 for air quality studies in California. The investigators will use the MM5 to determine how high pollutant concentrations are formed in layers aloft and brought to the surface during ozone and fine particle (PM2.5) episodes in the South Coast Air Basin (SoCAB) and will simulate wintertime fog events in the San Joaquin Valley and summertime fog events in the SoCAB.

Importance to ARB's Program: Meteorology is an important factor in ozone and PM2.5 formation. The predictive skill of air quality models depends strongly on the accuracy of externally generated meteorological fields. This study will provide improved meteorological modeling results for subsequent use in developing effective emission control strategies for ozone and PM2.5 in southern and central California.

DETERMINATION OF THE HORIZONTAL DIFFUSION COEFFICIENT FOR USE IN THE SARMAP AIR QUALITY MODEL. 96-314: EarthTech.

Objectives: To improve the coefficient for horizontal diffusion of air in the ARB's SARMAP Air Quality Model, a three-dimensional region-scale comprehensive air quality model that calculates the concentrations of both inert and chemically reactive pollutants by simulating atmospheric processes such as advection, turbulent diffusion, chemical transformation, and removal.

Importance to ARB's Program: An improved horizontal diffusion coefficient will permit greater confidence in model performance and in model-generated estimates of emissions reductions needed to attain air quality goals.

YIELDS AND REACTIONS OF INTERMEDIATE COMPOUNDS FORMED FROM THE INITIAL ATMOSPHERIC REACTIONS OF SELECTED VOCS. 96-306: University of California, Riverside.

Objectives: To determine ambient levels of NO_3 radicals (important in ozone formation) by measuring ambient levels of PAH compounds. PAH compound profiles are sensitive to reaction with NO_3 and can be used as a measure of NO_3-related concentration.

Importance to ARB's Program: The improved understanding of NO_3 atmospheric chemistry resulting from this study will lead to more accurate airshed models used in development of California's plans for implementation of Federal emission and air quality requirements, and to more scientifically sound control plans and strategies.

THE IDENTITIES AND BEHAVIOR OF MULTI-FUNCTIONAL CARBONYLS IN SIMULATED AND AMBIENT ATMOSPHERIC ENVIRONMENTS. 96-303: University of California, Davis.

Objectives: To improve upon a promising sampling and analytical technique that has demonstrated the ability to capture and quantify multi-functional carbonyl compounds.

Importance to ARB's Program: It is believed that the contribution of these compounds to ozone formation is significant, and that the inclusion of multi-functional carbonyl compound data in airshed models and data analyses will improve the basis for California's plans for implementing Federal emission and air quality requirements.

IMPROVEMENT OF SPECIATION PROFILES FOR AEROSOL COATINGS. 95-336: California Polytechnic State University, San Luis Obispo.

Objectives: To determine the identity and amounts of the organic gases in approximately 50 aerosol paint and coatings products that are representative of the many consumer products sold in California.

Importance to ARB's Program: The study results will assist in developing mid- and long-term consumer product control measures, and will improve emissions inventories for organic species and air toxics.

TOTAL NON-METHANE ORGANIC CARBON: DEVELOPMENT AND VALIDATION OF A NEW INSTRUMENT; MEASUREMENTS OF TOTAL NON-METHANE ORGANIC CARBON AND C_2-C_{10} HYDROCARBONS IN THE SOUTH COAST AIR BASIN. 95-335: University of California, Los Angeles.

Objectives: To develop a sampling and analytical system for measuring total reactive carbon in the atmosphere and to field-test the system to ensure accurate ambient total reactive carbon measurements.

Importance to ARB's Program: With the development of a successful reactive carbon analyzer, information can be generated to improve our understanding of photochemical pollutant formation and improve strategies for their control.

ANALYSIS OF WEEKDAY/WEEKEND DIFFERENCES IN AMBIENT AIR QUALITY AND METEOROLOGY IN THE SOUTH COAST AIR BASIN. 95-334: University of California, Los Angeles.

Objectives: To determine weekend/weekday differences in emissions, ambient air quality, and meteorologic parameters of the south coast air basin.

Importance to ARB's Program: This research will provide the ARB with insight into the interaction between uniform emission control strategies and non-uniform ozone concentration reductions. This insight will be useful in judging the effectiveness of current ozone control strategies and developing approaches for meeting future air quality needs of the south coast air basin as the basin goes through dynamic economic and demographic changes.

UNCERTAINTY ANALYSES OF CHEMICAL MECHANISMS DERIVED FROM ENVIRONMENTAL CHAMBER DATA. 95-331: University of California, Riverside.

Objectives: To determine the environmental chamber parameters and assumptions -- used in interpreting chamber data -- that contribute the most to the uncertainty in the atmospheric reactivity estimates for several important aromatic and oxygenated hydrocarbons.

Importance to ARB's Program: Better designed chamber experiments leading to more certain reactivity estimates will result from this project. The more certain reactivity estimates will improve atmospheric chemistry mechanisms used in the reactivity scale for the ARB's Low-Emission Vehicle/Clean Fuels regulations and the photochemical airshed models used for development of California's plans for implementation of Federal emission and air quality requirements for ozone, and assist in the development of consumer products regulations.

BIOGENIC HYDROCARBON INVENTORIES FOR CALIFORNIA: GENERATION OF ESSENTIAL DATABASES. 95-309: University of California, Los Angeles.

Objectives: To measure biogenic hydrocarbon emission rates and leaf biomass rates, to develop, demonstrate and validate a new approach for predicting emission rates using information on a plant's family and genus, to measure leaf biomass data, to validate the "GAP" geographic biogenic emissions inventory database in Southern California, and to conduct ambient air measurements of biogenic hydrocarbons in southern California to test airshed model predictions.

Importance to ARB's Program: Because control options for vegetation are limited, improving the ARB's ability to estimate biogenic emissions is critical for understanding the extent of the contribution of biogenic vs. anthropogenic emissions, for improving decisions as to whether to focus future ozone control strategies on NO_x or on hydrocarbons, and for decisions regarding the degree of control necessary.

INVESTIGATION OF ATMOSPHERIC REACTIVITIES OF SELECTED STATIONARY SOURCE VOCs. 95-308: University of California, Riverside.

Objectives: To determine the reactivity of several oxygenated compounds found in consumer products that are suspected of being major contributors to ozone formation.

Importance to ARB's Program: The study results will be used to develop control strategies for consumer products and to improve the chemistry mechanism used in photochemical models used for development of California's plans for implementation of Federal emission and air quality requirements for ozone.

DEVELOPMENT AND FIELD TEST OF A TWO-DIMENSIONAL VERTICALLY SCANNING OZONE LIDAR. 93-330: National Oceanic and Atmospheric Administration - Environmental Technology Laboratory.

Objectives: To upgrade existing ozone light detecting and ranging (lidar) technology and to develop a scanning capability for the lidar that will enable the mapping of ozone concentrations in two dimensions.

Importance to ARB's Program: Continuous measurements of ozone concentrations aloft will be very useful for the assessment of ozone transport between air basins as required by the California Clean Air Act. When combined with remote sensing of winds aloft, the lidar will provide greatly improved estimates of ozone flux between air basins.

ENVIRONMENTAL CHAMBER STUDIES FOR DEVELOPMENT OF AN UPDATED PHOTOCHEMICAL MECHANISM FOR VOC REACTIVITY ASSESSMENT. 92-345: University of California, Riverside.

Objectives: To provide experimental data for another ARB-funded project (92-329, below) to update the maximum incremental reactivity (MIR) scale used in the Low-Emission Vehicles/Clean Fuels (LEV/CF) regulations.

Importance to ARB's Program: The update to the MIR scale is required by the Board's LEV/CF regulations.

DEVELOPMENT AND APPLICATION OF AN UPDATED PHOTOCHEMICAL MECHANISM FOR VOC REACTIVITY ASSESSMENT. 92-329: University of California, Riverside.

Objectives: To update the chemical mechanism used to calculate ozone reactivity scales (scales of ozone-forming potential) of VOCs. To recalculate the MIR scale for the update required by the LEV/CF regulations. To provide a condensed version of the updated chemical mechanism suitable for airshed models.

Importance to ARB's Program: The update to the MIR scale is required by the Board's LEV/CF regulations.

ADVANCED RECEPTOR MODELING OF DATA FROM THE SOUTHERN CALIFORNIA AIR QUALITY STUDY: INTERPRETIVE DATA ANALYSIS. A832-131: University of Southern California.

Objectives: To apply two new receptor modeling techniques to the data collected during the 1987 Southern California Air Quality Study in order to apportion sources of fine particles and volatile organic gases, determine the contributions of direct emissions and atmospheric transformation to ambient concentrations, and estimate ozone formation and deposition rates as a function of time and location.

Importance to ARB's Program: The results, in combination with the results of other studies, will help us understand the sources, transformation, and ultimate fate of smog-forming pollutants as required by the California and Federal Clean Air Acts.

Completed Projects

1998

CHARACTERIZATION AND CONTROL OF ORGANIC COMPOUNDS EMITTED FROM AIR POLLUTION SOURCES. 93-329: California Institute of Technology.

Objectives: To quantify the atmospheric emissions of hundreds of organic compounds -- in both gaseous and particulate phases -- from a variety of sources.

Findings: Sources tested included meat charbroiling operations, the cooking of vegetables in seed oils, diesel trucks, gasoline-powered automobiles, fireplaces, cigarette smoke, and industrial paint spraying operations. The information gathered was used to determine what fraction of the total PM2.5 (particulate matter having an aerodynamic diameter less than 2.5 micrometers) these sources contribute to ambient air concentrations in southern California.

Importance to ARB's Program: Airborne organic compounds contribute to ozone and particulate matter formation. A better understanding of the identity and sources of these compounds will improve our ability to develop more technically sound control plans and strategies by providing more useful data for validating inventories and testing urban airshed models.

PLANNING, COORDINATION, AND FIELD MANAGEMENT OF THE 1997 SOUTHERN CALIFORNIA OZONE STUDY (SCOS97-NARSTO). 93-326: Desert Research Institute.

Objectives: To conduct planning activities for the 1997 Southern California Ozone Study/North American Research Strategy for Tropospheric Ozone (SCOS97-NARSTO) field study.

Findings: Research objectives were identified, a work plan developed, costs estimated, co-sponsors identifying, quality assurance plans and protocols developed, a field study plan produced, and a field management protocol delivered. A draft field study plan is available on the Web at www.arb.ac.gov/scos/scos.htm.

Importance to ARB's Program: The results of the SCOS97-NARSTO study are needed for a better understanding of the complex meteorological and chemical processes taking place in the region so that the most cost-effective route toward attainment of the ozone standards can be determined. The air pollution control districts in southern California, the Environmental Protection Agency, the United States Navy, the North American Research Strategy for Tropospheric Ozone, and the Coordinating Research Council are co-sponsoring the field study.

TRACKING THE SACRAMENTO POLLUTANT PLUME OVER THE WESTERN SIERRA NEVADA. 94-334: University of California, Davis.

Objectives: To make three-dimensional measurements of Sacramento's pollutant plume on seven days when the plume was advected into the foothills of the Sierra Nevada mountain range.

Findings: The implications from the data collected are that (1) it appears that high residual ozone concentrations above the surface layer in the early morning are necessary for the production of concentrations above 125 ppb (the national 1-hr standard), (2) modeling applications have had difficulty simulating the transport and fate of pollutant emissions, in part because the horizontal variability within the mixed layer is often significant at scales less than 5 km (the typical grid size of air quality models), (3) high concentrations of ozone do not appear to reach the high altitude slopes of the Sierra Nevada, and (4) concentrations of oxides of nitrogen were generally low, about one ppb.

Importance to ARB's Program: Analysis of the data from this study will lead to improved air monitoring networks. Data from these networks will be used for quantifying transport from the greater Sacramento area, for assessing ecological impacts of air pollution on the Sierra Nevada, and for improving the performance of the meteorological and air quality models that are used to quantify the reductions in emissions that will be necessary in order to attain air quality standards.

1997

ENVIRONMENTAL CHAMBER STUDIES FOR DEVELOPMENT OF AN UPDATED PHOTOCHEMICAL MECHANISM FOR VOC REACTIVITY ASSESSMENT. 92-345: University of California, Riverside.

Objectives: To provide experimental data for another ARB-funded project (92-329, below) to update the maximum incremental reactivity (MIR) scale used in calculating reactivity adjustment factors (RAFs) for the Low-Emission Vehicles/Clean Fuels (LEV/CF) regulations. "Reactivity" refers to the tendency of airborne chemicals to form ozone. The RAFs are used to equalize the stringent hydrocarbon exhaust emission standards for reformulated gasoline and other alternative fuels against conventional gasoline in terms of their reactivity.

Findings: MIRs have been calculated using assumed chemical mechanisms in models. In this study, (1) a xenon arc light source was used to assess whether current chemical mechanisms adequately treat the effects of real light on reactivity; (2) light intensity measurement methods used to characterize the conditions within the chambers were evaluated; (3) the effects of humidity on the reproducibility of chamber runs were assessed; and (4) the environmental chamber database was extended to include aromatic hydrocarbons (which are usually highly reactive and, before these experiments, not well characterized).

Importance to ARB's Program: The update to the MIR scale is required by the Board's LEV/CF regulations. In all, 283 environmental chamber experiments were conducted to provide a comprehensive set of experiments that can be used to develop and test models' chemical mechanisms and evaluate the reactivity of hydrocarbons.

DEVELOPMENT AND FIELD TEST OF A TWO-DIMENSIONAL VERTICALLY SCANNING OZONE LIDAR. 93-330: National Oceanic and Atmospheric Administration - Environmental Technology Laboratory.

Objectives: To upgrade existing ozone light detecting and ranging (lidar) technology and to develop a scanning capability for the lidar that will enable the mapping of ozone concentrations in two dimensions.

Findings: The two-dimensional feature proved to be a valuable tool for assessing the quality of the vertical profiles of ozone concentrations. However, the project was unable to produce high-quality ozone data because an inhospitable environment made beam alignment problematic. Design and operational changes are being made to improve the capabilities of this instrument under these kinds of conditions.

Importance to ARB's Program: Continuous measurements of ozone concentrations aloft are very useful for the assessment of ozone transport between air basins as required by the California Clean Air Act. When combined with remote sensing of winds aloft, the two-dimensional lidar should provide greatly improved estimates of ozone flux between air basins.

ANALYSIS OF THE SOUTHERN CALIFORNIA WIND PROFILER AND AIRCRAFT DATA. 94-317: Systems Applications International.

Objectives: To assess air pollutant transport between the south coast air basin and the Southeast Desert Air Basin (SEDAB) and between the SoCAB and the San Diego Air Basin (SDAB). To determine pollutant distribution in and wind flow patterns between the SoCAB and the SEDAB and quantify the effect of transport on ozone concentrations in the SEDAB and SDAB.

Findings: The results indicate that temperature and wind upper-air data from radiosonde launches collocated with the ARB's radio wind profiler/radio acoustic sounding system (RWP-RASS) network are needed to assure that the RWP-RASS data are of the highest quality. To use the RWP-RASS data for advanced simulation of the complex southern California meteorology impacting air pollution transport, vertical moisture profiles in coastal and high desert areas of southern California, available only from radiosonde launches, should also be collected. The conceptual model constructed from examination of composite winds and temperatures is representative of the majority of the prevailing meteorological conditions conducive to interbasin pollutant transport in southern California. Examination of the conceptual model suggests that the majority of ozone exceedence days in downwind air basins in the summer of 1992 were due to both local emissions and transport of air pollutants from the SoCAB.

Importance to ARB's Program: The results of this study will be used in the Board's triennial assessment of transport between air basins, as required by the California Clean Air Act.

AIRCRAFT MEASUREMENTS IN SUPPORT OF THE NOAA 2-D LIDAR DEMONSTRATION. 94-320: University of California, Davis.

Objectives: To collect air pollution and meteorological data, including concentrations of ozone, aerosols, and oxides of nitrogen, by aircraft in August 1995 during a transport corridor monitoring program in southern California's Mojave Desert. To validate ozone data collected by the National Oceanic and Atmospheric Administration using lidar (light detecting and ranging) equipment.

Findings: The measurements by aircraft were matched in time and place and compared with ozone measurements by the lidar. The aircraft measurements indicated a problem with the ozone measurements by NOAA's lidar. Further investigation by NOAA identified heat-induced distortion of the scanning mirror as the primary cause of the inaccurate ozone measurements.

Importance to ARB's Program: Data on air quality and meteorological conditions aloft are critical for a good understanding of air pollution transport, carryover, and recirculation. These factors are important in the evaluation of the performance of photochemical air quality models and the design of effective ozone control strategies.

PRODUCT STUDIES OF THE ATMOSPHERICALLY IMPORTANT REACTIONS OF ALKENES AND AROMATIC HYDROCARBONS. 94-311: Statewide Air Pollution Research Center, University of California, Riverside.

Objectives: To determine the products of the atmospheric reactions of aromatic compounds and to extend research on ozone-alkene reactions to all the important alkenes found in the atmosphere.

Findings: The products of important alkene reactions with ozone and OH were determined. The reactions studied included the reaction of ozone (in the presence of OH radical scavenger) with 2-methylpropene, trans-2 butene and 2,3-dimethyl-2-butene, propene, *cis*-2-butene, and 2-methyl-2-butene. Alkene and OH radical reactions studied included the reaction of *cis*-2-butene, 2,3-dimethyl-2-butene, 2-methylpropene, and 2-methyl-2-butene with OH radical (in the presence of and absence of NO_x). Aromatic compound reaction product studies were also performed. The reactions studied included the reaction of OH (in the presence of NO_x) and NO_3 radical reactions with naphthalene, 1- and 2-methylnaphthalene, acenaphthene, acenaphthylene, and the OH radical reaction with biphenyl (because biphenyl has been shown to not react with NO_3 radical). Reaction products included many carbonyl and multifunctional carbonyl products, as expected.

Importance to ARB's Program: About 30 percent of the total reactive organic gases in urban air consists of aromatic hydrocarbons and alkenes. Because of their high ozone formation potential, these compounds are the main precursors of ozone. It is important to understand their chemistry to ensure that appropriate control strategies are implemented. The results of this study will improve the chemical mechanisms used in the reactivity scale for the Board's Low-Emission Vehicle/Clean Fuel regulations and in the photochemical airshed models used for development of California's plans for implementation of Federal emission and air quality requirements for ozone. Additional funding was provided by the Coordinating Research Council, a research cooperative supported by the automobile and oil production industries.

MONITORING IN OZONE TRANSPORT CORRIDORS. 94-316: Technical and Business Services.

Objectives: To collect ozone and meteorological data during the summer of 1995 at eight sites that supplement the existing air quality monitoring network in southern California to enable better characterization of ozone transport between air basins, both near ground level and aloft.

Findings: Although the primary objective of this project was to collect data, some data analysis was also included. The findings indicate that monitoring on isolated mountain peaks can be used to represent conditions aloft in free air. During the study period, none of the exceedences of the California ozone standard that were observed at Barstow could be ascribed to local emissions. On Santa Catalina Island a surprisingly high number of exceedences of the California ozone standard were observed.

Importance to ARB's Program: The California Clean Air Act requires the ARB to assess the relative contribution of upwind emissions to downwind ambient ozone concentrations, to establish mitigation requirements commensurate with the level of contribution, and to conduct appropriate studies (including ambient air monitoring) to make a more accurate determination of the relative contributions to an ozone air quality problem. The data collected during this field program, when combined with other routinely available and special study data, will result in the most comprehensive analysis ever (horizontally, vertically, and temporally) of the relative contribution of local emissions and ozone transport to the ozone problem in the Mojave Desert. The measurements at Santa Catalina Island strongly influenced the design of the monitoring network for the 1997 Southern California Ozone Study (SCOS97-NARSTO).

1996

METEOROLOGICAL SUPPORT FOR THE ARB'S 1995 OZONE TRANSPORT CORRIDOR EXPERIMENT: A 449-MHz RADAR WIND PROFILER SYSTEM WITH RASS. 94-322: National Oceanic and Atmospheric Administration - Environmental Technology Laboratory.

Objectives: To characterize vertical profiles of wind and temperature in the Mojave Desert near Victorville, California, to about 10,000 feet using a 449-MHz radar wind profiler (RWP) in conjunction with a radio acoustic sounding system (RASS). Data for winds aloft are necessary for the calculation of ozone fluxes. NOAA's RWP was modified to improve resolution to under 100 meters to better match ozone data from their two-dimensional light detecting and ranging (lidar) equipment.

Findings: Although high-quality data can be gathered in the presence of radio frequency interference, care must be taken during site selection and data processing. Wind data collected during the two-week study showed consistent periods of southwesterly winds, indicating frequent potential for ozone transport through Cajon Pass.

Importance to ARB's Program: Wind data representing conditions aloft, combined with data from two-dimensional lidar technology, allowed direct calculation of ozone fluxes, an important step in characterizing ozone transport as required by the California Clean Air Act.

DEVELOPMENT OF A METEOROLOGICAL AND AIR QUALITY INFORMATION SYSTEM FOR THE GREATER SAN JOAQUIN VALLEY. 93-328: California State University, Chico. Research Note 1998-4.

Objectives: To design and implement a pilot air quality and meteorological information system (AQMIS) for the greater San Joaquin Valley.

Findings: This project demonstrated the feasibility of a near real-time AQMIS (with graphical and tabular displays) and documented the need for part-time support to maintain the scripts identifying and

reformatting data from a variety of sources. Resistance by data providers to releasing preliminary data declined during the project and is expected to decline further as groups experience the advantages of this AQMIS. No new development work will be necessary to expand this AQMIS to statewide coverage.

Importance to ARB's Program: This project satisfied the need expressed by several State and local groups for real-time sharing of air quality and meteorological data in order to improve smoke management activities, air quality forecasts, and understanding of pollutant transport.

CHARACTERIZATION OF OZONE EPISODES IN THE SOUTH COAST AIR BASIN: EFFECTS OF AIR PARCEL RESIDENCE TIME AND WEEKDAY/WEEKEND DIFFERENCES. 93-316: University of California, Los Angeles.

Objectives: To investigate the effects of residence time and weekday/weekend differences on ozone levels in the south coast air basin.

Findings: The subregions in the south coast air basin where control of nitrogen oxides (NO_x) emissions has apparently been most effective are the same subregions where reductions in the worst ozone episodes have been most significant. Analyses of the relative benefits of controlling volatile organic compounds and NO_x emissions did not detect a significant influence of air parcel transport between subregions at ground level.

Importance to ARB's Program: The results helped the ARB determine that there are differences in weekday and weekend ozone trends.

IMPACTS OF IMPROVED EMISSIONS CHARACTERIZATION FOR NITROGEN-CONTAINING AIR POLLUTANTS. 93-310: University of California, Berkeley. Research Note 1996-8.

Objectives: To study the air quality impacts of improving emissions inventory NO_x speciation profiles.

Findings: The study showed that predicted pollutant concentrations were much more sensitive to NO_x mass emissions than to NO_x speciation. Nighttime NO_x and nitrous acid concentrations were the only compounds dependent on NO_x speciation. Improvements are needed in the ammonia emissions inventory to support modeling and control strategy development for nitrogenous air pollutants.

Importance to ARB's Program: The results of the study were used to lower the priority for improvements in the speciation of the NO_x emissions inventory.

1995

DEVELOPMENT OF METHODS AND PROCEDURES FOR MONITORING AMBIENT CONCENTRATIONS OF OXYGENATED HYDROCARBONS. 92-306: AeroVironment, Inc. and AtmAA, Inc.

Objectives: To develop an oxygenated hydrocarbon (OHC) monitoring method suitable for regional monitoring programs. OHCs are important compounds in the photochemistry of pollutants and their emissions are expected to increase as reformulated gasolines and alcohol fuels become more widely used. It is important that a monitoring program for these compounds be established to assist in developing control strategies.

Findings: Routine analysis of some OHCs is possible using the developed methodology. More research is needed to improve the range of OHCs detected by the method and to fine-tune the analytical portion of the method.

Importance to ARB's Program: This study produced a method available for use by the ARB for regional monitoring programs for OHCs. This study fulfills requirements of the California and Federal Clean Air Acts for monitoring possible toxic air contaminants and ozone-forming compounds.

1994

DEMONSTRATION THE CAPABILITY OF A NEW AND INNOVATIVE OZONE LIDAR' TO MEASURE VERTICAL PROFILES OF OZONE CONCENTRATION AND AEROSOL IN THE LOWER TROPOSPHERE. 92-328: National Oceanic and Atmospheric Administration-Wave Propagation Laboratory. Research Note 1995-14.

Objectives: To evaluate ozone light detecting and ranging (lidar) technology as a method of measuring ozone concentrations at elevations of up to 10,000 feet and, in conjunction with other measurements, to better characterize the atmospheric processes involved in the formation of ozone.

Findings: Evaluations of the data indicate that lidar is a good method of measuring ozone concentrations aloft, and that the ozone and aerosol profiles are associated with similar meteorological profiles. Ozone lidar can provide continuous measurements of ozone concentrations aloft.

Importance to ARB's Program: This project demonstrated that continuous measurements of ozone concentrations aloft are very useful for the assessment of ozone transport between air basins, as required by the California Clean Air Act.

EXPERIMENTAL STUDIES OF ATMOSPHERIC REACTIVITIES OF VOLATILE ORGANIC COMPOUNDS. A032-096: University of California, Riverside.

Objectives: To conduct a comprehensive set of environmental chamber experiments to develop and test chemical mechanisms and evaluate hydrocarbon reactivity. A parallel project was funded by the Coordinating Research Council (the research arm of the auto and oil industries) to cover equipment costs and conduct experiments on hydrocarbons of interest to their industries.

Findings: There are still uncertainties in the chemical mechanisms for various hydrocarbons, but previous experimental techniques can result in compensating errors that mask the effects of these uncertainties in calculations of ambient reactivity. This project produced stringent tests of the chemical mechanisms.

Importance to ARB's Program: The results were used to update the chemical mechanism that is part of the airshed models used for developing California's plans for implementation of Federal emission and air quality requirements, and for performing the update to the maximum incremental reactivity scale required by the Board's Low-Emission Vehicles and Clean Fuels regulations.

CLAREMONT ATMOSPHERIC FREE-RADICAL STUDY: MEASUREMENTS OF FORMALDEHYDE, HYDROGEN PEROXIDE, NITRIC ACID, NITROUS ACID, PEROXYACETYL NITRATE, NITROGEN DIOXIDE, NITROGEN OXIDES, OZONE, CARBON MONOXIDE, HYDROCARBONS C_1-C_{12}, AND CARBONYL COMPOUNDS C_1-BENZALDEHYDE. 92-327: Unisearch Associates, Inc. and AtmAA, Inc. Research Note 1995-8.

Objectives: To create a database to enable airshed models to evaluate the free-radical balance in chemical mechanisms. Radicals initiate ozone production in the morning and sustain it during the day. Previous atmospheric measurements had implied that there are uninventoried sources of formaldehyde, nitrous acid, higher aldehydes, and other radical precursors, implying that current model applications may overestimate the effects of hydrocarbon control, leading to underestimates of NO_x control.

Findings: The field study captured data during a wide range of meteorological conditions and ozone concentrations, including the highest ozone episode for the year (over 0.30 ppm).

Importance to ARB's Program: The results will be used to evaluate the airshed models currently used for verification of compliance with progress in ozone control as noted in the State and Federal plans for implementation of emissions and air quality standards under the 1991 amendments to the Federal Clean Air Act.

PROJECT MOHAVE: POLLUTION TRANSPORT FROM SOUTHERN CALIFORNIA. A132-163: National Oceanic and Atmospheric Administration.

Objectives: To release tracer gas at El Centro, in California's Imperial Valley, for detection in an array of samplers scattered throughout the Mojave Desert and Arizona, southern Utah, and Nevada. This study is part of Southern California Edison's $4 million Project MOHAVE, which assessed the impacts of pollution sources on visibility in the Southwestern U.S.

Findings: This work provided data for Project MOHAVE.

Importance to ARB's Program: The results were used to assess the frequency of pollutant transport from different source areas to Grand Canyon National Park. In addition, the data collected in the Mojave Desert will allow us to evaluate the impact of air pollution from southern California and Mexico on air quality in California's southeast deserts. This study supports the efforts of the Grand Canyon Visibility Transport Commission established by the Federal Clean Air Act.

DEVELOPMENT OF AN OBJECTIVE CLASSIFICATION PROCEDURE FOR BAY AREA AIR FLOW TYPES REPRESENTING OZONE-RELATED SOURCE-RECEPTOR RELATIONSHIPS. A132-167: Systems Applications, Inc.

Objectives: To develop a straightforward and accurate classification scheme for the various source-receptor relationships found for ozone formation in the San Francisco Bay Area.

Findings: High ozone concentrations were associated with six airflow types. A meteorological screening procedure was used to segregate all days into clean days and days with potentially high ozone concentrations. Then a classification procedure based on 13 meteorological variables was developed to assign the days with potentially high ozone concentrations to one of the six air flow types.

Importance to ARB's Program: The classification scheme developed in this study was used to develop factors that can account for the influence of meteorology on ambient ozone concentrations. Removal of

this confounding meteorological influence will improve the ability of the ARB and air pollution control districts to evaluate the effectiveness of control plans and strategies.

A MULTI-YEAR OBSERVATIONAL STUDY OF ATMOSPHERIC TRANSPORT CORRIDORS AND PROCESSES IN CALIFORNIA. A032-145: National Oceanic and Atmospheric Administration-Wave Propagation Laboratory. Research Note 1994-21.

Objectives: To collect vertical profiles of wind speed, wind direction, and, in some locations, temperature data during the summers of 1991 and 1992 in areas where pollutants can be transported by winds from one air basin to another.

Findings: The data indicate almost continuous airflow between the air basin pairs studied. Supplemental data also indicate that thermally forced airflows in mountainous terrain can play a significant role in the recirculation and transport of pollutants.

Importance to ARB's Program: The data were used in the assessment of pollutant transport between air basins and in assigning appropriate control responsibilities in partial fulfillment of the California Clean Air Act requirements.

EXPERIMENTAL INVESTIGATION OF THE ATMOSPHERIC CHEMISTRY OF AROMATIC HYDROCARBONS AND LONG-CHAIN ALKANES. A032-067: University of California, Riverside.

Objectives: To study the reaction sequences of several hydrocarbons under ozone-forming conditions in environmental chambers. The unique feature of this study is the vast array of analytical approaches available to the investigators.

Findings: The investigators found direct evidence for reactions involving aromatic hydrocarbons and alkanes. This evidence has bearing on the controversy as to whether it is non-methane organic gases or nitrogen oxides that control ozone production in the atmosphere.

Importance to ARB's Program: The results were used to update the chemical mechanism that is part of the airshed models used for developing California's plans for implementing Federal air quality requirements, and for performing the update to the maximum incremental reactivity scale required by the Board's Low-Emission Vehicles and Clean Fuels regulations.

ANALYSIS OF DATA FROM THE LYNWOOD CARBON MONOXIDE STUDY. A032-184: Desert Research Institute.

Objectives: To determine, using the results of a field measurement program conducted during the winter of 1989-90 (contract no. A832-135), why carbon monoxide concentrations at the Lynwood site in the south coast air basin are the highest reported in California.

Findings: Analysis of the air quality data confirmed that Lynwood and vicinity constitutes a "hot spot" for carbon monoxide; concentrations are consistently higher than at other sites in the basin. Seven different causes of these high concentrations were identified from the data analyses, but the primary reasons were meteorological conditions (low wind speeds caused by flatter terrain) and local sources (older cars with higher emissions).

Importance to ARB's Program: This information helped the ARB determine that the existing motor vehicle control program is effective enough to bring Lynwood and other parts of California to attainment of the ambient air quality standards as required by the California and Federal Clean Air Acts.

COMPARISON OF IN-SITU AND REMOTELY SENSED OZONE CONCENTRATIONS. 92-330: University of California, Davis.

Objectives: To measure ozone concentrations up to 10,000 feet by aircraft. These data serve as a reference measurement against which concentrations by light detecting and ranging (lidar) technology will be compared (contract no. 92-328). The lidar technology, if accurate, could provide more information about ozone concentrations aloft easily, inexpensively, and routinely.

Findings: Although concentrations were generally below 10 pphm (the state standard is 9 pphm), initial results indicate agreement between the two measurement methods.

Importance to ARB's Program: Data on ozone concentrations aloft are needed to support the assessment of ozone transport required by the California Clean Air Act.

REMOTE SENSING AND IN-USE EMISSIONS OF MOTOR VEHICLES. A032-093: University of Denver. Research Note 1994-20.

Objectives: To test the University of Denver remote sensor for measuring instantaneous on-road emissions of carbon monoxide and hydrocarbons from motor vehicles, and to use it in various on-road situations.

Findings: The remote sensor is accurate to within about 5 percent for carbon monoxide and 15 percent for hydrocarbons. It was highly successful in identifying high-emitting vehicles for roadside inspections, with a misidentification rate of less than 0.5 percent. This project successfully measured emissions and matched registration records of over 90,000 vehicles.

Importance to ARB's Program: The ARB and the Bureau of Automotive Repair evaluated the potential of remote sensors to identify high-emitting vehicles to improve the inspection and maintenance program for light-duty vehicles as required by the Federal Clean Air Act.

1993

AIR QUALITY MONITORING IN SUPPORT OF TRANSPORT ASSESSMENT. A132-162: Sonoma Technology, Inc.

Objectives: To collect ozone, NO_x, hydrocarbon, and temperature data by aircraft traverses and spirals in support of the 1992 wind profiler study (contract no. A032-145).

Findings: Data were collected during aircraft flights over the south coast and southeast desert air basins in late summer and over the south coast and San Diego air basins in early fall. Forty-five hours of continuous NO_x, ozone, and temperature data and 65 reactive organic gas samples were collected during 13 flights consisting of 94 spirals and 11 traverses.

Importance to ARB's Program: The data were used in the assessment of ozone transport, which involves not only the movement of air aloft but also the concentrations of pollutants within the air mass. Determination of ozone transport is a requirement of the California Clean Air Act.

DEVELOPMENT AND APPLICATION OF AN UP-TO-DATE PHOTOCHEMICAL MECHANISM FOR AIRSHED MODELING AND REACTIVITY ASSESSMENTS. A932-094: University of California, Riverside.

Objectives: To develop a scale to account for the lower ozone-forming potential, or reactivity, of motor vehicle hydrocarbon emissions from alternate fuels using reactivity adjustment factors (RAFs).

Findings: Eighteen scales, including the maximum incremental reactivity (MIR) and maximum ozone incremental reactivity (MOIR) scales, were developed. A series of sensitivity tests found that the effect of uncertainties in the representation of airshed conditions used in the derivation of the reactivity scales had less than a 5 percent effect on the RAFs. Other sensitivity tests revealed that the last three years of chemical mechanism development had less than a 10 percent effect on the RAFs for several alternative fuels.

Importance to ARB's Program: The MIR scale has been adopted in the Board's Low-Emission Vehicles and Clean Fuels regulations.

PARTICULATE AND GASEOUS ORGANIC RECEPTOR MODELING FOR THE SOUTHERN CALIFORNIA AIR QUALITY STUDY. A832-132: Desert Research Institute. Research Note 1995-26.

Objectives: To quantify the source contributions of particulate matter and volatile organic compounds (VOCs), and to determine the portions of PM10 and PM2.5 that are of primary and secondary origin in the south coast air basin. PM10 and PM2.5 are particulate matter less than 10 and 2.5 μm in aerodynamic diameter, respectively. Pollutants of primary origin are directly emitted from the source. Pollutants of secondary origin result from chemical reactions after emission from the source.

Findings: The results provide an enormous amount of information on sources and their contributions to ambient concentrations of PM10 and VOCs.

Importance to ARB's Program: The results allow us to focus control efforts on the sources with the greatest contribution to PM10 and VOC in the south coast air basin in fulfillment of PM10 and ozone control provisions of the California and Federal Clean Air Acts.

METHODS DEVELOPMENT FOR QUANTIFICATION OF OZONE AND OZONE PRECURSOR TRANSPORT IN CALIFORNIA. A932-143: Sonoma Technology, Inc.

Objectives: To develop and apply data analysis methods to quantify ozone transport using the results of a field measurement program conducted in the Sacramento Valley in 1990 as part of this contract.

Findings: Although the field study was not carried out during typical transport conditions, there was evidence of pollutant transport at both the surface and aloft from the San Francisco Bay Area and broader Sacramento Valley to the upper Sacramento Valley.

Importance to ARB's Program: The data analysis methods were used to identify upwind/downwind transport couples in a biennial report published by the ARB, as required by the California Clean Air Act.

THE STUDY OF TEMPORAL AND VERTICAL OZONE PATTERNS AT SELECTED LOCATIONS IN CALIFORNIA. A132-165: AeroVironment, Inc. Research Note 1993-2.

Objectives: To determine the feasibility of using standard analyzers as well as long sampling lines attached to tall towers to determine the vertical distribution of ozone concentrations.

Findings: The study demonstrated that long-line ozone sampling is feasible. The data indicate that ozone concentrations aloft can be significantly higher than concentrations near the surface, particularly at night. It was also found that ozone aloft has the potential to persist for several days.

Importance to ARB's Program: The results have important implications for the assessment of transport and the design of appropriate control strategies, both of which are required by the California Clean Air Act.

AN INVESTIGATION OF ERROR PROPAGATION IN THE CALIFORNIA AIR RESOURCES BOARD'S AIRSHED MODEL. A932-091: Carnegie-Mellon University.

Objectives: To investigate errors in the California Air Resources Board's airshed model (CalGrid).

Findings: A large error (20 to 40 percent) was found in the treatment of horizontal transport by CalGrid and other airshed models. Other model components were found to exhibit less significant errors. This study also introduced some new computational procedures that improve assessment of error propagation.

Importance to ARB's Program: The results for the evaluation of the horizontal transport algorithm are especially significant and cast doubt on all airshed models currently in use for California's plans for implementing Federal air quality requirements.

OZONE AND PARTICULATE MATTER CASE STUDY ANALYSES FOR THE SOUTHERN CALIFORNIA AIR QUALITY STUDY. A932-050: Sonoma Technology, Inc.

Objectives: To investigate the three-dimensional evolution of two ozone episodes and three PM10 episodes during the 1987 Southern California Air Quality Study, including the transport and transformation processes that lead to maximum pollutant concentrations in the south coast air basin.

Findings: The most significant finding of the study is that airshed model predictions of ozone aloft do not agree well with the observed concentrations and structure.

Importance to ARB's Program: These results imply that current airshed modeling efforts may be missing an important upper air recirculation pattern, and research efforts are being undertaken to improve our understanding of this pattern. Recirculation patterns have important implications for photochemical modeling used to evaluate strategies to meet the ambient air quality standards as required by the California and Federal Clean Air Acts.

1992

COMPOSITION AND CONCENTRATIONS OF SEMI-VOLATILE HYDROCARBONS. A032-130: Desert Research Institute.

Objectives: To identify types and quantify ambient concentrations of semi-volatile hydrocarbons (those composed of more than 10 carbon atoms) typical of areas dominated by auto emissions, oil processing emissions, and urban emissions. Standard methods for determining hydrocarbon concentrations do not

measure in the semi-volatile range, possibly leading to a significant underestimation of ambient concentrations.

Findings: Up to 18 percent of the total hydrocarbons identified were compounds composed of between 10 and 12 carbon atoms. This indicates that accurate ambient measurements must analyze these hydrocarbons to avoid a significant underestimation of ambient concentrations.

Importance to ARB's Program: The results were used to identify the accuracy of ambient measurements and emissions inventories of hydrocarbons. Hydrocarbons are a key precursor of ozone, and their control is required by the California and Federal Clean Air Acts.

A STUDY TO DETERMINE THE NATURE AND EXTENT OF OZONE AND OZONE PRECURSOR TRANSPORT IN SELECTED AREAS OF CALIFORNIA. A932-129: Sonoma Technology, Inc.

Objectives: To determine the characteristics of ozone transport within four selected areas of California, and to identify, relative to locally emitted pollutants, the contribution of transported pollutants to ozone violations in each downwind area. The project concentrated on the broader Sacramento area (BSA), the upper Sacramento Valley (USV), the north central coast air basin (NCC), the southeast desert air basin (SEDAB), and the Imperial County portion of the SEDAB.

Findings: Local and transport violation days were recorded in the USV area, but for the monitoring dates in the study there were no overwhelming transport effects. Local and transport violation days were recorded in the BSA area upwind of the central business district (CBD), but at the CBD itself local emissions dominated. In the NCC, Carmel's only violation day was local, while Hollister and Pinnacles violation days were due to local sources and transported ozone. The San Bernardino portion of the SEDAB is dominated by transport from the south coast air basin with some contribution from the San Joaquin Valley. Ozone violation days in Imperial County were dominated by local emissions.

Importance to ARB's Program: This study helped satisfy the California Clean Air Act requirement to identify air basins whose emissions contribute to violations of the ozone standard in downwind air basins.

ANALYSIS OF AMBIENT VOC DATA COLLECTED IN THE SOUTHERN CALIFORNIA AIR QUALITY STUDY. A832-130: Sonoma Technology, Inc. Research Note 1994-9.

Objectives: To analyze the behavior of nonmethane organic gases (NMOG) in the south coast air basin using data collected during the 1987 Southern California Air Quality Study (SCAQS). NMOG are of concern because of their role in the formation of ozone.

Findings: NMOG composition and NMOG/NO_x ratios were similar throughout the basin. Ambient NMOG composition resembled that of motor vehicle exhaust, suggesting that the dominant source is most likely motor vehicles. The early morning ambient NMOG/NO_x and CO/NO_x ratios and profiles were inconsistent with those of the emissions inventory, indicating that CO and NMOG emissions from motor vehicles are underestimated in the inventory. There appear to be large amounts of carbonyl compounds (ozone precursors) formed in the urban atmosphere from photo-oxidation of hydrocarbons.

Importance to ARB's Program: This study contributed to new insights into the deficiencies of our emissions inventory, to the understanding of the widespread and continuous contribution of motor vehicle emissions to urban air pollution, and to the important contribution of carbonyls to the chemistry of air pollution.

1991

ANALYSIS OF THE 1987 SOUTHERN CALIFORNIA AIR QUALITY STUDY (SCAQS) ATMOSPHERIC TRACER DATA. A932-051: California Institute of Technology.

Objectives: To use state-of-the art methods to better define source-receptor relationships for ozone and particulate pollutants (PM10) by analyzing the ARB's database of concentrations of sulfur hexafluoride gas released as an emissions tracer near source areas and captured in downwind areas during the 1987 Southern California Air Quality Study.

Findings: Wind models that can be run from personal computers were able to accurately predict the path traveled by tracer gases.

Importance to ARB's Program: The study refines the analysis of precursor air pollution transport using a tracer gas technique and introduced new ways to analyze such data. This will be helpful in the planning of future field studies to monitor the relationship between precursor emissions and photochemical ozone. Better understanding of air pollution transport is required by the California and Federal Clean Air Acts.

IMPROVED PROCEDURES FOR QUANTIFYING KEY METEOROLOGICAL EFFECTS ON AMBIENT OZONE DATA. A832-134: Systems Applications, Inc.

Objectives: To quantify the effects of meteorological conditions on ambient ozone concentration in the south coast air basin (SoCAB). To develop procedures for classifying ozone episodes in order to identify and select representative modeling days.

Findings: Two basic meteorological flow regimes were identified. However, a large number of high ozone days fail to exhibit some or all of these patterns. Thus, episode selection criteria are complicated by the fact that high ozone concentrations can occur in the SoCAB under quite different meteorological scenarios.

Importance to ARB's Program: This study was used in the planning of future SoCAB field studies for ambient monitoring and modeling of ozone concentrations. These activities are required to assure compliance with California and Federal implementation plans for reduction of ambient air pollution as required by the California and Federal Clean Air Acts.

DIAGNOSTIC ANALYSIS OF WIND OBSERVATIONS COLLECTED DURING THE SOUTHERN CALIFORNIA AIR QUALITY STUDY. A832-133: Systems Applications, Inc.

Objectives: To generate three-dimensional wind fields for analysis of airflow and transport patterns in the south coast air basin during the 1987 Southern California Air Quality Study (SCAQS).

Findings: Gridded wind fields were generated hourly for the eight SCAQS intensive monitoring periods, and forward and backward trajectories were calculated using the wind fields.

Importance to ARB's Program: The results of this study were used to study source-receptor relationships for ozone, particulate matter (PM10), and other pollutants. This research was incorporated into development of air pollution modeling used in demonstrating progress toward attainment of the ozone and PM10 standards.

SECONDARY ORGANIC AEROSOL IN THE LOS ANGELES BASIN. A832-129: Oregon Graduate Institute of Science and Technology.

Objectives: To develop a better understanding of the factors, particularly the secondary processes, that contribute to high organic aerosol concentrations.

Findings: During the peak 2-hour periods of aerosol concentrations in the summer 1987 measuring period, up to 80 percent of the organic carbon was produced by secondary processes. The highest concentrations of secondary organic carbon occurred on weekends, possibly due to the decline in primary production.

Importance to ARB's Program: The report provided valuable information to the air quality modeling community and atmospheric chemists on formation of particulate pollutants, whose control is one objective of the California and Federal Clean Air Acts.

DETERMINATION OF SOURCE CONTRIBUTIONS TO HIGH AMBIENT CARBON MONOXIDE CONCENTRATIONS AND CATEGORIZATION OF CARBON MONOXIDE POTENTIAL. A832-135: AeroVironment, Inc. Research Note 1992-4.

Objectives: To understand and quantify the relative contributions of various emission sources to elevated ambient carbon monoxide (CO) concentrations.

Findings: The Lynwood area of the south coast air basin constitutes a "hot spot" for CO due to high traffic counts, low inversion heights, low wind speed, and a decrease in the mixing volume in the evening. Combustion processes, primarily automotive exhaust, are the main contributor to high CO concentrations.

Importance to ARB's Program: This study contributed to the ARB's development of effective control strategies to reduce ambient CO at sites with high concentrations, as required by the California and Federal Clean Air Acts.

CHEMICAL ANALYSIS OF AEROSOL SAMPLES FROM THE CARBONACEOUS SPECIES METHODS COMPARISON STUDY. A832-127: Global Geochemistry Corporation.

Objectives: To more completely characterize the aerosols collected during the 1986 Carbonaceous Species Methods Comparison Study, and to better understand the nature and origins of airborne carbonaceous particles in Los Angeles.

Findings: Approximately one-third of the organic carbon in aerosol particles is from non-fossil fuel sources. The same is true for one-third of the elemental carbon.

Importance to ARB's Program: This study contributed to identification of the sources of aerosols in Los Angeles for development of PM10 control strategies as required by the California and Federal Clean Air Acts.

IMPACTS OF CHANGES IN PRECURSOR EMISSIONS IN THE SAN FRANCISCO BAY AREA ON OZONE IN THE NORTH CENTRAL COAST AND SAN JOAQUIN VALLEY AIR BASINS. A932-133: Systems Applications, Inc.

Objectives: To examine the effect of reductions in emissions from all sources in the San Francisco Bay Area (SFBA) on ozone levels in the north central coast (NCC) and San Joaquin Valley (SJV) air basins.

Findings: Air quality model calculations indicated that elimination of SFBA emissions could significantly reduce ozone concentrations in the NCC and SJV during meteorological conditions that are conducive to transport. However, despite apparently large decreases in SFBA emissions, no statistically significant ozone trends were observed in the SFBA or the downwind basins over the 1979 to 1988 period.

Importance to ARB's Program: This study in part satisfied the California Clean Air Act requirement for identification of air basins where emissions contribute to violations of the ozone standard in downwind air basins.

SPATIAL INHOMOGENEITIES IN SCAQS FILTERS. A832-128: University of California, Davis.

Objectives: To determine the effect on PM10 and PM2.5 measurements of non-uniform deposits in the 1987 Southern California Air Quality Study (SCAQS) sampler, and to develop correction factors for these efforts.

Findings: The extent of the non-uniformities and calculated corrections that could be used to minimize their impact were determined. The corrections ranged from 25 percent to over 200 percent, depending on the size and type of the particulate matter.

Importance to ARB's Program: The resulting corrections to the SCAQS data provide modeling and emissions inventory assessment, as required to show compliance with targets in the PM10 provisions of the California and Federal Clean Air Acts.

1990

IMPROVEMENT OF PROCEDURES FOR EVALUATING PHOTOCHEMICAL MODELS. A832-103: Radian Corporation. Research Note 1991-4.

Objectives: To improve procedures used for evaluating photochemical grid model performance, and to develop methods for evaluating photochemical model performance as it relates to assessment of ozone control strategies, with emphasis on the analysis of the 1987 Southern California Air Quality Study database.

Findings: The investigators recommended a set of ten statistical measures for assessing a model's accuracy in predicting ozone concentrations, along with statistical standards that each modeling study should try to meet. Diagnostic simulations of zero emissions, initial conditions, boundary conditions, deposition, increased mixing heights, and reduced wind speeds are also recommended. In addition, the sensitivity of the model to uncertainties in hydrocarbon emission rates and speciation, and to other parameters, should be assessed. Comparisons between measurements and predictions of species other than ozone will help ensure that the model predicts the right ozone concentrations for the right reasons.

Importance to ARB's Program: This report was incorporated into ARB's Photochemical Air Quality Modeling Guidelines. These guidelines assure better modeling of the progress toward attainment of the ambient air quality standards for ozone.

SOUTHERN CALIFORNIA AIR QUALITY STUDY. PART I: HYDROCARBON COLLECTION AND ANALYSES. PART II: AIR TOXICS COLLECTION AND ANALYSES. A6-179-32: Biospherics Research Corporation.

Objectives: To collect and analyze air samples for hydrocarbons, carbon monoxide, and toxic air contaminants for the 1987 Southern California Air Quality Study (SCAQS).

Findings: The data were gathered in a novel way using internally electropolished stainless steel canisters.

Importance to ARB's Program: This study's database is part of the large SCAQS database, which is a resource for monitoring compliance with California's air pollution and toxic air contaminant standards.

1989

SOUTHERN CALIFORNIA AIR QUALITY STUDY (SCAQS): DESCRIPTION OF MEASUREMENT ACTIVITIES. A5-157-32: Sonoma Technology, Inc.

Objectives: To create a reference document providing an overview of the entire 1987 Southern California Air Quality Study.

Findings: The reference document was created.

Importance to ARB's Program: This document is a valuable reference for those interested in using the data collected during the $12 million study. Academics and researchers engaged in atmospheric chemistry, other states' air pollution agencies, the U.S. EPA, and various other research agencies have used this document and its associated database to reshape clean air management policy.

SOUTHERN CALIFORNIA AIR QUALITY STUDY: QUALITY ASSURANCE PROGRAM. A6-122-32: ENSR Consulting and Engineering.

Objectives: To provide quality assurance for the data collected during the 1987 Southern California Air Quality Study, and to document the precision, accuracy, and validity of the data.

Findings: The program identified a number of problems, and these were subsequently corrected. Audits performed during the study also uncovered some problems, most of which were correctable with post-processing of the data.

Importance to ARB's Program: This program illustrated the importance of a well designed quality assurance program to the ultimate success of air pollution field studies.

ORGANIC AND ELEMENTAL CARBON SIZE DISTRIBUTIONS OF LOS ANGELES AEROSOLS MEASURED DURING SCAQS. A732-075: University of Minnesota.

Objectives: To measure the particle sizes and concentrations of the elemental carbon (EC) and residual organic carbon (ROC) portions of particulate matter at four sites during the 1987 Southern California Air Quality Study. Carbonaceous particulate matter is of concern due to its adverse impacts on visibility and health.

Findings: The ROC mass mean diameter is greater than that of the EC at all sites. The ratio of the masses of ROC to EC varied with season, site, and particle size.

Importance to ARB's Program: These results added to our understanding of this pollutant and provided insight into appropriate control strategies.

MONITORING OF ATMOSPHERIC PARTICLES AND OZONE IN SEQUOIA NATIONAL PARK. A5-180-32: Air Quality Group, University of California, Davis.

Objectives: To monitor ozone and particulate matter in the Sequoia National Park over a three-year period to better understand the impact of acid deposition and other air pollutants on the park's forests and watersheds.

Findings: Particulate matter concentrations and ozone concentrations are dominated by transport from the San Joaquin Valley via thermally generated winds. These winds efficiently transport pollutants to above 6000 feet. At 10,000 feet, the transport is greatly weakened, resulting in abrupt pollutant concentration decreases.

Importance to ARB's Program: This report in part satisfied the California Clean Air Act requirements for the acid deposition program.

SOUTHERN CALIFORNIA AIR QUALITY STUDY: IN-SITU MEASUREMENT OF AEROSOL ORGANIC AND ELEMENTAL CARBON. A732-072: Oregon Graduate Center.

Objectives: To make organic and elemental carbon measurements to provide time-resolved information on the diurnal variation in the concentrations of carbon aerosols. Carbon is a major component of the aerosol burden in the Los Angeles area.

Findings: Both organic and elemental carbon exhibited large diurnal variations. The limited amount of data indicate that the carbon aerosol burden is higher in the fall than in the summer. The origin of the carbon appears to be directly emitted (primary) during the fall; during the summer, primary carbon was dominant on some days and photochemically produced carbon (secondary) was dominant on other days.

Importance to ARB's Program: This study provided additional insight into the nature of carbon aerosol and will be useful for further research and the design of future studies and control policies.

SUMMARY OF SCAQS UPPER AIR MEASUREMENTS PERFORMED BY THE STI AIRCRAFT. A6-098-32: Sonoma Technology, Inc. Research Note 1990-3.

Objectives: To document the three-dimensional distribution of ozone, aerosols, and their precursors throughout the SCAQS study area. To document the chemical composition of the aerosols, hydrocarbons, and other species at selected locations aloft.

Findings: During the three study periods, aerial flights gathered three-dimensional data on ozone, aerosols, and their precursors, as well as information on their chemical composition.

Importance to ARB's Program: A wealth of data were provided to use in evaluating and improving emissions inventories and modeling.

SOUTHERN CALIFORNIA AIR QUALITY STUDY: B-SITE OPERATIONS. A5-196-32: AeroVironment, Inc.

Objectives: To collect a variety of air quality data at several sites on the intensive sampling days during the 1987 Southern California Air Quality Study to support specialized measurements made by other researchers.

Findings: All data were collected according to the contract.

Importance to ARB's Program: These routine and specialized data on the intensive study days have been used by other researchers to understand the air quality problem better and to evaluate the performance of air quality models.

SOUTHERN CALIFORNIA AIR QUALITY STUDY: PEROXYACETYL NITRATE (PAN) MEASUREMENTS. A6-099-32: Daniel Grosjean and Associates, Inc. Research Note 1989-4.

Objectives: To measure peroxyacetyl nitrate concentrations during the 1987 Southern California Air Quality Study. PAN can act as a reservoir of NO_x as well as of oxygenated hydrocarbons, with possible participation in ozone photochemistry in the latter case.

Findings: Maximum PAN concentrations measured at ground level and aloft conformed to expectations. The data indicated spatial and temporal patterns consistent with current photochemistry concepts. PAN concentrations measured by another method indicated a 25-30 percent uncertainty in the measurements.

Importance to ARB's Program: These data are useful for assessing the performance of photochemical air quality modeling efforts. Modeling is a cornerstone in the determination of future compliance with the ambient air quality standards.

DERIVATION OF FORMIC ACID DATA FROM FTIR SPECTRA RECORDED DURING THE 1986 CARBONACEOUS SPECIES METHOD COMPARISON STUDY. A733-167: University of California, Riverside.

Objectives: To determine formic acid concentrations at Glendora, California, as part of the Carbonaceous Species Methods Comparison Study (CSMCS). Formic acid and other organic acids are formed as part of the atmospheric photochemical process. In some alpine lakes and water catchments in California with low tolerance for acidity, organic acids may have detrimental effects on the ecosystem.

Findings: Low to average concentrations of formic acid were observed. For the first several days the formic acid concentrations were higher in the afternoon (consistent with photochemical activity, as expected). However, during the last days of the study, the highest levels were in the early morning hours, presumably as a result of buildup from as-yet-undetermined primary sources.

Importance to ARB's Program: The CSMCS database is a unique and valuable air quality resource for modeling and emissions inventory assessment.

SOUTHERN CALIFORNIA AIR QUALITY STUDY: SCAQS SAMPLER CHEMISTRY. A5-186-32: Combustion Engineering Environmental, Inc.

Objectives: To document the methods and procedures used to collect and verify the data collected with the Southern California Air Quality Study (SCAQS) sampler.

Findings: The SCAQS sampler measured nitric acid, sulfur dioxide, ammonia, total suspended nitrate, PM2.5 and PM10 mass, ammonium, nitrate, sulfate, sodium, chloride, various elements, organic and elemental carbon, and light absorption by fine particles. Suspect data were identified based on pre-established acceptance criteria and appropriately flagged in the SCAQS database.

Importance to ARB's Program: This project's report can be used in the analysis of data collected by the SCAQS samplers and in appropriate interpretation of the results.

POLLUTANT TRANSPORT STUDY: BAY AREA TO NORTH CENTRAL COAST. A3-078-32: Bay Area Air Quality Management District.

Objectives: To update the existing air quality model used by the Bay Area Air Quality Management District to identify control strategies. An earlier study had shown that transport from the Bay Area into the Monterey Bay Area is important, and control strategies proposed in the Bay Area might adversely impact the Monterey Bay Area due to this transport.

Findings: The model was improved to satisfactorily reproduce the transport of ozone and its precursors into the Monterey Bay area.

Importance to ARB's Program: The updated model shows that decreases in NO_x and HC emissions in the Bay Area will not adversely affect the Monterey Bay Area, confirming the assumptions in the 1987 State Implementation Plan for Ozone.

California Clean Air Act:

Economic Studies

Economic Studies

Projects in Progress

(None)

Completed Projects

1997

POPULATION GROWTH AND ATMOSPHERIC EMISSIONS IN CALIFORNIA. 95-333: University of California, Davis.

Objectives: California has a complex economy whose sectors are affected differently by population growth. This study explored the effects of population growth on stationary emission sources and estimated the degree to which benefits of air quality management programs have been offset by population growth.

Findings: The study found that population growth has larger impacts on some industrial sources of emissions than on others and that stationary emissions grow more slowly than population. A one percent growth in population causes an increase in stationary emissions in the range of 0.3 to 0.7 percent.

Importance to ARB's Program: The results of this study will be used to improve California's emissions inventory and to provide better emissions predictions for use in regulatory programs.

EVALUATING THE EFFECTS OF PARKING CASH-OUT. 93-308: University of California, Los Angeles. Research Note 1998-3.

Objectives: To estimate the effectiveness of the legislatively mandated parking cash-out program. The cash-out program would require employers to offer a cash allowance to their employees equivalent to "the difference between the out-of-pocket amount paid by an employer on a regular basis in order to secure the availability of an employee parking space not owned by the employer and the price, if any, charged to an employee for the use of that space." The intent of this program is to provide an incentive that would encourage employees to give up their parking spaces and use the cash to ride alternative modes of transportation, such as transit or vanpools.

Findings: The parking cash-out program can significantly reduce vehicle miles traveled, and therefore emissions, and fuel at a reasonable cost to employers.

Importance to ARB's Program: The ARB was designated by legislation to implement the parking cash-out program. The results of this research will help the ARB evaluate the effects of the transportation-related air quality programs it manages and to recommend to the legislature changes that would enhance the program cost-effectively.

1996

AIR QUALITY, CONGESTION, ENERGY, AND EQUITY IMPACTS OF MARKET-BASED TRANSPORTATION CONTROL MEASURES. 92-316: Deakin, Harvey, Skabardonis, Inc. Research Note 1998-1.

Objectives: To use advanced travel demand models to analyze the impacts of congestion pricing, employee parking charges, fuel tax increases, and mileage and emission fees on driving-related behavior in the four major metropolitan areas of California, and to evaluate public opinion and legal and institutional issues that should be considered in designing transportation pricing measures.

Findings: The study concluded that transportation pricing measures can effectively reduce emissions, congestion, and energy use. However, price increases must be significant to obtain sizable reductions. Public focus groups revealed many barriers to public acceptance of transportation pricing, but also uncovered ways to increase public support. Federal and State laws govern, and in some cases restrict, the implementation of pricing strategies. These and other institutional issues would have to be resolved before specific pricing measures can be implemented in California.

Importance to ARB's Program: The results will help the ARB determine whether market-based programs for vehicular emissions reductions are potentially effective and could be implemented.

1995

TRANSPORTATION-RELATED LAND USE STRATEGIES TO MINIMIZE MOTOR VEHICLE EMISSIONS - AN INDIRECT SOURCE RESEARCH STUDY. 92-348: JHK and Associates. Research Note 1995-18.

Objectives: To suggest community-level performance goals for vehicle travel and related air quality emissions that could reasonably be achieved in California by implementing transportation-related land use strategies that reduce the need for reliance on automobile travel. Also, to develop combinations and specific levels of transportation-related land use strategies that can assist communities in achieving these goals, and to provide a list of mechanisms for implementing these strategies.

Findings: The investigators identified combinations of strategies that are appropriate to different situations and types of communities (urban, suburban, and exurban). The recommended strategies are: strong downtowns and concentrated activity centers, density near transit, infill (development within an existing urban area), mixed-use development, pedestrian facilities, interconnected street networks, and strategic parking facilities. The investigators also suggest performance goals or quantifiable results that can be expected from strategy implementation and describe implementation mechanisms for the strategies, including policies that jurisdictions can adopt, documents that can be updated, administrative actions, financial resources, and barriers and uncertainties associated with implementation. The report for the study includes an annotated bibliography of over 150 sources, along with summaries of the quantified findings of each.

Importance to ARB's Program: This research helps the ARB provide guidelines and information to districts, local governments, and others regarding long-term air quality improvement strategies.

A STUDY TO EVALUATE THE SIGNIFICANCE OF CALIFORNIA AIR POLLUTION CONTROL REGULATIONS ON BUSINESSES' LOCATION DECISIONS. 92-349: California State University, Fullerton. Research Note 1996-1.

Objectives: To identify and assess the impact of air pollution control regulations on businesses' decisions to locate or expand in or outside of California.

Findings: This study found that the primary cause of complaints about air pollution regulations is the complex, slow, and sometimes costly process of getting information about the regulations and obtaining permits. Compliance with air quality regulations was found to impose a relatively small cost on businesses (0.29 percent of revenues), and to be only one of many factors in business location decisions. Further, business relocations were not a significant cause of the downturn of California's economy in the early 1990s.

Importance to ARB's Program: This study will contribute to the ARB's efforts to ascertain the effects of costs of its regulations on California businesses.

1994

A STUDY TO DEVELOP STATEWIDE AND COUNTY-LEVEL ECONOMIC PROJECTIONS. 92-326: DRI/McGraw-Hill.

Objectives: To develop detailed economic projections of the California economy to improve the ARB's emissions inventory projections.

Findings: Annual historical data and forecasts of employment and real output by industry were developed for the period 1970 to 2020 using a long-run county-level forecasting system. Historical data were collected at 2-, 3-, and 4-digit Standard Industrial Classification detail. Projections were prepared for four separate scenarios: business cycle, high growth or optimistic, low growth or pessimistic, and best estimate or base case.

Importance to ARB's Program: The projections will be used as inputs in the ARB emissions forecasting model and by Air Quality Management Districts and Air Pollution Control Districts to demonstrate that their air quality management plans will achieve the mandated goal of a 15 percent reduction in emissions for each three-year period.

LAND USE AND TRAVEL BEHAVIOR (Parts 1 and 2). A132-103: University of California, Davis.

Objectives: To determine the relationships between land use patterns and vehicle trips and miles traveled by studying travel patterns of residents of five neighborhoods in the San Francisco Bay Area.

Findings: The results of this study suggest that integrated land use and transportation planning can reduce vehicle trips and improve air quality. Researchers conducted a detailed study of five neighborhoods in the San Francisco Bay Area using travel surveys from about 1,100 households. They found that local land use characteristics are associated with the amount of driving and travel by other modes, such as transit and walking. The neighborhood characteristics found to be most important were: housing density, access to services, the availability of transit service, and the interconnection of travel routes. Residents in higher density, mixed-use areas were found to make more trips by transit, walking, and biking than those living in lower density areas.

Importance to ARB's Program: The results assist the ARB in providing guidelines and information to districts, local governments, and others regarding long-term air quality improvement strategies.

EFFECTS OF INCREASED HIGHWAY CAPACITY ON TRAVEL BEHAVIOR. 92-325: Dowling Associates. Research Note 1995-19.

Objectives: To assess the impacts that highway expansion may have on travel behavior and the emissions related to travel.

Findings: This study used a stated preference survey and case studies to assess the short-term effects of reduced travel time resulting from additional highway capacity on choice of route, departure time, travel mode, and trip frequency. The most significant effects of new highway capacity were found on temporal shifts in travel demand: more trips are likely during the peak travel periods, with impacts on emissions. Highway capacity expansion projects that result in major time savings would also lead to a 3 to 5 percent increase in trip frequency. Long-term effects on land use and home location decisions may be especially significant, but were beyond the scope of this study.

The investigators recommend adjusting travel models and/or project-level assessments to account for the trip scheduling and trip generation effects of highway capacity changes. A longitudinal panel survey was suggested as additional research to provide a more useful assessment of traveler response to highway congestion.

Importance to ARB's Programs: Results and recommendations from this study can be used in the improvement of the motor vehicle emissions inventory and in transportation/air quality planning decisions.

A REVIEW OF BENEFIT/COST AND OTHER DECISION ANALYSES ASSOCIATED WITH ENVIRONMENTAL REGULATORY PROGRAMS. 92-337: M.CUBED. Funded by Cal/EPA.

Objectives: To develop a handbook to help evaluate benefit/cost studies and other decision analyses prepared by interested parties regarding Cal/EPA programs and regulations.

Findings: The handbook was developed as planned.

Importance to ARB's Program: To help Cal/EPA agencies better assess the costs and benefits of their programs.

IMPACTS OF COMPRESSED WORKWEEK ON TOTAL VEHICULAR TRIPS AND MILES TRAVELED. A132-136: University of Southern California. Research Note 1995-12.

Objectives: To determine whether compressed workweek schedules lead to net trip reductions for commuters and reductions in associated vehicle emissions.

Findings: A travel survey of about 2,500 employees in Southern California revealed that the average employee on compressed work week schedules (4/40 or 9/80) is male, between 25 and 54 years old, and from a single-worker household. These employees reduce their home-to-work trips an average of 0.8 trip per week. Home-to-work trip reductions tend to occur at the morning and afternoon peak periods; most non-work-related trips in this study occurred at non-peak periods. Reduced trips resulted in 13 miles less travel for those on 9/80 and 20 miles less for those on 4/40 schedules. The study concluded

that, for significant air quality benefits, the compressed work week alternatives need to be widely implemented by employers who can integrate flexibility into their operations.

Importance to ARB's Program: This study will help the ARB evaluate the transportation portion of the districts' air quality plans.

NPTS SUBJECT AREA REPORT ON HOUSEHOLD SOCIAL STRUCTURE AND TRAVEL BEHAVIOR. 92-351: California State University Sacramento, CSUS Foundation.

Objectives: To develop a new action-based methodology for analyzing travel survey data, and to develop measures of travel behavior that reflect the extent to which individual trips are linked together into complex travel strategies.

Findings: A promising methodology for analyzing travel behavior for 12 different social structural types of households and for 12 types of roles of persons within those households was developed. Both household structure and person role were found to be effective in differentiating values for travel variables. The number of vehicles owned by the household, number of persons in the household, and work status were the only conventional variables found to be comparable to household structure and person role in this respect.

Importance to ARB's Program: This research will be used to provide better estimates of the effectiveness of transportation control measures and to help in calculating the distribution of benefits and costs from transportation-related regulations, programs, and policies.

1993

INVESTIGATION OF THE EFFECTS OF ATMOSPHERIC ACIDITY UPON ECONOMICALLY SIGNIFICANT MATERIALS. A932-113: University of Southern California. Research Note 1993-3.

Objectives: To determine correlations between air quality, meteorological conditions, and damage to materials of economic significance in Southern California using data collected from a previous research project (A5-137-32, 1989) as well as data collected under this project.

Findings: Correlations between corrosion rates, air quality, and meteorological parameters were developed for galvanized steel, nickel, and aluminum for the test sites (Burbank, Long Beach, Upland, and the background site, Salinas). The differences among sites, seasons, and materials were also examined. Corrosion rates were low at all four test sites. For galvanized steel, nickel, and aluminum, corrosion rates were higher in the summer than in the winter. At most other locations worldwide, higher corrosion rates in are found in the winter.

Importance to ARB's Program: Under the Atmospheric Acidity Protection Program, this information will be used in the assessment of the economic impact on California of atmospheric acidity.

ECONOMIC IMPACTS OF ALTERNATIVES TO OPEN-FIELD BURNING OF AGRICULTURAL RESIDUES. A132-121: Foster Associates, Inc. Research Note 1995-16.

Objectives: To identify alternatives to open-field burning of agricultural residues, and to quantify the economic and financial impacts of these alternatives, particularly with respect to burning rice straw in the Central Valley of California.

Findings: A ban on residue burning is likely to have modest impacts on growers and minimal impacts on the Sacramento Valley economy. Soil incorporation is the most economically viable alternative to burning for most rice and wheat growers. If significant yield reductions occur from limits placed on burning, noticeable individual and regional economic impacts would be seen. Given the limited economically feasible methods of off-site residue disposal for almond and walnut growers, a ban on residue burning could create substantial economic and technical difficulties for these growers.

Importance to ARB's Program: This study will assist the Board in preparing biennial reports to the Legislature on the status of feasible and cost-effective alternatives to residue burning and the economic implications of their widespread adoption; this information may be used by the Board in its rule development.

ANALYSIS OF INDIRECT SOURCE TRIP ACTIVITY: REGIONAL SHOPPING CENTERS. A132-094: JHK and Associates. Research Note 1995-27.

Objectives: To develop an understanding of the characteristics of travel (non-work-related) to regional shopping centers, to evaluate the features of regional shopping centers that impact travel behavior, and to develop a methodology for evaluating the impact of potential motor vehicle trip reduction measures on travel behavior at regional shopping centers.

Findings: A significant portion of the variation found in travel mode to regional shopping centers can be explained by the amount and regional coverage of public transit service as well as the density and proximity of the surrounding land uses. Differences in the demographic and trip characteristics of travelers to each of the case study sites do not appear to explain the variation in travel mode, which ranged from a low of 5% non-auto mode to a high of 62% non-auto mode (mostly transit and walking).

For the five case study sites, the estimated impact of individual travel reduction measures on the number of trips to the regional shopping center ranges from 0.1 percent to 6.2 percent. This does not include the measure parking pricing (10.5) percent, since the survey found that trips to the shopping center would shift to other locations rather than switch modes and thus have a negative economic impact. In combination, packages of travel reduction measures were estimated to reduce trips by five to seven percent.

Importance to ARB's Program: These results assist ARB in providing information to districts, local governments, and others regarding voluntary long-term air quality improvement strategies.

INCENTIVES FOR TRIP REDUCTION THROUGH LOCATION OF HOUSING NEAR CALIFORNIA RAIL TRANSIT STATIONS. A032-185: University of California, Berkeley.

Objectives: To evaluate the long-term incentive-based strategy of developing housing near public rail transit to reduce vehicle usage.

Findings: Residents living within walking distance of stations had a high rate of transit usage and were willing to pay more to live near the stations. Transit-based housing in California is at an early stage and is not specifically targeted for State and local financial and zoning incentives. The main tool used by local governments to encourage higher density housing near rail transit stations has been redevelopment powers. Incentives such as reduced parking requirements and density bonuses have not had significant effects.

Importance to ARB's Program: This project assists ARB in providing information to districts, local governments, and other regarding long-term air quality improvement strategies.

A SURVEY AND ANALYSIS OF EMPLOYEE RESPONSES TO EMPLOYER-SPONSORED TRIP REDUCTION INCENTIVES PROGRAMS. A932-187: COMSIS, Inc. Research Note 1995-22.

Objectives: To quantify the effectiveness of incentives offered to employees by employers to reduce work-related vehicle trips.

Findings: Financial incentives are the most effective in reducing single-occupant vehicle trips. Other effective incentives are guaranteed ride home, company vanpools, transportation allowance, and carpool subsidies. The annual average program cost $13,000 for the companies in the study. The "correct" incentives mix for a particular company was much more conducive to reducing trips than the amount of money spent.

Importance to ARB's Program: This project helped ARB provide more effective guidelines to local districts for air quality management and planning.

1990

STUDY OF ECONOMIC INCENTIVES TO CONTROL PHOTOCHEMICALLY REACTIVE ORGANIC COMPOUNDS FROM CONSUMER PRODUCTS. A732-150: ICF Consulting Associates.

Objectives: To evaluate economic incentives for reducing ozone precursors (hydrocarbons) emitted from consumer products.

Findings: Hydrocarbon emissions from paint and hair sprays can be significantly reduced. Fees produce large revenues. Marketable quotas avoid large monetary transfers and leave the funds with the sources to invest in emissions reduction activities. The study recommended the use of marketable quotas and suggested a program design.

Importance to ARB's Program: The results were used to evaluate the efficacy of economic incentives as a control strategy for consumer products.

1989

INVESTIGATION OF THE EFFECTS OF ATMOSPHERIC ACIDITY UPON ECONOMICALLY SIGNIFICANT MATERIALS. A5-137-32: Combustion Engineering.

Objectives: To determine the effects of acidic deposition on two types of paint, galvanized steel, nickel, concrete, aluminum, nylon fabric, and polyethylene in the South Coast Air Basin under controlled field conditions.

Findings: The relationships among material damage, air quality, and meteorological variables were developed for galvanized steel, nickel, and one type of paint. Reliable exposure-response relationships could not be developed for the other materials, primarily due to insufficient amounts of exposure data.

Importance to ARB's Program: Data collected under this project were used in a subsequent research project (Contract No. A932-113, 1993).

ECONOMIC ASSESSMENT OF FIELD CROP LOSSES DUE TO AIR POLLUTION. A5-105-32: University of California, Davis. Research Note 1990-5.

Objectives: To evaluate the effect of ozone-caused crop damage upon California's economy, especially that of farmers and consumers.

Findings: Economic loss from ozone damage to crops in California in 1984 was approximately $333 million. About 90 percent of this damage occurred in the San Joaquin Valley.

Importance to ARB's Program: To estimate the damage to crops in California from ozone and the benefit to farmers and consumers from reducing ozone levels.

ECONOMIC ASSESSMENT OF MATERIALS DAMAGE IN THE SOUTH COAST AIR BASIN: A CASE STUDY OF ACID DEPOSITION EFFECTS ON PAINTED WOOD SURFACES USING INDIVIDUAL MAINTENANCE BEHAVIOR DATA. A732-062: Mathtech, Inc.

Objectives: To develop, implement, and evaluate a methodology for estimating the economic impact of acid deposition effects on painted wood surfaces, and to estimate the annual cost savings for a 10 percent reduction in nitrogen dioxide (NO_2) concentrations for individuals who live in single family homes and make their own maintenance decisions. NO_2 was considered a proxy for components of photochemical smog that are the causative damage factors.

Findings: Using two methodologies, the annual cost savings were estimated to be between $0.7 and $3.6 million (1988 dollars) for 2.2 million single family homes from a 10 percent reduction in atmospheric NO_2 concentrations for six selected maintenance tasks that involved only painting of wood surfaces.

Importance to ARB's Program: Under the Atmospheric Acidity Protection Program, this information will be used in the assessment of the economic impact on California of atmospheric acidity.

Air Quality Standards

Air Quality Standards:

Health Effects

Health Effects of Air Pollution

Projects in Progress

MECHANISMS OF PARTICULATE TOXICITY: EXPOSURE EFFECTS ON THE RESPIRATORY SYSTEM. 96-310: University of California, Davis.

Objectives: To examine the mechanisms of short-term particulate damage on cells that line the respiratory tracts of adult, young, and old rats upon exposure to varying concentrations of PM10 for varying lengths of time.

Importance to ARB's Program: Results from this study will augment current epidemiology findings concerning the relationship between health effects and particulate matter exposure by determining the mechanisms of cellular damage.

STUDIES TO DETERMINE THE LONG-TERM HEALTH EFFECTS OF ACIDIC ATMOSPHERES. A033-088 and A033-089: University of California, Irvine, and New York University.

Objectives: To assess for humans, using appropriate animal models, the potential for harmful chronic effects resulting from exposure to acidic atmospheres typical of California. This was the first multi-species study to evaluate long-term noncancer effects of air pollution.

Importance to ARB's Program: The results from this project will be critical in evaluating the long-term effects of acidic exposures either alone or in combination with ozone. Preliminary results indicate that extended exposure to low levels of acids in both situations poses a health risk, as evinced by decreased lung elasticity and airway reactivity and a breakdown in some lung defense mechanisms.

HEALTH EFFECTS OF PM COMPONENTS ON SENSITIVE ANIMAL MODELS. 96-311: University of California, Irvine.

Objectives: To examine the mechanisms of short-term particulate damage on cells that line the respiratory tracts of adult and old rats upon exposure to varying sizes of particulate matter for varying lengths of time.

Importance to ARB's Program: Results from this study will augment current epidemiology findings concerning the relationships between health effects and particulate matter exposure by determining the mechanisms of cellular damage.

NITRIC ACID AIRWAY TOXICITY: POTENTIAL FOR PARTICLE AND OZONE INTERACTIONS. 92-334: University of California, Irvine.

Objectives: To determine whether adverse effects resulting from exposures to low levels of nitric acid (comparable to ambient conditions in Los Angeles) are enhanced in the presence of particles and ozone.

Importance to ARB's Program: In order to evaluate the chronic effects resulting from ambient acidic exposures it is necessary to evaluate the co-pollutant effects of ozone and particles because they often co-

exist with acids in urban ambient atmospheres. The results of this and other studies will be used by ARB staff to evaluate the risk posed by ambient acidity as required by the Atmospheric Acidity Protection Act.

EFFECTS OF MULTI-DAY EXPOSURES TO NITRIC ACID VAPOR AND ITS INFLUENCE ON OZONE-INDUCED INFLAMMATION IN HUMAN LUNGS. 93-303: University of California, San Francisco.

Objectives: To test the hypothesis that extended exposure to ambient levels of acidity 1) reduces lung elasticity as a result of connective tissue pathology and 2) exacerbates the inflammatory response of ozone.

Importance to ARB's Program: If the study establishes a correlation between the effects of multi-day exposures in humans and the previously reported effects in animals, the findings will play a key role in determining the need to set an ambient acidity standard as required by the Atmospheric Acidity Protection Act.

Completed Projects

1998

THE EFFECTS OF MULTI-DAY EXPOSURE TO NITROGEN DIOXIDE ON CELLULAR IMMUNITY: HUMAN MACROPHAGE RESPONSES. 95-311: University of California, Irvine.

Objectives: To determine whether repeated short-term exposure to nitrogen dioxide (NO_2 causes changes in macrophage function such as phagocytic activity and the ability to release inflammatory substances, and to determine whether NO_2 exposure causes macrophage overactivation, which could lead to increased cellular damage.

Findings: The results indicate that NO_2 exposure does not affect the body's production of macrophages, and that NO_2 exposure does not affect the potential ability of macrophage cells to recognize and ingest invading pathogens such as bacteria or viruses. Nor did NO_2 exposure appear to alter the ability of macrophage cells to recruit other infection-fighting cells. However, following NO_2 exposure, macrophages were found to become "overexcitable" and release more potentially toxic inflammatory chemicals than normal. This could cause tissue damage in the lungs of humans exposed to NO_2 in the ambient environment.

Importance to ARB's Program: Because oxides of nitrogen are common ambient air pollutants, and because epidemiologic evidence suggests that exposure to ambient NO_2 is associated with increased incidence of respiratory symptoms, infection, and illness in humans and depressed immune system function in animals, the ARB needs to determine the actual effects of NO_2 on humans so that this knowledge can be used in considering air pollution standards.

ALLERGENS IN PAVED ROAD DUST AND AIRBORNE PARTICLES. 95-312: California Institute of Technology, Pasadena, California.

Objectives: To detect, characterize and compare the main allergens found in both paved road dust and ambient air PM10 samples and to estimate paved road dust contributions to PM10 ambient levels.

Findings: At least 25 different allergens were found in the paved road dust and ambient particle samples analyzed, including pollen, pollen fragments, animal dander, and molds. Five to 13 percent of the total allergenicity of atmospheric particulate matter found in urban areas of Long Beach and Rubidoux was

directly attributable to paved road dust emissions. The allergenic content of particles collected in the industrial area of central Los Angeles, which has little or no proximity to vegetation and domestic activities, was much lower, on the order of only 0.5%. Using chemical speciation techniques and mass balance modeling, the investigators estimated that 26-33% of the airborne PM10 samples and 36-64% of the total suspended particulate samples were composed of paved road dust. Three to nine percent of the road dust material was found to be around 2 μm in aerodynamic diameter.

Importance to ARB's Program: The results of this study will provide an understanding of the importance of paved road dust in creating PM10 and will aid in the overall understanding of the role of particulate air pollution in respiratory disease.

1997

CARDIOVASCULAR EFFECTS OF CONTROLLED OZONE EXPOSURE IN CARDIAC PATIENTS. 93-327: Rancho Los Amigos Research and Education Institute.

Objectives: To conduct a pilot study to determine whether acute exposure to ozone can adversely affect people suffering from ischemic heart disease or hypertension.

Findings: The investigators were unable to locate, enroll, and study an adequate number of patients with ischemia, so the study was performed on patients with hypertension. While the study reports no clinically manifested adverse consequences of brief ozone exposure to hypertensives, even though this group is considered to be at risk, it does suggest a physiologic basis for concern for those with existing cardiovascular disease. Further experimental work of this type will be required to resolve the issue.

Importance to ARB's Program: In recent years epidemiological studies have reported a consistent correlation between urban air pollution levels and an increase in mortality. In addition, it appears that people suffering from cardiac and/or pulmonary disease are more prone than others to die from effects of air pollution. However, prior to this study, controlled laboratory studies had not reported any biological response(s) that could explain the mortality effect resulting from ambient pollutant exposures. This study provides evidence of biological response(s) to ozone that suggest that ozone exposure added stress to the hearts of people studied. The evidence from this study suggests one mechanism whereby ozone could impact the well-being of people with existing heart problems. The results provide further justification for modification of existing public health advisories to explicitly protect people with heart disease.

TOXICITY OF CHEMICAL CONSTITUENTS OF PM10 IN THE SOUTH COAST AIR BASIN OF CALIFORNIA. 93-318: University of California, Irvine.

Objectives: To evaluate animal responses to inhalation of particulate matter (PM) mixtures of various compositions and concentrations that reflect ambient PM levels found in California and which are suspected of being toxic in humans.

Findings: This study consistently showed that exposure to PM (composed of elemental carbon and ammonium bisulfate) delivered under well controlled conditions caused measurable and perhaps biologically significant injury to lung cells. The study also showed that PM exposure caused functional depression of an important component -- macrophage cells -- of the lung's natural immune system defenses. The study also showed that the effects of PM exposure are amplified by the presence of ozone. This suggests that previous controlled exposure studies that examined only single pollutants may have underestimated the health effects of PM pollution.

Importance to ARB's Program: Epidemiological evidence indicates that particulate matter air pollution is associated with increased incidence of mortality and morbidity among people living in polluted urban areas. Development of good control strategies to reduce the health risk from PM10 requires determination of the relative toxic potentials of its various components, with regard to both their chemical nature and their size distribution.

PULMONARY MACROPHAGE RELEASE OF INFLAMMATORY CYTOKINES AFTER MULTI-DAY EXPOSURE TO OZONE AND NITRIC ACID. 93-331: University of California, San Francisco.

Objectives: The magnitude of breathing capacity declines following acute single exposure to ozone progressively diminishes with successive days of ozone exposure. The objective of this study was to include additional health effects evaluation parameters (levels of cytokines) for ARB-funded clinical studies in progress that are evaluating the multi-day exposure effects of ozone and nitric acid. (Cytokines are biochemical mediators that are indicators of lung injury and are also responsible for inflammatory changes in the lung.)

Findings: The utility of this work awaits the completion of the core clinical study. Specific observations made in this study include: (1) Two of the measured cytokines produced a clear indication of pollution-related response; (2) responses to ozone were found to be similar in 1-day and 4-day exposure protocols; (3) nitric acid was found to stimulate production of the two cytokines by itself but cytokine levels were reduced when nitric acid and ozone were administered together. The findings of this study should prove useful in the interpretation of the results of the core clinical exposure study -- they provide a mechanistic link among pollutant exposure, observed lung function changes, and injury observations.

Importance to ARB's Program: Adding cytokine measurements to the ongoing studies will permit better evaluation of multi-day exposure effects of ozone and/or nitric acid.

THE SECOND COLLOQUIUM ON PARTICULATE AIR POLLUTION AND HUMAN HEALTH AND MORBIDITY. 95-323: University of California, Irvine.

Objectives: To hold a meeting of health experts to present and discuss the findings of research conducted to determine the health effects of particulate matter (PM) pollution and statistical methods for determining the properties of PM that may relate to the observed effects.

Findings: The meeting was attended by approximately 300 scientists and others interested in the regulatory aspects of PM. It was a valuable means for moving forward the state of air pollution science as it relates to the health effects of PM. The meeting sharpened the issues and several even larger meetings on the issues followed.

Importance to ARB's Program: The information presented at this and the following meetings was useful in reviews of PM regulatory actions taken by the U.S. EPA, which was a principal co-sponsor of the meeting.

THE EFFECTS OF MULTI-DAY EXPOSURE TO NITROGEN DIOXIDE ON HUMAN CELLULAR IMMUNITY. 93-317: University of California San Francisco.

Objectives: To determine whether extended exposures to nitrogen dioxide (NO_2) at the current California one-hour ambient air quality standard level (0.25 ppm) can compromise the human immune system.

Recent evidence suggests that low-level NO_2 exposures may weaken the immune system, compromising resistance to infections.

Findings: The results of this study, when viewed with other clinical and epidemiological investigations, do not resolve the uncertainties of NO_2 health and immune system impacts. It appears that NO_2 can impact the cellular processes of the lung by its simple oxidative damage potential as is found with ozone exposure. These oxidative injuries are reflected by the neutrophil cell increases reported in this study. Further, other studies find that NO_2 appears to produce complex alterations in immune system function or function of individual cellular components of the immune system. However, the timeframes of this and other past clinical exposure studies were short, and little change has been found, even -- in this study -- following exposure to relatively high levels of NO_2. The investigators suggest that more prolonged exposures may impact immune system function. Such studies area very difficult to perform on human volunteers exposed in experimental chambers.

Importance to ARB's Program: The study provides the information required by the ARB to establish whether extended exposures to NO_2 at the current standard level poses a threat to public health. It does not support the findings of other studies in which NO_2 was observed to cause changes in the immune system.

1996

EPIDEMIOLOGIC INVESTIGATION TO IDENTIFY CHRONIC HEALTH EFFECTS OF AMBIENT AIR POLLUTANTS IN SOUTHERN CALIFORNIA (Three-phase project). A033-186: University of Southern California.

Objectives: The objectives of the project in its entirety are: 1) to determine whether long-term exposure to southern California's unique mixtures and concentrations of ambient air pollutants during childhood development leads to changes in lung function or identifiable adverse health effects, especially chronic respiratory effects; and 2) to quantify the prevalence and severity of the observed health effects and the levels of exposure to specific pollutants at which the effects occur.

The primary specific objective of Phase I was to produce a cost-effective research plan for Phases II and III that offered the greatest likelihood of success in meeting the overall project objectives, and to develop a final detailed protocol for Phase II.

The specific objectives of Phase II are to verify community exposure classifications, collect data to be used in personal exposure models, gather baseline health and lifestyle data for the children under study, perform cross-sectional analyses to determine community differences that are a function of air pollution, and finalize the Phase III protocol, based on Phase II findings.

Findings: Phase I: 1) Based on potential long term exposure health effects, and on high ambient concentrations, the project should focus on ozone, particulate pollution, nitrogen dioxide, and acidic pollutants (nitric, hydrochloric, and organic acids); 2) to achieve statistically meaningful results, twelve communities with different ratios of these pollutants should be included in the study; 3) during Phase II, the project should study between-community differences in the health of school children from the fourth, seventh, and tenth grades, and then follow these children's health status through their high school graduation (year 2 of Phase II, and Phase III); and 4) a state-of-the-science exposure assessment program should be implemented to help separate out the effects of one pollutant from another. Phase II: This phase of the study was recently completed. ARB staff are in the process of reviewing the data for completeness and accuracy.

Importance to ARB's Program: Information obtained from this project, which is the cornerstone of the ARB's Long-Term Exposure Health Effects Research Program, will allow, for the first time, quantitative consideration of long-term exposure effects of ambient criteria air pollutants. The information will have direct application in the review and, if necessary, revision of California's health-based ambient air quality standards. The project will also provide information necessary to determine the need for an ambient air quality standard for atmospheric acidity.

RELATIONSHIP BETWEEN ACUTE OZONE RESPONSIVENESS AND THE CHRONIC LOSS OF LUNG FUNCTION IN RESIDENTS EXPOSED TO RECURRENT OXIDANT AIR POLLUTION. A6-158-33: University of California, Los Angeles.

Objectives: In the early 1970s a long-term study of chronic obstructive respiratory disease was initiated in Los Angeles County to monitor lung function responses in residents of three air-polluted areas and one less-polluted site. By the mid-1980s, it was found that subjects living in the polluted areas exhibited more rapid lung function declines than those living at the less-polluted site. This study was conducted to retest a subset of the participants of the earlier study to determine what, if any, changes had occurred in lung function over an additional 5-year period.

Findings: Residents of the most polluted area exhibited normal rates of lung function loss over the retest period. In a separate set of tests, subjects with the most severe losses in lung function were found to have the same sensitivity to acute ozone exposures as subjects with less lung function damage.

Importance to ARB's Program: It was hoped that this study would shed light on chronic effects of exposure to ambient ozone. It did not prove useful for clarifying this issue; findings of lung function decline proved equivocal. Uncertainties remain with regard to the chronic effects of air pollution on human health; It is premature to discount the earlier long-term findings. These uncertainties can only be resolved through further studies with stable funding.

EFFECTS OF OZONE ON PROTEASES AND PROTEASE INHIBITORS OF THE HUMAN AND RAT LUNG. A033-175: University of California, Irvine.

Objectives: To perform a detailed analysis of the biochemical events (changes in proteases and protease inhibitors) that are believed to precede connective tissue fibrosis (scarring) in lungs following exposure to air pollutants. In this study levels were measured of connective tissue proteases and protease inhibitors in lung lavage fluid collected from rats and humans following acute and/or chronic exposures to ozone alone or in combination with nitric acid.

Findings: No changes in protease levels were found in rats or humans for any of the exposure conditions. The investigators did find that, in both humans and rats, relatively low-level acute (but not subacute or chronic) ozone exposures resulted in striking increases in the protease-inhibiting capacity of lung lavage fluid. These increases in protease-inhibiting capacity were due to extensive cellular membrane damage and the release of intracellular contents and do not imply that acute ozone exposure offers a protective effect by "increasing" the amount of inhibitory species in lung fluids. Indeed, over time, because of the potential for permanent tissue damage, exposure to ozone could lead to an overall reduction in the production of protective inhibitory species. The study confirms that acute ozone exposure does cause tissue damage; however, it is unclear whether the mechanism leading to pulmonary fibrosis is tied to changes in protease levels or to the possible reduction over time of protease inhibitory species due to direct tissue damage.

Importance to ARB's Program: California's current ambient ozone standard is based on a number of factors that include short-term changes in lung function. The results of this study will contribute to the

determination of whether the standards adequately protect the public against the long-term effects of ozone exposure.

1995

EFFECTS OF NITRIC ACID VAPOR AND OZONE ON THE RESPONSE TO INHALED ANTIGEN IN ALLERGIC SUBJECTS. A133-150: University of California, San Francisco.

Objectives: To conduct a pilot investigation to determine how ozone and nitric acid might interact with allergens to affect asthmatic response processes.

Findings: Trends (non-statistically significant changes) were found that indicate that ozone may influence the asthmatic response to allergens. No influence of acid alone was detected and there appeared to be no augmentation of effects when acid was added to the ozone test atmosphere.

Importance to ARB's Program: The results of this and other studies will be combined to evaluate the health risk that ambient acidity poses to Californians and in considering the need for a health-based standard for this pollutant.

COLLOQUIUM ON PARTICULATE AIR POLLUTION AND HUMAN MORTALITY AND MORBIDITY. 92-341: University of California, Irvine.

Objectives: To conduct a scientific meeting to discuss the recently reported statistical associations between ambient levels of particulate matter (PM10) and human mortality and/or morbidity. Although several investigators have linked an increase in death rates and respiratory infections with day-to-day changes in ambient levels of PM10, the cause/effect relationships and the contributory role of specific components of PM10 need to be explored more fully.

Findings: The meeting was held as scheduled January 24-25, 1994, at the Arnold and Mabel Beckman Center of the National Academies of Sciences and Engineering in Irvine, California. The colloquium was very well attended. The topics and issues discussed set the stage for future particulate matter research. The papers and abstracts from the colloquium can be found in two special issues of the journal *Inhalation Toxicology*: Vols. 7(1) and 7(5).

Importance to ARB's Program: The discussions that took place at this meeting will provide a platform for scientists to clarify the issues related to a) the degree to which life span may be affected; b) the population subgroups that are at increased risk at ambient levels of PM10; and c) the suitability of biostatistical methods used to analyze and refine PM10-related mortality and morbidity changes. These discussions are the first step in the ARB's scheduled review of the State's ambient air quality standard for PM10 and will help identify future research projects enabling the ARB to place the standard on a firmer scientific base.

USE OF SPUTUM INDUCTION TO OBTAIN AIRWAY LINING FLUID AFTER OZONE EXPOSURE: A PILOT STUDY TO VALIDATE SPUTUM INDUCTION AS AN ALTERNATIVE TO BRONCHOSCOPY. 92-340: University of California, San Francisco.

Objectives: To validate a simple, safe method (sputum induction) of collecting samples of airway lining fluid and cells from human lungs after exposure to ozone. The new method would replace the present complicated and invasive procedure, bronchoscopy.

Findings: Physiological responses to ozone were evident in the lung function measurements. Biochemical indicators of cellular change were found, indicating cellular damage. Overall, this pilot-level study supports the use of sputum induction as an alternative to invasive lavage/biopsy methods.

Importance to ARB's Program: Sputum induction can now be applied to a small cohort of children participating in the ARB's epidemiological study (contract no. A033-186, 1996) and other clinical studies to determine the effects of repeated and long-term exposures to pollutants and to understand the sequential course of changes taking place in human lungs.

EVALUATION OF COPD PATIENTS FOR OZONE SENSITIVITY: VALIDATION OF HEALTH ADVISORIES. A133-123: University of California, Los Angeles.

Objectives: To determine whether people with chronic obstructive pulmonary disease (COPD) are more sensitive than healthy humans to low levels of ozone exposure such as those commonly observed during smoggy days in the Los Angeles area.

Findings: After low-level ozone exposure, small but statistically significant changes in FEV1 (forced expiratory volume in one second) were found in both healthy and COPD subjects. Although these changes were small, the effects on the lung function of emphysemics, who are already at a decreased lung performance level, are considered adverse, since these changes cannot be accommodated without a health risk.

Importance to ARB's Program: The results will be useful in evaluating and, if necessary, modifying the health advisories issued by local air pollution control districts when pollutant levels reach various alert stages.

1994

MONITORING FOR ACIDIC POLLUTANTS IN SUPPORT OF EPIDEMIOLOGICAL STUDIES IN THE SOUTH COAST AIR BASIN OF CALIFORNIA. 92-336: Desert Research Institute.

Objectives: In support of an epidemiological study being conducted by California's Office of Environmental Health Hazard Assessment (OEHHA) and the Centers for Disease Control and Prevention (CDCP), ARB funded this study to measure concentration of several air pollutants and to identify periods of high concentration of acidic species. The OEHHA/CDCP project is examining the short-term effects of air pollution on asthmatic African-American children in the Los Angeles area.

Findings: Desert Research Institute measured PM2.5 mass collected over a 12-hour daytime period and determined the concentrations of its constituents: sulfate, nitrate, ammonium, and aerosol strong acidity. Sulfate and total nitrate concentrations were within the range expected for the site. Total nitrate consisted of approximately equal quantities of particulate nitrate and nitric acid. Strong aerosol acidity was present in most samples, but in amounts that were small compared to those of nitric acid.

Importance to ARB's Program: The results of this research project will be used in evaluating the need to develop acid deposition and atmospheric acidity standards for California.

THE EFFECTS OF OZONE INHALATION ON FIBROBLAST ACTIVATION IN THE LUNG: POSSIBLE RELATIONSHIP TO LONG-TERM FIBROTIC LUNG CHANGES. A133-122: University of California, San Francisco. Research Note 1995-10.

Objectives: To determine whether ozone exposure stimulates human fibroblasts. (Fibroblasts are lung cells responsible for fibrotic changes, which can be harmful. While chronic exposure to ozone is known to cause some fibrotic changes in animal lung, there are no documented studies that similar changes can occur in humans.)

Findings: Ozone exposures were associated with increased levels of a substance, cytokine, that is implicated in the pathogenesis of lung fibrosis. Other measures of cellular changes related to fibrosis were not found to increase following ozone exposure.

Importance to ARB's Program: The results of this study provide a tool to be used in further studies of chronic effects to humans of ozone exposure.

STUDY OF NEUROLOGICAL EFFECTS OF LOW-LEVEL METHANOL EXPOSURE IN NORMAL AND FOLATE-DEFICIENT SUBJECTS. A033-172: University of California, San Francisco. Research Note 1995-11.

Objectives: To determine the neurological effects of exposure to methanol vapor using normal and folate-deficient human volunteers. Because methanol is used as an alternative fuel for motor vehicles, research is needed to determine whether exposure to the vapors is harmful at the threshold limit value (TLV). TLVs are the maximum allowable concentrations at a work site. Folate-deficient subjects need to be tested as a sensitive subgroup because folate tends to inhibit the formation of formate, a toxic metabolite of methanol.

Findings: In normal individuals, exposure to TLV levels of methanol causes a transient increase in blood methanol levels but no change in formate levels or in neurological test results. Evaluation of the folate-deficient subjects is currently in progress.

Importance to ARB's Program: The findings from this project will be used to estimate the health risk posed by methanol vapors during motor vehicle refueling activities.

1993

INCIDENCE OF RESPIRATORY SYMPTOMS AND CHRONIC DISEASES IN A NON-SMOKING POPULATION AS A FUNCTION OF LONG-TERM CUMULATIVE EXPOSURES TO NO2, PM2.5, AND PM10. A933-160: Loma Linda University. Research Note 1995-1 .

Objectives: To re-examine 6,000 non-smokers studied in 1977 and 1987 to determine whether diseases previously documented are now worse or more apparent, and whether other observed effects are related to air pollution exposures. To examine the impacts of nitrogen dioxide and particulate material of two sizes (2.5 and 10 μm aerodynamic diameter).

Findings: The results show stronger association between disease symptoms and level of air pollution than did those of the previous studies. PM2.5 levels correlated with increased severity of symptoms of airway obstructive disease (AOD), chronic bronchitis, and asthma. PM10 levels correlated with an increase in the number of cases of AOD and chronic bronchitis, and also with the severity of symptoms of AOD and asthma. Total particulate levels were correlated with slightly increased cancer rates in females.

Importance to ARB's Program: This study provided insight into the chronic exposure effects of air pollution. The information will be useful in both design of future dose-response related work and review of the air quality standards. This study will be useful in drawing some basic conclusions regarding the impact of air pollution on people in the Los Angeles metropolitan area.

TOXICITIES OF CHEMICAL CONSTITUENTS OF PM10 IN THE SOUTH COAST AIR BASIN IN CALIFORNIA. A933-158: University of California, Irvine.

Objectives: To determine relative toxicities of various chemical constituents of fine particulate matter (PM10) found in the South Coast Air Basin.

Findings: Changes in responses (airway permeability, immune functions, and mucus secretion) that are associated with disease processes were observed in rats exposed to sulfates, nitrates, and road dust. These substances are major constituents of PM10.

Importance to ARB's Program: This was the first study conducted in the United States to evaluate the relative toxicities of PM10 components. It provided insight into types of studies required in the future to address the issue in more detail.

CHRONIC TOXICITY OF MIXED AIR POLLUTANTS: OXIDANTS, ACIDS, AND FINE PARTICLES. A833-104: University of California, Irvine.

Objectives: To determine the adverse effects resulting from long term (9 months) episodic exposures to low levels of ozone both alone and in combination with other pollutants, simulating ambient conditions in Los Angeles.

Findings: The effects included lung structural changes and a breakdown in lung defense mechanisms. The magnitude of adverse effects was greater in the ozone group than in the clean air group, but was statistically significant only in the group exposed to ozone with other pollutants. Although the acute effects of air pollution appear to be mainly caused by oxidants, the chronic effects may be influenced to a large extent by the presence of particulate material and ambient acids.

Importance to ARB's Program: These findings will be useful in evaluating the chronic effects of air pollution and in estimating the risk from air pollution for various districts.

1992

TIME SERIES ANALYSIS OF MORTALITY AND ASSOCIATED WEATHER AND POLLUTION EFFECTS IN LOS ANGELES COUNTY and STRUCTURAL MODELING OF EPIDEMIOLOGICAL TIME SERIES. A5-152-33 and A833-136: University of California, Davis. Research Note 1996-4 .

Objectives: To determine whether there is a significant relationship between daily air pollution and daily mortality in Los Angeles County after adjusting for the effects of temperature.

Findings: Daily mortality significantly increased with increasing pollution at all temperatures. Mortality of persons 65 and older increased with pollution five to ten times faster than mortality of persons aged 45-64, suggesting that persons in relatively poor health are more likely to die prematurely from pollution.

Importance to ARB's Program: Relationships between daily pollution and mortality have played an important role in the setting of air quality standards for particulate pollutants. These studies showed that

relationships between daily pollution and mortality in Los Angeles are similar to those in other cities that have very different patterns of pollution and weather.

SINGLE-CELL PROBES OF ACID AND OXIDANT EXPOSURES. A933-194: University of California, Irvine.

Objectives: To evaluate and explore the feasibility of using a new technique (single-cell cytometry) to provide insight into the relative risks of chemical species contributing to atmospheric acidity.

Findings: The results indicate that this method is sensitive enough to detect changes both inside and on the surface of individual cells after pollutant exposures.

Importance to ARB's Program: This was one of a series of preliminary studies conducted to evaluate effects of ambient acidity for the Atmospheric Acidity Protection Program. Efforts are underway to include this method in analysis of samples obtained from current animal and clinical studies.

PILOT STUDIES TO DEVELOP SENSITIVE MARKERS FOR DETECTING THE HEALTH EFFECTS OF ACIDIC ATMOSPHERES. A933-077: University of Cincinnati.

Objectives: To determine the utility of molecular methods in developing sensitive indicators (biomarkers) to evaluate the adverse health effects of acidic atmospheres. Other, more routine methods are not sensitive enough to detect these effects.

Findings: The results indicate that biomarkers developed and tested in one species may not be sensitive enough to detect lung injury in other animal species. It was also determined that molecular probes to detect lung injuries were more effective on lung tissue slices than on homogenized lung extracts.

Importance to ARB's Program: This was one of a series of preliminary studies conducted to evaluate effects of ambient acidity for the Atmospheric Acidity Protection Program. Limitations of the methods employed and recommendations for selection of biomarkers were used in designing further studies for this program.

DERMAL ABSORPTION OF METHANOL AND METHANOL/GASOLINE MIXTURES. A933-186: University of California, Davis. Research Note 1994-13 .

Objectives: To determine whether the skin absorption of methanol is increased in methanol/gasoline mixtures. Because methanol is used as an alternative fuel for motor vehicles, research is needed to determine whether skin absorption of methanol from accidental spills is enhanced by the presence of gasoline in methanol/gasoline mixtures.

Findings: Methanol/gasoline mixtures with greater than 50 percent gasoline increased the relative degree to which methanol was absorbed by rat skin. The total amount of methanol absorbed from the mixtures, however, was less than that from pure methanol fuel because of the lower content of methanol in the mixtures.

Importance to ARB's Program: These findings helped ARB conclude that accidental spills of methanol/gasoline mixtures that occur in gas stations are not likely to pose a risk to humans.

ARE MUCIN AND MUCIN RNA RELIABLE MARKERS FOR HYPERSECRETION IN HUMANS WITH IRRITANT-INDUCED BRONCHITIS? A933-095: University of California, Irvine.

Objectives: To develop and evaluate two new test methods for early detection of increased mucus production in the respiratory tract of humans. One measures an increase in the levels of mucin in airway lining fluid; the other identifies a signal inside the cells that indicates increased mucus production. Increased mucus production is one of the first signs of chronic bronchitis.

Findings: The study was successful in developing and validating the new test methods and in assuring a high degree of sensitivity in detecting changes in mucus production.

Importance to ARB's Program: The tests have been included for further evaluation in other pollutant exposure studies.

THE EFFECTS OF NITRIC ACID VAPOR ALONE, AND IN COMBINATION WITH OZONE, IN EXERCISING HEALTHY SUBJECTS AS ASSESSED BY BRONCHOALVEOLAR AND PROXIMAL AIRWAY LAVAGE. A933-146: University of California, San Francisco. Research Note 1996-6 .

Objectives: To determine whether simultaneous exposure to nitric acid vapor enhances the acute effects of ozone in healthy humans. To develop a method for identifying sites of injury in the lungs after pollutant exposures.

Findings: The results of this study, along with those of other recently complete clinical and animal studies, indicate that ambient acidity by itself does not pose an acute health risk to healthy individuals. The magnitude of the ozone response was slightly affected by the presence of nitric acid. The combination effect is being evaluated further. The method developed is useful in identifying the location of lung injury due to pollutant exposure.

Importance to ARB's Program: As required by the Atmospheric Acidity Protection Act, the information from this study will be used to evaluate the risk to humans posed by acidity.

COMPARISON OF YOUNG ADULT MALE AND FEMALE RESPONSES TO OZONE INHALATION CONSEQUENT TO CONTINUOUS EXERCISE AT THE SAME ABSOLUTE AND RELEVANT MINUTE VENTILATION and EFFECTS OF ACUTE OZONE INHALATION IN YOUNG ADULT FEMALES. A933-096 and A033-176: University of California, Davis. Research Note 1994-12 .

Objectives: To determine differences between lung function responses to ozone in healthy women and men during exercise. To confirm the previous observation that menstrual cycles are disrupted and that women in the early phase of the cycle (when progesterone levels are lower) respond more strongly than men to ozone.

Findings: Brief single exposures to Stage II alert levels of ozone (.30 ppm) disrupted some specific hormone responses in over half the women studied. The changes included surges in estrogen levels in the latter half of the menstrual cycle and delay in ovulation.

Importance to ARB's Program: Further research including blood hormone levels is needed to understand the implications of these observations before modifying the health advisories issued during various alert levels for air pollution on smoggy days in the Los Angeles area.

1991

EFFECTS OF ACIDITY AND OZONE ON AIRWAY EPITHELIUM. A933-075: University of California, San Francisco.

Objectives: To evaluate the effects of nitric acid and ozone exposures on cells lining the airways of guinea pigs.

Findings: Biochemical changes indicative of cellular stress were observed when the liquid medium in which the cells were kept was even slightly acidified. However, when cell surfaces were exposed to nitric acid vapor, even at high levels no changes were observed. In contrast, ozone exposures even at very low concentrations resulted in cell death.

Importance to ARB's Program: This was one of a series of preliminary studies conducted to evaluate effects of ambient acidity for the Atmospheric Acidity Protection Program. The results were communicated to other investigators evaluating the effects of ambient acids. Studies in progress are making efforts to relate these findings to responses in other animals and humans.

CLINICAL PILOT STUDY TO DEVELOP SENSITIVE MARKERS FOR DETECTING THE HEALTH EFFECTS OF ACIDIC ATMOSPHERES. A933-112: Alliance Technology Corporation.

Objectives: To evaluate biomarkers of inflammation and of reduced defense in the lungs of human subjects after nitric acid exposures. These markers were chosen because repeated or chronic inflammation may eventually lead to a chronic disease. Disruption in macrophage function (the biomarker for reduced lung defense) may increase susceptibility of an individual to respiratory infection.

Findings: The results indicate that macrophage function was compromised after nitric acid exposures.

Importance to ARB's Program: This was one of a series of preliminary studies conducted to evaluate effects of ambient acidity for the Atmospheric Acidity Protection Program. The methods developed and evaluated in this study were included in other ongoing clinical and animal studies involving nitric acid exposures.

EFFECTS OF ACIDIC MIXTURES ON PULMONARY MACROPHAGE FUNCTIONS: A PILOT STUDY. A933-078: University of California, Irvine.

Objectives: To develop biomarkers for identifying early lung injury resulting from acid exposures.

Findings: Alteration in defense function parameters and biochemical changes that can lead to structural changes were observed in the lungs of experimental animals after nitric acid vapor exposures. These changes (called biomarkers) are known to play a role in lung infection, exacerbation of asthma attack, and changes in the lung architecture.

Importance to ARB's Program: This was one of a series of preliminary studies conducted to evaluate effects of ambient acidity for the Atmospheric Acidity Protection Program. These biomarkers were selected for further evaluation and validation in sub-chronic and chronic exposure studies.

EFFECTS OF OZONE ON NEUROPEPTIDE-MEDIATED RESPONSES IN HUMAN SUBJECTS. A833-186: University of California, San Francisco.

Objectives: To determine whether ozone -- the main component of smog in urban areas -- is responsible for coughing experienced by individuals living in those areas. This was the first effort made to evaluate whether this nerve-mediated response is affected by ozone.

Findings: A single two-hour exposure to 0.40 ppm of ozone (higher than ambient levels) caused significant decrease in the cough threshold, supporting the hypothesis that ozone exposure increases the sensitivity of nerves in the airway to a stimulus known to produce a cough response.

Importance to ARB's Program: Further research is needed to determine the concentration of ozone that can alter the nerve-mediated responses. However, it is clear from this and other recent results that air pollution may affect tissues other than the lung.

EFFECTS OF EXPOSURE TO LOW-LEVEL CARBON MONOXIDE AT SEA LEVEL AND HIGH ALTITUDE IN SENSITIVE SUBJECTS. A833-159, A6-203-33, and A3-138-33: University of California, Irvine.

Objectives: To determine whether the current high-altitude standard for carbon monoxide is justified in view of the fact that the parameters used in the model calculations for deriving the standard were flawed. To validate with state-of-the-science techniques some of the variables used in calculating the sea level CO standard. Three studies were funded to address specific issues involved in order to draw definitive conclusions.

Findings: In patients suffering from ischemic heart disease, carbon monoxide exposure reduced the time before onset of angina to a greater degree at a simulated altitude of 7,000 feet than at sea level.

Importance to ARB's Program: The results indicated the need for a separate high altitude carbon monoxide standard for the State and reconfirmed the existing sea level standard during the recent review of the standard by ARB.

1990

PLANNING COLLOQUIUM ON EPIDEMIOLOGY AND AIR POLLUTION. A833-114: University of California, Irvine.

Objectives: To gather together leading scientists in air pollution epidemiology and related disciplines to discuss the problems encountered in past air pollution epidemiologic research, and outline possible approaches for future research.

Findings: These critical determinations made were: 1) epidemiologic projects should focus on a subpopulation (such as children) with high likelihood of showing a quantifiable health effect; 2) the population should be followed over time; 3) a thorough assessment of exposure is critical for deciphering health effects of air pollutants, alone or in combination; 4) effects of ozone should be studied; 5) plans for statistical analyses should be developed at the time of study design; 6) a rigorous quality assurance program should be implemented in all studies, and 7) a stable long term funding base is necessary for any large-scale long term epidemiology study to succeed.

Importance to ARB's Program: The findings were used by ARB staff to develop a comprehensive research plan for the Long-Term Exposure Health Effects Research Program (contract no. A033-186, 1996), and to

lay the framework for a full-scale epidemiologic investigation that could answer specific questions and could accommodate adjunct research designed to address additional questions.

INCIDENCE OF RESPIRATORY SYMPTOMS AND CHRONIC DISEASES IN A NON-SMOKING POPULATION AS A FUNCTION OF LONG-TERM CUMULATIVE EXPOSURE TO AMBIENT AIR POLLUTANTS. A833-057: Loma Linda University.

Objectives: To examine the current incidence and severity of chronic bronchitis, airway obstructive disease, asthma, and all types of cancers in a population of non-smokers living in the Los Angeles area who were studied in 1977. This is one of a series of studies designed to obtain information on the relationships between health effects and long term exposure to ambient concentrations of various air pollutants.

Findings: Subjects exposed to high levels of particulate material exhibited higher incidence of chronic bronchitis, airway obstructive disease, and asthma, and the symptoms of these diseases were more severe. Women, but not men, had more incidence of cancers. Subjects exposed to higher levels of ozone had more severe symptoms of asthma.

Importance to ARB's Program: This large and well planned and executed epidemiological study has helped in identifying the relationships between chronic pollutant exposures and disease incidences. The information will be used in future review of the air quality standards.

EFFECTS OF PROLONGED, SEQUENTIAL EXPOSURE TO ACID FOG AND OZONE ON PULMONARY FUNCTION IN EXERCISING NORMAL SUBJECTS. A833-078: University of California, San Francisco. Research Note 1991-1.

Objectives: To determine whether pre-exposure to an acidic fog increases the effects of acute ozone exposure in healthy human subjects.

Findings: Pre-exposure to acidic fog did not have an additive or synergistic effect on ozone exposure responses. However, the results indicated the possible existence of a susceptible or sensitive population subgroup, who appear healthy and/or are asymptomatic, who are adversely affected by ozone exposure.

Importance to ARB's Program: The results were used in the final assessment of the Kapiloff program projects. (The Kapiloff program was the first formal investigation of atmospheric acidity in the world. The ARB's Atmospheric Acidity Protection Program was a more detailed investigation that was implemented as a result of Kapiloff findings.) If the increased sensitivity in the silent or asymptomatic group is confirmed in a randomly selected group from the general population, it will be necessary to modify the health advisories issued to protect the sub-group.

A PILOT SURVEY OF HUMAN LUNG TISSUE FOR AIR POLLUTION EFFECTS IN LOS ANGELES COUNTY. A6-202-33: University of Southern California.

Objectives: To test the feasibility of collecting pathological specimens for analysis of lung tissue for air pollution effects from victims of traffic accidents and homicides and correlating this information with demographic, health, and lifestyle data. This study was a part of ARB efforts to determine chronic and lifetime effects of exposure to ambient air pollution.

Findings: The method was demonstrated to be feasible if it includes individuals younger than 15 years. Presence of lung lesions at a young age was higher than expected. ARB staff recommend further studies to determine whether these findings are linked to air pollution.

Importance to ARB's Program: Most existing air quality standards are aimed at protecting the public against acute effects. Information on chronic effects is critical for future review of the standards.

1989

ACID AIR POLLUTANT MIXTURES: RESPIRATORY SYSTEM RESPONSES AND EFFECTS OF EXERCISE. A6-148-33: University of California, Irvine.

Objectives: To determine whether inhalation of airborne organic acids influences the adverse effects of ozone and whether exercise enhances the magnitude of the responses observed.

Findings: Acute exposure to an organic acid (hydroxymethane sulfonic acid) did not have significant effect on any of the measured parameters either alone or in combination with ozone. Exercise did increase the magnitude of ozone effects.

Importance to ARB's Program: This was one of a series of preliminary studies conducted to evaluate effects of ambient acidity for the Atmospheric Acidity Protection Program. The results of this study were used in the design of a clinical study to evaluate the acute effects of hydroxymethane sulfonic acid.

DETERMINATION OF BODY BURDENS FOR POLYCHLORINATED DIBENZO-*p*-DIOXINS (PCDDs) AND POLYCHLORINATED DIBENZOFURANS IN CALIFORNIA RESIDENTS. A6-195-33: Midwest Research Institute, Inc.

Objectives: To determine the extent to which the bodies of California residents contain polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). Human fatty tissue specimens were collected at hospitals in the San Francisco and Los Angeles areas and analyzed for PCDDs and PCDFs.

Findings: Detectable levels were measured in most of the fatty tissue samples. The patterns of distribution of specific PCDD and PCDF compounds were consistent with those observed in studies done at other locations. Concentrations did not correlate well with geographical location, age, or sex.

Importance to ARB's Program: Results of the study were used to help determine the need for regulation of airborne emissions of these substances.

Air Quality Standards:

Ecological Effects of Air Pollution

Ecological Effects of Air Pollution

Project in Progress

HISTORICAL-SCALE BIOCHEMICAL MARKERS OF OXIDANT INJURY AND EXPOSURE IN PINES. 97-309: University of California, Davis.

Objectives: To identify differences in wood biochemistry between ozone-damaged and undamaged trees growing at the same site and differences between trees growing at polluted and clean forest sites along known gradients of ambient ozone exposure in southern California and the Sierra Nevada.

Importance to ARB's Program: This project is needed to fulfill requirements in California's Health and Safety Code to collect research data on the effects of air pollution on plants. The findings will be used to evaluate the effects of ozone on forest resources in the state as part of the Board's research program to combat the effects of air pollution. The results will be useful to policy-makers charged with assessing the effects of air pollution on the public welfare.

Completed Projects

1998

AIR POLLUTION AND CHANGES IN FOREST NITROGEN STATUS: FOG AND RAIN DEPOSITION AND NITROGEN LOSSES FROM FORESTED WATERSHEDS IN THE SAN BERNARDINO MOUNTAINS. 95-329: USDA Forest Service. Research Note 1998-5.

Objectives: To gather data to be used to evaluate the combined effects of nitrogenous pollutants and ozone on the health of conifer forests in southern California. Nitrogen inputs from fog had not previously been quantified, and only limited data had been collected on nitrogen losses via stream water runoff and biogenic emissions from soil. At two pine forest sites in the San Bernardino Mountains (SBM), the investigators measured nitrogen deposition from fog and rain, measured biogenic nitrogen emissions from forest soil, and monitored nitrogen levels in streams.

Findings: Fog was found to be an important source of nitrogen at the western end of the SBM because it occurs frequently and is present in high concentrations. Nitrogen deposition from throughfall (precipitation that comes into contact with tree foliage before dripping to the ground) was found to be similar to levels at other sites in the U.S. where nitrogen saturation is reported to occur. At the highly polluted western end of the SBM, nitrate levels in stream water draining from Devil Canyon were the highest values reported to date for undisturbed watersheds.

Importance to ARB's Program: The information from this study will be used to develop a more accurate understanding of nitrogen cycling in forests in the San Bernardino Mountains. Symptoms of soil nitrogen saturation were found at Camp Paivika, and the long-term deterioration of forest health in the SBM will continue unless action is taken to reduce the deposition of atmospheric nitrogen.

1997

STATEWIDE POTENTIAL YIELD LOSSES FROM OZONE EXPOSURE. 94-345: University of California, Davis.

Objectives: To conduct the 1993 annual crop loss assessment for the Crop Loss Air Pollutant Assessment Program initiated by the ARB in 1985. To refine the geographic information system (GIS)-based methodology used to estimate potential ozone-caused yield losses in the major agricultural production areas in California.

Findings: In 1993, ozone-caused yield losses of 20-30% were estimated for cataloupes, grapes, and cotton, which are known to be ozone-sensitive crops. Moderate losses (10-15%) were projected for dry beans, oranges, alfalfa, onions, and lemons. Minor losses (1-7%) were expected for ozone-tolerant crops such as tomato, wheat, rice, corn, and lettuce. GIS-based techniques were used to refine county-averaged estimates of yield loss in selected agricultural production areas. By plotting effects to acreages of irrigated farmlands only, differences in crop loss within a county could be accurately displayed. For example, cotton yield losses were 5-10% greater in the eastern portions of Fresno, Kings, and Tulare counties than in the western portions.

Importance to ARB's Program: This information is used to identify crops or trees that are being adversely affected by air pollution and provides the technical basis for setting air quality standards to protect vegetation from damage by air pollution. The Crop Loss Air Pollutant Assessment Program has provided information to guide efforts to design crop-effects studies, to perform economic analyses of yield loss, and to prepare reports for other local, State, and Federal agencies on the effects of air pollution on the public welfare.

1995

CROP LOSSES FROM AIR POLLUTANTS: A GIS REGIONAL ANALYSIS and STATEWIDE CROP LOSSES FROM AIR POLLUTANTS. A133-185 and 92-350: University of California, Riverside. Research Note 1997-1.

Objectives: To conduct the 1991 and 1992 annual crop loss assessments for the Crop Loss Air Pollutant Assessment Program initiated by the ARB in 1985. To perform computer-based evaluations of crop losses in California and to determine how these results reflect actual field conditions.

Findings: Estimated statewide crop-by-county yield losses were similar in 1991 and 1992. For most crops, loss estimates differed by less than 20 percent between years. Using GIS technology to plot the location of irrigated farmlands in the Sacramento Valley, San Joaquin Valley, Salinas Valley, and Imperial/Riverside County growing areas, color maps depicting the variation in ozone-caused yield loss for grape, cotton, and tomato were generated for 1991 and 1992. For example, potential cotton yield losses ranged from less than 10 percent to almost 30 percent within the San Joaquin Valley.

Importance to ARB's Program: This information is used to identify the crops or trees that are being adversely affected by air pollution and provides the scientific basis for setting air quality standards to protect crops from damage by air pollution. The Crop Loss Air Pollutant Assessment Program has provided information to guide efforts to design crop-effects studies, to perform economic analyses of yield loss, and to prepare reports for other local, State, and Federal agencies.

EFFECT OF CANOPY STRUCTURE AND OPEN-TOP CHAMBER TECHNIQUES ON MICROMETEOROLOGICAL PARAMETERS AND THE GRADIENTS AND TRANSPORT OF WATER VAPOR, CARBON DIOXIDE, AND OZONE IN THE CANOPIES OF PLUM TREES (*Prunus salicina*) IN THE SAN JOAQUIN VALLEY. A133-053: University of California, Riverside.

Objectives: To develop estimates of ozone uptake in plum trees based on plant physiology and measured changes in microenvironmental parameters (e.g., wind speed, air temperature, and gas concentrations). To determine whether ozone uptake in chamber-grown plants differs from plants grown outside chambers.

Findings: The most reliable estimates of ozone exposure were obtained by using measures of stomatal conductance and ozone concentration at the leaf surface, rather than the ozone concentration at a reference point exterior to the plum tree canopy. As a result of the design of open-top chambers, some of the ozone in the air blown into the chambers absorbs onto the chamber walls, resulting in lower ozone concentrations at the leaf surface. Because ozone levels at the leaf surface are lower in chamber-grown trees, ozone doses in plants grown outside of chambers were projected to be higher than in chamber-grown trees.

Importance to ARB's Program: The results of this project provide detailed information about microenvironmental gradients that influence rates of ozone uptake by plum trees and possibly other types of plants. A better understanding of the amounts of ozone taken up by chamber-grown plants vs. plants grown outside chambers will enable decisionmakers to evaluate results from past studies on an equivalent ozone uptake basis.

1994

THE EFFECTS OF OZONE ON PHOTOSYNTHESIS, VEGETATIVE GROWTH, AND PRODUCTIVITY OF PLUM TREES (*Prunus salicina*, cv. "Casselman") IN THE SAN JOAQUIN VALLEY OF CALIFORNIA, YEAR 4. A133-137: University of California, Davis.

Objectives: To conduct the final year of a multi-year study of the long-term effects of ambient and experimental levels of ozone on the growth and yield of plum trees in their initial commercial fruit-bearing years. To estimate the effect of ozone on plum tree productivity by adapting a carbon-assimilation-based model used to predict peach tree yields.

Findings: Ambient and twice-ambient levels of ozone reduced Casselman plum yields by an average of 19 percent and 48 percent, respectively, over a three-year period. The results indicate that ozone levels in both the preceding and current growing years influence plum yield. It was suggested that ozone levels in the preceding year affect the number of flowers formed, while levels in the current year affect fruit drop. By simulating an ozone-caused decrease in plum tree photosynthesis, the yield model for peach trees accurately predicted plum yields measured in the study.

Importance to ARB's Program: The development of a model that simulates the effects of ozone on photosynthesis, growth, and yield in Casselman plum trees can be used to improve the estimates developed in the ARB's Crop Loss Air Pollutant Assessment Program for stone-fruit trees. Currently, no California stone fruit yield losses are ascribed to ozone.

A DEMONSTRATION OF THE EFFECTS OF SMOG ON ORNAMENTAL AND HOME GARDEN PLANTS. A933-188: The Arboretum Foundation, Inc., of the Los Angeles City and County Arboretum.

Objectives: To determine the range of visible symptoms of injury to over 200 species of plants never previously studied -- but which are commonly grown in home gardens and yards -- using a pair of filtered

and unfiltered greenhouses. To increase awareness on the part of the public, growers, landscape architects, botanists, and others of the impacts of air pollution on these ornamentals by the use of a greenhouse display of living plants and an outreach program.

Findings: Over 150,000 visitors received guided tours of familiar plants displaying the full range of air pollution symptoms. In response to requests, a speaker presented a slide show of photographs taken in the Air Pollution Greenhouse to local and State government employees, local civic groups, and schools. In 1993 high school and college students conducted short research projects in the greenhouse. The Air Pollution Greenhouse display was featured in television, radio, and press interviews, and received coverage in widely read magazines, technical trade papers, and journals.

Importance to ARB's Program: This project increased the understanding of visitors from the South Coast Air Basin, other locations in California, other states, and other countries of the impact of air pollution on vegetation and identified ways people can contribute to reduction of air pollution.

1993

CROP AND FOREST LOSSES FROM AIR POLLUTANTS; COMPUTER AND FIELD-BASED ASSESSMENT PROGRAM. A033-174 and A933-190: University of California, Riverside. Research Note 1997-1.

Objectives: To conduct the 1991 annual crop loss assessment for the Crop Loss Air Pollutant Assessment Program initiated by the ARB in 1985, including losses for forests.

Findings: A GIS database was created for Kern County cotton production and air-quality-related statistics on a one-square-mile basis, as opposed to the countywide estimates of previous years. The annual statewide crop loss projections for 1989 and 1990 were also completed.

Importance to ARB's Program: The improvements to the Crop Loss Air Pollution and Assessment Program that were initiated in 1991 can be used to provide greatly improved estimates of losses to commercial crops and forests caused by air pollution, and their economic impact. This improved information will assist in the evaluation of the ARB's air quality standards and regulatory programs and their impact on the state's largest industry. The program complements the ARB's cooperative research efforts with the U.S. Forest Service.

THE EFFECTS OF OZONE ON PHOTOSYNTHESIS, VEGETATIVE GROWTH, AND PRODUCTIVITY OF *Prunus salicina* IN THE SAN JOAQUIN VALLEY OF CALIFORNIA, YEAR 3. A033-128: University of California, Davis.

Objectives: To conduct the third year of a multi-year study of the long-term effects of ambient and experimental levels of ozone on the growth, yield, and fruit quality of plum trees between the orchard establishment stage and the full production stage.

Findings: Ambient and twice ambient levels of ozone caused adverse impacts in a range of biochemical, physiological, and performance parameters. Compared to trees grown in filtered air, the yield of plum trees exposed to mean daily ozone concentrations greater than 0.09 ppm (the State standard) in the first commercial bearing year was 65 percent. This reduction in yield was greater than the yield reduction of 35 percent in the first bearing year, indicating that ozone injury may indeed accumulate from season to season. The yield loss is related to the numbers of fruit set; fruit setting occurs before the high ozone season begins.

Importance to ARB's Program: ARB's statewide Crop Loss Air Pollutant Assessment Program assumes that there are no yield losses in the more than $1 billion per year stone fruit industry in areas of poor air quality because there are no experimental data that relate the response of the vegetation to specific levels of air pollutants. The data collected can be used to evaluate ozone effects on stone crops.

1991

THE EFFECTS OF OZONE ON PHOTOSYNTHESIS, VEGETATIVE GROWTH, AND PRODUCTIVITY OF *Prunus salicina* IN THE SAN JOAQUIN VALLEY OF CALIFORNIA, YEAR 2. A933-145: University of California, Davis.

Objectives: To conduct year two of a multi-year study of the long-term effects of ambient and twice-ambient levels of ozone on the growth and yield of a plum orchard between the orchard establishment stage and the full production stage.

Findings: Fruit bearing began in the second year. Compared to trees grown in filtered air, the numbers and size of the fruit yield were 28 percent lower in the ambient and 38 percent lower in the twice ambient exposures. Photosynthesis was reduced 11 percent and 40 percent respectively. Adverse impacts on physiological responses and growth increased when ozone levels exceeded 0.09 ppm (the State standard). Measurements of biochemical, physiological, and growth parameters were collected to develop a stone fruit tree photosynthesis, growth, and air quality model.

Importance to ARB's Program: The data collected in this study can be used to test tree growth models to improve information on the relationship between specific levels of air quality and the wide range of responses of the trees to pollution.

CROP LOSS FROM AIR POLLUTANTS AND INJURY TO FOREST TREES ASSESSMENT PROGRAM (STATUS REPORT: CROP LOSS FROM AIR POLLUTANT ASSESSMENT PROGRAM, PHASE III). A833-138: University of California, Riverside.

Objectives: To conduct the 1990 annual crop loss assessment for the Crop Loss Air Pollutant Assessment Program initiated by ARB in 1985.

Findings: The researchers concluded that as yet no satisfactory models exist for assessing losses in forest productivity due to ozone injury. Visible adverse ozone effects on crops in the San Joaquin valley -- leaf injury and defoliation -- were most pronounced in the southern portions of the valley. Yield loss estimates prepared for 52 different crops on a county basis gave results similar to those of the survey of the previous year: Compared to expected yields in clean air, losses ranged from 0 to 63 percent, except for onions, potatoes, and wheat, whose losses doubled. To assist county agricultural experts, photographs were taken for "fact sheets", a portable display was made on the effects of air pollutants on plants, and a workshop was held to discuss current research efforts and future requirements needed to enhance the vegetation loss program.

Importance to ARB's Program: Each year this program provides a more accurate estimate of the relationship between specific levels of air quality and the expected and actual losses suffered by specific crops on a countywide basis, and on forest resources. This information is used to assist in the evaluation of the ARB's ambient air quality standards and regulatory programs and their impact on the State's largest industry.

THE EFFECTS OF OZONE ON PHOTOSYNTHESIS, VEGETATIVE GROWTH, AND PRODUCTIVITY OF *Prunus salicina* IN THE SAN JOAQUIN VALLEY OF CALIFORNIA, YEAR 1. A833-113: University of California, Davis.

Objectives: To begin a multi-year study to determine the long-term effects of ambient and experimental levels of ozone on growth, yield, and fruit quality of a plum orchard from the orchard establishment stage to the fruit bearing stage.

Findings: The experimental Casselman plum orchard planted as part of a related project (A733-126, 1990) conducted the previous year continued to show decreased photosynthetic rates, increased leaf drop, and reduced trunk circumference, compared to plums grown in filtered air. A database was set up to collect information on fruit size and number, fruit quality, stored carbohydrates, and weight of branches under different levels of pollution to determine whether air pollution injury can accumulate over the 20-to-30 year productive life of fruit trees.

Importance to ARB's Program: Before this project, the ARB's statewide Crop Loss Air Pollutant Assessment Program contained no information on the effects of ozone pollution on stone fruit trees and nuts. The ARB is now able to provide information of this type to local planning authorities seeking to determine adverse economic impacts of ozone pollution on agricultural operations, the largest industry in California.

1990

FIELD VERIFICATION OF YIELD LOSSES FROM AMBIENT OZONE TO COTTON (*Gossypium hirsutum*) IN THE SAN JOAQUIN VALLEY. A833-105: University of California, Riverside.

Objectives: To confirm that the yield losses to cotton estimated by air quality models do occur under commercial growing conditions in several locations in the San Joaquin Valley's cotton growing region, which has a range of ambient pollution levels.

Findings: This study validates the ability of the models used in the Crop Loss Air Pollutant Assessment Program to predict the impact of ambient ozone on cotton yields. Ten to 19 percent of the billion-plus dollar production was lost during the 1989 growing season due to ambient levels of ozone, and a significant loss occurs at levels below the current State and Federal ambient air quality standards. One of the 14 cultivars tested, a promising newly-introduced cotton variety, suffered severe leaf injury.

Importance to ARB's Program: This project and the related cotton study (Contract no. A733-088, 1989) confirm that the model used in ARB's statewide Air Pollution Assessment Program provides a firm scientific foundation for setting ambient air quality standards.

THE EFFECTS OF OZONE ON PHOTOSYNTHESIS, VEGETATIVE GROWTH, AND DEVELOPMENT OF WOODY PERENNIALS IN THE SAN JOAQUIN VALLEY OF CALIFORNIA. A733-126: University of California, Davis. Research Note 1990-13.

Objectives: To develop the methodology for a multi-year study of the long-term response of stone fruit trees to ambient levels of ozone by screening seedlings of nine of the most valuable species of fruit trees for sensitivity to this pollutant. To establish an experimental orchard that can be grown in large open-top field chambers from the orchard establishment stage through the commercial fruit bearing stage. Casselman plum was selected for the experimental orchard because its commercial hedge-row configuration produces trees small enough to fit in the experimental chambers.

Findings: This study provides the first experimental data on the response of stone-fruit trees to ambient ozone levels in the San Joaquin Valley. The nine species differ in their sensitivity to ambient levels of ozone as measured at the physiological, biochemical, and performance levels. Reduced starch reserves for the next year's growth and greater than expected reductions in tree-trunk growth occurred. These effects could have a serious negative impact on future tree health and yields.

Importance to ARB's Program: The results can be used to correct a serious underestimate in the existing ARB statewide Crop Loss Air Pollutant Assessment Program, which has assumed that no losses occur to the stone- and other fruit harvest due to ozone.

1989

THE ECONOMIC ASSESSMENT OF CALIFORNIA FIELD CROP LOSSES DUE TO AIR POLLUTION. A5-105-32: University of California, Davis. Research Note 1990-5.

Objectives: To perform the first comprehensive effort to synthesize information on pollution damage to California's crops with appropriate economic and air quality data, and to evaluate the impact of air pollution to agriculture.

Findings: California's agricultural revenues in 1987 were greater than $17 billion. In 1989, the industry suffered an estimated crop loss of $265 million from ambient levels of ozone alone. Assuming that the ARB's regulatory programs could reduce ozone to a seasonal level of .025 ppm, the estimated total benefit would be $330 million per year in increased agricultural production and grower profit.

Importance to ARB's Program: Damage estimates from this study were used in the 1987 staff report to the Board entitled "Effects of Ozone on Vegetation and Possible Alternative Ambient Air Quality Standards", as part of the ARB's review of the ambient air quality standard for ozone.

CROP LOSS FROM AIR POLLUTANTS ASSESSMENT PROGRAM (STATUS REPORT, PHASE III). A733-108: University of California, Riverside.

Objectives: To conduct the 1989 annual crop loss assessment and related work efforts for the Crop Loss Air Pollutant Assessment Program initiated by the ARB in 1985.

Findings: As a result of work conducted in 1988 and 1989 (Phase III), recommendations on how to conduct tree fruit and nut crop research were helpful in the design of a multi-year study of plums funded by the ARB (A133-137, A033-128, A933-145, A833-113, and A733-126, all described above). Three of 79 known tree-exposure systems were judged acceptable for future tree research. Forty-eight fields were evaluated in the cotton survey, with a diagnosis of clear ozone injury symptoms only on leaves in Kern county. Statewide losses for 27 crops were determined; 6 crops had losses greater than 15 percent (dry beans, cantaloupe, cotton, honeydew melons, grapes, and watermelons); 7 crops had losses greater than 6 percent (alfalfa hay, alfalfa seed, sweet corn, lemons, oranges, potatoes, and spinach); 8 crops had small losses of 1 to 3 percent (field corn, grain sorghum, onion, rice, corn-silage, fresh tomatoes, processing tomatoes, and wheat); and 6 crops showed no loss (barley, broccoli, celery, lettuce, strawberries, and sugar beets). Future projections were made for the air quality expected in 1995 and 2010, when losses were expected to increase by 8 to 14 percent compared to 1986 levels because of expected increases in NOx emissions.

Importance to ARB's Program: The results of this study provide a more reliable basis for estimating crop losses caused by air pollution, and were useful in shifting the emphasis in ARB plant-effects research toward the effects of air pollution on forests.

FIELD ASSESSMENT OF THE EFFECTS OF AMBIENT OZONE ON COTTON (*Gossypium hirsutum*) IN THE SAN JOAQUIN VALLEY. A733-088: University of California, Riverside. Research Note 1989-7.

Objectives: To determine whether yield losses predicted for cotton by the ARB's statewide Crop Loss Assessment Program actually occurs on cotton grown in the field in the San Joaquin Valley and to determine whether the losses occur at the levels predicted by laboratory fumigation chamber experiments and are not impacted by the response of the plant to environmental conditions inside the chambers.

Findings: Yield reductions due to ambient ozone in cotton grown in open-top field chambers and in the field in the San Joaquin Valley were similar to the loss of lint (fiber) predicted by the crop loss equations, except at Dinuba, where the actual field losses were higher than predicted. This study demonstrates that yield loss estimates based on open-topped field chamber exposures are representative of the responses of commercial cotton, which is California's most valuable cash crop. The SJ-2 cultivar, the most widely grown, showed the greatest injury at all sites.

Importance to ARB's Program: This study and a related cotton study (contract no. A833-105) confirmed that the model used in ARB's statewide Air Pollutant Assessment Program provides a firm scientific foundation for setting ambient air quality standards.

THE GROWTH AND YIELD EFFECTS OF AMBIENT AIR POLLUTION ON VALENCIA ORANGE TREES (*Citrus sinensis*). A733-087: University of California, Riverside. Research Note 1991-3.

Objectives: To determine the physiological and biochemical bases for the effects of ambient ozone on the yield of Valencia oranges in Southern California and the San Joaquin Valley. To determine how susceptible oranges are to chronic SO_2 exposures near oil fields.

Findings: Ambient air pollution reduced the numbers of fruits and lowered individual leaf weights by 30 percent. These reductions are similar to those seen in navel oranges. Twenty different growth, physiological, or biochemical parameters were investigated to identify the mechanism for the yield reduction. The researchers suggest that fewer fruit were set because starches were retained in the leaves rather than allocated to fruit production. Sulfur dioxide reduced fruit weight by 35 percent and fruit numbers by 39 percent, compared to trees grown in filtered air.

Importance to ARB's Program: The ozone concentration/yield loss equation developed by this project for Valencia oranges is used to improve the ARB's statewide Crop Loss Air Pollutant Assessment Program.

RISKS TO CALIFORNIA FORESTS DUE TO REGIONAL OZONE POLLUTION A6-049-32: RCG/Hagler, Bailly, Inc. Research Note 1989-5.

Objectives: To construct a geographically based database of forested resources in California. To evaluate the sensitivity of California forest tree species to ozone. To perform a risk assessment for the most valuable commercial tree species in the forested areas of California.

Findings: Based on air quality during the period 1977 through 1981, 50 percent of the forests in 13 counties are at high risk; over 50 percent of the 70 most valuable commercial trees in 5 of the 19 national forests are at high risk; and 50 percent or more of the land area in 13 California watersheds are in the high risk category.

Importance to ARB's Program: Forested areas, which cover 1/3 of California's land, provide 85 percent of the water supply, jobs for about 80,000 workers, and recreation for millions. The information from this project can be used in setting ambient air quality standards because significant damage to forests can occur at pollutant levels below those that protect human health. The existing regulatory program provides only partial protection to the forested areas in California.

Indoor Air Quality

Indoor Air Quality

Projects in Progress

MEASURING CONCENTRATIONS OF SELECTED AIR POLLUTANTS INSIDE CALIFORNIA VEHICLES. 95-339: Research Triangle Institute.

Objectives: The primary objective of this project is to measure concentrations of particles, toxic gases, metals, carbon monoxide, and other pollutants inside vehicles as they are driven on California roadways under various driving conditions. In addition to in-vehicle measurements, the pollutants will be measured simultaneously just outside the vehicle, along the roadway, and at nearby ambient monitoring stations in order to examine how concentrations in those locations affect in-vehicle exposures.

Importance to ARB's Program: Although Californians spend an average of seven percent of their time travelling inside vehicles, few in-vehicle measurements of particles, volatile organic chemicals, and toxic metals have been made. The results of this project will be used to improve estimates of Californians' current in-vehicle exposures to particles, diesel exhaust, methyl tertiary butyl ether (MTBE), and other pollutants and to determine the relative contribution of in-vehicle exposures to total air exposures to these pollutants. The results will also be used to identify actions that drivers and passengers may take to reduce their in-vehicle exposures to air pollutants.

DEVELOPMENT OF A SHORT-AVERAGING-TIME INDOOR NITROGEN DIOXIDE MONITOR. 96-312: Battelle.

Objectives: The objective of this project is to develop and test a small, quiet, economical nitrogen dioxide monitor capable of measuring concentrations indoors for short averaging times of one hour or less. The monitor must be able to accurately measure nitrogen dioxide across the full range of expected indoor levels, including the very high levels sometimes seen during operation of gas appliances. Testing will include trials in residences and public buildings.

Importance to ARB's Program: This project will provide ARB with a fully characterized, economical, portable nitrogen dioxide sampler suitable for use in indoor air quality studies. The monitor will enable us to measure the full range of levels inside buildings, and thus provide data for improved population exposure estimates. The short averaging time will allow for comparison of measured levels to the one-hour ambient air quality standard for nitrogen dioxide, an indicator of safe versus potentially harmful levels of nitrogen dioxide.

A CONTINUOUS, REAL-TIME MINIATURE OZONE MONITOR. 94-342: University of California, Berkeley.

Objectives: Develop and test a miniature ozone monitor for continuous real-time measurements of ozone in indoor and outdoor microenvironments, with potential for future adaptation as a personal monitor. The primary performance objective for the prototype monitor is the ability to accurately and precisely measure 30 to 300 ppb ozone for periods of 30 minutes or less.

Importance to ARB's Program: This monitor will perform accurate ozone sampling over periods of one hour or less and will record and display the ozone level immediately. This will permit measurements of short-term peak exposures to ozone so that real-life exposures can be compared to health-based standards

and individual actions to mitigate ozone exposure can be assessed in different microenvironments. Data obtained using this monitoring technology will be used to improve exposure and risk assessments, to identify populations with high ozone exposures, and to evaluate the effectiveness of immediate risk reduction measures.

COMMON INDOOR SOURCES OF VOLATILE ORGANIC COMPOUNDS: EMISSION RATES AND TECHNIQUES FOR REDUCING CONSUMER EXPOSURES. 95-302: University of California, Lawrence Berkeley Laboratory.

Objectives: To quantify the emission rates of volatile organic compounds (VOCs), including a number of toxic air contaminants, from three general categories of common indoor building and decorating materials. The investigators will also examine various practical measures that consumers can take to reduce their exposures to VOCs from these materials. Materials to be studied include carpets, carpet pads, adhesives, vinyl flooring, and interior latex paint.

Importance to ARB's Program: Results from this study will provide a scientific basis for future indoor air quality guidelines that advise Californians on how to reduce their exposures to indoor pollutants in new or remodeled homes. emission data will be used in models to improve estimates of indoor exposures to toxic air contaminants, as required by California Health and Safety Code.

ASSESSING EXPOSURE TO AIR TOXICS FROM ENVIRONMENTAL TOBACCO SMOKE. 94-344: The University of California, Berkeley.

Objectives: This study will estimate Californians' recent exposures to 16 selected toxic air contaminants (TACs) emitted from cigarette smoke and, where possible, estimate the proportion of Californians' exposures to TACs that is attributable to environmental tobacco smoke (ETS) and the proportion that is attributable to other sources. The study will also estimate the potential future reduction in exposure to these ETS chemicals that is likely to result from changes in Californians' smoking habits, new laws, and other factors.

Importance to ARB's Program: Results from this project will be used to estimate the risks posed by selected TACs emitted in cigarette smoke, taking into account factors likely to change future levels of exposure to ETS. In addition, the ARB can use the exposure estimates from this project in combination with other data to estimate the residual public health risk of the 16 TACs from non-ETS sources and to prioritize mitigation strategies to reduce public health risks from these chemicals.

RESIDENTIAL MICROENVIRONMENTAL AND PERSONAL SAMPLING FOR EXPOSURE CLASSIFICATION. 92-317: University of Southern California.

Objectives: To measure residential exposures to ozone, particles, formaldehyde, and airborne acids in a representative sample of children's homes in the ARB/USC Epidemiology Study (A033-186, see Health Effects section, 1996). To examine the relationships between indoor ozone levels and: outdoor ozone levels, house characteristics, occupants' activities, and air exchange rates.

Importance to ARB's Program: The results will be used to improve estimates of Californians' exposures to ozone, particulate matter, and formaldehyde and to develop effective strategies for reducing the resultant health risks. They will also be used to refine the exposure model used in the epidemiology study and improve estimates of the participants' exposures to these pollutants.

Completed Projects

1998

ASSESSING EXPOSURE TO AIR TOXICS FROM ENVIRONMENTAL TOBACCO SMOKE. 94-344: The University of California, Berkeley.

Objectives: This study estimated the proportion of Californians' exposures to 17 selected toxic air contaminants (TACs) that is attributable to environmental tobacco smoke (ETS) and the proportion that is attributable to other sources. In addition, the study estimated the potential future reduction in exposure to these ETS chemicals that is likely to result from changes in Californians' smoking habits, new smoking laws, and other factors.

Findings: ETS was found to contribute significantly to the exposure of nonsmokers to toxic air contaminants. For example, in the mid-to-late 1980s, the estimated average contribution of ETS to benzene exposures was 3-10% of the total benzene exposure. (Benzene is a potent carcinogen.) Because of legislation prohibiting smoking in enclosed workspaces and other factors, ETS-caused exposures to the VOCs is predicted to be reduced in the late 1990s by 60-80% for adults, 45-55% for adolescents, and 30-35% for children. The smaller reduction for adolescents and children is due to the fact that these groups spend a greater portion of their time in unregulated indoor environments such as private residences.

Importance to ARB's Program: Results from this project can be used in conjunction with other recently available data to estimate the relative contributions of indoor and outdoor sources of these toxic air contaminants to Californians' current exposures and risks. This information will help the ARB identify effective mitigation strategies for reducing the residual public health risks from these TACs.

1996

DETERMINATION OF FORMALDEHYDE AND TOLUENE DIISOCYANATE EMISSIONS FROM INDOOR RESIDENTIAL SOURCES. 93-315: Battelle. Research Note 1997-9.

Objectives: To measure the emissions of formaldehyde and toluene diisocyanate from their indoor sources. Measurements were made in medium and large chambers under conditions that reflect typical indoor conditions as well as conditions approximating extreme but realistic indoor conditions that would cause higher emissions.

Findings: Major residential sources of formaldehyde generally emit less formaldehyde than in the past, but some products, including pressed wood products, permanent press fabric, and a wood floor finish, still emit significant amounts of formaldehyde. Toluene diisocyanate was not emitted in measurable amounts from any of the residential sources tested.

Importance to ARB's Program: Formaldehyde and toluene diisocyanate can cause adverse health effects at low levels and are used in the manufacture of products widely found and used inside residences and offices. The results will be used to better estimate Californians' exposures to these compounds and to provide guidance to California citizens on steps they can take to reduce their exposures to them.

1994

TOXIC VOLATILE ORGANIC COMPOUNDS IN ENVIRONMENTAL TOBACCO SMOKE: EMISSION FACTORS FOR MODELING EXPOSURE OF CALIFORNIA POPULATIONS. A133-186: Lawrence Berkeley Laboratory. Research Note 1996-2.

Objectives: To measure the levels of over 20 toxic air pollutants in aged second-hand smoke (environmental tobacco smoke, or ETS) from the brands of cigarettes most smoked in California. In order to compare the results with existing data, emissions of the same pollutants from fresh sidestream smoke (smoke from the burning end of the cigarette, or SS) were also measured.

Findings: Most of the target compounds were present in levels high enough to be measured in both ETS and SS. ETS emissions were highest for particles, aldehydes, nicotine, and the aromatic hydrocarbons. The ETS emissions were fairly consistent among the different cigarette brands, even when "regular" cigarettes were compared to mentholated and "light" cigarettes. ETS emissions were generally higher than emissions measured in SS, apparently due to chemical losses in the SS apparatus. The ETS emission factors agree with other literature values and the investigators recommend their use in exposure modeling.

Importance to ARB's Program: Cigarettes are a major indoor source of many toxic air pollutants. This study provides unique information to help estimate Californians' exposures to many toxic components of ETS.

DEVELOPMENT OF A MODEL FOR ASSESSING INDOOR EXPOSURE TO AIR POLLUTANTS. A933-157: Geomet Technologies, Inc.

Objectives: To develop a user-friendly model to estimate the population's average and high-end exposures to both gaseous and particulate pollutants. The model will use indoor concentration data, California activity patterns data, indoor source emission data, air exchange rate data, and other information.

Findings: The project is in its final phase. ARB staff are further evaluating the model. The model is unique: It incorporates detailed activity information and other California-specific data to provide improved indoor exposure estimates and total exposure estimates for the California population. The model estimates the central tendency of exposure distributions well, but like other population exposure models, is less reliable in estimating the extremes (high and low ends) of the distributions.

Importance to ARB's Program: The model will improve our current ability to accurately estimate Californians' exposures to air pollutants. It will especially improve indoor assessments required for the ARB's Toxic Air Contaminants Program, as required under the California Health and Safety Code.

1993

DATABASE DEVELOPMENT AND DATA ANALYSIS FOR CALIFORNIA INDOOR EXPOSURE STUDIES. A133-187: Research Triangle Institute. Research Note 1994-14.

Objectives: To combine data from six California indoor exposure studies into a unified database to facilitate further analysis of the data from all the studies. To demonstrate the usefulness of the consolidated database by conducting several analyses, such as examining differences in exposure across seasons and location.

Findings: Data from six California exposure studies are now compatible and can be easily accessed through the database. The analytical results suggest that indoor and personal exposures are higher in winter than in summer for common volatile organic compounds. Some indoor exposures to chemicals correlate with the presence of indoor emission sources and human activities in the home.

Importance to ARB's Program: The ARB will use the database to more fully analyze the large body of exposure information collected by the ARB and the U.S. EPA in California over the last decade. The database has already been used to estimate Californians' exposures to about 20 toxic pollutants for the California Comparative Risk Project.

INDOOR CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS IN CALIFORNIA RESIDENCES. A033-132: Research Triangle Institute.

Objectives: To measure the levels of selected toxic combustion by-products (polycyclic aromatic hydrocarbons [PAHs] and carbon monoxide) in California homes and to evaluate the relative contributions of sources -- such as cigarette smoking, wood burning, and use of gas heaters -- to indoor levels of those pollutants.

Findings: Cigarette smoking, wood stoves, fireplaces, and kerosene heaters were major sources of PAHs in the homes where they were used. Infiltration of polluted outdoor air also contributed significantly to indoor levels. Only a few homes showed elevated levels of carbon monoxide, associated mostly with the use of gas heat and fireplaces.

Importance to ARB's Program: The findings will be used to estimate Californians' indoor exposures to PAHs and carbon monoxide and to provide guidance to the public on how they can avoid unhealthful exposures.

MEASUREMENT OF BREATHING RATE AND VOLUME IN ROUTINELY PERFORMED DAILY ACTIVITIES. A033-205: University of California, Davis. Research Note 1994-11.

Objectives: To measure the amount of air breathed during routine activities in the first comprehensive study of males and females of all ages, in order to fill a major data gap in exposure/dose calculations.

Findings: The amount of air breathed during defined activities and for various age groups is now known. Adult males of all ages breathe similar amounts of air during similar activities. Likewise, adult females of all ages breathe similar amounts of air during similar activities. When differences in body size are accounted for, children inhale a greater quantity of air than adults during similar exercising conditions.

Importance to ARB's Program: Breathing measurements are being used to refine estimates of the amount of air pollutants inhaled. This study eliminates much of the uncertainty of estimating inhaled dose from laboratory measurements by actually measuring the amount of air breathed by a wide variety of individuals during actual activities.

1992

PTEAM: PARTICLE TOTAL EXPOSURE ASSESSMENT METHODOLOGY STUDY. A933-144: Research Triangle Institute. Research Note 1994-10.

Objectives: To measure exposures to inhalable particles and some associated elements. ARB participation ensured that the study was conducted in California and provided funding for measuring indoor and outdoor levels of two classes of toxic air pollutants: polycyclic aromatic hydrocarbons (PAHs), which are combustion by-products, and phthalates, which are commonly used plasticizers.

Findings: Personal monitoring showed that people are exposed to about 50 percent more particulate matter during the day than would have been predicted using stationary monitors. Indoor PAH levels ranged from about one-half to two times outdoor levels. Phthalates were ubiquitous, and average indoor levels were 2 to 15 times higher than outdoor levels.

Importance to ARB's Program: The ARB is using the data to assess Californians' indoor and personal exposures to inhalable particles and a number of toxic air pollutants, including benzo(a)pyrene, phthalates, lead, and other metals.

1991

INDOOR POLLUTANT CONCENTRATIONS AND EXPOSURES. A833-156: Research Triangle Institute. Research Note 1994-3.

Objectives: To measure indoor air levels of pollutants to be addressed in the Toxic Air Contaminants Program. To determine whether indoor/personal air levels in a small, inland Northern California community are similar to those in Los Angeles. To attempt to measure for the first time the indoor concentrations of certain semi-volatile pollutants.

Findings: This study confirmed findings of previous California studies that personal exposure levels to volatile organic compounds (VOCs) are somewhat higher than indoor air levels, and that indoor levels of many VOCs are higher than outdoor levels. The indoor and personal VOC levels were similar to those measured in other northern California homes but lower than those found in southern California homes. Semi-volatile chemicals were difficult to measure but appeared to be low indoors.

Importance to ARB's Program: The data have been used to estimate indoor exposures to several pollutants for the Toxic Air Contaminants Program, as required under the California Health and Safety Code. The results also are being used to estimate Californians' indoor and total exposure to air pollution for the Comparative Risk Project, and to provide guidance to the public on how to reduce their exposures to these pollutants.

STUDY OF CHILDREN'S ACTIVITY PATTERNS. A733-149: University of California, Berkeley. Research Note 1994-6.

Objectives: To obtain representative data on the time spent by California children in different activities and locations, with the focus on potential exposure to harmful air pollutants. To examine regional, seasonal, and socioeconomic/demographic differences to the extent possible.

Findings: Children spend, on average, 76 percent of their time indoors at home, 10 percent indoors at other locations, about 10 percent outdoors, and 4 percent in enclosed transit. Potential exposure to pollutants as a result of activity patterns was quite variable.

Importance to ARB's Program: The findings improved our understanding of how and where children are exposed to air pollution and how to most effectively reduce the resultant health risks. The ARB, other agencies, and researchers are using the data in models to more accurately estimate people's exposures to pollutants.

STUDY OF ACTIVITY PATTERNS OF CALIFORNIA RESIDENTS. A6-177-33: University of California, Berkeley. Research Note 1993-1.

Objectives: To obtain representative data on the time spent by California adults and adolescents in different activities and locations, with the focus on potential exposure to harmful air pollutants. To examine regional, seasonal, and socioeconomic/demographic differences.

Findings: Adults and adolescents spend, on average, 62 percent of their time indoors at home, 25 percent indoors at other locations, about 6 percent outdoors, and 7 percent in enclosed transit. The frequency, duration, and time of day of potential exposures to various indoor and outdoor air pollutants vary greatly across the population.

Importance to ARB's Program: The findings improved our understanding of how and where Californians are exposed to air pollution. The ARB has used the results to improve the indoor exposure assessments for toxic air contaminants required by the California Health and Safety Code. The ARB and other researchers are using the data in models to improve exposure estimates.

ASSESSMENT OF INDOOR CONCENTRATIONS, INDOOR SOURCES, AND EMISSIONS OF SELECTED ORGANIC COMPOUNDS. A933-063: Lawrence Berkeley Laboratory. Research Note 1992-5.

Objectives: To survey and summarize available information on indoor concentrations and sources of 47 toxic air pollutants, and to identify data gaps that could be filled by conducting indoor source emission tests.

Findings: Except for four of the compounds, available data are generally not sufficient for estimating indoor exposures. The investigators identified compounds for which it would be useful to conduct indoor source emission tests and outlined a general plan for conducting such tests.

Importance to ARB's Program: The information compiled on indoor concentrations and sources has been used to estimate indoor exposures for the Toxic Air Contaminants Program. This project prompted two further ARB studies to measure emissions from indoor pollutant sources.

1990

PTEAM PILOT: EVALUATION OF METHODS FOR MONITORING PAHs, PHTHALATES, NITROSAMINES, AND ACIDS. A833-060: Research Triangle Institute.

Objectives: To field test indoor sampling and analysis methods for four classes of air pollutants (polycyclic aromatic hydrocarbons, or PAHs; phthalates; nitrosamines; and acids) in nine southern California homes to ensure that resources would be properly focused in a proposed, larger field study.

Findings: The investigators demonstrated the feasibility of measuring PAHs and phthalates indoors and refined the methods for use in the larger study. They determined that the methods for monitoring indoor levels of nitrosamines and acids required further improvement and testing prior to use in the field.

Importance to ARB's Program: The methods for PAHs and phthalates were used in the subsequent large field study (A933-144, 1992). Nitrosamines and acids were dropped from the sampling plan of the large field study. The PAH and phthalate methods were also used in another residential study sponsored by ARB (A033-132, 1993).

DEVELOPMENT OF A METHOD FOR MEASURING INDOOR CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS. A732-106: Indoor Environmental Engineering and Lawrence Berkeley Laboratory.

Objectives: To develop sampling and analytical methods in the laboratory for monitoring indoor concentrations of polycyclic aromatic hydrocarbons (PAHs), which are toxic by-products of combustion. To field test these methods to determine their feasibility for use in larger studies.

Findings: The investigators successfully developed methods to measure gas phase PAHs indoors. They concluded that methods for measuring particle-phase PAHs and gas phase nitro-PAHs required further development prior to field use.

Importance to ARB's Program: Information obtained was useful in developing the monitors that were used in two large-scale ARB residential PAH studies (A933-144, 1992 and A033-132, 1993).

STUDY OF RESIDENTIAL INDOOR AND OUTDOOR RADON CONCENTRATIONS IN CALIFORNIA. A6-194-53: California Public Health Foundation/California Department of Health Services. Research Note 1992-3.

Objectives: To characterize the magnitude of the radon problem in California through the first statewide study of radon levels in air, soil, and water in randomly selected residences.

Findings: The statewide annual average indoor radon concentration was about 60 percent of the national average and well below the U.S. EPA's recommended action level. The radon concentrations in the Sierra foothills and Ventura County were elevated relative to those in the rest of California.

Importance to ARB's Program: Results have been used by the ARB and the Department of Health Services (DHS) to estimate Californians' exposures to radon, and by DHS and the U.S. EPA to guide additional monitoring efforts to further characterize possible problem areas in the state.

1989

PILOT STUDY TO MEASURE INDOOR AND PERSONAL PM10, ASSOCIATED IONS, AND MUTAGENIC ACTIVITY. A6-129-33: University of California, Irvine.

Objectives: To test sampling equipment and methods for measuring indoor and personal exposures to respirable particles (PM10) and particle constituents and properties relevant to assessing health effects.

Findings: Different types of sampling equipment were tested in the laboratory and inside and outside ten southern California homes. This study successfully demonstrated the feasibility of monitoring indoor and personal exposures to particles and their constituents in a large field study.

Importance to ARB's Program: This study helped set the stage for conducting a large-scale residential particle study (called PTEAM) co-funded by ARB and U.S. EPA (A933-144, 1992).

DEVELOPMENT AND IMPLEMENTATION OF EXPOSURE ASSESSMENT PROCEDURES FOR TOXIC AIR POLLUTANTS IN SEVERAL LOS ANGELES COUNTY, CALIFORNIA, COMMUNITIES (also called the 1987 TEAM study). A5-174-33: Research Triangle Institute.

Objectives: To determine similarities and differences in air levels of volatile organic compounds (VOCs) in 50 Los Angeles homes monitored three years earlier. To identify possible indoor sources of the pollutants and estimate the rate of pollutant emission from those sources.

Findings: The personal and indoor air levels were higher than outdoor levels for most of the pollutants. These findings were similar to those of the previous study. Indoor source strengths were successfully calculated for 12 prevalent compounds. A few were notably high.

Importance to ARB's Program: The results have been used extensively to develop estimates of Californians' exposures to toxic VOCs from inhalation of indoor air, as required by the California Health and Safety Code. The results also have been used in the Comparative Risk Project and to provide guidance to the public in reducing their exposures to these pollutants.

Acid Deposition

Acid Deposition

Projects in Progress

DEVELOPMENT OF A COMPUTATIONALLY EFFICIENT ACID DEPOSITION MODEL FOR CALIFORNIA. 93-304: The California Institute of Technology.

Objectives: To develop an efficient model for determining the relationships between emissions from sources of acidic pollutants and the deposition of these pollutants in receptor areas. The model will contain state-of-the-science treatments of gas-phase chemistry, aerosol physics and chemistry, dry and wet deposition, and cloud physics and chemistry.

Importance to ARB's Program: The model will be used to characterize long-term regional source-receptor relationships and to examine the effects of emission control strategies on ambient concentrations of acidic species. The results of the project will be used to design potential acid deposition management strategies and to evaluate the need for atmospheric acidity standards in California, as required by the Health and Safety Code.

EVALUATION OF A SAMPLING METHODOLOGY FOR ACIDIC SPECIES. 93-338: University of California, Riverside.

Objectives: To design an innovative methodology that will allow comprehensive measurements of atmospheric acidic species, and which employs an easy-to-operate, reliable, durable, low-cost sampler. The system will be designed to be very flexible: denuders and backfilters could be removed or added and sampling frequencies and duration could be adjusted to meet the specific monitoring objectives of future studies. Denuder and substrate performance will be evaluated under laboratory and field conditions for accuracy, precision, and interferences.

Importance to ARB's Program: This study will provide a simple, reliable, and inexpensive sampler that will be used for monitoring atmospheric acidic species in California. This monitoring is critical for maintaining reliable databases on acidic deposition that can be used to support ongoing research programs on atmospheric processes, forest ecosystems, and human health.

COMPARATIVE ANALYSES OF HIGH-ALTITUDE LAKES AND CATCHMENTS IN THE SIERRA NEVADA: SUSCEPTIBILITY TO ACIDIFICATION. A032-188: University of California, Santa Barbara.

Objectives: To monitor temporal trends and patterns of wet acidic deposition and surface water chemistry in seven watersheds in the Sierra Nevada. These are years 3 and 4 of a four-year study. See contract no. A932-060 (1993) for Years 1 and 2.

Importance to ARB's Program: To document long-term trends in atmospheric acidity that may affect aquatic ecosystems in the Sierra Nevada as required by the Atmospheric Acidity Protection Program.

MONITORING FOR ACIDIC SNOWMELT EPISODES IN THE SIERRA NEVADA. A132-048: U.S. Environmental Protection Agency.

Objectives: To determine the frequency, duration, and magnitude of episodic acidification events during Sierra Nevada spring snowmelt. In nine of the Sierra's most acid-sensitive lakes, samples of snowpack,

snowmelt water, and lake and stream water are being collected to determine whether the lakes become acidified during snowmelt, and whether levels of acidity become high enough to affect aquatic populations.

Importance to ARB's Program: The results of this project will be used in evaluating the need to develop a standard to protect sensitive ecosystems in the Sierra Nevada.

WATERSHED BIOGEOCHEMICAL PROCESSES AFFECTING SURFACE WATERS IN THE SIERRA NEVADA, WITH EMPHASIS ON SNOWMELT EPISODES. A032-116: University of California, Santa Barbara.

Objectives: To determine the extent to which the chemistry of snowmelt runoff reaching high elevation lakes and streams is altered by watershed soils in the Sierra Nevada.

Importance to ARB's Program: This study will provide information that will improve our understanding of how atmospheric acidity may affect aquatic ecosystems in the Sierra Nevada.

ASSESSING THE POTENTIAL IMPACT OF ACID DEPOSITION ON HIGH ALTITUDE AQUATIC ECOSYSTEMS IN CALIFORNIA: INTEGRATING TEN YEARS OF INVESTIGATION. 93-312: University of California, Santa Barbara.

Objectives: To synthesize the results of the ARB's Aquatic Ecosystems Research Program for the technical assessment of the Atmospheric Acidity Protection Program. Studies of effects of acidic deposition to aquatic ecosystems in the watersheds and lakes of the Sierra Nevada will be evaluated, along with work done elsewhere. Recommendations will be made for interpretation of the results of the research.

Importance to ARB's Program: The information from this study will help the Board determine the need for establishing a standard for protecting sensitive ecosystems from atmospheric acidity.

DEVELOPMENT OF AN ACID DEPOSITION MODEL FOR THE SOUTH COAST AIR BASIN IN CALIFORNIA. 92-311: California Institute of Technology.

Objectives: To develop, evaluate, and apply a comprehensive acid deposition model for the South Coast Air Basin (SoCAB) for predicting episodic acid deposition levels.

Importance to ARB's Program: The model will be used in the future to evaluate trade-offs in gas and particle emission control measures in conjunction with the pending PM2.5 air quality standard.

Completed Projects

1996

STUDY TO EVALUATE THE CADMP SAMPLER. 93-333: University of California, Riverside.

Objectives: To perform a comprehensive evaluation of nitric acid losses in the ARB's CADMP (California Acid Deposition Monitoring Program) sampler and to quantify denuder and cyclone efficiency so that the accuracy of the nitrate and nitric acid measurements could be assessed.

Findings: The results of this study show that the CADMP sampler, when reconditioned annually and cleaned somewhat more frequently, is useful in measuring nitric acid concentrations. However, the values recorded will be 10 to 20 percent lower than actual values because nitric acid adheres to the walls and because the denuders do not remove all the nitric acid or they do not permit all the nitrate-containing particles to pass through. This project has provided an effective test of the CADMP sampler in a series of field and laboratory evaluations.

Importance to ARB's Program: At many locations, nitric acid is the largest component of total nitrogen deposition. Therefore, accurate measurement of nitric acid is critical. This project has provided an effective test of the CADMP sampler in a series of field and laboratory evaluations. The results of this study have provided information regarding accurate measurement of nitric acid.

CALIFORNIA ACID DEPOSITION MONITORING PROGRAM DATA VALIDATION AND DATA ANALYSIS. 93-332: Envair. Research Note 1996-13.

Objectives: To review the methods employed by the ARB for validating wet- and dry-deposition data from the California Acid Deposition Monitoring Program and to update deposition flux estimates for the program.

Findings: For most years, wet nitrate deposition was estimated to be greater in the South Coast Air Basin (SoCAB) and the southern Sierra Nevada than in other parts of California. In some areas where wet sulfate deposition is highest, such as the northwestern California coast, much of the sulfate has its origin as sea salt. At the urban sites, nitric acid deposition accounted for 30 to 80 percent of the dry deposition of oxidized nitrogen species and 20 to 70 percent of the total nitrogen dry deposition.

Importance to ARB's Program: This project produced updated estimates of wet- and dry-deposition fluxes in California. These estimates improve our understanding of the magnitude of acidic deposition in California. The results of this study also provided information directly relevant to whether an ambient air quality standard for atmospheric acidity and acidic deposition is needed in California.

1995

WET DEPOSITION MONITORING IN THE ALPINE ZONE IN THE SIERRA NEVADA. A932-081: University of California, Santa Barbara. Research Note 1997-7 .

Objectives: To initiate a long-term wet deposition monitoring program in the alpine zone (above 7200 feet) of the Sierra Nevada to measure the loading of solutes that may acidify surface waters in high-elevation areas with sensitive lakes and streams.

Findings: Selected ranges of annual wet deposition of solutes in units of Eq/ha were: hydrogen 24.1 to 60.9, ammonium 21.6 to 58.4, nitrate 22.4 to 53.7, and sulfate 16.9 to 44.5. Understanding of the significance of these figures is limited by the fact that watershed processes that act upon this deposition are not completely understood.

Importance to ARB's Program: Documentation of trends in atmospheric acidity in aquatic ecosystems in the Sierra Nevada is a goal of the Atmospheric Acidity Protection Program.

FURTHER EVALUATION OF A TWO-WEEK SAMPLER FOR ACIDIC GASES AND FINE PARTICLES. 93-339: University of California, Riverside.

Objectives: To evaluate an ARB two-week sampler for nitric and acetic acid interferences, for stability of collected formic and acetic acid, and for the feasibility of short-duration (24-hour) sampling. The sampler is used to provide exposure data for acidic gases and fine particles for the Children's Health Study (A033-186, see the Health Effects section).

Findings: Overall, this study confirmed that the two-week sampler is operating in complex atmospheres about as expected. Laboratory tests confirmed that peroxyacetyl nitrate (PAN) and nitrous acid were capable of interfering with nitric acid measurements. Field tests performed in ambient air indicated, however, that the sampler measured nitric acid in good agreement with nylon filters. Laboratory tests confirmed that PAN was capable of interfering with acetic acid. Field tests showed that up to 20 percent of total acetate measured may be due to PAN. Formic and acetic acid were retained with good stability. Laboratory and field tests indicated that the two-week sampler can be operated for periods as short as 24 hours.

Importance to ARB's Program: Understanding of the effects of nitrous acid on nitric acid monitoring and of the effects of PAN on nitric and acetic acid monitoring can lead to improvement in the measurement of these acidic gases. Confirmation of the stability of formic and acetic acids leads to increased confidence in these measurements. Short-term (24-hour) sampling may be important for future health study needs in the area of microenvironmental sampling, especially in capturing transient events or in determining indoor/outdoor ratios of acidic gases and fine particles.

ECOSYSTEM-LEVEL ALTERATIONS IN SOIL NUTRIENT CYCLING: AN INTEGRATED MEASURE OF CUMULATIVE EFFECTS OF ACIDIC DEPOSITION ON A MIXED CONIFER FOREST IN SOUTHERN CALIFORNIA. 93-335: USDA Forest Service. Research Note 1997-5.

Objectives: To apply the Nutrient Cycling Model (NuCM) in the investigation of long-term effects of acidic deposition on soil biogeochemistry at a mixed conifer forest in southern California. To support this effort, measurements were also made to: (1) quantify nutrient pools in vegetation and soil; (2) measure water vapor emission and carbon dioxide uptake rates and soil moisture availability; (3) monitor wet and dry acidic deposition; and (4) assess short-term variations in nitrogenous air pollutants.

Findings: The results of the 40-year NuCM simulations indicated that elevated levels of nitrogen deposition would eventually lead to the leaching of base cations and nitrate from forest soil, a change that would be similar to changes that have occurred in other forests. Measurements of pine tree gas exchange rates indicated that up to 70 percent of annual ozone uptake occurs during the period May through July. In a two-week intensive study, levels of dry-deposited nitrogen-derived species were two times higher in the afternoon than in the morning or at night.

Importance to ARB's Program: Because of the long-term nature of acidic-deposition-induced effects on forests, simulation models are needed to project the adverse impacts, if any, that result from chronic exposure to nitrogenous air pollutants. The NuCM will be used to assess the potential long-term combined effects of ozone and nitrogen deposition on soil properties and ground water quality in forests in southern California. The results of this study will guide the Board in considering a standard for forest ecosystems in California.

ATMOSPHERIC ACIDITY PROTECTION PROGRAM ASSESSMENT WORKSHOP. 93-336: University of California, Irvine.

Objectives: To provide a forum for discussion of California's acid deposition problem among members of ARB's Scientific Advisory Committee on Acid Deposition, its Research Screening Committee, its staff, and research contractors. The discussions will serve as the foundation for the program assessment report required by the Atmospheric Acidity Protection Act.

Findings: The proceedings of the workshop are available from the Research Division, (916) 445-0753. (Ask for PROCEEDINGS OF THE ATMOSPHERIC ACIDITY PROTECTION PROGRAM ASSESSMENT WORKSHOP.)

Importance to ARB's Program: The written opinions on the acidic deposition problem in California will be a valuable resource in the preparation of the Atmospheric Acidity Protection Program Assessment.

A REVIEW OF NITRIC ACID MEASUREMENTS BY TDLAS. 93-340: University of California, Riverside.

Objectives: To evaluate the accuracy of the tunable diode laser absorption spectroscopy (TDLAS) measurements made during the ARB's 1993 Azusa nitric acid study, and to determine through analysis of existing data whether there were systematic errors in the TDLAS sampling method that contributed to the discrepancies between its results and those of other nitric acid samplers.

Findings: Based on data from 1993 and other years, the TDLAS nitric acid time profiles, when compared with those of the concurrent ozone and PAN profiles, showed no evidence of a nitric acid adsorption/desorption process occurring along the TDLAS sampling line nor of nitric acid vaporization from particles on the Teflon® front filter. Further, no errors in TDLAS calibration were found. It may be that a satisfactory explanation of the large discrepancies among the nitric acid measurements by various samplers will require controlled experimentation to directly measure losses that occur in the sampling lines of the different samplers.

Importance to ARB's Program: An objective of the Atmospheric Acidity Protection Program is to measure the concentrations of acidic pollutants in ambient air. TDLAS sampling has been considered for use as a reference method for monitoring nitric acid concentrations in the atmosphere. This study was performed toward ensuring the accuracy of the TDLAS method.

SIERRA COOPERATIVE OZONE IMPACT STUDY. Year 1 (1990-1991): A933-097. Year 2 (1991-1992): A033-129. Year 3 (1992-1993): A132-188. Year 4 (1993-1994): 92-346. University of California, Davis. Research Notes 1994-2 and 1996-3.

Objectives: To conduct a four-year study to investigate the effects of ozone on vegetation using a network of aerometric monitoring stations in national forests on the western slope of the Sierra Nevada. Year 1: To establish a network of five aerometric monitoring stations; to measure concentrations of ozone and a suite of meteorological variables (wind speed, wind direction, air temperature, and relative humidity). Year 2: To establish a sixth station and collect the first full growing season of air quality data. Year 3: To evaluate year-to-year variability in selected measures of ozone. Year 4: To identify trends in ozone in these forests.

Findings: Year 1: Ozone levels in these forests reach levels that can cause injury to pine foliage. Year 2: Ozone concentrations peaked in mid-to-late afternoon; daily maxima were higher at the southern stations. Year 3: Three sites exhibited distinct diurnal ozone profiles, with peak concentrations in the afternoon and lowest levels in the early morning. The other three sites had flat profiles, characteristic of remote,

non-urban areas. Year 4: In 1993 and 1994, summertime ozone concentrations were similar to those measured in 1991 and 1992.

Importance to ARB's Program: The ARB is required by the California Health and Safety Code to investigate the effects of air pollution on vegetation. The findings allow for identification and characterization of trends (e.g., temporal patterns and extent of variability) in the effects of ozone on air quality.

ASSESSMENT OF ACIDIC DEPOSITION AND OZONE EFFECTS ON CONIFER FORESTS IN THE SAN BERNARDINO MOUNTAINS. A032-180: U.S. Forest Service. Research Note 1997-5.

Objectives: To establish and maintain a forest health monitoring site at Barton Flats in the San Bernardino National Forest. The main tasks were: (1) to monitor air quality and meteorological conditions; (2) to assess tree health and characterize soil properties; and (3) to estimate rates of ozone and nitrogen deposition to pine trees.

Findings: The findings indicate that the co-deposition of ozone and nitrogen to ponderosa pine occurs at levels that can cause long-term, adverse impacts on forest tree productivity and soil fertility. Given the time frame of ecological effects (20 to 50 years) and data documenting higher levels of ozone exposure in the 1950s, it was proposed that conifer forest productivity in southern California may be at risk within the next 10 to 20 years.

Importance to ARB's Program: In fulfillment of the Atmospheric Acidity Protection Program, the findings will be used to quantify rates of ozone and acidic deposition to forests in southern California as a basis for determining the need to establish an acidic deposition standard.

ATMOSPHERIC DEPOSITION TO AGRICULTURAL SOILS. 93-334: University of California, Riverside. Research Note 1995-17.

Objectives: To determine the contribution of nitrogen, sulfur, and calcium in atmospheric acidity to the nutritional environment of certain of California's commercial crops.

Findings: The findings indicate that, on a regional basis, atmospheric depositions of nitrogen could be an important nutrient source for crops such as lettuce that have low requirements for those elements. For most commercially important crops, there is a limited possibility that atmospheric deposition would be the principal contributor to a buildup of soil nutrients to levels that could cause adverse effects on crop productivity. Nutrient depositions of magnitudes determined in this study could have pronounced adverse effects on plants in natural, unmanaged ecosystems, such as grasslands or forests, that are adapted to growing in nutrient-poor conditions.

Importance to ARB's Program: The results of this study will be used to evaluate the overall effects of acidic deposition on agricultural resources for the Atmospheric Acidity Protection Program Assessment. The GIS-compatible data can be used to evaluate the effects on agricultural resources of acidic deposition in combination with other air pollutants.

1994

AQUATIC BIOTA IN THE SIERRA NEVADA: CURRENT STATUS AND POTENTIAL EFFECTS OF ACID DEPOSITION ON POPULATIONS. A932-138: University of California, Santa Barbara. Research Note 1996-12.

Objectives: To estimate the number of fish populations in the Sierra Nevada that could be damaged by chemical pollution and to conduct field experiments on the acid sensitivity of golden trout.

Findings: Of an estimated 1,400 high-elevation lakes, about 900 contain trout populations. Golden trout embryos are in the stage of development most likely to encounter episodic acidification during snowmelt. This study found that these embryos can tolerate pH to about 4.5 -- about the same as for other species.

Importance to ARB's Program: The findings will be used to develop indicators to detect changes in aquatic ecosystems and, as required by the Atmospheric Acidity Protection Program, to establish the economic value of the loss of fisheries and recreation.

SOUTHERN CALIFORNIA AIR QUALITY STUDY - ATMOSPHERIC ACIDITY DATA ANALYSIS. A932-079: AeroVironment, Inc.

Objectives: To identify precursor sources and formation rates of atmospheric acidity using data collected during the 1987 Southern California Air Quality Study.

Findings: A number of findings important to understanding atmospheric acidity resulted from this contract. First, formic, acetic, and total organic acid emissions were estimated for the South Coast Air Basin (SoCAB) at 6,500, 9,000, and 19,700 kg/day, respectively. The ozone olefin reaction was estimated to be a major source of organic acids. Dry deposition far exceeds removal by rain, accounting for 95 percent of formic acid removal and 91 percent of acetic acid removal. Overall, dry deposition accounts for 14 times the deposition by wet processes in the SoCAB. Second, when aerosol droplets that are individually in Henry's Law equilibrium with the surrounding air are mixed together, the resulting bulk mixture is always supersaturated with weak acids and bases. Third, trajectory analysis suggests that high sulfate concentrations are associated with air parcels that passed through a fog layer the previous night. Finally, multivariate receptor analysis indicates that the atmospheric transport of gaseous precursors, and their conversion into particulate-phase acidic species, tends to decouple them from the variations observed in primary particles co-emitted with the gaseous precursors. Major sources of acidic compounds were found along the coast in these analyses.

Importance to ARB's Program: The results of this project will help guide the Board in setting atmospheric acidity and/or deposition standards, should they become necessary.

REGIONAL ESTIMATES OF ACID DEPOSITION FLUXES IN CALIFORNIA. A132-149: ENVAIR. Research Note 1996-13.

Objectives: To evaluate the quality of the available deposition data, and to estimate fluxes of wet and dry acidic deposition on a regional scale, using existing acidic deposition databases in California.

Findings: At the three remote sites (Gasquet, Yosemite, and Sequoia), wet nitrate and sulfate deposition approximately equaled or slightly exceeded dry deposition of oxidized nitrogen and sulfur species. In contrast, at the urban sites (Sacramento, Fremont, Bakersfield, Santa Barbara, Long Beach, Los Angeles, and Azusa) dry sulfur deposition values were approximately one to three times the magnitude of those of

wet sulfur deposition. Dry deposition values for oxidized nitrogen species at the urban sites ranged from about 5 to 30 times the magnitude of wet nitrate deposition values.

Importance to ARB's Program: The results of this project will help guide the ARB in setting atmospheric acidity and/or deposition standards, should they become necessary.

MEASUREMENT OF NITRIC ACID BY TUNABLE DIODE LASER ABSORPTION SPECTROSCOPY. 93-300: Unisearch Associates, Inc.

Objectives: To measure concentrations of nitric acid in Azusa continuously during October 1993 to support an ARB study of nitric acid measurements by the California Acid Deposition Monitoring Program (CADMP) sampler and a new two-week sampler constructed for the Board's long-term epidemiology study (A033-186, see the Health Effects section). The CADMP sampler has shown anomalous measurements of nitric acid.

Findings: Data were collected and the one-minute averages were compiled into hourly, daily (10:00 am - 6:00 pm), and 24-hour averages.

Importance to ARB's Program: The data were used by ARB to assess the performance of the Azusa CADMP sampler and the two-week sampler.

GEOLOGIC CONTROLS ON NATURAL ACIDIFICATION OF ALPINE LAKES IN THE EASTERN SIERRA NEVADA. A132-192: Dr. Gail Mahood.

Objectives: To identify potential influences of bedrock lithology on the acidity of the lakes in the Mt. Pinchot region of California's Sierra Nevada.

Findings: Oxidation of the mineral pyrite during surficial weathering is the source of acid water that causes lakes in this area to be naturally acidified.

Importance to ARB's Program: This geological evaluation contributed to a survey of the chemical conditions and aquatic animal life in the 104 lakes of this area.

DISTRIBUTION OF AQUATIC ANIMALS RELATIVE TO NATURALLY ACIDIC WATERS IN THE SIERRA NEVADA. A132-173: University of California, Los Angeles. Research Note 1996-5.

Objectives: To survey several forms of animal life in Sierran aquatic ecosystems of varying acidity. Previous research had been limited to experimental manipulation, because naturally acidic lakes are rare in the Sierra Nevada.

Findings: For 104 lakes in Kings Canyon National Park, pH ranged from somewhat acidic (5.0) to highly alkaline (9.3) and included ten lakes defined as acidic. Typical Sierran lakes are dominated by calcium, sodium, and bicarbonate. However, concentrations were high enough to classify 19 lakes in this region as having sulfate as the dominant anion. The source of acidity and sulfate is sulfuric acid produced by the oxidation of pyrite found in the rocks in the area. Three animal species surveyed were rare or absent in acidic lakes and common in lakes defined as nonacidic (pH > 6.0).

Importance to ARB's Program: This study increased our understanding of potential acidification effects on aquatic ecosystems in the Sierra Nevada by allowing observation of whole ecosystems in a unique area having naturally acidic lakes.

1993

REGIONAL SOURCE-RECEPTOR RELATIONSHIPS FOR ATMOSPHERIC ACIDITY AND ACID DEPOSITION IN CALIFORNIA. A032-189: ENSR Consulting and Engineering.

Objectives: To evaluate semi-empirical source-receptor models and their capability of establishing relationships between sources and sensitive receptors of acidic species and acidic precursors. The model used in this study is a nonlinear semi-empirical long-range transport model, referred to as STATMOD.

Findings: The source-receptor analysis showed that the contribution of local sources dominated the total sulfur dry deposition at receptors located in urban regions or close to large sources. Long-range transport was found to be a factor in nitrogen dry deposition, even at receptors that were located close to high NO_x sources.

Importance to ARB's Program: The results of this research project will be used in designing potential acid deposition management strategies and in evaluating the need for atmospheric acidity standards in California.

GAS EXCHANGE BY Pinus ponderosa IN RELATION TO ATMOSPHERIC POLLUTANTS. A132-101: University of California, Berkeley. Research Note 1995-7.

Objectives: To evaluate the combined effects of acidic rain and ozone on water vapor emission and carbon dioxide uptake rates in seedlings and mature branches of ponderosa pine.

Findings: The findings provide evidence that ambient levels of ozone may be causing physiological alterations in pine trees throughout the state. This could have long-term implications with respect to seedling establishment.

Importance to ARB's Program: The findings will be used in future efforts to re-evaluate the basis for a secondary ambient air quality standard for ozone.

DEVELOPMENT OF A MODULAR SYSTEM FOR ACIDIC DEPOSITION MONITORING. A132-102: University of California, Davis.

Objectives: To develop and test a simple and inexpensive monitoring system for measuring concentrations of acidic gases and particles deposited in a dry state in remote field sites (e.g., forests).

Findings: A large part of this project involved establishing comparability between the UCD Modular System for Acid Deposition Monitoring (MSAM) and the existing California Acid Deposition Monitoring Program (CADMP) sampler before considering large-scale statewide deployment of MSAM.

Importance to ARB's Program: This long-term monitoring program will advance the ARB's understanding of the potential for long-term, cumulative damage to forest vegetation and soils due to dry deposition of acidic gases and particles.

RECEPTOR MODELING OF TRANSPORT OF ACIDIC AIR POLLUTANTS AND OXIDANTS TO FORESTED REGIONS IN THE SIERRA NEVADA. A932-140: Desert Research Institute.

Objectives: To model acidic air pollutants in the Sierra Nevada based upon source apportionment. The first phase of the study involved field measurements of chemical and meteorological data. The second involved use of a source-receptor model to determine the relationship between acidic species or precursors emitted in the San Joaquin Valley source region and their eventual deposition at susceptible forests in the Sierra Nevada: Blodgett (northern Sierra), Yosemite, Sequoia, and Tehachapi (southern Sierra).

Findings: The results of this study show that the major sources of particulates at Blodgett were of local origin (geological and motor vehicle). Yosemite and Sequoia were dominated by burning of vegetable material. Tehachapi was impacted by both regional and local (geological and motor vehicle) sources.

Importance to ARB's Program: In fulfillment of the Atmospheric Acidity Protection Program, the results of this project provide information on sources and contributions to ambient concentrations of particulate matter. It also provides insight into the level of organic acids in the forested regions of the Sierra Nevada.

DETERMINATION OF ACIDIC GAS AND PARTICLE CONCENTRATIONS IN OPEN-TOP FIELD CHAMBERS. A132-174: U.S. Forest Service. Research Note 1995-7.

Objectives: To measure concentrations of gaseous and particulate air pollutants in open-top field chambers used to expose seedlings of ponderosa pine to acidic rain and ozone. This was a companion study to a larger effort to evaluate the combined effects of acidic rain and ozone on water vapor and carbon dioxide uptake in ponderosa pine (A132-101, above).

Findings: Daytime average concentrations of nitric and nitrous acid are typical of levels reported in other studies across the United States and Canada.

Importance to ARB's Program: As part of the Atmospheric Acidity Protection Program, the data will be used to calculate estimates of nitrogen deposition, which may be a factor contributing to variability in plant responses to ozone. These data also provide an indication of acidic pollutant levels in urban areas in northern California.

AQUATIC AMPHIBIANS IN THE SIERRA NEVADA: CURRENT STATUS AND POTENTIAL EFFECTS OF ACID DEPOSITION ON POPULATIONS. A932-139: University of California, Los Angeles. Research Note 1995-25.

Objectives: Several species of amphibians were studied as potential indicators of adverse ecological effects of acidic deposition in the Sierra Nevada.

Findings: In a survey of high-elevation sites, no relationships were detected between water characteristics during snowmelt and the distribution of declining and non-declining amphibian species. Complementary laboratory toxicity tests indicated that amphibian species in the Sierra Nevada are at little risk from high acidity (pH < 5.0) and exposure to aluminum. However, sublethal effects observed in these tests may represent long-term threats to amphibian populations.

Importance to ARB's Program: Results were used to determine the role of atmospheric deposition on the decline of amphibians in the Sierra, in fulfillment of the Atmospheric Acidity Protection Program.

SOUTHERN CALIFORNIA AIR QUALITY STUDY ATMOSPHERIC ACIDITY DATA ANALYSIS. A932-079: Aerovironment, Inc.

Objectives: To analyze atmospheric acidity data from the Southern California Air Quality Study of 1987 (SCAQS). The major tasks were to examine the role of fog formation and dispersion in transforming acidic precursors to acidic air pollutants, and to evaluate the sources, transformation, and transport of acidic air pollutants.

Findings: The results of this study show that fog droplets can combine with pollutants in the air and carry some of them to the ground, thus reducing aerosol concentrations. However, evaporating fogs often leave behind aerosols formed from material (such as sulfates) dissolved in droplets, thereby increasing concentrations of those pollutants in the air. There were several clear cases of transport across two SCAQS sites (Long Beach and Hawthorne).

Importance to ARB's Program: The results of the project will help guide the ARB in setting atmospheric acidity and/or deposition standards, should they become necessary.

LONG-TERM STUDIES OF LAKES AND WATERSHEDS IN THE SIERRA NEVADA, PATTERNS AND PROCESSES OF SURFACE-WATER ACIDIFICATION. A932-060: University of California, Santa Barbara.

Objectives: To assess potential effects of atmospheric acidic deposition on the hydrology, hydrochemistry, and zooplankton of seven high-altitude Sierran catchments.

Findings: The snow in these catchments was slightly acidic. The acidity is attributed to weak organic acids and strong acids of nitrate and sulfate. Weathering and soil processes in the catchments are sufficient to buffer current acidic atmospheric deposition on an annual basis. Zooplankton species known to be intolerant of acidification occur in all seven lakes, and their presence is evidence that Sierran lakes are not currently showing chronic biological effects of acidic deposition.

Importance to ARB's Program: These data will be compared with those obtained from future monitoring studies to determine trends in deposition, water quality, and biological populations in considering the need for a standard to protect aquatic ecosystems in the Sierra Nevada.

1992

TRANSPORT OF ACIDIC AIR POLLUTANTS TO FORESTS AND ALPINE REGIONS OF THE SIERRA NEVADA. A932-141: Tracer Technologies, Inc.

Objectives: To study the summer and fall transport of air pollutants from the San Joaquin Valley (SJV) into the Sierra Nevada range.

Findings: The results of this study show that transport mechanisms of air pollutants into the Sierra are not simple processes. In most instances, the pollutants are trapped (by atmospheric inversion) along the foothills and slowly seep into the upper Sierra through major canyons and valleys. This decreases the peak pollutant concentration levels that impact the upper Sierra, but can substantially prolong episodes of elevated concentrations.

Importance to ARB's Program: In partial fulfillment of the Atmospheric Acidity Protection Program, this study provided some important findings concerning the transport of pollutants from the San Joaquin Valley.

APPLICATION OF A HYDROCHEMICAL MODEL AND A MULTIVARIATE SOIL-SOLUTION MIXING MODEL TO ALPINE WATERSHEDS IN THE SIERRA NEVADA, CALIFORNIA. A932-076: United States Geological Survey. Research Note 1994-8.

Objectives: To determine whether the Alpine Lake forecaster, developed to predict the alkalinity of Emerald Lake and its inlet streams during snowmelt, could be applied to other watersheds in the Sierra Nevada.

Findings: Of the four watersheds considered, the Forecaster was applicable to two. The results indicate that an index composed of soil silica and other compounds can be used to predict alkalinity of watersheds that are hydrologically similar to Emerald Lake.

Importance to ARB's Program: The model was used to direct field experimentation and to predict the consequences of changes in the amount of acidic deposition and its chemical makeup on high-elevation watersheds and surface waters in California.

MODELING AEROSOL PROCESSES AND VISIBILITY BASED ON THE SCAQS DATA. A932-054: California Institute of Technology.

Objectives: To identify the factors that influence the equilibrium distribution of pollutant materials between gas and aerosol phases. (An aerosol is a gaseous suspension of fine solid or liquid particles.) To evaluate the relationships between ambient aerosol composition and visibility deterioration in the South Coast Air Basin. The data from the Southern California Air Quality Study of 1987 (SCAQS) were used to address these issues.

Findings: It was shown that it is possible to maintain a network of monitoring sites that can be used to track the effect of pollutant properties on visibility.

Importance to ARB's Program: In fulfillment of the California Clean Air Act of 1988, this project provided important information with respect to air quality problems related to visibility-reducing particles.

1991

MATHEMATICAL MODELING AND CONTROL OF THE DRY DEPOSITION FLUX OF NITROGEN-CONTAINING AIR POLLUTANTS. A6-188-32: Carnegie-Mellon University.

Objectives: To determine the effects that alternative emission control strategies would have on the dry deposition of oxides of nitrogen, nitric acid, aerosol nitrate, and ammonia.

Findings: A dry deposition model was employed to examine the nature of the effects that would occur if emission controls were applied to the NO_x and hydrocarbon sources in the South Coast Air Basin as they existed in 1982. It was found that as emission controls are applied to reactive hydrocarbon and NO_x, the dry deposition of acid gases declines while the dry deposition of ammonia increases. This is due to the greater ammonia emissions and higher ammonia concentrations that result from lower aerosol nitrate formation.

Importance to ARB's Program: The result of this research project will be used in evaluating the need for designing potential acid deposition management strategies and in developing acid deposition and atmospheric acidity standards for California.

1990

INTEGRATED SOIL PROCESSES STUDIES AT EMERALD LAKE WATERSHED. A5-204-32: University of California, Riverside.

Objectives: To characterize watershed soil processes at Emerald Lake. This project was Part 2 of a three-year study.

Findings: Three major soil types were identified and changes in soil water chemistry were monitored during snowmelt. In spring 1987, loss of acid-neutralizing capacity and elevated concentrations of nitrate were detected in soil water during snowmelt. These indicate an episodic pulse of acidity.

Importance to ARB's Program: Results were used to estimate the fates of chemicals in the watershed and the influence of different soil types on soil-water and surface-water chemistry. The results of this study will guide the board in considering a standard for sensitive ecosystems in the Sierra Nevada.

1989

PROFILE MEASUREMENTS OF SULFUR DIOXIDE, NITROGEN OXIDES, AND NITRIC ACID DEPOSITION VELOCITIES IN CALIFORNIA'S SOUTH COAST AIR BASIN. A4-145-32: Desert Research Institute.

Objectives: To quantify the dry deposition velocities of five acidic species in order to determine each component's contribution to acid deposition processes in California. Dry deposition is the major route of acid deposition in California. The measurements were taken in late spring 1986.

Findings: The results agreed well with published values for the species studied, except that nitric acid deposition velocities were lower than expected.

Importance to ARB's Program: The results will be used in the development of appropriate acid deposition control strategies.

SURVEY OF SOILS OF THE SIERRA NEVADA FOR SENSITIVITY TO ACID DEPOSITION. A732-037: North State Resources, Inc.

Objectives: To rank the sensitivity of soils to acid deposition in a selected 527,000-acre study area and map the distribution of highly sensitive, moderately sensitive, and less sensitive soil types.

Findings: Approximately 56 percent of the study area was designated as highly sensitive, 18 percent as moderately sensitive, and 25 percent as less sensitive. Soil depth was identified as the most important determinant of soil sensitivity to acidic deposition.

Importance to ARB's Program: This project was the first step in constructing a regional database for an assessment of the potential for damage to soils and surface waters from acidic deposition in high-elevation areas of the western slope of the Sierra Nevada.

STEADY STATE MODEL TO DETERMINE LAKE RESOURCES AT RISK TO ACID DEPOSITION IN THE SIERRA NEVADA, CALIFORNIA and ASSESSMENT OF EPISODIC ACIDIFICATION IN THE SIERRA NEVADA OF CALIFORNIA. A732-036A and A732-036B: University of Iowa.

Objectives: To determine the extent of acidic deposition-sensitive waters in the Sierra Nevada.

Findings: Using the models chosen during the evaluation, only a small number of Sierran lakes were projected to become chronically acidified if current rates of acidic deposition were to double, but the models suggested that the effects of episodic acidification may be of greater concern than those of chronic acidification.

Importance to ARB's Program: In partial fulfillment of the Atmospheric Acidity Protection Program, models were developed to predict how change during snowmelt and summer rain would affect lake chemistry.

DEVELOPMENT OF WATERSHED MODELS FOR EMERALD LAKE WATERSHED IN SEQUOIA NATIONAL PARK AND FOR OTHER LAKES OF THE SIERRA NEVADA. A732-035: University of Arizona.

Objectives: To design and calibrate a compartmental model of Emerald Lake Watershed using data from water year 1986 and to develop a systems-theoretical model of the Watershed to assess the potential for lake acidification.

Findings: Further research on watershed process rates is needed before the compartmental model can be used for evaluating effects on other Sierra Nevada watersheds.

Importance to ARB's Program: In partial fulfillment of the Atmospheric Acidity Protection Program, this model was used as an aid to understanding watershed processes and how they may be altered by acidic deposition. It was also used in the design of experiments in the watershed.

ASSESSING THE RESPONSE OF EMERALD LAKE, AN ALPINE WATERSHED IN SEQUOIA NATIONAL PARK, CALIFORNIA, TO ACIDIFICATION DURING SNOWMELT USING A SIMPLE HYDROCHEMICAL MODEL. A732-034: United States Geological Survey.

Objectives: To develop a watershed acidification model based on the hydrology of and the mineral weathering rates in the Emerald Lake watershed.

Findings: The investigators recommend that additional work be done to improve existing databases on rates of mineral weathering and soil processes, the timing and magnitude of snowmelt episodes, and the rates of sulfate adsorption by watershed soils. The model identified the greatest acidic stress to Emerald Lake as that which occurs when acidic rainstorms coincide with snowmelt.

Importance to ARB's Program: The model was used to direct field experimentation and to predict the consequences of changes in the amount of acidic deposition and its chemical makeup on high-elevation watersheds and surface waters.

BIOLOGICAL AND CHEMICAL CHARACTERISTICS OF EMERALD LAKE AND STREAMS AND THEIR RESPONSES TO ACIDIC DEPOSITION. A6-184-32: University of California, Santa Barbara.

Objectives: To monitor water chemistry and aquatic populations in Emerald Lake in the Southern Sierra Nevada and its associated streams. Special emphasis was placed on monitoring populations of brook trout and stream invertebrates.

Findings: Though no direct biological damage was recorded at this site, the effect of polluted rainstorms in May 1987, when the chemistry of Emerald Lake was dominated by dilute snowmelt, may have been to exacerbate the adverse impacts of episodic acidification that occur during snowmelt.

Importance to ARB's Program: The report for this study provided a compilation and synthesis of the biology and hydrochemistry of Emerald Lake to aid the Board in considering the need for a standard in the Atmospheric Acidity Protection Program.

SNOW, SNOWMELT, RAIN, RUNOFF, AND CHEMISTRY IN A SIERRA NEVADA WATERSHED. A6-147-32: University of California, Santa Barbara.

Objectives: To develop a statistical sampling regime for obtaining estimates of parameters that influence snow accumulation in the Emerald Lake watershed.

Findings: The annual mass of water that entered the basin closely matched the measurements of outflow through streams, evaporation, and sublimation. Solutes from snowmelt and wet deposition were identified and measured during intense sampling periods in 1987 and 1988.

Importance to ARB's Program: The data will be used to evaluate natural variability in snow deposition and melt to predict the range of possible surface water responses during snowmelt. This information is needed to fulfill ARB's goal of documenting trends in chemistry of lakes and stream watersheds under the Atmospheric Acidity Protection Program.

CHARACTERIZATION OF YEAR-ROUND SENSITIVITY OF CALIFORNIA'S MONTANE LAKES TO ACIDIC DEPOSITION. A5-203-32: University of California, Santa Barbara.

Objectives: To evaluate Emerald Lake watershed as to whether its hydrological characteristics are representative of high-elevation lakes in the Sierra Nevada.

Findings: Important differences in hydrologic characteristics were observed among the high elevation lakes surveyed in the project.

Importance to ARB's Program: These data related the more detailed information obtained from Emerald Lake to a range of lake types found in the Sierra. This information is needed in the consideration of a standard required by the Atmospheric Acidity Protection Program.

Particulate Matter Studies

Particulate Matter Studies

Projects in Progress

LOSS OF PARTICLE NITRATE FROM TEFLON SAMPLING FILTERS: EFFECTS ON MEASURED GRAVIMETRIC MASS. 96-305: University of California, Davis.

Objectives: It is well known that systematic biases exist in the quantification of airborne particle concentrations by gravimetric determination. Many studies have shown that particulate nitrates, which are one of the main components of fine particle pollution in California and the Western U.S., are easily volatilized from Teflon filters. The objective of this proposal is to prepare a comprehensive review of existing data to assess the magnitude of nitrate losses due to volatilization from Teflon sampling filters and quantify the bias in gravimetric mass determination resulting from nitrate loss.

Importance to ARB's Program: This study will be useful in elucidating problems associated with use of Teflon filters and will result in concrete recommendations that can be considered by the U.S. EPA for particulate matter rulemaking.

AIRCRAFT SAMPLING TO DETERMINE ATMOSPHERIC CONCENTRATIONS AND SIZE DISTRIBUTIONS OF PARTICULATE MATTER AND OTHER POLLUTANTS OVER THE SOUTH COAST AIR BASIN. 96-315: California Institute of Technology.

Objectives: To determine vertical distributions, concentrations, and size distributions of particulate matter (PM) and its constituent chemical species, and to measure parameters related to visibility reduction such as light scattering coefficient above the South Coast Air Basin (SoCAB).

Importance to ARB's Program: With the advent of small, highly instrumented aircraft capable of performing measurements aloft in large, complex regions like the SoCAB, aircraft sampling has become an essential component of field programs aimed at producing a comprehensive picture of the dynamics of pollutant formation during episodes of high particulate matter concentration. This study will provide such measurements during the 1997 Southern California Ozone Study - North American Research Strategy for Tropospheric Ozone (SCOS97-NARSTO). With the new data, the ARB will be better able to characterize particles and their precursors in layers aloft and to understand the diurnal history of these particles. This understanding will contribute to promulgation of appropriate air quality control strategies.

AEROSOL TIME-OF-FLIGHT MASS SPECTROMETRY (ATOFMS) MEASUREMENTS OF INDIVIDUAL AEROSOL PARTICLES IN FIELD STUDIES. 96-307: University of California, Riverside.

Objectives: To apply advanced instruments that can measure, in real time, the size, mass, and chemical composition of individual airborne particles to the study of aerosol dynamics and to develop detailed aerosol characterizations at various locations in California. Projects include aerosol trajectory studies in conjunction with the SCOS97-NARSTO, development of signatures for various PM sources, analysis of the temporal (diurnal, seasonal) variation in aerosols ("aerosol climatology") at Riverside, studies of aerosols in the San Joaquin Valley, and studies of aerosol chemistry in ambient air.

Importance to ARB's Program: The control of airborne particles (PM10 and PM2.5) requires identification of the sources of directly-emitted particles and detailed understanding of atmospheric particle dynamics, especially the formation of "secondary" particles from "precursor" gaseous pollutants. The new ATOFMS measurement technology permits sampling and experimentation that was previously prohibitively expensive

or too time-consuming to be practical. Studies planned for this technique will give fundamental insight into the formation of secondary pollutants, which dominate the PM2.5 in Los Angeles and other western cities, and will advance knowledge regarding interactions between natural aerosols (e.g., sea salt) and human-generated pollutants.

LOSS OF PARTICLE NITRATE FROM TEFLON® SAMPLING FILTERS: EFFECTS ON MEASURED GRAVIMETRIC MASS. 96-305: University of California, Davis.

Objectives: To quantify the magnitude of the loss of nitrate from Teflon® sampling filters by analyzing existing sampling data.

Importance to ARB's Program: This study will be useful in elucidating problems associated with use of Teflon® filters and will produce concrete recommendations that can be considered by the U.S. EPA for particulate matter rulemaking.

IMPACT OF REFORMULATED FUELS ON PARTICLE- AND GAS-PHASE EMISSIONS FROM MOTOR VEHICLES. 95-330: University of California, Berkeley.

Objectives: To measure gaseous and particulate emissions from in-use motor vehicles operating under specific conditions in the Caldecott Tunnel east of Oakland. The results will be used, along with those of studies performed in the tunnel in 1994 and 1995, to determine the effects of cleaner burning gasoline on the amounts of ozone and particulate precursors emitted from motor vehicles.

Importance to ARB's Program: An evaluation of actual benefits is needed for determination of the success of the cleaner burning gasoline program. Better understanding of particulate matter emitted from motor vehicles will provide for more cost-effective programs for reducing exposure to unhealthy levels of PM10 and PM2.5.

AEROSOL TIME-OF-FLIGHT MASS SPECTROMETRY (ATOFMS) AS A REAL-TIME MONITOR OF INDIVIDUAL AEROSOL PARTICLES IN FIELD STUDIES. 95-305: University of California, Riverside.

Objectives: To develop advanced instruments that can measure, in real time, the size, mass, and chemical composition of individual airborne particles, and which can be moved as needed to sample at existing air quality monitoring sites.

Preliminary Findings: The ATOFMS instruments built under this contract have been successfully demonstrated in ambient particle monitoring, with good correlation between ATOFMS measurements and bulk samples collected by multi-stage impactors. Papers that detail instrument design and operation are published and/or in press. Papers discussing new aerosol findings gathered during the instrument test experiments are in preparation.

Importance to ARB's Program: The control of airborne particles (PM10 and PM2.5) requires identification of the sources of directly emitted particles and detailed understanding of atmospheric particle dynamics, especially the formation of "secondary" particles from "precursor" gaseous pollutants. ARB's aerosol research requires new measurement technology to overcome the weaknesses of conventional filter-based particle measurements.

CHARACTERIZATION AND CONTROL OF ORGANIC COMPOUNDS EMITTED FROM AIR POLLUTION SOURCES. 93-329: California Institute of Technology.

Objectives: To determine very complete source profiles for the carbonaceous fine fraction of particulate matter from major source categories in the Los Angeles area.

Importance to ARB's Program: The results will be used in a follow-up project to develop PM10 and PM2.5 control strategies for the Los Angeles area.

MEASUREMENT AND MODELING OF PM10 AND PM2.5 EMISSIONS FROM PAVED ROADS IN CALIFORNIA. 94-336: CE-CERT, University of California, Riverside.

Objectives: To develop a paved road emissions model to replace current generic dust loading calculations, and to develop a methodology for compiling statewide paved road PM10 and PM2.5 emissions inventories based on the improved model.

Preliminary Findings: The investigators have found that the equations recommended by the U.S. EPA (and currently used in emissions inventories in California) are not physically correct and that their outputs are not well correlated with actual emissions as measured in this study on various roadways in the Riverside, California, area. In addition, the investigators have found that the current methodology used to estimate roadway dust emissions cannot simply be revised or adjusted to generate more reliable emissions estimates. It is recommended that the physical processes controlling paved road dust emission be further studied to identify the underlying factors that control actual roadway emission rates.

Importance to ARB's Program: It was hoped that the results of this study could be used to restructure PM10 and PM2.5 emissions inventory procedures to estimate levels of emissions that are more realistic than those now calculated. However, the study revealed that local variables must be accounted for, and this study was not designed to gather emission data on a large enough sample of roads to identify those variables. Further research and development are required.

Completed Projects

1998

REVEGETATION TECHNIQUES FOR CONTROL OF FUGITIVE DUST IN THE WESTERN MOJAVE DESERT. 94-337: Statewide Air Pollution Research Center, University of California, Riverside.

Objectives: To identify cost-effective means by which to establish stable vegetative cover on abandoned farmland in the California deserts, and to quantify the emission reductions that would result from revegetation. This is a continuation of a cooperative project begun in 1994 with the U.S. Soil Conservation Service, the South Coast Air Quality Management District, Southern California Edison, and the University of California.

Findings: The main findings of this study were the following: Shrub cover cannot be reliably established from seeding or planting. Soil disturbance (tilling, etc.) delays shrub establishment. High soil nitrogen levels left over from previous farming were found to favor invasive, undesirable annuals; low-nutrient soils -- those more like natural desert soil -- resisted non-native species and were hospitable to colonization by native shrubs. Physical barriers (wind fences, etc.) are useful short-term controls. Stabilization of abandoned farmland may require several attempts before an "artificial" plant cover can be established.

Land-use history and soil nutrient and soil mycofloral status were found to influence perennial shrub establishment. Burning pest species without disturbing the soil was found to promote establishment of native plant cover. Physical treatments can provide immediate, effective dust suppression, but furrowing may be counterproductive if long-term stabilization is the goal.

Importance to ARB's Program: Dust from abandoned fields has been identified as the cause of episodes of high PM10 with attendant health and nuisance impacts in the Antelope Valley and elsewhere in California. This research documented the feasibility and effectiveness of several approaches to establishing a stable shrub cover on abandoned farmlands to reduce windblown dust.

1997

BIOLOGICAL MARKERS FOR CHARACTERIZATION OF POTENTIAL SOURCES OF SOIL-DERIVED AND GEOLOGICAL FUGITIVE DUST. 94-321: University of California, Davis.

Objectives: To explore the use of biochemical markers to distinguish among soil sources of airborne dust and to test these markers in source apportionment for fugitive dust. The biomarkers to be tested are phospholipid fatty acids and microbial DNA.

Findings: This "proof of concept" project successfully demonstrated that the soil biomarkers studied can be readily and repeatably extracted from both bulk soil and dust samples, that these chemical signatures allow discrimination of soils as dust sources by crop type and soil type, and that these techniques can be applied to non-agricultural soils as well (e.g., dirt roads).

Importance to ARB's Program: Soil-derived dust is a significant fraction of the particulate matter in California's air and contributes to violations of both State and Federal ambient air quality standards. Present analytical techniques cannot distinguish among the various sources of soil-derived dust. This research has shown that biological materials associated with particular soil environments (croplands, pasture, vacant urban land, dirt roads, etc.) can be used to pinpoint the sources of soil dust at various monitoring sites. Once source environments have been identified, appropriate control measures can be developed.

1995

EVALUATION AND DEMONSTRATION OF METHODS FOR REDUCING PM10 LEVELS IN THE ANTELOPE VALLEY (WESTERN MOJAVE DESERT) BY SUPPRESSION OF FUGITIVE DUST, YEAR 1. 92-347: Statewide Air Pollution Research Center, the University of California, Riverside.

Objectives: To test the practicality and effectiveness of various revegetation techniques as a strategy for controlling fugitive dust from abandoned farmland.

Findings: In February 1992 the United States Department of Agriculture Emergency Watershed Program (EWP), conducted an emergency soil stabilization project on 2500 acres in the western Antelope Valley. This ARB project assessed the success of those plantings. Three major findings can be stated at this time: 1) Even the modest success of the EWP in establishing shrubs from seed was a fortuitous outcome; seed germination in desert areas is highly unreliable. 2) In the absence of seed germination, soil disturbance associated with tilling and planting appears to increase dust generation compared to that from undisturbed bare soil. 3) The dust generated from all treatments decreased over the course of the study period, probably due to wind removing the loosest surface material. Follow-on work will assess other approaches to dust control and evaluate the long-term prospects for revegetation.

Importance to ARB's Program: Much of California's irrigated agriculture is practiced in desert or near-desert environments. The limited and unreliable rainfall in these areas effectively prevents natural re-establishment of a stable vegetative cover on abandoned farmland, leaving the farmland a source of wind-blown dust for many years. This project helped develop practical methods for stabilizing these soils. Lessons learned here should be applicable to other desert and semi-desert environments in California, including the southern San Joaquin Valley, the Salton trough, and the lower Colorado River Valley.

1994

A COLLABORATIVE OWENS LAKE AEROSOL STUDY. A132-105: Air Quality Group, the University of California, Davis. Research Note 1994-15.

Objectives: To identify the mechanisms of dust generation on the dry Owens Lake bed in Inyo County, the largest source of fugitive PM10 in the country. The project is in support of work funded by the California State Lands Commission to identify, test, and establish dust mitigation strategies for the lake bed.

Findings: The dust is generated by sand particles bouncing over the surface, ejecting small particles of dry salt crust into the air.

Importance to ARB's Program: A mitigation strategy was developed to halt the progress of wind-blown sand in support of the PM10 reductions mandated by the Federal Clean Air Act.

1993

DETERMINATION OF KEY ORGANIC COMPOUNDS PRESENT IN THE PARTICULATE MATTER EMISSIONS FROM AIR POLLUTION SOURCES. A932-127: California Institute of Technology. Research Note 1994-19.

Objectives: To better understand the carbonaceous fine fraction of particulate matter in the Los Angeles area.

Findings: The investigators identified over 400 different compounds in primary emissions from 18 different sources, and found many of these compounds in ambient samples from the Los Angeles area. They also identified compounds that can be used as unique tracers of emissions for several of the sources. Through comparison of the relative amounts of primarily emitted fine organic compounds to their ambient levels, an understanding of source/receptor relationships has been achieved.

Importance to ARB's Program: The results were used in follow-up projects funded by other organizations to determine the sources of PM10 and PM2.5 in the Los Angeles area.

1990

CARBONACEOUS SPECIES METHODS COMPARISON STUDY, INTERLABORATORY ROUND ROBIN: INTERPRETATION OF RESULTS. A832-154: G2 Environmental.

Objectives: To conduct a 13-member interlaboratory comparison for measurements of total carbon (TC), organic carbon (OC), and elemental carbon (EC), major constituents of ambient particulate matter. Interlaboratory measurement differences for OC and EC are typically quite large, and the object of this study was to determine the magnitude of the differences and the reasons for this variation.

Findings: The interlaboratory variations were attributed to several different causes. These results indicate where modifications in the analytical process need to be made.

Importance to ARB's Program: The resulting improvement in ambient particulate matter measurement accuracy is a necessary step toward attainment of the ambient air quality standards for PM10.

1989

DETERMINATION OF PARTICLE SIZE DISTRIBUTION AND CHEMICAL COMPOSITION OF PARTICULATE MATTER FROM SELECTED SOURCES IN CALIFORNIA. A6-175-32: OMNI Environmental Services, Inc. Research Note 1990-2.

Objectives: To determine the size distribution and chemical composition of particles directly emitted from selected sources: agricultural burning, soils, crude oil combustion, diesel trucks, paved and unpaved roads, residential wood combustion, sand and cinder storage dust, and unpaved urban areas.

Findings: Chemical profiles were developed for each of the sources in seven particle size categories and total suspended particulate. Chemical analyses were conducted for 43 different chemical species.

Importance to ARB's Program: The results of this study were used to relate source contributions to measured particulate concentrations in the atmosphere to provide insight into the environmental and human health impacts of specific sources, and for attainment of the State and Federal ambient air quality standards for particulate pollution (PM10).