The Air Pollution Prevention and Control Division's Program within U.S. EPA'S Office of Research and Development

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EPA MISSION AND RESEARCH PROGRAM

Since its creation in December 1970, the U.S. Environmental Protection Agency (EPA) has had as its primary goal the mitigation of adverse impacts of pollution on human health and the environment. Toward that end, the Agency implements important environmental legislation relating to pollution affecting all media. The Agency's mandate, to a large extent, is based on direction provided by the Clean Air Act (CAA), Clean Water Act (CWA), Resource Conservation and Recovery Act (RCRA), and other environmental legislation. Agency management must make critical decisions regarding the development of policy, guidance, standards, and the appropriate tools for implementing pollution abatement strategies. EPA's Office of Research and Development has the primary mission to provide high quality, timely, scientific and technical information in the service of Agency goals.

Figure 1, a simplified organizational diagram of the U.S. EPA, illustrates that the Agency is generally organized around its legislative mandate; i.e., media-oriented programs. Ten Regional Offices implement the Agency's program, working closely with state and local agencies. Since this article focuses on air pollution engineering research, it highlights two of the relevant Assistant Administrator components. The Air and Radiation Office is responsible for setting the agenda for the Agency regarding implementation of air (and radiation) abatement programs, especially implementation of the recently passed Clean Air Act Amendments. The Research and Development Office provides scientific and technical information to support Agency programs. The following discussion focuses on air pollution problems and the engineering challenges associated with dealing with them.

AIR POLLUTION PROBLEMS

Without a viable atmosphere, the Earth would be barren. The atmosphere is Earth's "film" that nourishes life, regulates the climate, and protects life from harmful solar radiation. Human (anthropogenic) activities associated with industry, transportation, and even agriculture are having profound effects on the atmosphere, creating important health and environmental problems. Figure 2 is a simplified flowsheet of the major air pollutants, their transport and transformation in the atmosphere, and the problems they create. Anthropogenic emissions can directly contaminate the air we breathe or can be converted tn the atmosphere to harmful pollution; e.g., elevated ground level ozone caused by photochemical atmospheric reactions. Such emissions can yield serious environmental impacts, such as acid precipitation associated with atmospheric conversion of anthropogenic sulfur oxides and nitrogen oxides. Such emissions are increasing the troposphere's heat trapping properties, and chlorinated organics are degrading the stratosphere's ozone protective properties. As Figure 2 illustrates, gases such as sulfur oxide, nitrogen oxide, and carbon monoxide, all short-lived in the atmosphere, yield the most immediate health impact; whereas long-lived gases such as carbon dioxide and chlorofluorocarbons are associated with serious long-term atmospheric changes, such as global warming and ozone depletion.

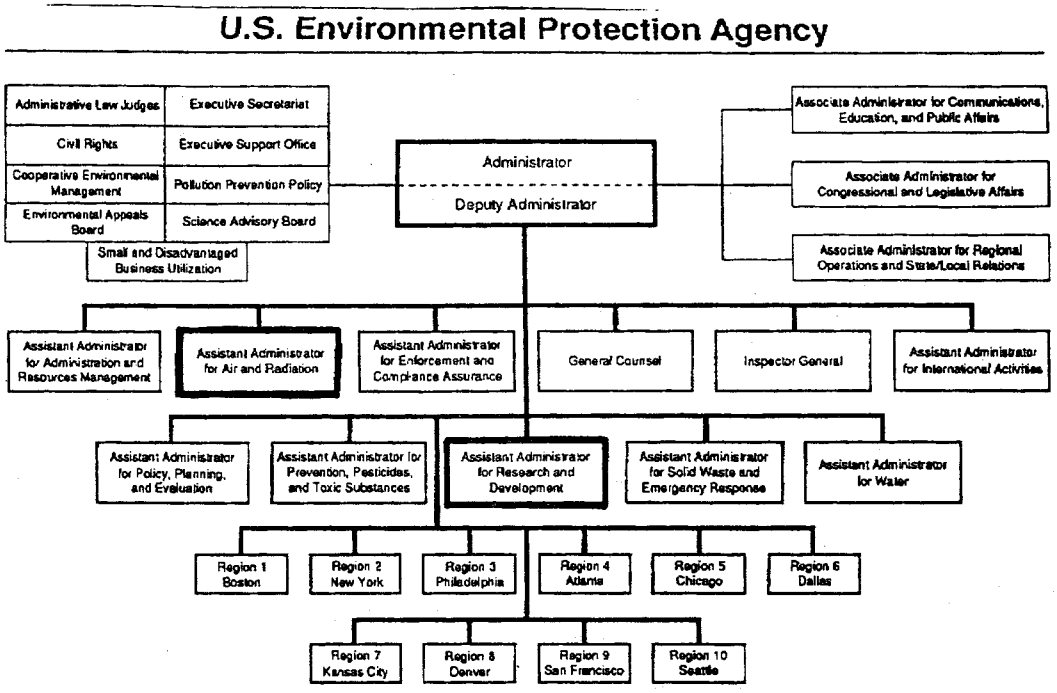

Fig. 1 U.S. Environmental protection agency

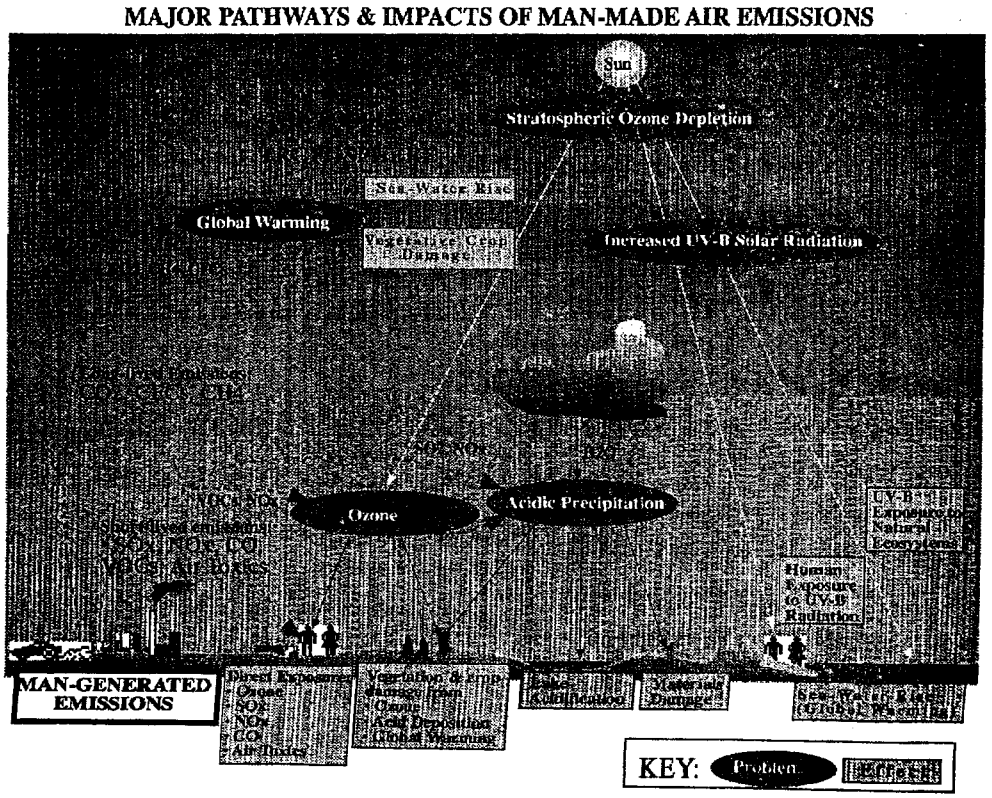

Fig. 2 Major pathways & impacts of man-made air emissions

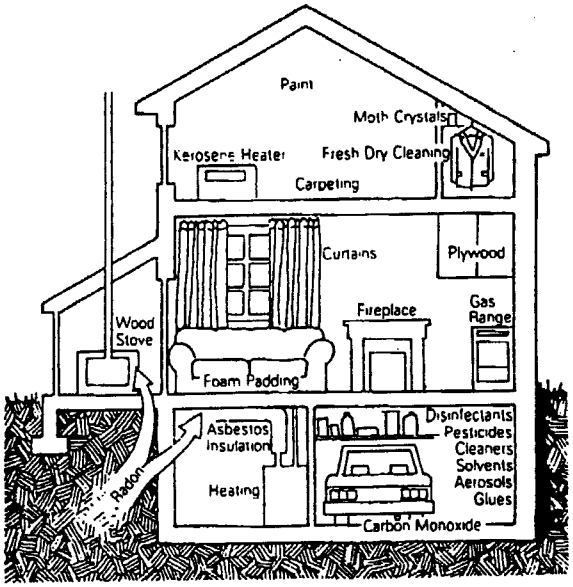

Fig. 3 Basic diagram of potential air pollution sources in the home

Also important are the health impacts associated with indoor pollution. Figure 3 shows potential air pollution sources in the home which can yield elevated and harmful levels of gases and particulates. In fact, some indoor environments have higher levels of toxics and other air pollutants than polluted outdoor air. A subtle yet major indoor pollution source is naturally occurring uranium and its daughter products which can yield radon gas capable of infiltrating a home and contaminating the indoor environment.

In 1989, former EPA Administrator William K. Reilly requested his Science Advisory Board (SAB) to seek the best opportunities to reduce environmental risks impacting all media. He was interested in updating an earlier report (EPA-1987) which prioritized environmental and health risks associated with anthropogenic pollution. Two panels were convened to carefully evaluate the magnitude of the environmental and health challenges associated with all the major environmental problems of the day. Table 1 summarizes the results of the SAB study and report (EPA-1990) to the Administrator. Air pollution problems dominate the risk categories. Insofar as environmental risks were concerned, stratospheric ozone depletion and global climate change were in the high risk category. Acid deposition and airborne toxic contamination were in the relatively medium risk category. Note that high publicity problem areas, such as oil spills and ground water pollution (associated with Superfund and hazardous waste sites), were deemed to be relatively low environmental risks. Regarding human health risks, the SAB found that ambient air pollution and indoor pollution are in the high risk category. They limited their ranking to just the high risk category since they felt there was insufficient information to rank other pollution problems. The generally high risks associated with air problems illustrate the critical importance of our atmosphere in sustaining life and human welfare.

Table 2 summarizes the major air pollution problems, their status with regard to action or regulation, relevant engineering challenges, and the relative risk per the SAB evaluation for both health and environmental impacts. These problems are complex, are at various levels of mitigative action, have high risks, and present substantial challenges to the engineering research community.

DIVISION RESEARCH PROGRAM

The Air Pollution Prevention and Control Division (APPCD) is one of 6 divisions of the National Risk Management Research Laboratory (NRMRL). The NRMRL is one of three Laboratories within the ORD. Figure 4 shows an organization chart of the APPCD. This Division and its predecessor organizations have been conducting research since the inception of EPA 20 years ago (its roots initially go back even longer than that, to pre-EPA days). Its research agenda has closely matched the Agency's priorities with regard to air and energy related pollution problems. For the first 10 years of the Division's existence, the emphasis was on developing and demonstrating cost-effective sulfur dioxide, nitrogen oxide, and particulate control technologies for fossil fuel combustion sources. In

ENVIRONMENTAL RISK: RISKS TO NATURAL ECOLOGY AND HUMAN WELFARE

Relatively High Risk

* Stratospheric Ozone Depletion
* Global Climate Change
- Habitat Alteration and Destruction
- Species Extinction and Overall Loss of Biological Diversity

Relatively Medium Risk

* Acid Deposition
* Airborne Toxics
- Herbicides and Pesticides
- Surface Water Pollution: Toxics, Nutrients
- Biochemical Oxygen Demand and Turbidity

Relatively Low Risk

- Oil Spills
- Groundwater Pollution
- Radionuclides
- Acid Runoff to Surface Waters
- Thermal Pollution

HUMAN HEALTH RISK

Relatively High Risk

* Ambient Air Pollution
    = Ozone, carbon monoxide, sulfur dioxide
    = Air Toxics: lead, arsenic, carcinogenic hydrocarbons
* Indoor Pollution
    = Radon
    = Combustion products
    = Toxic agents in consumer products
- Worker Exposure to Chemicals in Industry and Agriculture
- Pollutants in Drinking Water

* Air related problems

Table 1. SAB RANKING OF MAJOR ENVIRONMENTAL PROBLEM

AIR POLLUTION PROBLEM	STATUS	ENGINEERING CHALLENGES	RELATIVE RISK PER SAB (EPA-1990)
Indoor Air - quality of indoor air can be adversely affected by high concentrations of radon, organic chemicals, biocontaminants, and particles. Sources include natural uranium deposits(radon), consumer products & appli-ances, and construction & decorative materials.	- Non-regulatory program - Research being conducted to assess problem, define risks, and identify mitigrate measures - Info transferred to home-owners to provide guidance on risks and mitigration oppurtunities	-Understand and characterize sources of indoor air quality problems -Develop approaches to prevent problems via proper material selection/treatment -Develop cost effective organic & particle air cleaning devices -Develop low cost radon mitigration technology	Health Risk -High(radon risk alone estimated to cause about 10,000 U.S. lung cancer death annually)
High Levels of Atmospheric Ozone - Elevated ground level ozone concentrations can increases morbidity via respiratory tract problems, reduced lung function, aggravation of asthma, and eye irritation. Ozone is produced in atmosphere photochemically with VOCs and NO_2 as major ingradients.	- 1970/77 CAA attempted to resolve problem thru VOC control from autos & industrial sources. Program was not sufficiently effective; many areas still have eleva ted ozone levels - 1990 CAAA calls for enhanced control of VOC and NO_x sources. Included are autos, major stationary sources, and commercial and consumer products	-Develop autos capable of lower VOC/NO_x emissions via fuel, catalyst, or engine modifications -Develop replacement for various processes & pro-ducts to lower emissions of VOCs -Update in-process perfor-mance of VOC controls installed on major sources	Health Risk - High(tens of millions of persons are exposed to high levels of ozone during summer months)
Hazardous Air Pollution - Anthropogenic emissions of certain organic & inorganic chemicals can yield unacceptable ambient concentrations which can cause cancer and a variety of other lung diseases	- 1970/77 CAA attempted to deal with problem via a health-based standard setting program. Program was largely ineffective - 1990 CAAA (Title III) mandates stringent technology-based regulatory program for sources of 189 listed substances. Standards based on Maximum Achievable Control Technology(MACT) to be determined by EPA	-Redesign industrial pro-cesses to prevent formation of potential air toxics -Evaluate/develop controls that can cost effectively mitigate important air toxic emissions from key source categories	Health Risk - High(especially lead, arsenic, and carci-nogenic hydrocarbons) Environmental Risk - medium
Acid "Rain"/Health Impacts Associated with SO_2/NOx Emissions Emissions of SO_2 and NO_x primarliy from anthropogenic combustion of fossil fuels yield elevated of SO_2 and NOx which are harmful to humans and other species and can be cause via atmospheric processes acid deposition potentially detrimental to lakes, forests, and anthropogenic structures	- 1970/77 CAA mandated program to deal with SO_2 & NO_x via New Source Performance Standards (NSPS) based on "Best Available Control Technologies" and tailpipe NO_x standards for mobile sources - 1970/77 CAA mandated states to control local existing sources to achieve ambient standards for NO_x & SO_2 - 1990 CAAA activated acid deposition control program to control SO_2 & NO_x in two-phase program aimed at 10 million & 2 million ton reduction for SO_2 & NO_x emissions (by 2000), respectively.	-Develop and demonstrate low cost, effective technolo-gies capable of retrofitting existing coal-fired power plants -Develop fossil fuel and renewable electricity produ-cing technology yielding low SO_2, NO_x emissions at acceptable cost.	Health Risk - High for acid aerosols (SAB ranked "Ambient Air Pollutants " as high risk of which "acid aerosols" was high-lighted) Environmental Risk - Medium (Acid Deposition)

Table 2. MAJOR AIR POLLUTION PROBLEMS AND THEIR STATUS

AIR POLLUTION PROBLEM	STATUS	SELECTED ENGINEERING CHALLENGES	RELATIVE RISK PER SAB (EPA-1990)
Global Climate Change - Antropogenic emissions of CO_2, CH_4, CFCs and other green-house gases are increasing effectiveness of atmosphere in absorbing infrared radiation yielding the potential for unprecedented global warming, such warming will lead to scawater rise and could damage natural ecosystems unable to adjust to higher temperatures. Also precipitation pattern changes could adversely affect agriculture	- Atmospheric concentrations of CO_2, CH_4, CFCs are increasing at substantial rate - Global warming observed; 0.3 to 0.6℃ over last 100 years - Global Change Models (GCMs) predict warming of 1 to 4℃ within 100 years - International community de-bating need for mitigration program	-Develop and demonstrate renewable energy technologies; e.g., solar, biomass -Develop/demonstrate safe, economical nuclear (fission & fusion) power plants -Develop technologies to mitigate CH_4 emissions from major sources (e.g., landfills, pipelines, coal mines) -Develop energy conserving autos, motors, industrial processes	Environmental Risk -High(due to massive potential for long-term environmental damage to global ecosystems)
Stratospheric Ozone Depletion - Anthropogenic emissions of chlorinated organic chemicals, especially chlorofluorocarbons (CFCs) are destroying ozone in stratosphere. Ozone acts to protect life from potentially harmful ultra-violet rays from the sun	- NASA data show alarming rate of ozone depletion at all latitudes. (depletion is 1.8% to 4.7% per decade; highest at high latitudes) - Such depletion can yield millions of skin cancers and tens of thousands of cancer deaths - Potential for damage to sensitive ocean and land ecosystems - Most of the international community has agreed to CFC phaseout	-Develop products or chemical alternatives for CFC and related compounds for refrigeration, solvent cleaning, and foam insulation applications. -Develop cost effective recycling approaches to allow more time before massive equipment changes needed -Develop cost-effective techniques to convert or destroy stored CFCs	Health Risk - Although not ranked by SAB, author believes risk high since recent depletion rates suggest large numbers of skin cancer deaths over the next 50 years Environmental Risk - High (in light of thinning ozone layer, enhanced UV-B radiation will stress many sensitive organisms)

Table 2. Continued

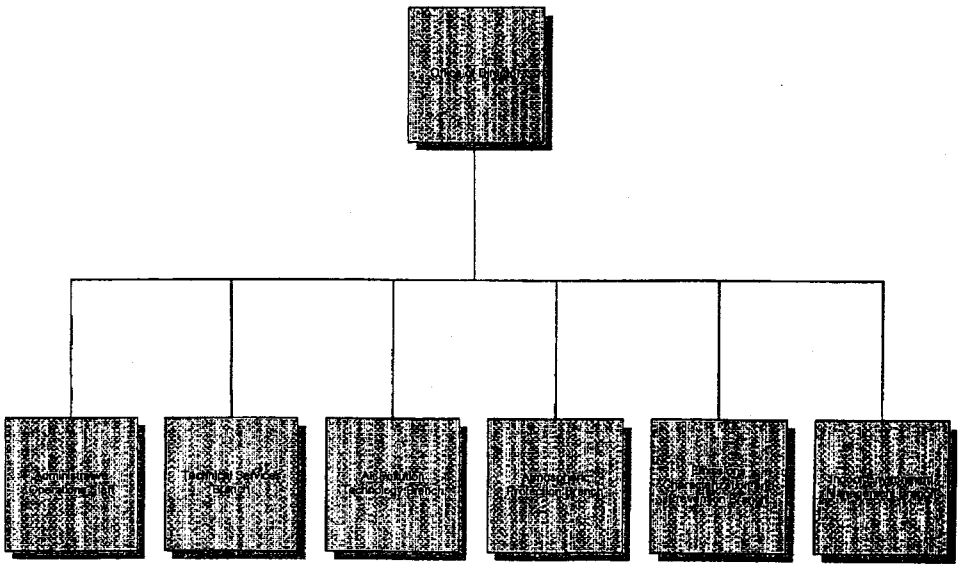

Figure 4. Air pollution prevention and control division

recent years, the program has expanded to deal with indoor air problems, including radon infiltration, and more recently it has been expanded deal with ozone depletion and global warming concerns.

APPCD has a staff of about 100 federal employees supplemented by about 50 on-site contractors. The fiscal year 1996 budget is about $17 million. Table 3 provides examples of past accomplishments of the APPCD research program. Such accomplishments include developing the state-of the art in sulfur dioxide and nitrogen oxide control, refining and demonstrating radon mitigation technology, and substantially increasing our knowledge of the sources and sinks associated with important indoor air pollutants. The Division has also been productive in characterizing and improving combustion in woodstoves, and elucidating the mechanism of dioxin formation from municipal waste combustors. The Division has worked cooperatively with industry to successfully demonstrate the feasibility of recycling refrigerant(CFC-12) from automobile air-conditioners and has synthesized and evaluated potential replacements of chlorofluorocarbons which appear quite promising.

As significant as have been the past challenges to the Division's research program, they pale in comparison to the awesome engineering challenges that face us as we deal with complex problems such as air toxics, and global warming. As Table 2 illustrated the engineering challenges associated with all the major air pollution problems are quite substantial and certainly beyond the resources of APPCD alone. It is clear that the private sector, the Department of Energy, the Department of Defense, as well as the Environmental Protection Agency, must work cooperatively and productively on an international basis to provide the technology we will need to sustain and improve our standard of living during a period of increased population growth and increased dependence on technology.

The balance of this discussion will be devoted toward briefly summarizing recent and ongoing EPA research associated with each of the major research programs dealing with the key environmental issues.

GLOBAL CLIMATE CHANGE

Global change risk management research investigated the viability of using biomass as a renewable energy source to produce an alternative transportation fuel and to generate power directly in small combustion systems. The FY96 program also included studies to improve the accuracy of U.S. and global greenhouse gas emissions estimates. In the biomass area. in-house and field research was conducted to further evaluate the viability of a promising technology known as Hynol which uses high temperature and high pressure gasification of biomass and steam reforming of the gasification products to produce methanol- a potential alternative transportation fuel. Bench-scale Hynol research evaluated the (1)hydro-gasification rate of woody biomass as a function of gas feed composition, particle size, temperature and pressure; and (2) the operating conditions best suited for steam reforming of the gasification products. Design for a pilot scale (50 lb/hr) facility to test the Hynol process at a larger scale were completed and activities to construct the facility initiated. The use of small biomass combustion system for direct power generation was also investigated with emphasis on (1) determining emissions which result from burning untreated and treated wood products such as utility poles, railroad ties, decking, plywood and sawdust; (2) developing fundamental data on the reaction rates and gas composition of various biomass fuels and feedstocks under a variety of gasification and combustion conditions and atmospheric pressures; and (3) demonstrating the feasibility of small biomass conversion technologies in actual field applications.

The emission component of the global change program focused on improving estimates of methane from man-made sources including coal mines and waste management facilities. The focus of the program was to improve the accuracy of methane emission estimates for the U.S. gas and coal industry and to further develop the methodology and emission factors needed to improve estimates of greenhouse gases(methane, N_2O)

from treated wastewater sources.

STRATOSPHERIC OZONE DEPLETION

Research on ozone depleting compounds focused on alternatives for refrigerator/freezers, motor vehicles, heat pumps, supermarket systems, and foam blowing applications. Property studies were conducted to evaluate the flammability, lubricant miscibility, materials compatibility and other pertinent characteristics of new chemicals identified as potential long-term replacements for OCD. Cooperative research with the private sector to evaluate new lubricants for use with alternative refrigerants and work to obtain fundamental property data on chemical mixtures which could be used as replacement refrigerants were emphasized. Studies to examine the performance of these new refrigerants in specific applications focused on alternatives for R-502 which is now used in supermarket systems, and alternatives for heat pump which now use HCFC-22. Second generation alternatives for refrigerator/freezers and automobile air conditioners were also studied due to the high global warming potential of the existing substitutes now in use.

TROPOSPHERIC OZONE-NOx, VOC CONTROL

Risk management research focused on improving estimates of ozone precursors (VOCs/NOx) emitted from mobile and biogenic (natural) sources and evaluation of low-cost technologies to reduce nitrogen oxides from stationary combustion sources. The mobile emissions program included studies of both light-duty gasoline powered vehicles and heavy-duty diesel trucks. The light-duty vehicle work was focused on development of the next generation mobile emissions model which will include improved capability to estimate how different modes of vehicle operation influence emissions. Studies were conducted to: (1) establish baseline fleet characteristics in multiple cities and determine the input of fleet turnover; (2) evaluate the effectiveness of inspection and maintenance programs; (3) evaluate current model capabilities to predict power enrichment (this leads to increased emissions); (4) better understand how driver behavior, vehicle type and traffic/roadway conditions influence emissions; (5) obtain improved data on vehicle use pattern to upgrade activity factors. In the diesel area, several truck tractors were used to collect actual on-road emissions data in an effort to improve the accuracy of emissions estimates for heavy-duty diesel vehicles. The biogenic emissions research program focused on studies to : (1) improve information on the rate of biogenic VOC (i.e., isoprene, monoterpenes and methyl butenol) emissions at the leaf-level under various conditions such as high temperature episodes and moisture stress events and during different seasons; (2) incorporate improved biogenic emissions data into the Biogenic Emissions Inventory System(BFIS); (3) measure fluxes of biogenic emission at large scale to compare measured emissions with BEIS predicted emissions; and (4) reduce uncertainties associated with soil NOx emissions.

NOx control technology research focused on innovative low-cost control approaches applicable to small combustion sources located in ozone non-attainment areas. Specific activities included : (1) a cost-shared demonstration with the California Air Resources Board (CARB) and the cement industry to demonstrate the effectiveness of using advanced reburning to reduce NOx emissions from cement kilns; (2) bench and pilot scale testing of combined sorbent injection and combustion modification NOx control systems; and (3) investigation of NOx control methods such as ignition timing retard, external gas recirculation (EGR) and water/catalyst injection applicable for the fleet of U.S. Navy diesel engines.

SULFUR OXIDE/ACID "RAIN'

APPCD has had a long tradition of innovative and productive research in the sulfur oxide control area (Table 3). In recent years, emphasis has been on developing technology which could be applicable to

Table 3. Examples of Past Accomplishments of EPA's Air Pollution Prevention and Control Division

SOx and NOx Control

- Worked cooperative with industry to develop current stat-of the are technology for controlling SO_2 from coal-boilers; lime and limestone flue gas technology. Currently 80,000 MWE of such technology is utilized by U.S. utility industry representing an investment of $13 billion and controlling 2 million tons per day of SO_2.

- Identified the role of fuel nitrogen in the generation of NOx from coal- and oil- fired boilers. Based on this research, developed low-NOx burners utilizing staged combustion(rich fuel zone) principles to limit NO formation. Such combustors are the basis of technology-based regulations for utility and industrial boilers in the U.S.

- Successfully developed and demonstrated Lime injection Multistage Burner (LMB) technology for low cost SO_2 and control NOx for existing wall-fired boilers. This technology is expected to be a candidate for older, small boilers requiring acid rain controls mandated by the 1990 Clean Air Act.

- Developed and demonstrated, in Ohio and Ukraine, reburning for control NO_x of coal-fired boilers. Reburning uses natural gas combustion in the downstream side of the boiler to decompose NO formed in the main combustor. This technology appears capable of 50-60% control and is especially significant for certain boiler types(e.g., cyclone boilers) where low-NO_x combustion systems have not been successful.

Indoor Air

- Refined and demonstrated sub-slab ventilation technology to allow mitigation of homes and other buildings with elevated radon levels. This technology now being offered commercially by hundreds of mitigators across the country; deemed the technology of choice for most applications.

- Test methods for determining emission rates of pollutants from a variety of products have been developed (and approved by ASTM). Builders and manufacturers are increasingly using these test methods to evaluate their consumer products.

- Developed theory of pollutant moment to and from sinks (indoor surfaces which adsorb and re-emit pollutants). Developed and utilized indoor air model to relate indoor concentrations of pollutants to sources, sinks and building characteristics. Model has been validated via residential building testing.

Air Toxics/VOC Control

- Characterized emissions from woodstoves, documenting high emission levels of organics and particulates from first generation (pre-New Source Performance Standards (NSPS)) stoves. Identified frequent degradation in environmental performance of second generation catalytic and non-catalytic stoves. Recently developed a stove using a small gas source for enhanced combustion, which yields exceedingly low pollutant emissions. Tests are planned with an industrial papers to field test this innovative stove concept.

- Made major contribution in elucidating mechanism of dioxin formation fro, municipal waste combustors. Determined that HCl, is necessarily precursor, quantified effects of reaction temperature, and identified importance of cooper as a catalytic agent.

- Maintain and operate is partnership with the air regulatory office an innovative assistance program for sate an local air agencies and EPA's Regional Offices. The Control Technology Center provides information for controlling important sources of air toxics and VOCs.

Stratosphere Ozone Depletion

- Worked cooperatively with industry to successfully demonstrate feasibility of recycling refrigerant (CFC-12) from automobile air conditioners. This is resulting in major changes in the repair industry relating to routine cleaning and recycling of used refrigerant during the repair process.

- Synthesized and evaluated potential replacements for CFCs which appear to have attractive properties for refrigeration and foam blowing application. Two classes of compounds have been evaluated; fluorinated ethers and propane/butane-based hydrofluorocarbons (HCFCs). Replacements have been identified for CFC-114 and CFC-11 which look particularly promising. Recently, the U.S. Navy has selected an APPCD ships. The Navy estimates a $350 million savings versus hardware changes which would have been necessary in the absence of the APPCD-developed chemicals.

Global Climate Change

- Have made major contributions in characterizing emissions of methane fro, anthropogenic sources. Emphasis has been on natural gas extraction transportation and distribution; coal mines and landfills.

- Successfully demonstrated application of fuel cell to process methane-rich land fill gas to generate electricity.

- In process of testing potential breakthrough technology allowing utilization of biomass (with methane as co-feedstock) to yield low cost methanol for transportation applications.

retrofit on existing coal-fired boilers for acid "rain" control. The goal is to develop sulfur dioxide control technology, substantially less expensive than conventional wet limestone scrubbing technology. Such technology will have to be low in cost, reliable, and capable of good sulfur dioxide (SO_2) removals. Two technologies which were recently developed are limestone injection multistage burners (LIMB) and advanced silicate (ADVACATE).

LIMB is a retrofit technology developed by APPCD. This approach utilizes low nitrogen oxide (NOx) bueners and upper furnace sorbent injection utilizing a high surface area lime sorbent. The Division has successfully demonstrated this low-capital-cost technology on both a wall-fired coal boiler and a tangentially-fired boiler. The technology successfully achieved its goals of goals of removing up to 60% SO_2 and controlling up to 50% NO_x from initial levels. Taken together, wall-fired and tangentially fired units represent about 90% of the current coal-fired boiler population. LIBM technology could be utilized by the utility industry for certain smaller, older boilers for which this technology is cost effective relative to the high capital cost but higher performance (90%) wet limestone scrubbers.

The Division tested at large pilot scale what could be a breakthrough technology. Engineers from APPCD, the University of Taxas, and Acurex Corporation have co-invented the ADVACATE process which is based on the ability of lime and flyash to form non-crystalline calcium silicate under carefully controlled conditions. The silicate sorbent is injected as a damp powder and is typically four to five times as reactive as lime toward SO_2. The unique ability to carry an equal weight of water and be handled as a dry powder allows the ADVACATE sorbent to be integrated into a process which is substantially lower by about 50% in both capital and operating costs than conventional wet limestone system. Pilot testing has been conducted; full-scale demonstration is required before this technology can be considered available for commercialization.

AIR TOXICS CONTROL

Risk management research focused on technologies to reduce emissions of hazardous air pollutants from combustion sources. The focus of the program was on reduction of trace metals and toxic organic compounds. Specific activities included: (1) characterizing metal transformation, speciation, vaporization, and aerosol formation; (2) exploring technologies such as sorbents to improve the collection efficiency of toxic metals; (3) studying the effects of flue gas temperatures, quench rates, and sorbents properties on the formation, destruction and capture of halogenated organics; (4) developing sorbents for mercury emissions control; (5) identifying conditions which lead to the formation of dioxin-like compounds during combustion of natural gas, oil and/or liquid wastes; and (6) determining the effects of fuel composition and combustion conditions on the formation and emissions of hazardous trace organics and metals. Technical assistance was also provided through the Control Technology Center which provides information on the performance and cost of air pollution emission reduction approaches to state and local environmental offices, industries, small businesses, other government agencies, universities and foreign governments. The technical assistance provided included telephone hotline responses to inquiries concerning air pollution issues, engineering projects to determine answers to pressing state and local problems and computer access to a bulletin board system which provides important information, data and reports.

INDOOR AIR QUALITY

Risk management research focused on characterizing sources of indoor air pollutants and developing data to determine the capability of air cleaners and ventilation systems to reduce concentrations of indoor air pollutants. Source characterization studies were conducted to quantify latex paint emissions including determining the sink (absorption and re-emissions of a particular indoor contaminant) behavior of the polar

VOCs typically found in latex paint products. In addition, construction of a new, large state-of-the-art chamber was completed. This new facility provides the capability to investigate parameters which influence indoor emissions that cannot be evaluated using small chambers, such as paint application, and use of personal care products in the home and provides the capability to evaluate emissions from larger indoor products, such as copiers. Initial testing of the facility was conducted to document baseline performance including air distribution, velocities, and wall losses. Ventilation studies were conducted to determine the effectiveness of air duct cleaning on common porous and non-porous surfaces. Methodologies to determine cleaning effectiveness were developed and validated. Air cleaner studies were conducted to determine the overall performance of volatile organic compound (VOC) and particulate air cleaners. The impact of upset conditions on air cleaner performance and the capability of air cleaners to reduce biocontaminant levels were determined. In addition, data were collected on the re-emission of collected VOCs.

COMBUSTION RESEARCH

Many air pollutants result from the combustion of fuels or wastes. Therefore, the combustion research program at APPCD covers a broad range of stationary sources, including boilers, industrial process equipment, incinerators, and engines. The early focus of APPCD's combustion program was the control of NOx by combustion modification. A most significant recent research activity in this area has been the development of what is referred to as reburning technology for NOx control. Reburning involves adding a clean fuel, such as natural gas, in a downstream portion of a coal boiler with the aim of chemically reducing any NOx formed in the hotter, earlier stages of combustion. Research in-house and extramurally has suggested that this can be an effective technology, especially for boilers difficult to control for NOx by conventional combustion modification techniques. This technology has been successfully demonstrated on a 108 MWe Ohio Edison cyclone boiler. Tests have indicated that 50% to 60% control is achievable with reasonable additions of natural gas. Reburning tests have been successfully completed on a 300 MWe boiler in the Ukraine with similar results

The combustion program has also investigated controlling air toxic emissions from municipal waste and hazardous waste incineration. In-house research for municipal incinerators has centered on dioxin formation and destruction, and on mercury capture. An in-house pilot scale combustor capable of burning municipal waste, biomass or coal, has been built and is now in operation. A Resource and Conservation and Recovery Act (RCRA) research, development, and demonstration permit for hazardous waste incineration is in place allowing testing of a wide variety of hazardous wastes.

SUMMARY

Air pollution problems are serious and present significant challenges to the engineering research community. EPA's engineering research programs have shifted from a primary focus on SO_2 and NOx pollution control to more complex and more difficult problems such as indoor air quality, air toxics, and global climate change.

EPA research engineers are working closely with other research organizations in both the private sector and other federal research organizations to identify, evaluate, and develop cost-effective engineering solutions. The APPCE works closely with the EPA regulatory and regional offices to ensure that the best engineering information is utilized to formulate and implement the Agency's environmental protection program.

REFERENCES

1. USEPA, Unfinished Business: A Comparative Assessment of Environmental Problems: Office of Policy, Planning and Evaluation, Overview Report (NTIS PB 88-127048) February 1987

2. USEPA, Reducing Risk: Setting Priorities and Strategies for Environmental Protection, SAB-EC-90-021, 1992