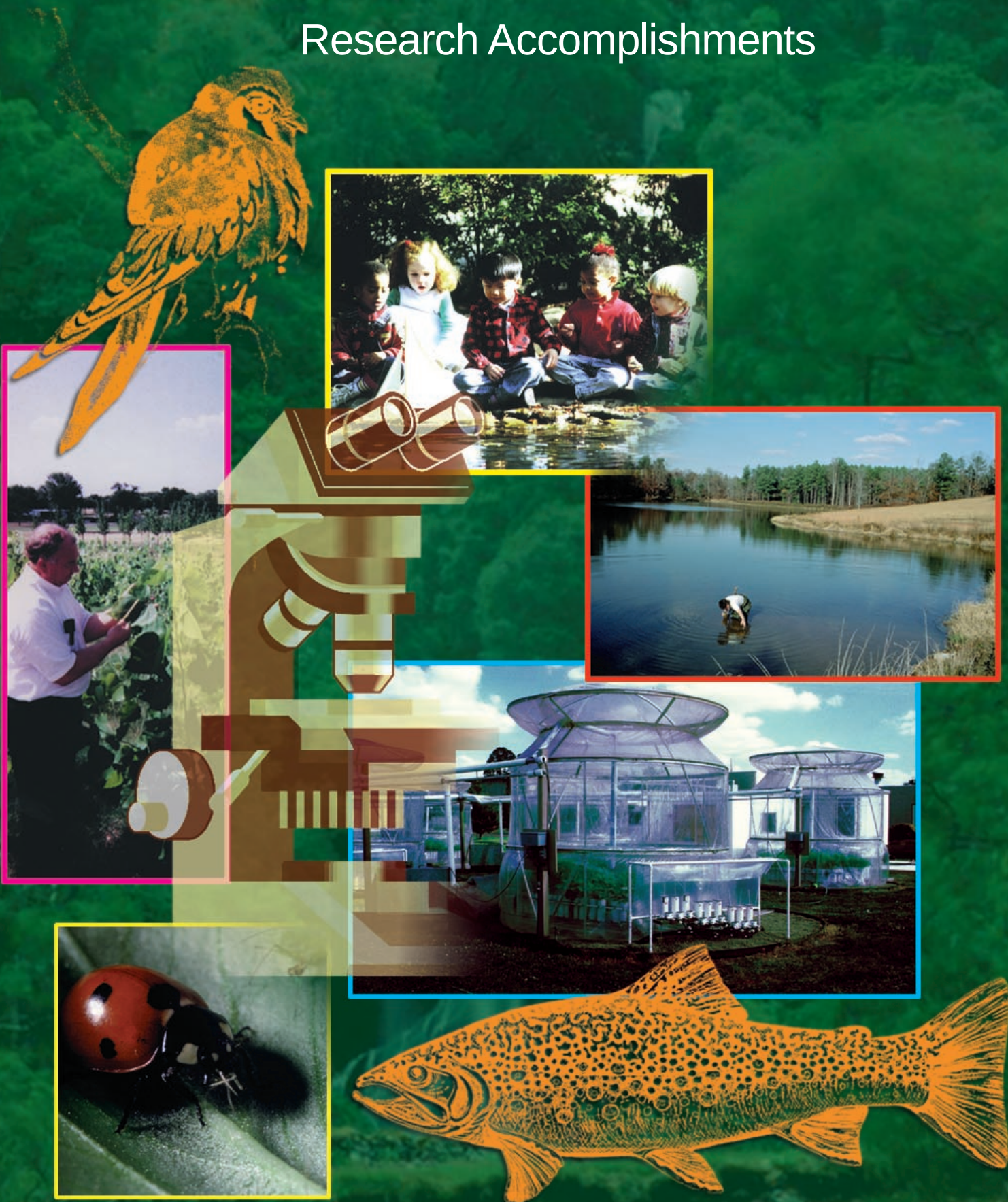


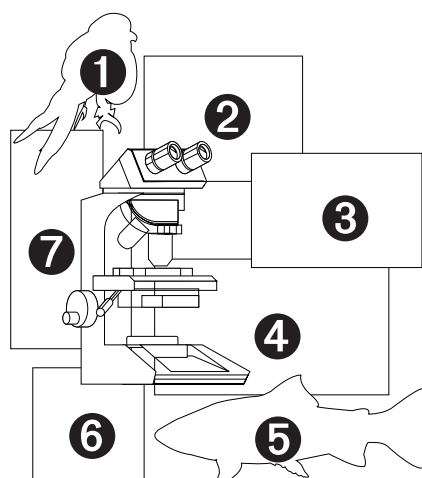


Research and Development

Fiscal Years 1995-1996

Research Accomplishments





- 1 The American Kestrel is one of the species of birds in the United States classified as a neotropical migratory bird. In the course of their yearly cycle, birds like the American Kestrel may pass through a dozen or more countries, each with their own conservation priorities, politics, and problems. ORD and EPA have joined *Partners in Flight*, a coordinated effort to maintain populations of neotropical migratory bird species. Launched by the National Fish and Wildlife foundation, the partnership includes 15 federal agencies, over 60 state agencies, 30 private conservation groups, and 145 forest products industries. (illustration: Keith Hansen)
- 2 Children's exposures to pollutants and their potential health effects differ from those of adults. As part of an EPA initiative, ORD scientists research the factors that make children more vulnerable than adults to health effects from pollutants. (photo: Steve Delaney)
- 3 Since 1990, scientists, like the one collecting samples from this lake, have been gathering data for the Environmental Monitoring and Assessment Program for demonstrating concepts and assessing environmental protection programs. (photo: U.S. EPA)
- 4 The open top chamber, 12 feet tall and 18 feet in diameter, was designed in the late 1970s by scientists from EPA and the U.S. Department of Agriculture. Used all over the United States and Europe to study the exposure of plants and trees to pollutants, this gazebo-like structure allows scientists to monitor adverse effects under conditions close to actual light, temperature, and relative humidity. Recently, ORD scientists used the chambers to measure the response of plants to various levels of ozone. Data from these studies have been incorporated into the proposal for revising the secondary standard for ozone. (photo: U.S. EPA)
- 5 Trout serve as a sensitive model for evaluating the effects of a variety of stressors on aquatic species.
- 6 Using biological alternatives to chemical pesticides—like the ladybug—can reduce exposures from water runoff and spray drift.
- 7 Scientists with ORD's Superfund Innovative Technology Evaluation (SITE) program, the U.S. Geological Survey, and the Air Force are evaluating phytoremediation, a process that uses plants to clean up contaminated soil and water, at the former Carswell Air Force Station. Rows of Eastern Cottonwood trees planted at this site degrade contaminants in the soil near the tree roots, draw contaminants in the soil up through the roots and metabolize them into harmless compounds, and transpire them through the leaves into the atmosphere.

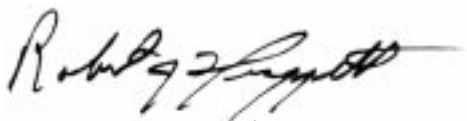
To Our Readers—

Research results from EPA's Office of Research and Development (ORD) help protect and improve the quality of the environment for everyone, everyday. Water quality criteria developed by our scientists are used by every state in the nation for issuing permits to discharge into lakes and rivers. Risk assessments done by our scientists are incorporated into the standards set for the air pollutants regulated by the National Ambient Air Quality Standards. Neurotoxicity test guidelines developed by our scientists are part of the testing requirements for screening pesticides for neurological effects. These are but a few examples of how results from ORD's research are integral to EPA activities as well as environmental protection efforts throughout our nation.

Our program today is based on over 25 years of environmental research, much of it done by ORD, funded by ORD, or influenced by ORD work. From this knowledge base, and guided by our Strategic Plan, ORD is tackling the highest priority environmental problems—those of the greatest risk, those with the greatest uncertainty associated with characterizing risk, and those where there is the greatest need to reduce the costs and improve the effectiveness of managing risk. In addition, all aspects of ORD's program, including research plans, products, and our organizations are being evaluated by panels of outside scientists through our peer review program.

Understanding the science—and the scientific debates—surrounding environmental issues is critical for making sound public policies and economic investments. To ensure that results from ORD's research program contribute positively to such debates and to environmental protection, we must explain our efforts to many stakeholders. This report is one effort towards communicating our science more broadly. Accomplishments from our FY 1995-96 in-house program are discussed, as is the progress we have made implementing our expanded extramural program.

ORD's program is strong—with hard work at the bench and in the field, ongoing consultation with EPA's program and regional offices, and energetic collaboration with our colleagues in industry, academia, and other government research organizations. We will continue to bring our science, creativity, and technical expertise to solving environmental problems today, and in the future, by building on the scientific foundation of our work in the past.



Robert J. Huggett, Ph.D.

Assistant Administrator, Office of Research and Development

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INTRODUCTION

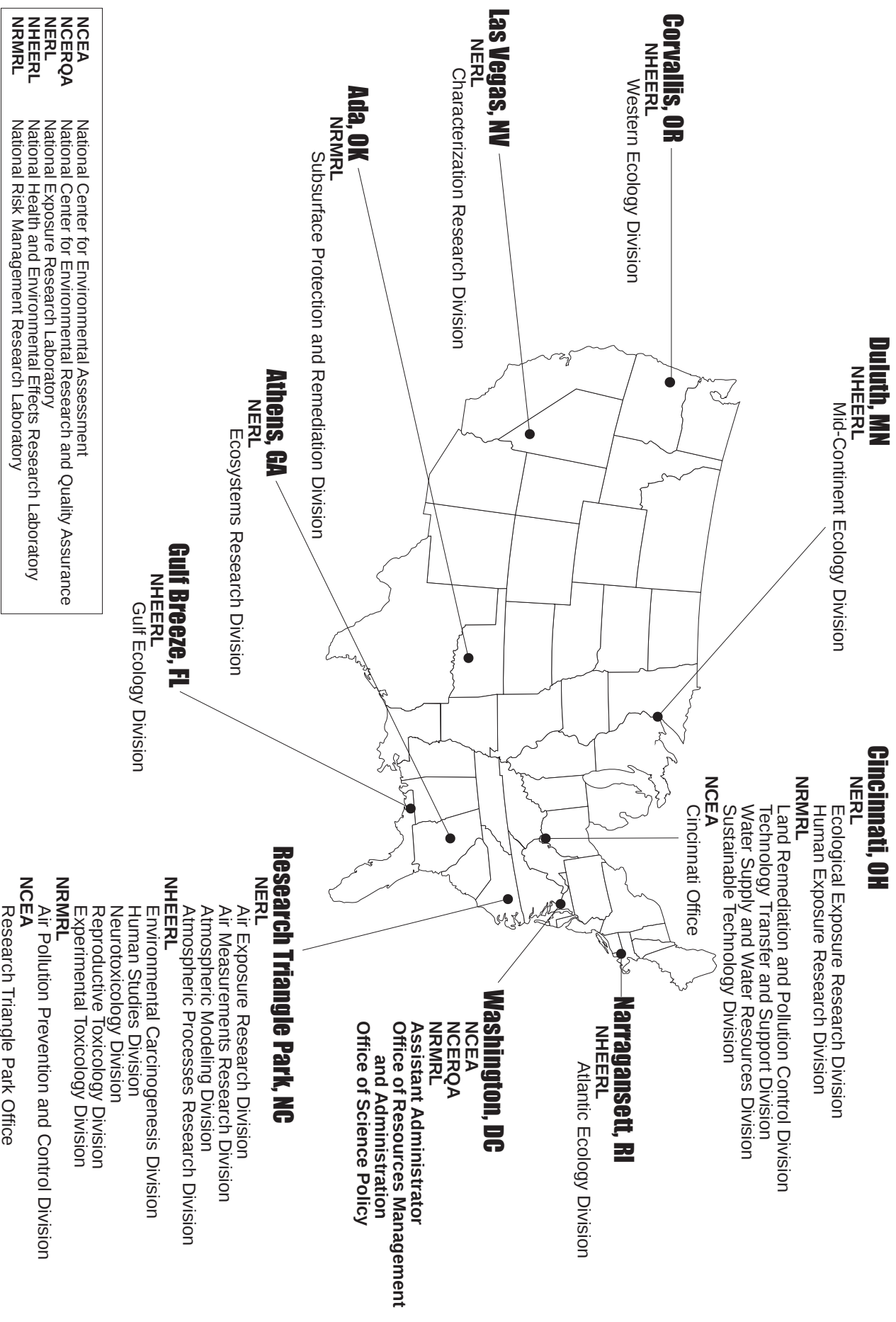


EPA's Office of Research and Development (ORD) ✓¹ is composed of three national laboratories and two national centers with research facilities located across the United States. The missions of the laboratories or centers listed below each align with a component of the risk paradigm: effects, exposure, assessment, or management.

- ▶ National Health and Environmental Effects Research Laboratory (NHEERL) performs laboratory and field research to understand health and ecological effects of exposures to man-made stressors and the likelihood the effects will occur under conditions of environmental exposure.
- ▶ National Exposure Research Laboratory (NERL) performs research to improve the scientific bases for human and ecosystem exposure assessment that are part of the risk assessment, risk management, and compliance processes.
- ▶ National Center for Environmental Assessment (NCEA) serves as a national resource for the overall process of risk assessment, conducting assessments and developing new methods and tools for risk assessment.
- ▶ National Risk Management Research Laboratory (NRMRL) provides the scientific basis for environmental risk management, focusing on characterizing sources of pollution and technology for preventing and solving environmental problems.
- ▶ National Center for Environmental Research and Quality Assurance (NCERQA) ✓ ensures the highest quality of science possible for Agency decisionmaking through ORD's extramural grants and fellowships, peer review, and quality assurance programs.

¹ A check mark ✓ indicates that an Internet address related to the subject is provided at the end of this document.

Locations of ORD Laboratory and Center Divisions



With research facilities across the country and professionals in many scientific and engineering disciplines, ORD's research program addresses a wide range of environmental science questions.

During FY95-96, ORD built on the success of its first Strategic Plan, implementing a strategic decisionmaking process and finalizing the more effectively organized laboratory structure. ORD has a results-oriented management process necessary to meet the requirements of the Government Performance and Results Act. With heightened attention to peer review, ORD has improved the quality and credibility of its science. Partnerships with the scientific community across the country have been expanded through the Science To Achieve Results (STAR) program. And ORD has expanded its research partnerships with other federal agencies to leverage total investments in environmental science.

ORD uses a risk-based strategic planning process to set priorities among the possible research areas. In consultation with EPA's programs and regions and the external scientific community, ORD identifies potential research areas. The pool of potential topics is narrowed by selecting areas that clearly will contribute to fulfilling Agency mandates. ORD then applies a series of human health, ecological health, and risk management criteria to set priorities according to their potential to support effective risk assessment and enhance risk reduction.

Using this planning process, ORD has established six high-priority areas that will receive expanded attention within the broader ORD program. This report highlights the research results and science activities in these six priority areas, identified and outlined in 1997 *Update to ORD's Strategic Plan*, April 1997:

- Safe Drinking Water
- High Priority Air Pollutants
- Emerging Issues
- Research to Improve Ecological Risk Assessments
- Research to Improve Human Health Risk Assessments
- Pollution Prevention and New Technology for Environmental Protection

These high priorities include three areas of research on specific environmental problems and three broadbased areas of research on methods and approaches that will impact many additional topics. While work in the priority areas has been ongoing in ORD's laboratories, the prioritization of the research within ORD's program is new.

In addition, this report includes examples of grants awarded through the STAR program to give the reader a sense of how the extramural program complements ORD's in-house research program. Taken together, the programs demonstrate the breadth, significance, and potential of ORD's research.

Science To Achieve Results— Research Grants and Fellowships Focus on Priority Environmental Issues

The STAR Program is new, one result of ORD's transformation to provide better science specifically targeted to meet the needs of EPA decisionmakers. NCERQA administers ORD's competitive research grants and graduate fellowship program to engage the best scientists from this country's universities and non-profit centers in our research program, and to ensure the highest possible quality of science in areas of highest risk and greatest importance to the Agency. The areas of research funded by the program are aligned with the priority areas of ORD's Strategic Plan.

The four components of the STAR program include:

- *Focused Requests for Applications (RFAs)*—are targeted to specific research topics defined by the ORD Strategic Plan and address the science needs of EPA's programs and regions. The program supports investigator-initiated research by universities and other non-profit research institutions that complements in-house activities.

- *Exploratory Grants*—provide support for investigator-initiated grants in broad areas related to the Agency’s mission but not covered by RFAs—such as environmental chemistry and physics, and the health and ecological effects of pollution.
- *Graduate Fellowship Program*—provides support for master’s and doctoral students in environmental sciences and engineering by recruiting the “best and brightest” into environmental science and technology for careers with government, laboratories, and industry.
- *Environmental Research Center Program*—provides stable funding for universities to conduct long-term coordinated research on complex or emerging environmental issues. There are four competitively established Environmental Research Centers. ✓

Since the program was launched in FY94, NCERQA has administered two cycles of awards with each cycle requiring an extensive process for announcements, application reviews, peer reviews, and awards. In FY95, ORD awarded 172 new grants totaling \$33 million to institutions in 42 states. In FY96, ORD awarded 195 grants totaling \$97 million to 136 institutions in 45 states. In addition, ORD awarded 92 graduate fellowships in FY95 and 108 graduate fellowships in FY96.

SAFE DRINKING WATER



▲ Today, microbial pathogens and the by-products of drinking water disinfection processes are challenging ORD researchers to better understand the organisms that infect—and the processes and technologies that disinfect—our drinking water.

ozone, chloramines, or chlorine dioxide. While the disinfectants reduce the risk of getting sick from microbial organisms, some of the chemical by-products resulting from the treatment process have been shown to cause cancer and other toxic effects in laboratory animals. In addition, some epidemiology studies suggest that consumption of chlorinated water may be associated with increased rates of cancer and adverse effects to the reproductive system in people.

These two risks from drinking water—exposure to microbial pathogens and the by-products of the disinfection process—pose a significant challenge for water system managers. They must use just enough disinfectant to kill pathogens but keep the disinfection by-products at a minimum while running the process economically.

There is still a high degree of uncertainty about how to measure microorganisms in water and determine at what levels they can infect. Additionally, there is a high degree of uncertainty about whether disinfection by-products pose a significant human health threat. Because of the uncertainty, the widespread human exposure to drinking water, the severity of the known effects from certain microbes, and the potentially high costs of further regulation, this issue is of high priority to EPA's Office of Water and to ORD's research agenda.

More Americans are drinking safer water than ever before. And yet, waterborne disease is still a public health risk. There were 34 outbreaks of waterborne disease reported in 1991 and 1992, and the 1993 outbreak in Milwaukee was the largest documented occurrence of disease from a treated public water supply in the U.S.

To disinfect a public drinking water supply, water system managers use chlorine or alternatives such as

***Cryptosporidium* Research Focuses on Infection and Cleanup Techniques**

In April 1993, an outbreak of waterborne disease caused by *Cryptosporidium* killed almost 100 people and made 400,000 people ill in Milwaukee, Wisconsin. While ORD researchers and engineers were working with local officials, it became clear that better data on the infectivity of *Cryptosporidium* were needed. As a result, over the past several years ORD has undertaken a major research effort to understand and control *Cryptosporidium*.

Scientists with NERL and NHEERL conducted research to determine *Cryptosporidium*'s infectious dose in human volunteers. The initial study indicated that as few as 30 oocysts could cause illness. This research raises many more questions that ORD is now investigating:

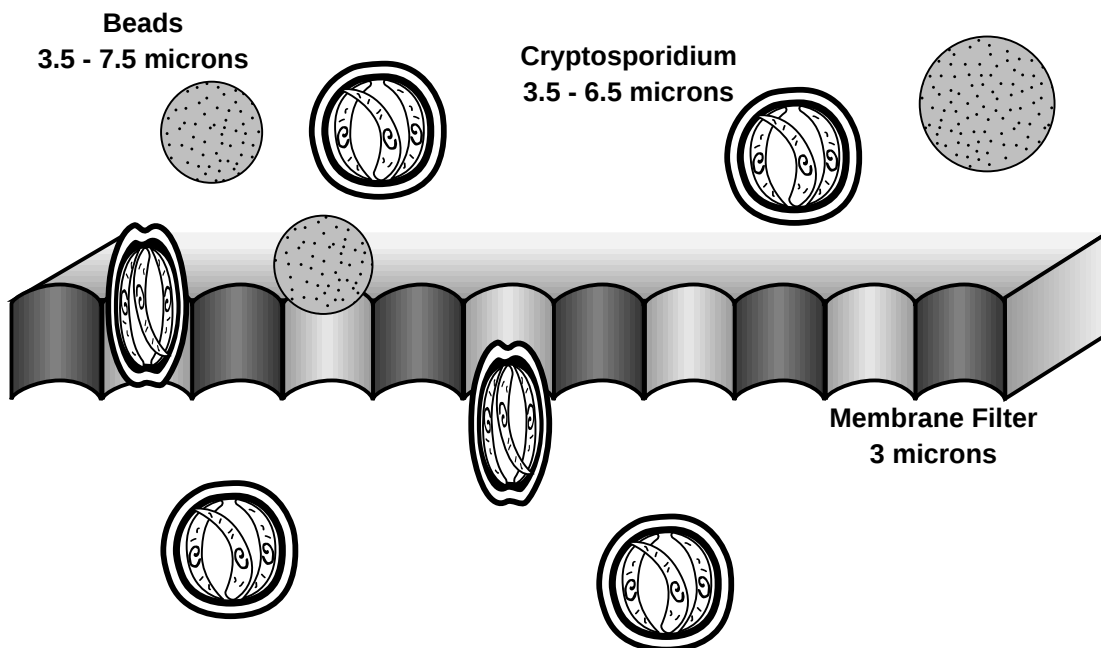
- Do people develop immunity to *Cryptosporidium* after multiple exposures?

- Are other strains of the pathogen as virulent as the one that has been studied to date?
- To what extent are children and adults with weakened immune systems at greater risk for infection?

A complete picture of the relationship between dose and response for *Cryptosporidium* is essential to developing an accurate assessment of risks as well as determining the best options for protecting public drinking water supplies.

NHEERL made important advances in the development of blood tests that detect *Cryptosporidium* infection. These tests will be used in epidemiologic studies to characterize exposure to *Cryptosporidium* from drinking water.

Because *Cryptosporidium* oocysts are much more resistant to disinfection than most other waterborne pathogens, scientists and engineers in the drinking water treatment program at NRMRL are focusing on new approaches to control the organism in the



Like other protozoan pathogens, *Cryptosporidium* has several stages to its life cycle. During the oocyst stage, the oocyst wall is a strong but flexible casing similar to a gel cap. While the oocyst may be larger than the openings of the filter used in the treatment process, its flexibility enables it to squeeze through the filter and pass on through the system. The casing also makes it very resistant to the chlorine or other chemical disinfectants used for final disinfection of drinking water.



STAR Grants for *Cryptosporidium*

The Metropolitan Water District of Southern California is developing a cell culture assay to combine with gene probe-based techniques for detecting and counting infectious *Cryptosporidium* in source and finished water. Current detection methods do not determine whether the pathogens measured are capable of infecting people.

Kansas State University is developing gene libraries for *Cryptosporidium* and other pathogens found in drinking water. When made available to the public, these gene libraries can be used to create genetic probes for diagnostic or environmental testing.

drinking water system. ORD research has shown that the organism can slip through water filters. EPA researchers are conducting comparative tests of different water filtration systems to determine optimal removal conditions and to evaluate the effectiveness of filtration followed by disinfection. Several technologies suitable for small water systems also are being evaluated. This new research will help the Agency to protect the public from further outbreaks of waterborne disease associated with *Cryptosporidium*.

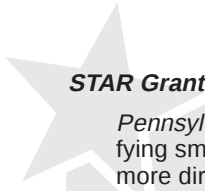
Health Research for Disinfection and Disinfection By-products

Several epidemiologic studies have suggested a possible association between exposure to disinfected water and cancer or reproductive effects. However, the findings have been inconsistent and causality has not been established. Accurate assessments of the risk posed by disinfection by-products and an understanding of the biological

basis for observed effects are needed. Scientists at NHEERL are investigating the toxic effects associated with disinfection by-products and the toxicologic bases for the adverse effects. In FY95, NHEERL researchers demonstrated for the first time that dichloroacetic acid, a by-product commonly found in disinfected drinking water, causes liver cancer in rats. Information from the research in this area may help to explain how the cancer process is activated by this chemical.

Method Identifies Disinfection By-Products from Innovative Process

Identifying the chemical by-products from water disinfection processes is the first step in assessing the risk from disinfection. Scientists from NERL in Athens, Georgia, and NRMRL in Cincinnati, Ohio, have joined in a study to identify any potentially harmful by-products from a unique disinfection process, that combines titanium dioxide with ultraviolet light. Using a combination of mass spectral and infrared techniques, the investigation identified only one by-product (3-methyl-2,4-hexanedione) of the titanium dioxide method. As expected, additional by-products were found when chlorine was used as a secondary disinfectant. Continuing research will extend the identification of disinfection by-products to permit improved risk assessments of drinking water exposures.



STAR Grants for Disinfection By-Products

Pennsylvania State University is developing a method for quantifying small amounts of haloacetic acid disinfection by-products more directly than existing methods, which can be done on-site without hazardous organic solvents.

The University of Massachusetts is developing, testing, and refining new analytical methods for organic disinfection by-products. This research project will also identify new disinfection by-products in water supply samples.

New Method Developed to Identify Health Risks in Groundwater

In support of EPA's Office of Water, scientists from NERL's Human Exposure Research Division in Cincinnati, Ohio, have developed a new method for testing groundwater sources for microbial contamination.

Until relatively recently, microbes in groundwater had not been researched since it was generally assumed that underground water sources were protected from contamination by the earth's surface. Working with the Office of Water and the American Water Works Association Research Foundation, under a Federal Technology Transfer Act agreement, scientists chose 30 sites across the country that supply water for public drinking water systems. ORD used this project to evaluate a new method of testing for viruses, which proved to be more sensitive and as fast as the traditional indicators method currently favored by water system engineers.

Using a culturing procedure from molecular biology methods, scientists run a 100 gallon sample of the groundwater through a filter. Because the pores of the filter are larger than the pathogens, the filter is positively charged in order to snatch the negatively charged microbes as they pass through the filter. The virus is scraped off the filter and put in large bottles along with human and animal cells. The bottles are rolled, creating more surface area for the microbes to land on than if the bottles were stable and increasing opportunities for contact with the cells. Microbes that land on the human or animal cells then can be observed to determine if they are alive and capable of infecting.

The results of the study, to be published in late 1997, found viruses in 23 percent of the groundwater supplies tested and demonstrated that the new method also could be used for surface waters.

ORD Technical Expertise Addresses Outbreaks of Waterborne Disease and Drinking Water Quality Problems

The risk of illness from drinking contaminated water is a major concern for consumers, drinking water utilities, and state and federal regulators. NRMRL's Water Supply and Water Resources Division in Cincinnati, Ohio, provides technical assistance to states and EPA's regional offices to investigate problems of non-compliance with regulations. For example, last year ORD experts assisted the Agency in diagnosing drinking water problems in the District of Columbia and devising measures to restore the integrity of the system.

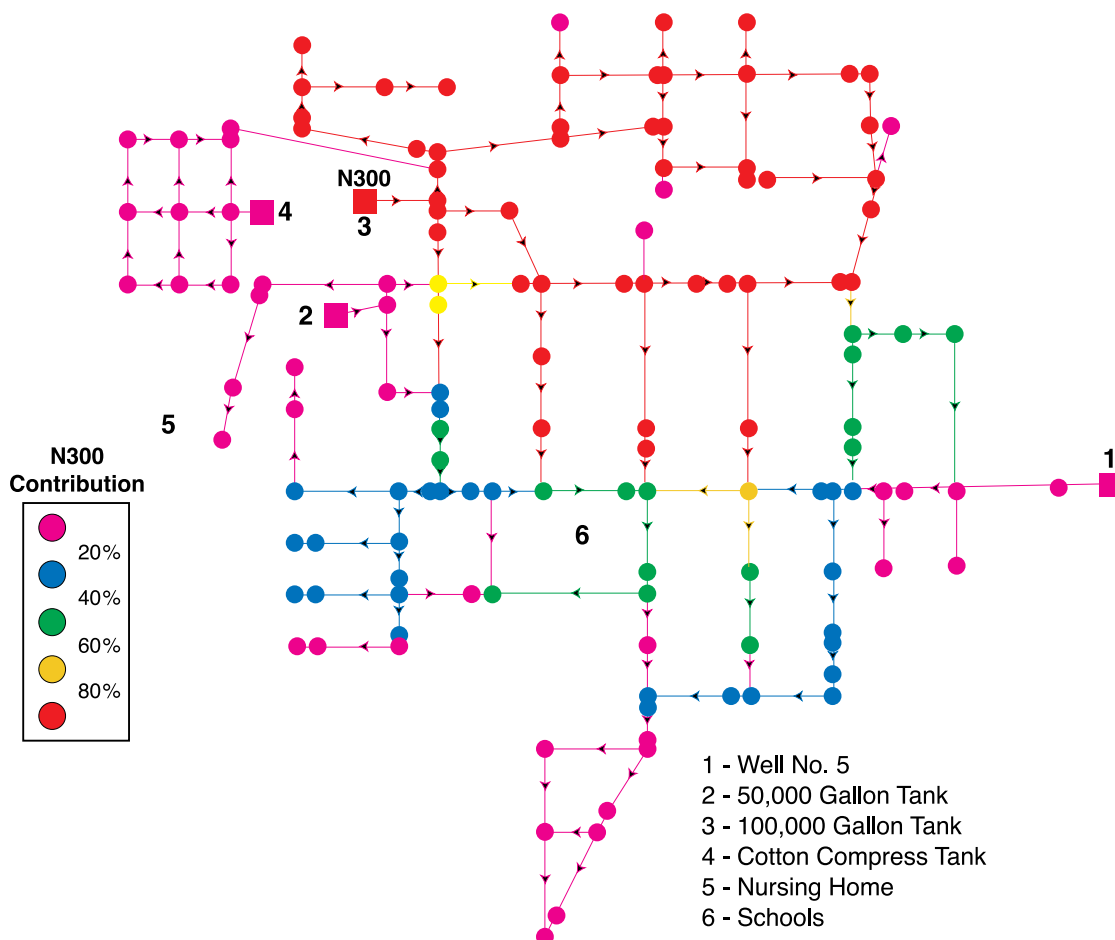
In addition, ORD staff have assisted the Centers for Disease Control and Prevention (CDCP) and states and regional offices with investigating identified waterborne disease outbreaks. ORD scientists and engineers consult on analysis of water samples, characterization of microbes isolated from water samples, and associated conclusions. In the past two years, ORD assisted CDCP as part of its response to an outbreak of chronic diarrhea in a small town in Texas, the State of Idaho in a suspected outbreak of the virus *Campylobacter* in a summer camp, and the Georgia Division of Public Health in a suspected outbreak of *E. coli* at a swimming pool. In addition, ORD and CDCP jointly published a biannual summary of the reported waterborne disease outbreaks in the U.S. from 1993 to 1994.

Water Quality Model Simulates Drinking Water Delivery Systems

The quality of drinking water can deteriorate as it flows from the treatment plant through the water distribution system to consumers' faucets. Water quality can be affected by several conditions in the system: supply sources going on and off line, contamination by cross connections, long holding times in storage facilities, bacterial regrowth, increase in turbidity, and the

formation of disinfection by-products. The complexity of a water delivery system can make it difficult to pinpoint the causes of contamination. For example, city water systems can have hundreds to thousands of miles of pipe arranged in intersecting, looped networks. Water can follow a myriad of pathways through these systems, depending on how the system is operated and what the demand for water is at any given time. Since monitoring offers a limited view of how well a distribution system is working, system managers use computer models to simulate the operation of the distribution system.

One such computer model is EPANET. Developed by ORD researchers at NRMRL, and based on more than ten years of research and field studies, EPANET predicts how water pressure, flow rates, substance concentrations, and the age of water throughout the pipe network change over an extended period of time. Besides its state-of-the-art numerical methods, the program uses graphics to display its simulation results. For example, results can be displayed on an animated color-coded map of the piping system to illustrate changing conditions throughout the system.



After an outbreak of salmonellosis in a small town, EPA researchers used EPANET to test the theory that the cause of the outbreak was bird infestation of a water storage tank in disrepair. This tank was completely drained during a system flushing episode that occurred two days prior to the outbreak.

The figure shows the percent of water from the suspect tank "N300"—point 3 in the diagram—reaching various points in the system during the flushing episode. The circles are consumer locations and the lines connecting them are water pipes. The arrows on the pipes indicate the direction of flow. The color of each circle represents the percent of the consumed water that originated from the suspect tank.

Typically, EPANET is used to manage water quality before an outbreak happens. For example, water system managers might use the model to optimize post-disinfection within their systems, making sure that levels of chlorine are high enough to provide adequate disinfecting power but not so high as to produce excessive amounts of unwanted disinfection by-products.

Two years after its release, over one thousand copies of the program have been requested by water utilities, consulting engineers, and universities to be used as a tool for studying how safer water can be delivered to customers. Utilities in Oakland, Detroit, Seattle, Madrid, and Sydney are using EPANET to model various aspects of their distribution systems. Dozens of smaller utilities have found EPANET to be a simple and inexpensive way to begin studying behavior within their own systems. The American Water Works Association and several universities are using EPANET in training workshops and courses. EPANET has spawned several commercial software products that offer enhanced data handling and graphical display capabilities.

HIGH PRIORITY AIR POLLUTANTS



Ambient exposures to major air pollutants—ozone, nitrogen oxides, carbon monoxide, particulate matter, sulfur oxides—while regulated by the Clean Air Act, continue to pose human health and ecological risks. Under the Clean Air Act, EPA establishes National Ambient Air Quality Standards (NAAQS) for these pollutants, and must periodically review the standards. Much of ORD's research program in this area is devoted to supporting the analysis needed to review the primary (for human health)

▲ Besides oxygen, the air we breathe can contain *bioaerosols*—airborne particles, large molecules, or volatile compounds released into the air from living organisms. Bioaerosols can be fungi, viruses, protozoa, antigens, and endotoxins. To determine whether bioaerosols may be related to health effects such as allergies, asthma, sick-building symptoms, and infectious diseases, scientists study bacteria samples like the ones being prepared above.

and secondary (for ecological health) NAAQS. The Clean Air Act places major responsibility for implementing the standards with the states, which submit State Implementation Plans to EPA for evaluation and approval. These plans provide specific information on emissions in nonattainment areas and describe actions that state and local authorities will use to attain the standard.

Consequently, the multidisciplinary research program that ORD conducts to support the Clean Air Act affects state programs as well as federal programs. In the last few years, ORD's research has supported the regulatory efforts of the Office of Air and Radiation to revise the NAAQS for ozone and particulate matter and provide better methods and models for assessing risks from these high priority air pollutants.

Criteria Document for Tropospheric Ozone Molds Research and Assessment for Standard Development

The Clean Air Act requires EPA to review NAAQS for six air pollutants including tropospheric, or ground-level, ozone. Under this legislative mandate, the current standard for ground-level ozone is being reviewed to determine whether it should be changed. An important part of the regulatory review of the standard includes an updated assessment, called a criteria document, of the latest scientific information on the nature and extent of health and welfare effects from exposure to ambient ozone.

In the most recent ozone criteria document, *Air Quality Criteria for Ozone and Related Photochemical Oxidants*, July 1996, scientists from NERL, NHEERL, and the Research Triangle Park, North Carolina, offices of NCEA led the review of the latest scientific data associated with exposure to the concentrations of ozone and other photochemical oxidants found in ambient air. The three-volume analysis includes an assessment of health and environmental effects data and the latest information on sources, distribution, measurement, atmospheric chemistry, and concentrations of ozone, related compounds, and their precursors in the environment.

STAR Grants for Tropospheric Ozone

ORD's grants program is one of several ways EPA is contributing to the North American Research Strategy for Tropospheric Ozone (NARSTO), a public/private sector cooperative research effort.

The University of California at Riverside is investigating atmospheric chemical reactions to determine the role of volatile organic compounds in ambient ozone levels.

The University of Colorado is conducting studies to improve the quality of analyses of atmospheric trajectory models used to predict tropospheric ozone levels.

Portions of the scientific information and analysis in the criteria document are based on research conducted in the last few years by ORD. To evaluate the primary ozone standard (protective of human health), scientists at NHEERL studied the adverse health effects from exposure to ozone including acute lung inflammation, changes in pulmonary function, and chronic respiratory damage. Collaborating with epidemiologists from Harvard University and Mexico City, NHEERL scientists demonstrated that exposure to ozone is associated with gradual decreases in lung function in children. A similar response was demonstrated in controlled clinical studies, indicating that data from clinical studies can be used to predict ozone response in children. Other studies demonstrated that age plays an important role in ozone sensitivity, with responsiveness to ozone greatest in young adults.

A particular focus of the research investigated whether asthmatics are more sensitive to ozone than nonasthmatics. In FY95, one study showed that severe asthmatics do indeed appear to be more susceptible to ozone than healthy subjects, as measured by lung function. In another study, NHEERL demonstrated that allergic asthmatics exposed to ozone experience a different kind of lung inflammation than normal subjects. Further, it was found that ozone exposure is significantly related to the development of asthma in males but not females.

For the ozone secondary standard (protective of vegetation and ecosystems), scientists with NHEERL's Western Ecology Division in Corvallis, Oregon, directed a national research program to assess crop loss in the United States due to exposure to tropospheric ozone. The program studied 12 major agricultural crops that represent 70 percent of the farm land in the U.S. and account for 73 percent of U.S. income from farming. This research concluded that tropospheric ozone caused significant crop loss.

The crop yield loss data indicate that reducing ozone by 10-25 percent from 1986-1990 levels in rural areas would save U.S. farmers \$1.7- \$2.4 billion each year.

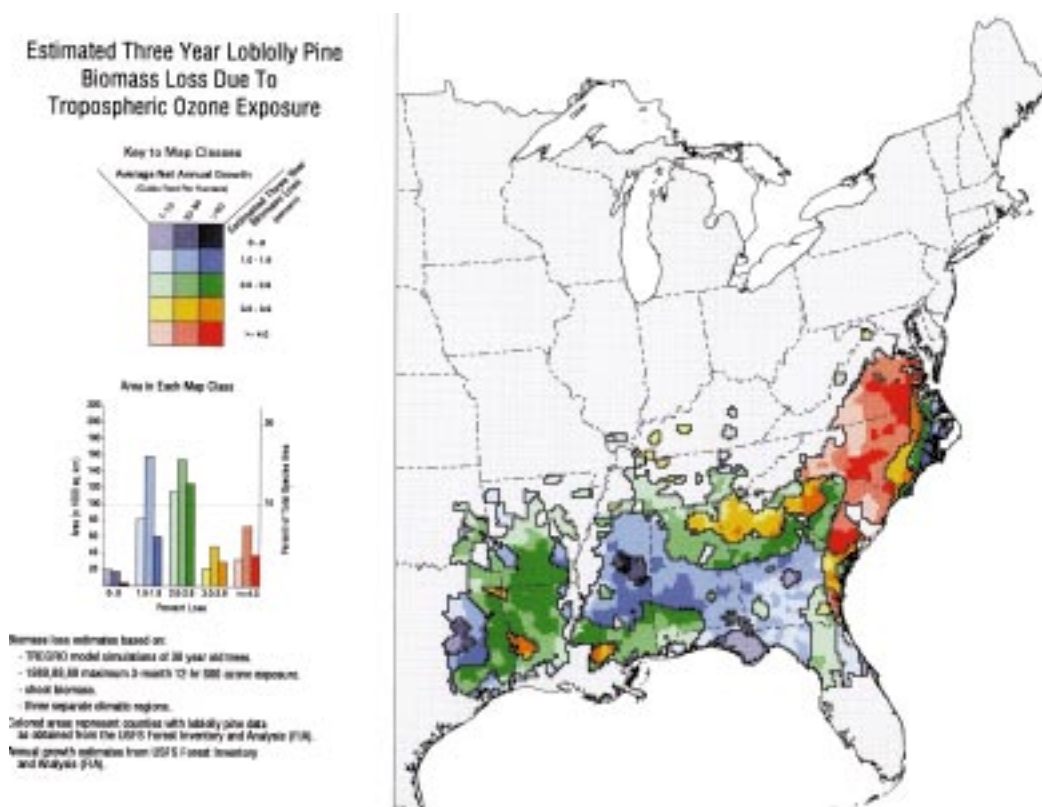
While crops are harvested annually, forests have much longer life cycles, and the effects of ozone are more difficult to assess. ORD's research program has examined 11 tree species, chosen for their economic and ecological significance, in exposure studies at sites across the country. This research provided the most important information available in the scientific literature on the effects of ozone on trees for EPA's 1995 ozone assessment document. These data are useful for assessing the relative protection afforded tree species under a standard based on crop data.

ORD scientists also characterized the effects of ozone on forest vegetation, showing that ozone has a profound effect on the

rhizosphere (the root/soil complex) of tree seedlings. ORD's recent research demonstrated that ozone depresses root growth and reduces the symbiotic association between roots and soil microbes. In addition, ozone often lowers the amount of carbohydrate available, making seedlings more susceptible to nutrient and moisture stress. By adversely affecting the rhizosphere, ozone's impacts on forest ecosystems may be more widespread than the previous predictions had estimated based on conventional measurements of damage to foliage.

Biogenic Emissions Modeled for More Accurate Ozone Attainment Plans

In the past two decades, over \$20 billion has been spent in this country on controls to reduce man-made emissions of volatile organic compounds (VOCs) in order to meet the



◀ In this map, a geographic information system (GIS) integrates three data sets—distribution of the loblolly pine, estimated seasonal ozone exposure for 1988, and simulations of biomass response—to illustrate the potential percentage of biomass loss from exposure to ozone over three years.

The color coding of the key (left to right) shows increase in standing biomass of loblolly. Top to bottom, the key shows reduction in biomass over three years. The darker colors point to areas at greater risk for biomass loss based on ozone levels and density of loblolly trees.

ORD scientists developed this GIS-based approach to integrate seasonal exposure data, biological effects data and environmental/meteorological data to show potential extent and magnitude of the effects of ozone on forests over time.

NAAQS for ozone. However, the control strategies in the eastern U.S. and on the west coast have been hindered because of the abundance of naturally emitted, or *biogenic*, VOCs from forests and other vegetation. In the U.S., approximately 30 million tons of VOCs are emitted annually from biogenic sources compared to 20 million tons from man-made sources. Consequently, accurate estimates of emissions of smog-producing chemicals from vegetation are important to factor when developing cost-effective air pollution control strategies.

Scientists with NRMRL and NERL in cooperation with the National Center for Atmospheric Research and four universities — Duke, Wisconsin, Washington State, and North Carolina State — have developed a new model that more accurately predicts biogenic emissions. The model, called Bio-

STAR Grants for Biogenic Emissions

Purdue University is developing and evaluating techniques to quantify ambient air levels of volatile organic compounds (VOCs) including biogenic VOCs. Since VOCs are major precursors to tropospheric ozone, real-time air quality data will improve our understanding of the factors that cause ozone levels to exceed the standard.

Pennsylvania State University is conducting studies to improve the predictive capability of air quality models that predict long range transport of ozone and its precursors.

Scientists gather data of actual leaf emissions to validate and improve the accuracy of BEIS2 predictions of natural ozone precursor emissions. Scientists use the Licor 6400, generally used to measure water vapor and carbon dioxide for photosynthesis studies, to sample isoprene emitted from the leaf of the white oak, the single most dominant tree species in the eastern U.S.



genic Emissions Inventory System Version 2 (BEIS2), is being used by several states to revise their State Implementation Plans for controlling ozone, and by other research organizations studying the process by which smog is produced.

As much as 5 percent of carbon fixed by common trees such as oaks, aspen, poplars, willows, and sweetgum can be emitted back into the atmosphere as isoprene, a highly reactive precursor to smog. By measuring the emissions of compounds such as isoprene from leaves under a variety of seasonal and environmental conditions, scientists have developed models at the leaf level that have been scaled to the landscape level using remote sensing and ecological survey data. Subsequent measurements from towers, balloons, and aircraft of actual emissions from the landscape have shown that BEIS2 is a significantly improved model for predicting isoprene emissions.

Criteria Document for Particulate Matter Developed for Revised NAAQS

EPA also may revise the NAAQS for particulate matter (PM). In the most recent PM criteria document, *Air Quality Criteria Document for Particulate Matter*, April 1996, scientists from NERL, NHEERL, and the Research Triangle Park, North Carolina, offices of NCEA led the review of the latest scientific data associated with the inhalation of both fine particles (less than 2.5 microns in diameter [$PM_{2.5}$]) and small coarse-mode particles (less than 10 microns in diameter [PM_{10}]) capable of being deposited in the lower portions of the lungs.

Portions of the scientific information and analysis in the criteria document are based on research conducted or supported by ORD in the last few years. For example, recent epidemiological studies funded by NHEERL of people living in cities have associated exposure to particulate matter at levels below the current PM_{10} standard with increased illness caused by lung disorders and increased premature death rates from heart and lung diseases. The consequence of these findings is that particulate matter has been estimated to cause up to tens of thousands of premature deaths and many more cases of adverse health effects in both adults and children.

A critically important but unresolved issue is how particulate matter produces its toxic effect: what are the biological mechanisms of PM toxicity and are there characteristic features related to particle size or composition that cause the injury and damage? To understand the mechanism by which PM exerts its effects, animal models of cardiopulmonary disease and asthma have been developed as surrogates for adverse human lung conditions. NHEERL studies with these animal models have shown that PM exposure resulted in more inflammation, lung impairment, and increased

mortality as compared to normal animals. To examine which constituents of particles cause the effects, research has focused on metals, which NHEERL scientists have determined play an important role in causing acute inflammatory response from PM exposures. Metal composition of particles varies according to the source of the emission, and NHEERL scientists have found that the type of genetic damage that may be induced by PM also varies among emission sources. Gene mutations, which can initiate the cancer process, have been detected in human lung tumors, and the type of mutation has been shown to differ depending on the source of PM exposure. This research indicates that both particle composition and emission source can affect the nature and degree of lung damage and other health risks.

Dosimetry research studies how much of an agent actually gets to the area or organ of the body where it may produce an effect. It is important for developing models that predict how much and where particles may be distributed in the human lung and for extrapolating the data from animal studies to humans. In FY95, NHEERL studies demonstrated that breathing pattern and airway resistance, not age or gender, are the most significant factors that affect how particles deposit in the lung. These studies help in identifying individuals most susceptible to PM exposures.

Single Breath Canister Collects A Deep Breath for Exposure Analysis

Scientists with NERL have developed a new method for quickly collecting a single alveolar breath (from deep within the lungs) for detecting the presence of a pollutant in the body after exposure. It is called a single breath canister or "SBC." Bioindicators of human exposures result in a more accurate assessment of exposure than measuring pollutant levels in the air

In this self-administered single-breath collection technique, the subject exhales through a sterile Teflon tube into an evacuated one-liter SUMMA® polished stainless steel canister. While the canister is held to the chest with one arm, the hand of that arm is used to pinch the subject's nose to avoid entrainment of ambient air. The subject then breathes smoothly and lightly through the mouth. At the end of a normal resting exhalation, the subject closes the mouth, opens the canister valve, and continues to expel the remaining air from deep within the lungs. When the flow stops, the subject shuts the canister valve. Once in the canister, the breath sample is stored or easily shipped for later analysis. The research into these methods was performed, in part, with analytical equipment developed under a Cooperative Research and Development Agreement between EPA and Graseby Nutech Corporation.

that the person is breathing. The method generally used for sampling is to take blood samples or use complex and cumbersome instruments to collect breath samples.

The new technique uses a small one-liter canister (about the size of a grapefruit) to capture a single breath. It is fast, easy, and does not require electricity; all the subject has to do is to breathe out into a small tube while opening a valve. Later on, the breath is analyzed in the laboratory. Just like the "breathalyzer" tests for alcohol in the blood, scientists can test for a variety of volatile organic pollutants in the breath and then relate the results to a blood level.

The new SBC method has several advantages over previous methods. The canisters are small and easy to transport. Most

subjects can give a sample successfully on the first try. The small inlet tubes are inexpensive and disposable so no disinfection of equipment is required, and SBC is less invasive than taking a blood sample. Scientists have already demonstrated this method for measuring chloroform exposure from chlorinated municipal water (showering and swimming), exposure to benzene and vinyl chloride from contaminated well water, exposure to gasoline additives from filling a car gas tank, and exposure to tobacco smoke in public places. The SBC also is being used by the U.S. Air Force to measure exposure to the partially burned fuel from cold starts of fighter planes, by the Canadian Health Directorate as part of a multimedia exposure study, and by the Australian Defense Department for assessing exposures in new submarines.

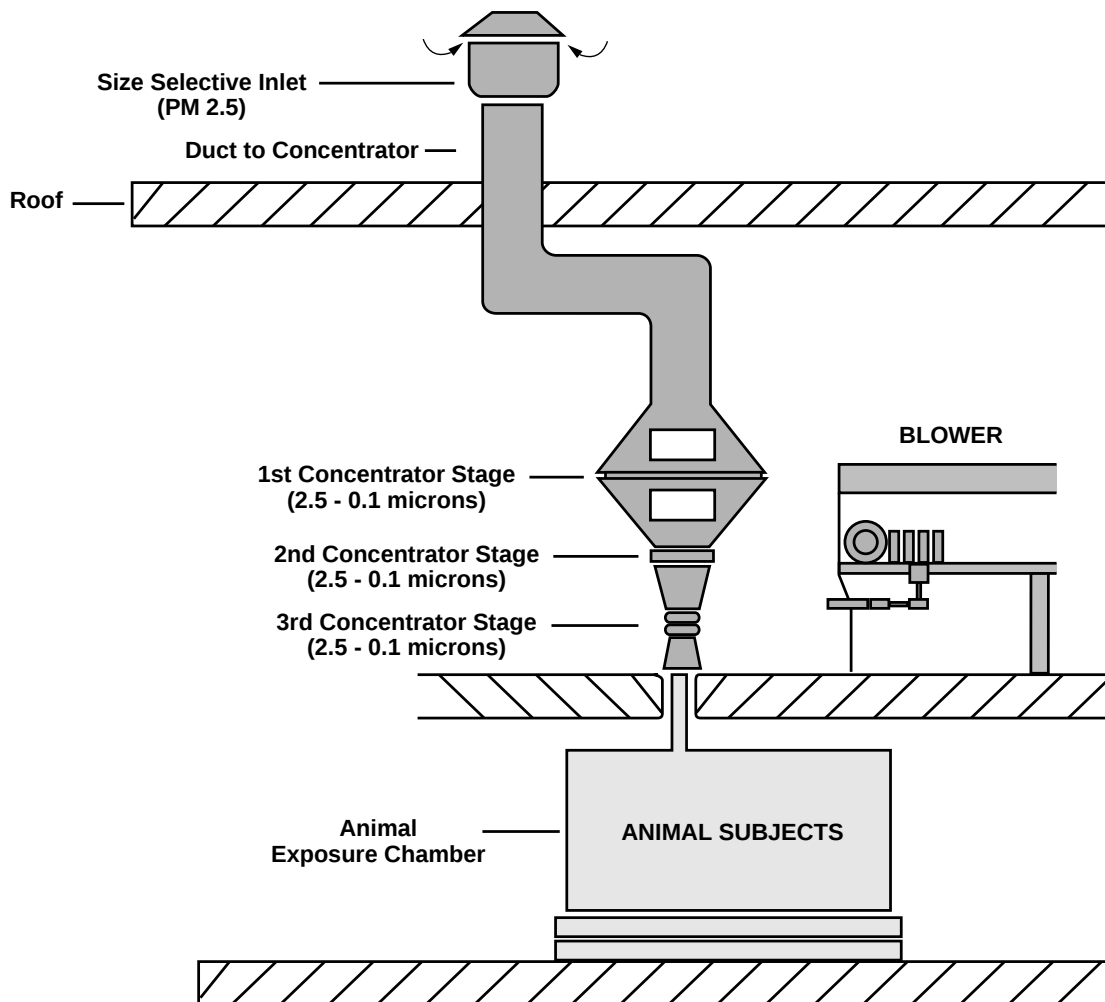


STAR Grants for Particulate Matter

New York University Medical Center is using existing ambient databases for three U.S. cities to evaluate the roles of various PM components on human mortality in the total population and in potentially sensitive populations.

Harvard University School of Public Health is conducting studies to identify the size fractions of ambient PM levels in urban air that are most highly associated with lung function performance in children.

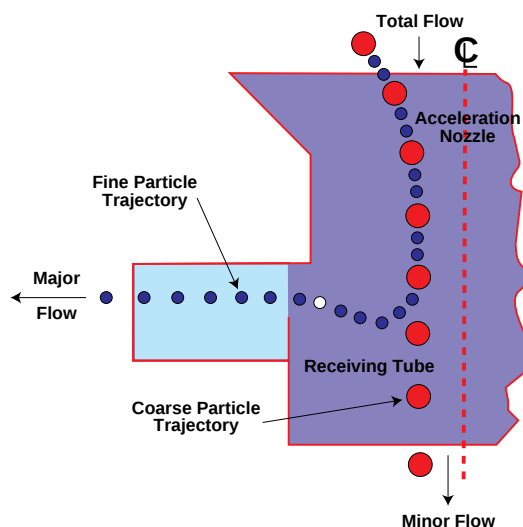
The National Jewish Center for Immunology and Respiratory Medicine is studying the relationship of submicron particulate matter from combustion with several indices of asthma.



◀ In this exposure chamber, a conventional impactor removes particles larger than 2.5 microns from the air sample while smaller particles escape collection. The smaller particles then pass through three virtual impactors. Each impactor concentrates the particles so that by the time the ambient aerosol reaches the test subjects in the exposure chamber the particle concentration has increased by a factor of 25-30. The particles maintain their physical and chemical characteristics. With this method, scientists can determine the toxicity of ambient particles by performing dose-response assessments of different exposures in real time.

Technology for Concentrating “Real World Atmospheric Aerosols” A Major Breakthrough for Laboratory Particulate Matter Exposure Studies

In cooperation with the Harvard University School of Public Health, ORD scientists with NERL and NHEERL have invented a new instrument for collecting, concentrating, and delivering atmospheric particles for use in laboratory exposure studies. The development of a unique 0.1 micron cutpoint virtual impactor now makes it possible to concentrate ambient particulate matter in the size range of 0.1 - 2.5 microns.



◀ Diagram of virtual impactor process that occurs at each of the three concentrator stages above.

This system is a major breakthrough for use in inhalation exposure studies for two reasons. First, it keeps the complex chemical and physical make-up of the mixtures intact. Second, it enables particles concentrated by a factor of 30 to be tested in laboratory studies, thus providing more of an opportunity to observe dose response relationships. Past animal and human laboratory exposure studies typically used laboratory-generated aerosols. The new technology is a major step forward for studies of the causality of the associations of PM and mortality and morbidity.

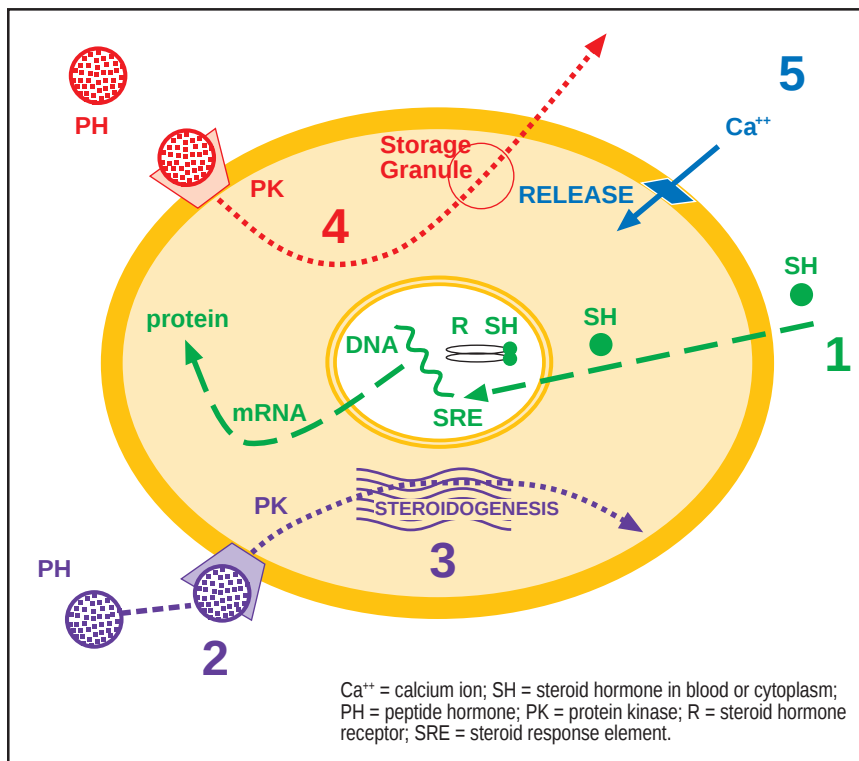
EMERGING ENVIRONMENTAL ISSUES



A major role for ORD is to look beyond the obvious problems of yesterday and today to identify and assess issues just over the horizon; we must determine the potential risks that these issues pose and work to solve them. Often, however, few data exist to support assessments of emerging issues. Consequently, ORD's challenge is to work with others or take a leading role to develop data and methods for credible decisions in areas of significant uncertainty.

In the *1997 Update to ORD's Strategic Plan*, April 1997, endocrine disrupting chemicals have been identified as an emerging environmental issue. Based on the potential scope of the problem, the possibility of serious effects on the health of populations, and the persistence of some endocrine-disrupting chemicals (EDCs) in the environment, this area has been designated a high priority for ORD research. ORD scientists have been researching in this area for several years. Because there are many unanswered questions about the nature and severity of the problem, ORD's research currently focuses on developing methods for characterizing the hazards and risks of EDCs, quantifying exposure levels, determining their fate and transport in the environment and developing extrapolation tools. The following research highlights illustrate ORD's contributions to the international scientific debates surrounding EDCs and to the Agency's mandated efforts to evaluate chemicals and pesticides for adverse effects.

The seemingly increased occurrences of deformed amphibians in the U. S., while not yet a major priority for ORD's research program, is another emerging environmental issue. ORD scientists with expertise in this area have been involved in discussions and are engaged in researching the many scientific questions that are arising from the increased sightings of deformed frogs. The second highlight details recent ORD's efforts in this area.



Research Milestones Reached on Endocrine Disrupting Chemicals

The endocrine system helps guide the development, growth, reproduction, behavior and other bodily functions of animals and humans. The system primarily includes the pituitary, thyroid, pancreas, adrenal, and the testes and ovaries as well as the hormones the glands produce. The hormones act as chemical messengers, traveling through the blood to tissues and organs, where they can bind to specific cell sites called receptors. By binding to receptors, hormones trigger various responses in the tissues containing the receptors.

An endocrine disrupter is an external agent, such as a chemical, that interferes in some way with the hormones. An agent might disrupt the endocrine system by affecting any of the various stages of hormone production and activity, by binding to hormone receptors, or by interfering with the natural breakdown of hormones.

▲ This diagram illustrates several ways in which an endocrine disrupting chemical can affect the function of cells within the body. The classical effect is illustrated by pathway 1, in which the chemical enters a cell, binds to a receptor (e.g., the estrogen receptor) and moves to the nucleus where the complex causes specific genes to be turned on or off. Chemicals also may act on receptors on the surface of the cell (pathway 2) to alter the production (pathway 3) or release (pathway 4) of endogenous hormones into the blood. The altered level of hormone in the blood would then affect the function of other cells that have hormone receptors. Finally, some endocrine disrupting chemicals can affect the movement of ions into, or out of, the cell, with subsequent changes in cellular processes (pathway 5). Environmental chemicals that operate by each of these pathways have been identified.

STAR Grants for Endocrine Disrupting Chemicals

The University of California-Davis is developing a short-term animal model to identify and characterize potential EDCs.

Boston University researchers are developing a test system for assessing the effects of EDCs on sperm production.

Duke University is developing a vertebrate animal model for developmental genetics analysis.

Mississippi State University is studying if PCB exposure during gestation and nursing can affect the ability of offspring to metabolize internal hormones and EDCs and whether this effect causes abnormal sexual development.

Emory University is studying a group of women and children in Michigan who were exposed inadvertently to substantial levels of polybrominated biphenyls in 1976 to determine if the exposure disrupted the endocrine system.

Bowman Gray School of Medicine is studying the effects on the brain and reproductive system of gestational and neonatal exposure to plant estrogens found in food soy products.

A variety of chemicals, including pesticides, have been found to cause endocrine disruption in laboratory animal studies. Scientists have hypothesized that effects seen in laboratory studies may also occur in wildlife and in human beings in response to environmental exposures. Research findings and observations have caused concern about the potential long-term effects of exposure to EDCs.

ORD scientists at NHEERL and NCEA have been in the forefront of research into EDCs. This work supports Agency mandates to evaluate chemicals and pesticides for toxicity as well as requirements of the Food Quality Protection Act and the Safe Drinking Water Act to screen substances for endocrine effects.

During FY95, a landmark paper published by scientists at NHEERL challenged the prevailing scientific notion of endocrine disruption. Scientists found that some environmental chemicals are potent anti-androgens (substances that inhibit the action of male hormones), and not environmental estrogens as previously thought. Exposure of rats to these chemicals demasculinized male offspring such that they displayed undescended testes, retained nipples, and delayed onset of puberty. These effects are consistent with activation of the androgen receptor. When these data were combined with observations of altered sex differentiation in male rats exposed to a fungicide whose metabolites inhibit binding of the androgen response elements on DNA, it became apparent that anti-androgens exist in the environment and that they can cause developmental effects. NHEERL scientists recently demonstrated that these chemicals also bind to the human androgen receptor. Publication of these important findings has contributed to the scientific community's

widening its research focus to include studies of anti-androgens.

As part of the research program to develop screening tests, NHEERL scientists are investigating how chemicals affect the endocrine system and determining the best indicators, or biomarkers, of early response to EDC exposure. In FY96, NHEERL reported the discovery of a protein in sperm membrane in the male rat that appears to be a biomarker for fertility. This protein, also common to humans, is altered when exposed to chemicals that disrupt the endocrine system and the effect is highly correlated with reduced fertility. The findings have received widespread commercial interest and are the subject of a recent EPA patent application. Currently, scientists are attempting to develop an antibody to this sperm biomarker that can be used to screen chemicals for endocrine disrupting activity and reduced fertility.

Under the auspices of the Risk Assessment Forum, an Agency-wide workgroup has completed a report that reviews key scientific findings to date, *Special Report on Environmental Endocrine Disruption: An Effects Assessment and Analysis*. ✓ The report provides an overview of the state of the science for endocrine disruption; a review of potential human health and ecological risks; and, an overview of research needs.

ORD's leadership in endocrine disrupter research has led to EPA chairing the Endocrine Disrupter Working Group of the Committee on the Environment and Natural Resources, a government-wide committee of the President's National Science and Technology Council. In FY96, the group developed a formal research planning framework to guide federally funded research, and conducted an inventory of existing research. The inventory is available on the Internet. ✓



▲ This over-endowed leopard frog was among some two hundred frogs gathered by scientists with the Minnesota Pollution Control Commission ✓ in August 1995. Of the frogs collected in this sample from the Ney Environmental Learning Farm in La Sueur County, Minnesota, two-thirds were found to be deformed. The majority had missing, incomplete, or contorted limbs, while this frog had two extra hind legs. Scientists suspect that the extra legs were immobile so this frog would have had an extra load to carry around. Its survival is all the more mysterious because it would have had to drag these legs around while trying to find food.

ORD Sponsors Workshop on Science Issues Surrounding Amphibian Deformities

Over the last several years, nature lovers, wildlife biologists, and even school-age children have been reporting sightings of deformed frogs—frogs with missing limbs, too many limbs, or withered and misshapen limbs. Among scientists who have been researching the increased incidence of deformity there is agreement on only one point: an alarming number of deformed frogs are being found. And, there is only speculation about what could be causing the deformities.

Scientists at the Mid-Continent Ecology Division of NHEERL in Duluth, Minnesota, along with the Minnesota Sea Grant and Natural Resources Research Institute of the University of Minnesota, sponsored a workshop in September 1996 to discuss the science issues surrounding amphibian deformities.

Since there are no historical data on the incidences of amphibian deformities, the number of incidences today cannot be compared with what may have occurred in the past. However, several very experienced herpetologists at the workshop did note that if the

deformities being reported now had been as prevalent in the past, they would have observed deformed frogs in their field studies. Several hypotheses for the cause of the phenomenon were discussed at the workshop as well as the many questions that need to be answered.

One such question is, “Where are the deformed frogs?” Because there has not been a systematic field sampling for deformed frogs, scientists are uncertain about the geographic distribution of the problem. Participants at the workshop agreed that systematic sampling by region needs to be conducted to better characterize the problem. Although data are being collected by state agencies, it is difficult to do regional or national analysis since the data are not available in one place. Consequently, ORD, EPA’s Regions 4 and 5, and the U.S. Geological Survey are establishing a national reporting center. The center will compile and analyze data collected by state agencies to determine the geographical significance of the data and to formulate hypotheses for what might be causing the deformities.

RESEARCH TO IMPROVE ECOLOGICAL RISK ASSESSMENT



Ecosystems provide valuable renewable resources and services such as food, water storage and flood control, wood for construction, biodegradation and removal of contaminants from air and water, pest and disease control, and moderation of climatic extremes. If these benefits are impaired by man-made environmental stressors, they must be replaced at great expense by civil works, man-made chemicals, and increased use of non-renewable energy supplies.



Scientists use a test organism, like the large water flea, to determine how much of a chemical is toxic to aquatic life. In ORD's Mid-Continent Ecology Division in Duluth, Minnesota, the chemical is diluted to provide a series of concentrations. The test organisms are added to each container to determine the level of pollutant that produces toxic effects.

We have made considerable progress in reducing the most egregious harm to the environment from air and water pollution but much remains to be understood.

Ecological research can significantly reduce the uncertainties surrounding decisions made about the use and protection of our ecological resources. The challenge in this area is to better understand the multiple stresses that can affect multiple endpoints at multiple scales. The goal of this research program is to develop the scientific understanding necessary to measure, model, and maintain or restore the integrity and sustainability of ecosystems now, and in the future.

▶ The Waquoit Bay Watershed covers 21 square miles on the south shore of Cape Cod, Massachusetts. The watershed includes freshwater streams and ponds, saltwater ponds and marshes, pine and oak forests, barrier beaches, and open estuarine waters.



Decreased water flow and velocity in the Mid-Snake River Watershed permit the growth of aquatic nuisance plant species. Cold fish species, including trout and sturgeon, lose critical habitat for spawning and their food base in these environments.



Ecological Risk Assessment Guidelines Proposed

In September 1996, EPA published the *Proposed Guidelines for Ecological Risk Assessment* (EPA 630-R-95-002B), the first Agency-wide ecological risk assessment guidelines.

These proposed guidelines, developed by a technical panel under the Risk Assessment Forum, are intended to improve the quality and consistency of EPA's ecological risk assessments. The Proposed Guidelines expand upon the widely used 1992 *Framework for Ecological Risk Assessment*, as a next step in a continuing process of EPA's ecological risk guidance development.

Ecological risk assessment is a process for organizing and analyzing data, information, assumptions, and uncertainties to evaluate the likelihood that one or more stressors are causing (or will cause) adverse ecological effects. Ecological risk assessment provides

▶ In the Middle Platte River Watershed, resident and migratory birds need open sandbars and shallow water for nesting and roosting. Reduced river flows have changed the characteristics of the river, allowing shrubs and trees to colonize sandbars. This forms islands surrounded by deep water and decreases critical habitat for these birds.



risk managers with a tool for considering available scientific information when selecting a course of action, in addition to other factors that may affect their decision (e.g., social, legal, political, or economic considerations). A major theme of the proposed guidelines is the interaction between risk assessors and risk managers at the beginning and end of the risk assessment process to ensure that the results of the assessment can be used to support a management decision.

Case Studies in Ecological Risk Assessment Demonstrate Watershed Level Resource Planning

The Risk Assessment Forum and NCEA are working with the Office of Water to apply the principles outlined in the Proposed Guidelines to improve decisionmaking in five watersheds. These ecological risk assessment case studies were undertaken to address local concerns and analyze stressors and resulting ecological effects. The five case study demonstrations are in the following watersheds: Waquoit Bay in Massachusetts; Big Darby Creek in Ohio; the Clinch River in Tennessee and Virginia; the middle segment of the Platte River in Nebraska; and the Mid-Snake River in Idaho. Each of the five case studies is being developed by an interdisciplinary, interagency team of scientists and natural resource managers and involves a different set of problems associated with managing the watershed as a resource. This case study approach has brought together numerous organizations to analyze an environmental problem, and it has stimulated public awareness and participation in decisionmaking.

Even though all the assessments are still going on, valuable lessons about the process have been learned already. The planning and problem formulation stages of the assessments forced managers to reflect carefully on their goals for managing the watershed and how the goals may have differed from the interests of local industry and community

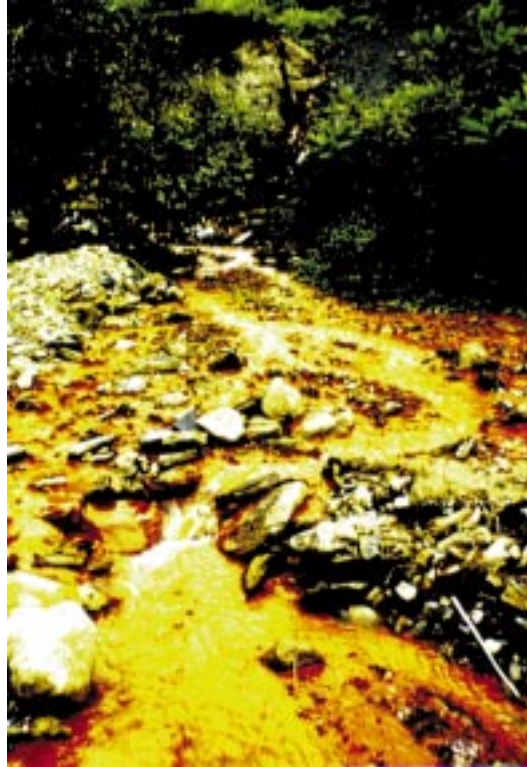
STAR Grants for Ecological Risk Assessment

The science of developing and using indicators of ecological condition is complex. There are multiple resource types (wetlands, rivers, estuaries) in different spatial scales (local, regional, and national) and different levels of biological organization (populations, communities, ecosystems). Since no one indicator can signal the condition of an ecosystem, suites of indicators need to be developed. The following are examples of previous grant awards in this area that will supplement results from research grants awarded this summer under the \$10 million RFA for FY97 on Ecosystem Indicators:

University of Georgia Research Foundation is developing simple, inexpensive, and rapid methods for assaying and monitoring the health of salt-marsh ecosystems in the southeastern United States.

Florida Department of Environmental Protection/ Florida Marine Research Institute is examining the spatial-scale dependence and sample size effects on the variability within populations of seagrass, as well as determining the most effective protocol for assessing the ecological condition of turtle grass and adjacent ecosystems.

Iowa State University is researching local biodiversity patterns in the Greater Yellowstone Ecoregion and assessing the accuracy of remote sensing data for indicating ecosystem change.



Nonpoint source pollution, including the orange acid mine drainage in this photograph, has been identified as the most severe cause of water pollution in the Clinch River Valley.



The presence of such sensitive species as the colorful rainbow darter indicates the exceptional quality of the Big Darby Creek Watershed. These darters require clear water to see their prey and sediment-free gravel for their nests.

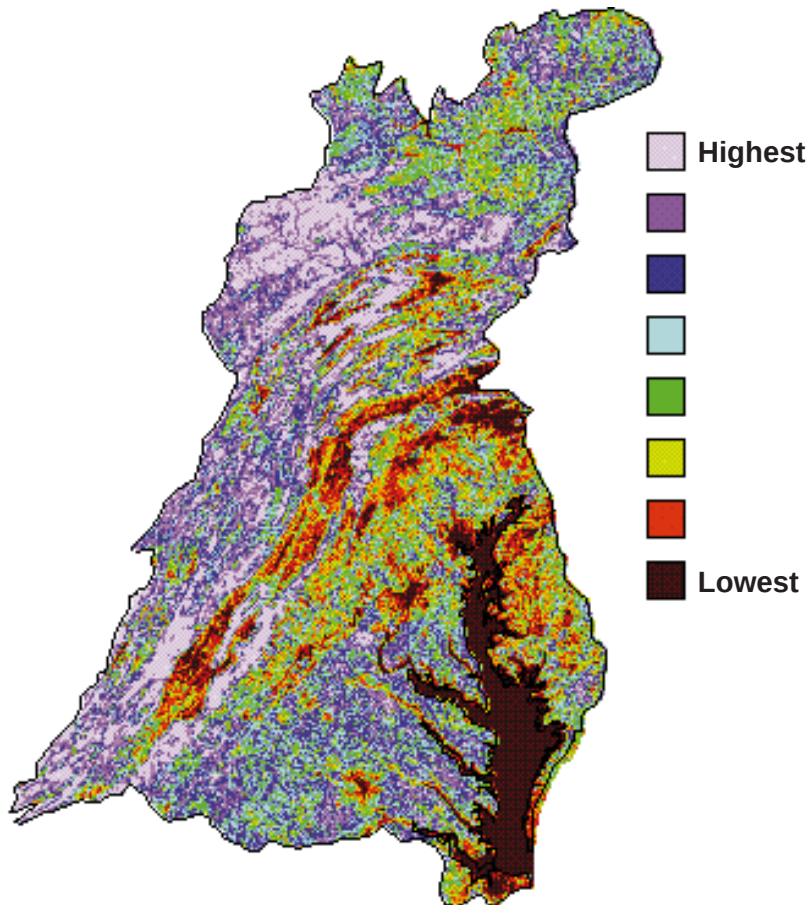
groups. The process generated vast and diverse amounts of information on resources, stressors, and concerns, which in turn helped to identify important issues that would not have surfaced in less systematic evaluations. These case studies offer great potential for demonstrating the use of ecological science for resource planning.

Atlas Demonstrates Landscape Characterization Principles

Understanding the impacts of landscapes and land use on ecological resources is critical to filling gaps in the science underpinning ecosystem protection. One approach to understanding these relationships, *landscape characterization*, is being researched by ORD and its collaborators. Landscape characterization relates the landscape—its composition, size, and spatial patterns—to ecological resources.

Changes in the composition and pattern of a landscape can significantly influence the conditions of a watershed that are usually considered important by the people who live in the area: productive forests; diverse wildlife; resistance to floods; and abundant, high quality water.

ORD has been conducting research in a number of different areas to better understand the ecological processes that occur in a watershed. As the science and databases build with information and more sophisticated techniques of analysis become available, the size of the geographic area that can be evaluated becomes larger. In 1996, scientists with the Characterization Research Division of NERL in Las Vegas, Nevada, and their collaborators with the Tennessee Valley Authority, Oak Ridge National Laboratory,



Because the Chesapeake Bay Watershed is home for many wildlife species, understanding how the landscape is viewed by different species at different scales is important for measuring how the change in land cover may affect wildlife. In this map, the surface area is divided and rated for interior forest habitat potential.

STAR Grants for Ecological Risk Assessment

Johns Hopkins University is developing and testing an integrated ecological assessment methodology for the Great Lakes.

The University of Colorado is developing prototype methods and tools for analysis of multi-scaled ecological data.

The University of Guam is improving techniques used for assessing the health and sustainability of coral reefs and developing protocols and guidelines for biomonitoring, restoration, and mitigating disturbances caused by humans.

and the Desert Research Institute published *A Landscape Atlas of the Chesapeake Bay Watershed*. The document illustrates several principles of landscape ecology and demonstrates their potential application for watershed management. Landscape analysis can be used to set priorities as well as to organize in-depth assessments of particular issues. In a multi-scaled regional assessment, broad questions are asked at the landscape scale, and detailed questions are asked at finer scales. Using landscape scale analysis as a “coarse filter” sets the backdrop and identifies relative priorities for a region.

EMAP Research Results Complement Redesign of the Program

Since 1990, ORD’s Environmental Monitoring and Assessment Program (EMAP) ✓ has undergone extensive external reviews—two by EPA’s Science Advisory Board and three by the National Research Council. As a result of the reviews, EMAP has been redesigned to fit the multi-tiered, national framework for environmental monitoring established by the Committee on Environment and Natural Resources of the President’s National Science and Technology Council. By translating monitoring data needed for assessments of ecological conditions and risks from pollutants, EMAP programs and activities are improving ecosystem risk assessment.

During the last few years, EMAP has produced over 222 publications, 149 of which were published in peer-reviewed journals. EMAP has sponsored symposia and workshops on ecological indicators, nitrogen cycling and loss in forests, monitoring of acid deposition effects, detecting trends in ecological systems, and statistical issues for monitoring ecological and natural resources.

Results from EMAP are impacting national and local environmental protection programs. EMAP demonstrations in estu-

aries, lakes, and streams have resulted in EPA’s Office of Water recommending to states that probability surveys need to be incorporated into state monitoring programs. EMAP has developed a monitoring program for EPA’s Office of Air and Radiation to identify changes in aquatic effects stemming from reductions in acid deposition. Through the EMAP program, eight coastal states have received technical support to develop or improve their monitoring programs. One example is the Southern California Bight Project, described below. EMAP has laid the foundation on which to develop and implement regional monitoring in the SCB. The statistical sampling design developed and tested by EMAP is flexible enough to address local as well as regional questions with known confidence. Adopting the EMAP approach in the SCB has facilitated more rapid and cost-effective development of a regional monitoring program than would have been possible otherwise. This effort has stimulated and strengthened cooperation among the participating agencies, and it will ultimately improve environmental monitoring, research, and decisionmaking in Southern California.

The Southern California Bight Pilot Project—EMAP Applied

Over the past 20 years, tens of millions of dollars have been spent by federal and local governments for monitoring off the coast of Southern California in order to comply with National Pollutant Discharge Elimination System (NPDES) permits for discharging wastes. Despite large annual expenditures on marine monitoring, Southern California’s environmental managers have not been able to use all the scientific information gathered from these efforts to answer questions such as, “Is it safe to swim in the ocean?” or “Is it safe to eat the fish caught in the ocean?”

ORD and EPA’s Region 9 established the Southern California Bight Pilot (SCB) project, a partnership of 12 federal, state, and

local agencies. SCB uses elements of EMAP to provide data on trends in large-scale, long-term physical and biological processes. This regional demonstration will help to distinguish environmental effects caused by natural occurrences from effects caused by human activities.

Multi-Resolution Land Characteristic Consortium

Since the Multi-Resolution Land Characteristic Consortium (MRLC) ✓ was formed three years ago, EPA, the Department of the Interior, the National Oceanic and Atmospheric Administration, and the U.S. Geo-

Starting with a satellite image called a Landsat Thematic Mapper, scientists produce a new map by color coding the elements of a landscape according to land use. For example, in this map of New York and New Jersey, water bodies such as the Finger Lakes are blue, species of vegetation are shades of green, and urban areas are rust and orange. Through the MRLC, maps such as this one can be used by federal, state, and local governments for answering questions about changing landscape conditions.



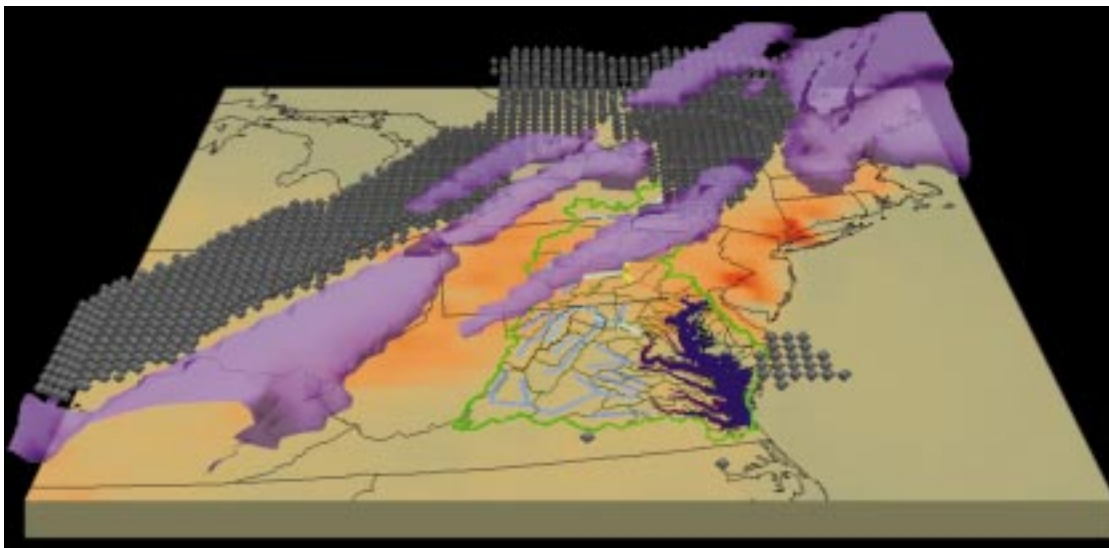
logical Survey have been pooling resources to purchase satellite data, to process the data into formats that are useful for environmental protection and resource management, and to set up a distribution system that makes the information available at a lower cost than if each of the agencies were to purchase it themselves.

While various federal and state agencies have used satellite data in the past, the MRLC started the momentum for a coordinated approach to using the data and to providing the imagery at a lower cost to users. It is estimated that the consortium could save the government \$30 million in purchasing costs and preparation of data, including archiving, data management, and distribution.

The consortium is providing its members enhanced satellite images—digital imagery and land cover maps—that illustrate the natural landscape of the continental U.S. These images provide a common baseline of information that can be used by agencies to answer questions about changing landscape conditions that relate to their programs.

For example, an interpretive landscape atlas is being used by EPA's Region 3 in its efforts to restore the Chesapeake Bay. The National Oceanic and Atmospheric Administration's Coastal Change Analysis Program is using the images to map coastal areas and watch how they change over time, analyzing how changes in land cover (such as urban development) affect aquatic life and the fishing industries in coastal regions. The National Water Quality Assessment program of U.S. Geological Survey is using land cover maps to assess the extent to which natural vegetation impacts the quality of surrounding water bodies.

As data are acquired and the maps are developed, they are added to the MRLC archive. The consortium is increasing the number of federal participants and plans to buy more recent data to increase the size and timeliness of the archive.



Three models—acid deposition, watershed, and nutrient loading—are integrated in the Models-3 framework to predict the sources of nitrogen in the Chesapeake Bay Watershed, and nitrogen's fate in the air, land, and water of the region.

Models-3: State-of-the-Art in Multimedia Modeling

Models-3, developed by NERL in cooperation with other federal agencies, is a state-of-the-art environmental modeling system that uses the advances in high performance computing technology to integrate fate and transport models developed for individual media such as air and water. The system is a computer framework that enables users to combine different scientific models, from different computer environments, and different computer programs to model environmental conditions.

For example, the first version of Models-3 combined models for simulating ground level ozone, acid deposition, visibility and particulate matter to predict urban to regional scale air quality. As lessons were learned from the first version, improvements were made and another application for the Models-3 framework was developed. This model, illustrated here, simulates nitrogen deposition in the Chesapeake Bay watershed. Three models—acid deposition, watershed, and nutrient loading—predict the sources, movement, and fate of nitrogen in the air, land, and water of the

region. These predictions can be used by regional environmental managers to develop risk management options for restoring the Chesapeake Bay.

Watershed Modeling System

Scientists at the Ecosystems Research Division of NERL in Athens, Georgia, have been working on models that predict the circulation, distribution, and properties of water at the watershed level. One such effort is the Watershed Modeling System (WMS). Developed in cooperation with the U.S. Army Corps of Engineers, WMS is one of the next generation of predictive watershed hydrology models.

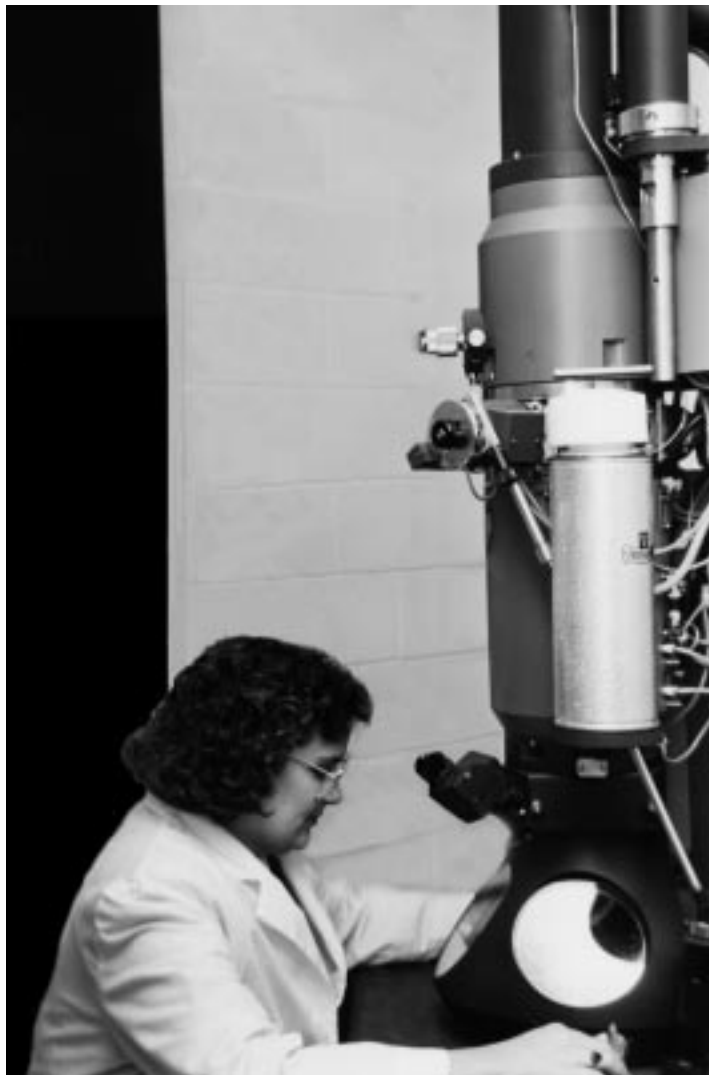
An unexpected use for the model came about when the U.S. Army joined the peace-keeping mission in Bosnia. In order to plan troop and equipment movements through the territory assigned to U.S. forces, the Corps needed the latest information on landscape conditions surrounding the Sava River, Bosnia's northern border with Croatia.

The Corps used data from the daily overnight runs of WMS to help locate the best approaches of the first pontoon bridge used

by US/NATO forces to cross the river into Bosnia. Set up for the Sava's 22,000 square mile watershed and using only data obtained on the Internet and through satellites, the first runs of the model predicted the river's stage height within 1 meter of its actual height. Subsequent fine-tuning of the model, which included data obtained from the old Yugoslav Ministry of Water, produced even more accurate predictions that were used to locate and construct the second pontoon bridge over the Sava and to locate dry emplacement areas for troops, armor, and artillery.

Closer to home, and with local data, WMS is being used to predict nitrate levels from septic tank waste contaminating ground water in La Plata County, Colorado. WMS provides a flexible and accurate representation of the site with its complex hydrogeology and potential for water quality degradation. The model will be used by county officials making land use decisions brought on by a development boom.

RESEARCH TO IMPROVE HUMAN HEALTH RISK ASSESSMENT



▲
Using an electron microscope, scientists examine tissue damaged by chemicals for neurotoxic effects. (photo: Congressional Office of Technology Assessment)

Health risk assessment is the process EPA uses to identify and characterize environmental health problems. ORD's research to improve health risk assessment addresses major deficiencies and uncertainties in health risk assessment (including both problem- or agent-specific risk assessment, and cross-cutting or generic risk assessment). ORD's research to improve health risk assessment includes studies and projects in each area of the risk assessment paradigm, for example:

- Develop models that trace the forward and backward relationships between sources and total exposure to better characterize the source-exposure relationship.
- Develop methods and models for estimating dose to target tissues to better understand the exposure-dose relationship for pollutants from each pathway.
- Develop screening methods to set testing priorities to improve our ability to detect hazards.
- Develop quantitative models for predicting tissue and organism response to target tissue dose to reduce uncertainty in extrapolations.

Ultimately the results of the research will enhance risk assessments to support national environmental goals, such as safe drinking water,

safe indoor environments, clean air, and safe food. Because of the broad applicability of improved methods for health risk assessment to many user communities, research to improve health risk assessment is a high priority for ORD's research agenda.

EPA Proposes Revised Guidelines for Cancer Risk Assessment

In April 1996, EPA published *The Proposed Guidelines for Carcinogen Risk Assessment*. ✓ These proposed guidelines, the result of a cross-agency effort under the Risk Assessment Forum, will replace the 1986 *Guidelines for Carcinogen Risk Assessment* (51 FR 33992) when final.

Since the publication of the 1986 cancer guidelines, scientific understanding of carcinogens has improved substantially. Today, many laboratories are moving toward adding new test protocols in their programs directed at mode of action questions. The proposed guidelines provide an analytical framework that allows for the incorporation of all relevant biological information, recognizes a variety of situations regarding cancer hazard, and is flexible enough to allow for consideration of future scientific advances.

STAR Grants for Cancer Risk Assessment

The University of Arkansas for Medical Sciences, the University of Colorado Health Sciences Center, and the Oregon Health Sciences University are researching the role of inter-individual genetic variation in human susceptibility to cancer, including cancers of the colon, rectum, and throat. Results should help EPA revise its cancer risk assessment guidelines to account for genetic variabilities.

The Hutchinson Cancer Research Center is developing a biologically based model for assessing the potential cancer effects from specific pollutant exposures to improve current cancer risk models.

Progress Continues Towards Finalizing EPA's Dioxin Reassessment

EPA, led by NCEA, has been engaged in a major effort to reassess risks associated with dioxins. A draft of the assessment entitled *Health Assessment Document for 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds* was reviewed by EPA's Science Advisory Board (SAB) in the Fall of 1995. In response to the SAB's comments, NCEA began revising two key sections of the report: the draft risk characterization

and the dose-response modeling chapter. Writing teams made up of scientific experts in the study of dioxin and related compounds from academia, consulting firms, industry, and federal and state agencies, including EPA, developed new drafts of both sections of the report. Following preliminary external review, the drafts are being reworked. The two sections will undergo external peer review and another review by the SAB in Summer 1997. It is expected that the reassessment will be finalized and available to the public before the end of 1997.

An important part of the dioxin reassessment effort is the Dioxin Exposure Initiative, a multi-phase research program to reduce uncertainties in dioxin exposure assessment, provide information for developing an Agency-wide Dioxin Exposure Reduction Strategy, and provide input to the document *Estimating Exposures to Dioxin-Like Compounds*. Several projects of this initiative have been completed in FY96, and the results will be incorporated into the exposure analysis of the reassessment.

NCEA has developed a preliminary inventory of measurements of multimedia emissions from combustion sources, industrial sources, chemical manufacturing, and natural/biogenic sources. The inventory is a primary reference for the national dioxin estimates from known sources in the U.S. It will be available to the public on the Internet in 1997, for use in analyzing emissions trends of sources.

With the U.S. Department of Agriculture, NCEA is coordinating three separate surveys—for beef, pork, and poultry—to evaluate the occurrence and levels of dioxins in animals at the point of slaughter production. The beef survey has been completed. The results have been published in *Chemosphere* and were presented at the 16th International Conference on Dioxin and Related Compounds held at the University of Amsterdam, The Netherlands. The pork and poultry surveys will be published this year.

Through a cooperative agreement with NCEA, scientists at the State University of New York in Binghamton studied the levels of dioxins present in cooked meat and fish products. Results of this study also were presented at the 16th International Conference on Dioxin and Related Compounds.

In a joint effort with the Department of Energy, NCEA scientists evaluated the chronology of the occurrence and levels of dioxins resulting from atmospheric deposition into lake sediments over the past century. Samples from 11 lakes throughout the continental U.S. and Alaska were evaluated. This provided the most convincing evidence to date regarding time-trends of dioxin-like compounds in the U.S. environment. The results of this study have been incorporated into the dioxin reassessment update.

Integrated Risk Information System Provides Consistent Risk Estimates

Consistent, high quality information on human health risk is needed by EPA program offices, regional risk assessors, and local policy-makers. The Integrated Risk Information System (IRIS) provides summaries of EPA-consensus information on health effects needed for risk assessments and other health evaluations in an easy-to-access, understandable form. IRIS unifies EPA assessments, ensuring consistent risk estimates for the same chemical across EPA programs. Since its release to the public in 1988, IRIS information on more than 500 chemicals has been used extensively by state and local governments, industries, and environmental action groups. The database and the process for developing the agency-wide consensus are managed and maintained by NCEA's Washington and Cincinnati offices. IRIS is available on the Internet, through the National Library of Medicine's TOXNET system, and distributed worldwide in cooperation with the



STAR Grants for Integrated Risk Information

The University of California at Berkley is developing a physiologically based model that will provide a method to predict effects at the population level that accounts for human variability.

The University of Rochester Medical Center is investigating the role of toxic chemicals to the nervous system and a possible relation to autism. This research looks at potential non-cancer effects as yet not characterized.

Harvard University is developing statistical methods for non-cancer risk assessment that will allow the utilization of distributions of exposure and toxicity data rather than point estimates that often extensively under- or over-predict risk.

World Health Organization and the Pan American Health Organization.

In early FY96, ORD initiated a pilot program to test improvements in the process for developing IRIS's consensus health information, improving external peer review, and enabling public input to the information collection process. The pilot will be completed in 1997, at which time an analysis of the pilot will help to define the best ways to improve IRIS.

Research Program Studies Pesticide Exposure and Effects for Children

ORD's research to protect children from the adverse health effects of pesticides has been influenced strongly by the 1993 National Academy of Sciences report, *Pesticides in the Diets of Infants and Children*. The Academy concluded that both exposure and health effects experienced by children are different from those of adults and that the federal government should do more to address their unique risks.

Children's exposures to pollutants and the potential health effects differ from those of adults. As part of an EPA initiative, ORD scientists research the factors that make children more vulnerable than adults to health effects from pollutants. (photo: Steve Delaney)



The major objectives of the research program are to advance understanding of factors that make children more vulnerable to health effects of pollutants than adults and to develop methods and guidance for assessing risks to children so that we can apply new-found understanding to reduce risks to children.

ORD's research program includes a multidisciplinary evaluation of age-related differences in sensitivity to pesticides. Studies are underway using laboratory animals to examine differences in the way pesticides are distributed and detoxified in the body among different age groups.

ORD also is studying the effects of pesticide exposure at critical stages of development, including prenatal and infancy, in laboratory animals. Special emphasis is being placed on evaluating effects on the developing nervous, immune, and reproductive

systems. Research is focusing on the evaluation of effects that might be expected to occur in humans, including subtle effects such as deficits in learning and memory. Finally, the program is evaluating better ways to use the data collected in animal studies to predict health outcomes in humans.

In addition to looking at health effects, NERL scientists are studying how children are exposed to pesticides. By understanding which pathways of exposure are of greatest concern, it is possible to better focus preventive measures. This research is in support of EPA's Office of Prevention, Pesticides, and Toxic Substances to revise the *Post-Application Exposure Monitoring and Assessment Guidelines for Pesticides and Consumer Use Products in Residential Environments*.

An important element of pesticide exposure research is an intensive study of how residues of pesticides are transported into and

around homes and the behaviors of children (such as crawling on the floor) that bring them into contact with these residues. For example, methods for detecting loose residues on carpets, bare floors, and lawns are being evaluated and field tested under controlled conditions. Round-robin performance tests have been completed with the assistance of pesticide manufacturers. New and improved methods for determining dermal exposure to pesticides have been developed including more precise procedures for gathering samples from hands and surfaces. This research has produced three draft protocols for EPA's Office of Pesticide Programs to use in issuing guidance on measuring dislodgeable pesticides. The goals of this research are to predict children's exposure and risks to pesticides used in and around homes, and to develop strategies for reducing risks to children.

Besides research underway in our own labs, NCERQA has recently awarded a special set of competitive research grants to universities in the area of children's exposure to pesticides.



STAR Grants for Pesticides

Arizona State University is currently measuring environmental concentrations of pesticides in and around the homes of 300 children in Yuma County, Arizona to evaluate multiple sources of exposure and their relative contributions.

Mississippi State University is assessing levels of pesticide that are transferred from dogs to children after flea control treatments.

The University of Washington is investigating the exposure of groups of urban, suburban, and rural children to pesticides. The data will be used to determine the relative contribution of the various pesticide sources and to develop models for predicting pesticide exposure.

Finally, in collaboration with the National Cancer Institute and the National Institute of Environmental Health Sciences, ORD is conducting the Agriculture Health Study, a long-term study of 75,000 subjects—primarily farmers—to examine pesticide exposure and health risks. EPA will measure exposure of a subset of 250 farmers, plus 50 spouses and 50 children, during periods of pesticide application. The study is expected to advance our understanding of the health risks experienced by farm families.

Agency Guidelines for Assessing Reproductive Toxicity Finalized

In October 1996, the Agency published the final *Guidelines for Reproductive Toxicity Risk Assessment* (EPA 630-R-96-009). These guidelines, the result of a cross-agency effort guided by the Risk Assessment Forum, will promote consistency in the Agency's assessment of toxic effects on the male and female reproductive systems.

The guidelines discuss the scientific basis for concern about exposure to agents that cause reproductive toxicity and describe the principles and procedures for conducting risk assessments for reproductive toxicity. They identify and discuss the use of default assumptions, present summaries of the standardized testing protocols used to generate information on reproductive toxicity, discuss the various types of information that may be encountered in evaluations of reproductive toxicity, and specify the approaches that are appropriate for quantitative risk assessment and exposure assessment. These guidelines complement the *Agency Guidelines for Developmental Toxicity Risk Assessment*.

ORD's Health Monitoring Experience Impacts U.S./Mexico Border Project

The U.S./Mexico Border Project is a good example of how ORD's unique expertise in environmental health research is contributing essential information needed for solving

a serious local health problem. The project also is a model for interagency cooperation in which stakeholders have been able to explain their needs, and the federal and state government organizations involved have not duplicated one another's efforts or resources to respond to those needs.

ORD has been a driving force in the Interagency Coordinating Committee (ICC) for U.S./Mexico Border Environmental Health, a coalition of eight organizations from the Department of Health and Human Services, the states of Texas, Arizona, New Mexico, and California, Mexico's Ministry of Health, and the Pan American Health Organization.

In 1992, ORD researchers, in an effort led by NHEERL and NERL, collected exposure data in the Lower Rio Grande Valley as part of the ICC response to reports from the Centers for Disease Control and Prevention (CDCP) of clusters of anencephaly in the Lower Rio Grande Valley. These data showed high levels of polychlorinated biphenyls (PCBs) contamination in fish. Based on the findings from the first phase of ORD's monitoring

pilot study, the State of Texas and CDCP reinforced fishing bans and advisories and provided information to the public on how to keep water bottles from being contaminated.

Since the initial studies, it became clear to the ICC member organizations that there was a dearth of exposure data needed to set priorities and determine the best courses of action. Through an open process involving the public and stakeholders, priorities were set for further research that built on the information existing with the federal and state agencies and utilized their unique areas of expertise to fill data gaps. Currently, ORD has the lead, is collaborating, or is supporting research in three main areas: surveillance and monitoring; exposure and epidemiology; and communications, training, and education.

New Framework Developed for Assessing Dose-Response for PCB Mixtures

Scientists with the Washington, DC office of NCEA developed a new cancer dose response assessment for environmental

On a rooftop in Brownsville, Texas, scientists collect and measure fine and coarse particles, acidic gases, and volatile and semi-volatile organic compounds. The project is one of many research efforts of Border XXI, a multi-agency, international effort to increase and improve the data needed to set priorities for environmental protection efforts in the region.



mixtures of PCBs. Prior assessments had been based on previously available information that did not allow differentiation among environmental mixtures. However, new data indicated that the “how” of exposure (or pathway) was an important factor in assessment. For example, the PCBs that bioaccumulate in fish are generally of greater concern than the PCBs that would be dissolved in drinking water. To make these judgments, the new assessment considers the processes that chemically change PCB mixtures after they are released into the environment. ORD’s report provides guidance on how to apply a range of dose-response parameters to different exposure routes, partial lifetime exposure, and different mixtures of PCBs. In addition, ORD is assisting the program offices with incorporating these results in the guidance they develop for analyzing samples of PCBs.

Superfund Technical Support Center Provides Toxicity Data for Superfund Cleanups

The Superfund Technical Support Center of NCEA in Cincinnati, Ohio, is the focal point for the assessment of toxicity information and the development of provisional toxicity values for chemicals commonly found at Superfund sites.

During FY95-96, the center responded to a total of 326 requests: 163 for specific Superfund sites and 163 from EPA regional offices. The center developed provisional risk assessments for 98 new chemicals and revised existing risk assessments for 33 chemicals. The Superfund Technical Support Center is an important information resource that enables ORD to reach out to communities by providing a central location for credible evaluations of toxicity information.

NHEXAS—Monitoring to Improve Exposure Assessments

The National Human Exposure Assessment Survey (NHEXAS) seeks to better under-

stand the complete picture of human exposure to toxic chemicals, by looking at various exposures to important toxic chemicals through all routes of exposure. ORD scientists developed the concept and design of the survey, and coordinated its implementation with the Food and Drug Administration and the National Institute of Standards and Technology. ORD scientists from NERL and NCEA serve along with scientists from other participating agencies on each of the study teams.

With NHEXAS data, scientists will have a baseline description of the normal range of human exposure to environmental chemicals that should improve estimates of total human exposure. The data will help identify groups of people who are more exposed or particularly sensitive to environmental chemicals, allow comparisons with studies of particular exposure routes, relate pollution sources to actual exposures, and allow comparisons of actual exposures to exposures predicted by models.

NHEXAS studies are being conducted in three different regions of the U.S. with other research organizations:

- Arizona—with the University of Arizona, Battelle Memorial Institute, and the Illinois Institute of Technology.
- Midwest states of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin—with the Research Triangle Institute and the Environmental and Occupational Health Sciences Institute of Rutgers University.
- Maryland—with Harvard University, Emory University, Johns Hopkins University, and Westat, a survey consulting firm.

Sampling began in FY95 and the laboratory analysis is expected to be finished by early 1998. Data from the studies are expected to be available for use in 1999.

Study Investigates Education and Cleanup to Reduce Lead Exposures in the Home

Nine percent of children six years old and younger in the U.S. have lead in their blood in amounts greater than the level believed to cause adverse effects to the neurological system. Public health measures to address this problem are hindered by a lack of practical and cost effective methods to prevent exposures.

During 1996, scientists from NERL and the University of Medicine and Dentistry of the New Jersey Robert Wood Johnson Medical School collaborated on the Childhood Lead Exposure and Reduction Study (CLEARS). The study, conducted in Jersey City, New Jersey, tested the effectiveness of a two part intervention in reducing the levels of lead found in children's blood.

The study compared two intervention approaches: education and biweekly cleaning

by professionals trained in methods to control lead contaminated dust. Study participants were divided into two groups. One group received routine information about lead and served as the control group. The second group received training and had their houses cleaned every two weeks. During the course of a one-year intervention, the treatment group was offered biweekly assistance with house dust control and a series of educational sessions about lead. The participants were followed over one to two years with measurements taken of blood lead levels and the levels of lead contamination in the participants' homes. After intervention, blood lead level fell by 17 percent in the treatment group and increased in the control group. The mean difference between the groups in final blood lead was most striking in the summer months. The reduction of blood lead in the treatment group was greater for the children whose houses were cleaned nine times compared to those in homes cleaned on fewer occasions.

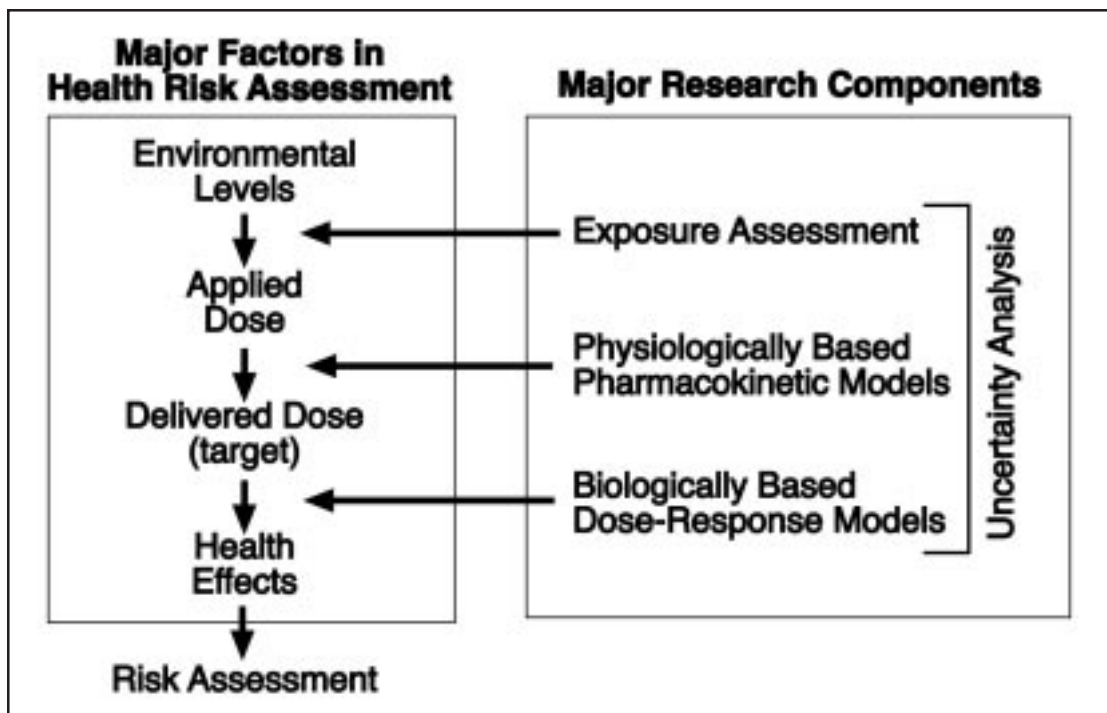
The study demonstrated that biweekly cleaning and education is a better approach for reducing children's blood levels and household lead exposure for children than education alone. These results confirm the importance of controlling dust and providing education as a practical strategy for children at risk of lead exposure.

Report Integrates Lead Studies of Three Cities

In April 1996, NCEA in Research Triangle Park, North Carolina, completed a report that integrates findings from three studies of whether abatement of lead in soil reduces the levels of lead in blood of inner city children. The project, known as the "Three Cities Lead Study," was authorized in 1986 under the Superfund Amendments and Reauthorization Act, and begun in December 1986, in cooperation with state health departments and local scientists.

The spirometer, a standard instrument that measures pulmonary function in medical patients, is used also by ORD's Human Studies Division of NHEERL to measure lung changes from exposure to environmental pollutants. At ORD's world class facility for human studies, the subject forcefully exhales into the tube and the spirometer measures the quality of breath exhaled and its rate of flow.





Physiologically Based Pharmacokinetic (PB-PK) models are mathematical descriptions of how pollutants are absorbed, distributed, metabolized, and eliminated in animals and humans. Improving PB-PK models reduces uncertainty associated with estimating the applied dose for a risk assessment. Biologically Based Dose-Response (BBDR) models describe the biological cascade of events from exposure to a pollutant to onset of disease. Improving BBDR models reduces uncertainty associated with estimating a delivered dose for a risk assessment.

The integrated report confirms the findings of the individual studies and reaches the following conclusions:

- When soil is a significant source of lead in the child's environment, the abatement of that soil will result in a reduction in exposure that will, under certain conditions, cause a reduction in childhood blood lead concentrations.
- Although these conditions for a reduction in blood lead levels are not fully understood, it is likely that four factors are important: 1) the past history of exposure of the child to lead, as reflected in the pre-abatement blood lead levels; 2) the magnitude of the reduction in soil lead concentrations; 3) the magnitude of the other sources of lead exposure, relative to soil; and 4) a direct exposure pathway between soil and the child.

PB-PK and BBDR Modeling

In risk assessments, scientists draw conclusions about how a chemical will effect

people from data gathered in studies of animals given large doses of the chemical. These conclusions, or extrapolations, are necessarily limited because the studies from which the conclusions are drawn do not mimic real exposures to real people. Extrapolations can be made from high to low doses, from laboratory animals to people, or from one route of exposure for which there are data to another route of exposure for which there are none. There are many unknowns connected with these extrapolations. Research to fill in the data gaps is necessary to improve risk assessments that use extrapolations.

Since 1988, ORD has been conducting studies to develop and improve the models used for extrapolations in risk assessments. Two such models are the physiologically based pharmacokinetic (PB-PK) model and the biologically based dose-response (BBDR) model.

In FY95, scientists with NHEERL studied the difference in dose of ozone to humans and animals and how those differences can

impact a risk assessment. The study demonstrated that humans received four times the dose to lung tissue at a given environmental level than did rats, largely due to differences in exercise levels and the associated breathing rates. The study also provided information on pulmonary dose levels that can be used for assessing similar gases for which there is no data. The results demonstrated the importance of factoring in human exercise and breathing patterns when extrapolating from laboratory animals to humans.

To understand and predict the mechanism of toxicity, scientists at NHEERL study the cascade of events that occur from exposure to a chemical to disease. Better understanding of these mechanisms improves the dose-response estimates used in risk assessments. ORD scientists are studying persistent substances, such as dioxin, to develop models of how toxicity occurs. Other ongoing studies of mechanisms of toxicity and repair include research on the hazardous air pollutant phosgene and the fungicide vinclozolin.

POLLUTION PREVENTION AND NEW TECHNOLOGY FOR ENVIRONMENTAL PROTECTION



Pollution prevention works as a powerful risk management tool because it is far more cost-effective and protective of the environment than waiting to solve environmental problems after they have been created. Pollution prevention, supported by objective scientific and technical data, reduces or eliminates the need for legal actions and regulatory standards, which can be costly and difficult to implement. It also offers an opportunity for meaningful stakeholder input and



Research into preventing pollution is an important aspect of ORD's research program. ORD also conducts research and demonstration of new technology, such as bioremediation methods for cleaning up oil spills.

participation as part of the risk management research and development process.

ORD's intramural and extramural research programs support cutting-edge research and development of new tools, techniques, and processes for preventing and cleaning up pollution. EPA's Small Business Innovation Research Program accesses and nurtures the expertise of private innovators for pollution prevention and other environmental technologies. The accelerating development of new environmental technologies has created growing opportunities for managing environmental threats to public health and natural resources, as well as economic opportunities in the U.S. and abroad.

Pollution Prevention Software Helps Industry Evaluate Impacts of Processes on the Environment

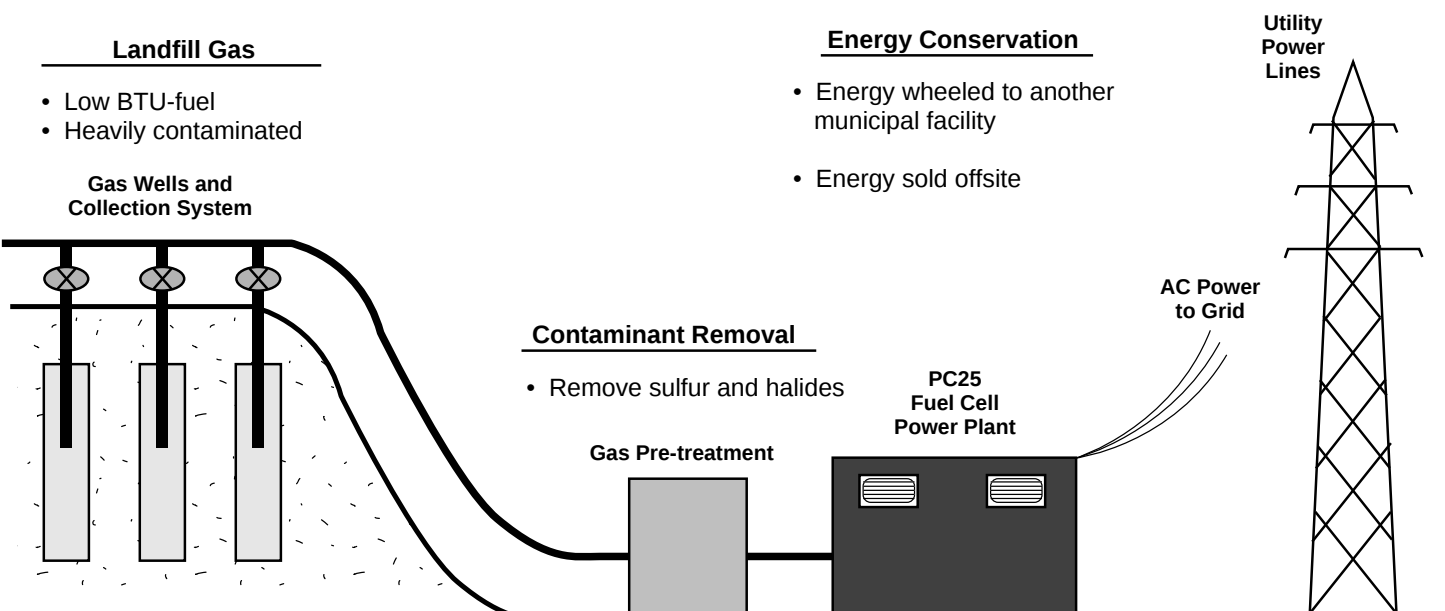
In 1995, a software program, Pollution Prevention Progress (P2P), was developed by the Sustainable Technology Division of NRMRL to assess how pollution can be prevented or decreased as a result of product redesign, reformulation, or replacement in industrial practices. The program tracks the environmental media affected and three categories of pollution impacts (human health, environmental use impairment, and disposal capacity). It also provides information about the specific classes of pollution prevented (*e.g.*, toxic organics, aquatic life toxicants, hazardous wastes). In 1996, a second version of the program was developed that has recently undergone beta testing by a number of users both in and outside of the Agency. The revised version of the software will be released to the public in 1997. This version, which will incorporate a database of almost 3,000 pollutants, will process uncertainties associated with incompletely

classified pollutants and provide reports of regulatory impacts.

U.S. Navy to Save Millions with ORD CFC Replacement

Many Navy shipboard chillers currently use the refrigerant CFC-114, an ozone-depleting compound. As part of its program for finding replacements for ozone depleting substances, scientists with the Air Pollution and Control Division of NRMRL in Research Triangle Park, North Carolina, have identified an acceptable replacement for the Navy's refrigerant. A chemical of the family of hydrofluorocarbon (HFC) 236 was selected based on synthesis, evaluation of properties, computer modeling, application testing, and safety testing conducted by ORD. Retrofitting shipboard chillers to HFC-236fa is estimated to save the Navy between \$300 million and \$500 million (depending on the number of ships converted) compared to having to completely replace the chillers. HFC-236fa has no ozone depletion potential.

Scientists estimate that over 4,000 megawatts of electric power could be generated from 7,480 existing and closed landfills.



Fuel Cell Developed That Uses Landfill “Waste” Gas to Make Electricity

Scientists with NRMRL’s Air Pollution Prevention and Control Division have developed an innovative filter that purifies the gaseous mixture that comes from landfills into pure methane. The methane can then be used in fuel cells that generate electricity.

In a recent test conducted at a California landfill, the filter removed more than 30 contaminants with 99.95 percent efficiency. An environmental assessment has shown that the fuel cell/gas cleanup technology can eliminate virtually all fugitive methane, non-methane organic compounds, and toxic emissions.

Scientists estimate that over 4,000 megawatts of electric power could be generated from 7,480 existing and closed landfills. Fuel cells, utilizing just 25 percent of landfill gas, could provide power to over 5 million homes. Testing of the technology continues at a Groton, Connecticut, landfill in partnership with International Fuel Cells Corporation, who developed the fuel cell, and Northeast Utilities, who is funding the test.

The technology placed second in the Environment Category of *Discover Magazine’s* 1996 Seventh Annual Technology Awards.

Pollution Prevention Approaches Applied to Indoor Air Quality

Since most people spend as much as 90 percent of their time indoors and indoor pollutant concentrations frequently exceed those outdoors, indoor air quality can pose an important environmental health risk. At the Air Pollution Prevention and Control Division of NRMRL in Research Triangle Park, North Carolina, researchers are applying the principles of pollution prevention in three different projects to improve indoor air quality. In one study, researchers are developing a standard test method that will assist manufacturers in characterizing

emissions from office equipment and examining how these emissions might be reduced. Research also is underway to develop an innovative spray nozzle that will allow manufacturers to reformulate certain aerosol consumer products using air and water in place of volatile organic compounds and hydrocarbons, without compromising acceptable product characteristics. Third, ORD scientists are evaluating emissions from engineered wood products. This project is targeted at identifying the primary sources of emissions from these products and evaluating lower-emitting alternatives.

STAR Grants on Pollution Prevention Applied to Indoor Air Quality

Several research projects at the *University of Iowa* and the *Georgia Institute of Technology* focus on finding non-toxic substitutes for organic solvents used in chemical reactions.

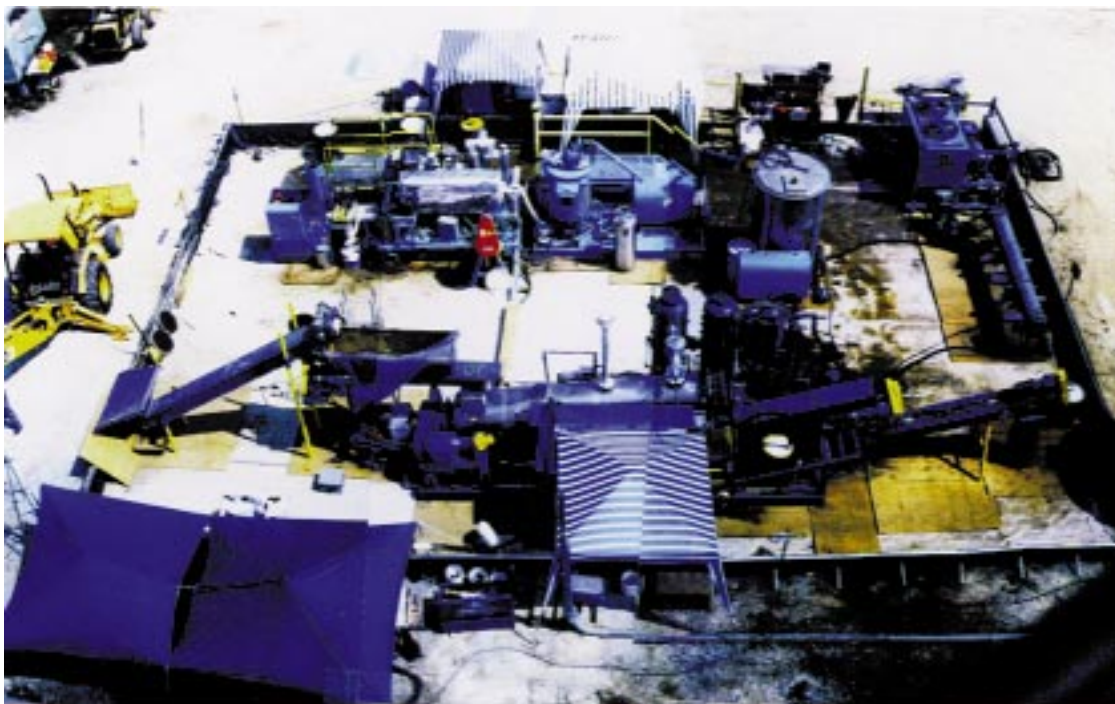
Oklahoma State University is developing a process for producing cutting tools with a coating that will eliminate the need for traditional oils and solvents in dry machining.

Michigan Technological University is developing a model based on Markovian decisionmaking that will enhance industry’s ability to conduct life-cycle assessments of a production process to identify targets for reducing pollution. The model will be evaluated in the automobile manufacturing industry.

Life Cycle Assessment Book Published

The principles of environmental life cycle analysis are described in a book recently edited and coauthored by a researcher in NRMRL’s Sustainable Technology Division.

One of the SITE projects demonstrated is the base-catalyzed decomposition (BCD) process developed by ORD for treating soils, sediments, and sludges contaminated with chlorinated compounds. At this demonstration conducted at the Koppers Company Superfund site in Morrisville, North Carolina, the process removed 99 percent of pentachlorophenol and 92 percent of the dioxins and furans.
(photo: Terry Lyons)



The book, *Environmental Life Cycle Assessment*, was developed for readers who want to learn more about how the concept is being applied in various industries for product and process design and improvement, as well as in public policy development. Numerous examples from practitioners in North America and Europe are included.

Environmental Technology Verification Program

Throughout its history, EPA has evaluated technologies to determine their effectiveness in preventing, controlling, and cleaning up pollution. EPA is now expanding these efforts through the Environmental Technology Verification Program (ETV) ✓. Initiated in late 1995 and coordinated by NRMRL's Washington office, ETV accelerates the commercialization of new technologies into the domestic and international marketplaces by using the facilities and expertise of partner "verification organizations" to carry out technology evaluations and, through these

evaluations, to verify the performance of commercial-ready innovative technologies.

In 1996, six pilot evaluations were initiated to evaluate drinking water systems, site characterization and monitoring devices, indoor air products, pollution prevention, treatment technologies, and an independent project that is not confined to any single technology area. In addition, five new pilot projects on pollution prevention were added.

SITE Program Builds on Past Success to Set New Direction

Through the Superfund Innovative Technology Evaluation (SITE) program, coordinated by NRMRL, EPA has developed, evaluated, and demonstrated a wide variety of innovative technologies that have reduced the uncertainty and costs associated with cleaning up hazardous waste sites. The program has completed 84 field demonstrations of remediation technologies and 29 demonstrations

of contaminant measuring and monitoring approaches. Today, due in large part to the success of the SITE program, more than half the technologies selected by EPA for site cleanups are innovative technologies not commonly used ten years ago. In a spot sampling of 17 cleanup decisions using SITE technologies, projected savings averaged \$12 million a site, with total projected savings, normalized to 1986 levels, of over \$213 million for the 17 sites.

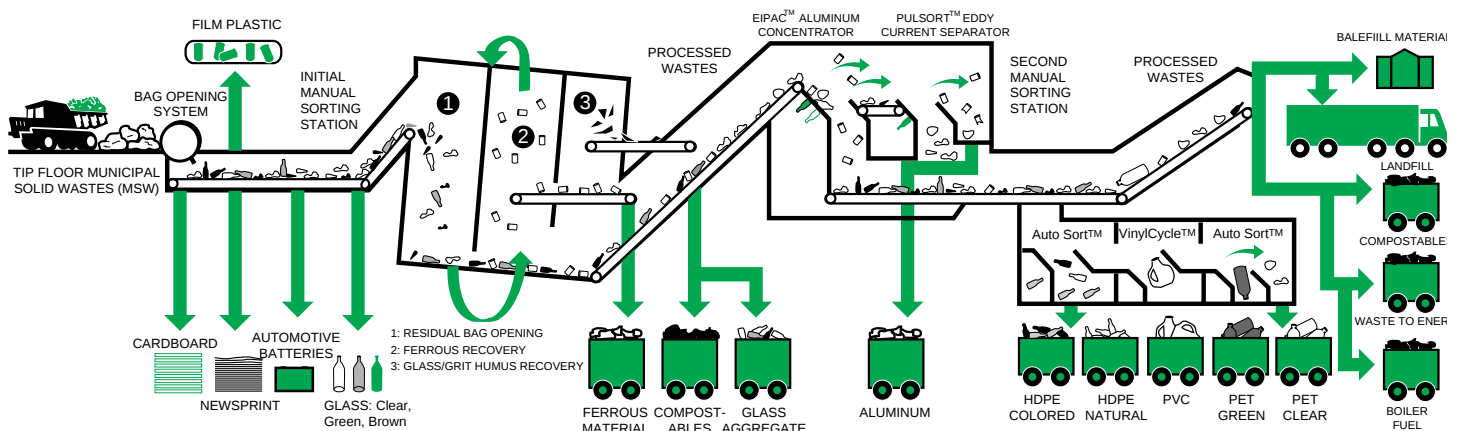
Building on the accomplishments of the past ten years, SITE is working with the remediation community to identify priority sites and the technology suppliers to match the sites with the technology solutions. SITE is combining efforts with other EPA offices and other agencies such as the states, the Department of Defense and the Department of Energy. The program focuses on low-cost, easily implemented, and highly effective technologies to solve hazardous waste problems; and develops credible quality assurance guidelines for testing those technologies.

SBIR Program: Small Business Innovations Solve Big Environmental Problems

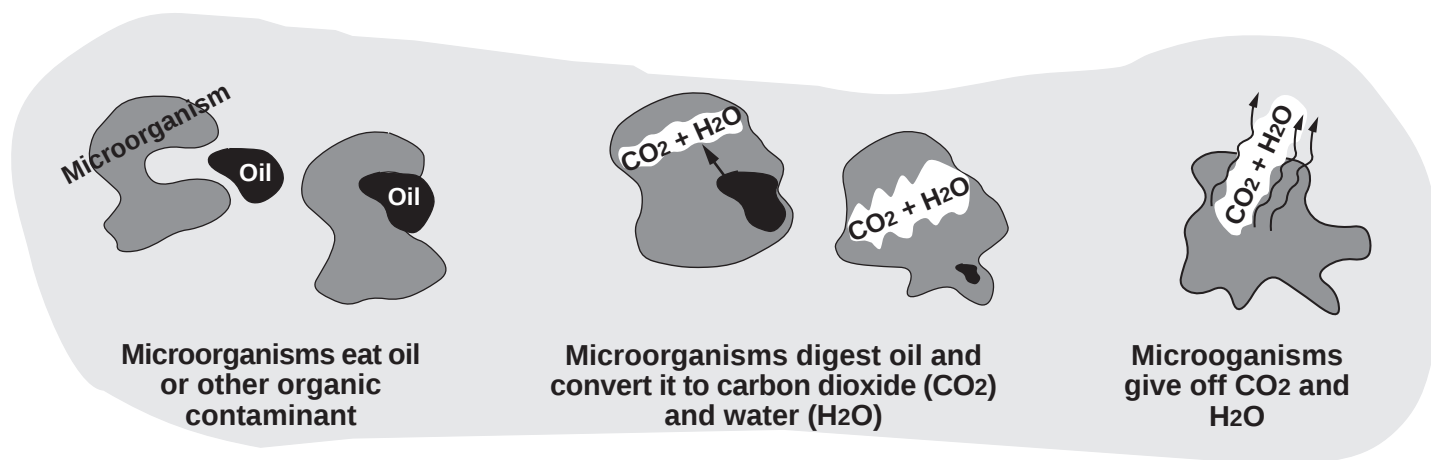
Created in 1982 by the Small Business Innovation Act, EPA's Small Business Innovation Research (SBIR) Program is an important part of the Agency's research and development efforts. Through the program, managed by NCERQA, EPA makes awards to small, high-technology firms for research and development of cutting-edge technologies.

Over the past decade, dozens of innovative technologies have emerged from this program. A number have moved quickly from "proof of concept" to commercialization. In other cases, companies are still seeking the start-up capital or other support needed to achieve commercialization of their technologies. A comprehensive discussion of the program and its success stories can be found in *EPA's Small Business Innovation Research (SBIR) Program: Innovative Solutions for Environmental Problems*, December 1996. The following two success stories give a sense of how the SBIR program works.

The Autosort® technology is set in motion three-fourths of the way through the sorting process. Further sorting of plastic containers into five categories removes the highly toxic PVC plastics before incineration. The remaining plastics can be used to produce many other products from carpet to clothing.



Example of a Bioremediation Process



National Recovery Technologies (NRT) was awarded an SBIR contract in 1988 to develop technology that uses an electromagnetic sensor to separate the different types of plastics found in recycling facilities. The resulting technology, AutoSort® and VinylCycle®, assists in recycling different types of plastic bottles by sorting them according to their chemical makeup. PVC plastics, which are highly toxic when burned, are removed before incineration. The remaining plastics can then be used in the production of many products—from carpet to clothing.

By 1996, over 40 VinylCycle® systems were in operation in the U.S., Europe, Japan, and Australia. The success of the technology has fostered development of a color/polymer sorter for plastics, Multisort®, which sorts 5,000 pounds of plastic bottles per hour by color and type. In recognition of its accomplishments, NRT became one of the first companies to receive the Tibbetts Award in 1996.

Membrane Technology and Research, Inc. (MTR) received an SBIR contract to develop a membrane separation process for recovering

VOCs from contaminated air streams. VOCs are the most common pollutants emitted from chemical manufacturing processes. The Clean Air Act requires that these emissions be eliminated or reduced. Each year, chemical manufacturers must remove some 500 million pounds of organic pollutants from 50 million cubic feet of air.

The system, VaporSep®, combines proven condensation techniques with a unique pressure-driven membrane vapor separation process. The combination produces far better recovery performance than condensation alone, achieving much higher recovery rates or maintaining existing recovery rates under less extreme temperature and pressure conditions. MTR has reported sales of \$4.4 million and has installed more than 30 systems in chemical and pharmaceutical plants.

Bioremediation Research Promotes “Natural” Cleanup Technologies

Bioremediation harnesses nature’s most efficient recycling agents—microorganisms—to reclaim contaminated environments. Because it relies on natural processes, bioremediation is far less expensive and

far less disruptive to the environment than conventional remediation. ORD launched a research program in 1987 to discover and develop bioremediation technologies as the U.S. was beginning the costly cleanup of thousands of sites contaminated by uncontrolled waste disposal, leaking underground storage tanks, and other sources. The following is a small sample of the technologies developed and tested under the bioremediation program managed by NRMRL.

Scientists with NRMRL and the U.S. Department of Agriculture have been awarded a patent for their research using fungi to degrade lignin, a naturally occurring polymer that is chemically related to pollutants that resist biodegradation. Fungi, unlike bacteria, can move through soil. The process is applicable to a wide range of organic pollutants such as aromatic hydrocarbons and munitions chemicals. New methods for the introduction of the fungi into the soil also have been developed to improve the cost effectiveness of the treatment.

One obstacle to successful bioremediation of deep soils is lack of oxygen needed by microorganisms. ORD scientists pioneered bioventing, a method of delivering enough oxygen to allow successful in situ bioremediation of deep soils. Bioventing costs about 20 times less than the traditional excavate-and-incinerate approach. In FY95, after several years of experience field testing the process, NRMRL combined efforts with the U.S. Air Force to compile a how-to manual, *Principles and Practices Manual for Bioventing*. The manual details the basic science behind the process and gives guidance on how to implement bioventing. The manual has become an essential reference for EPA remedial project managers (RPMs), state Underground Storage Tank program managers, and environmental engineering firms.

Monitoring Indicators Developed to Measure Effectiveness of Using Bioremediation to Clean Up Subsurface Contamination

Contamination of soil and groundwater from fuel hydrocarbons at Department of Defense facilities is a common problem due to heavy use and maintenance of military vehicles and aircraft. Under the sponsorship of the Strategic Environmental Research and Development Program, scientists at the Subsurface Remediation Division of NRMRL in Ada, Oklahoma, have developed monitoring indicators to identify the major inorganic and organic parameters that serve as yardsticks for subsurface bioremediation of fuels. This monitoring capability will result in substantial cost saving over traditional remediation monitoring activities. Conservative estimates predict a 20-25 percent savings in long-term monitoring costs.

The appropriateness of natural attenuation as an acceptable cleanup method must be evaluated on a site-by-site basis. In addition to monitoring for the contaminants found in the source, reliable indicators of the progress of the bioremediation process are needed.

The monitoring indicators are being validated at Wurtsmith Air Force Base.

WORLD WIDE WEB SITES

EPA's Office of Research and Development

<http://www.epa.gov/ORD/>
<http://www.epa.gov/ORD/publications/>
<http://www.epa.gov/ORD/whatsnew.htm>

ORD's National Center for Environmental Research and Quality Assurance

<http://www.epa.gov/ncerqa/>

Environmental Research Centers

<http://es.inel.gov/ncerqa/centers/>

Endocrine Disrupter Working Group of the Committee on the Environment and Natural Resources

<http://www.epa.gov/endocrine/frametext.html>

Special Report on Environmental Endocrine Disruption: An Effects Assessment and Analysis

<http://www.epa.gov/ORD/WebPubs/endocrine/>

Deformed Frogs Workshop in September 1996

<http://www.im.nbs.gov/naamp3/papers/59df.html>

Deformed Frog Pictures

<http://mncs.k12.mn.us/frog/picts.html>

Environmental Monitoring and Assessment Program (EMAP)

<http://www.epa.gov/emap/>

Multi-Resolution Land Characteristic Consortium

<http://www.epa.gov/mrlc/>

Interagency Coordinating Committee for U.S./Mexico Border Environmental Health

<http://www.epa.gov/orsearth/>

Environmental Technology Verification Program (ETV)

<http://www.epa.gov/etv/>

SITE Program

<http://www.epa.gov/ORD/SITE/>

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