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Research and Development
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RESEARCH OUTLOOK 1979

FOREWORD

In the past, EPA's research program has been criticized for not adequately supporting the agency's regulatory activities and, at the same time for not providing a longer range, "over the horizon" viewpoint needed to guide EPA's future strategies. In response, we have made major changes within the past year and a half to improve the planning and management of research in support of the regulatory programs. For instance, under the direction of a task force of top-level EPA managers, a new system for jointly planning research with the regulatory offices has been developed. This new system has been successfully implemented on a pilot scale. We are now extending it to the entire research program. Also, in response to these criticisms, we have recently established a multidisciplinary strategic analysis group to help identify future environmental trends and potential problems, and develop sound policies for averting the threats to human health and the environment. I believe that we have made significant progress in answering both criticisms of the research program.

This *Research Outlook* series, plays an important role in shaping the changes now taking place in EPA. It provides a mechanism for us to describe in a concise fashion our plans for future environmental research and development. It provides the vehicle for an important dialogue within the agency on how to achieve the best balance between research answering short-term regulatory needs and research anticipating future problems. Finally, it provides the basis for a creative exchange with our Science Advisory Board, the Congress, the scientific community, and the public.

As in last year's *Outlook*, we have relied on our analysis of EPA's legislative mandates, our scientific intuition, and an examination of environmental trends. However, just as research is a dynamic process, the plans which describe what will be done must also be constantly adjusted. Accordingly, the research directions described here will change, some slightly and some more significantly, as our understanding improves.

While there is still a long way to go, I sincerely believe that EPA's research program is steadily moving toward a full partnership with the agency's regulatory programs. I hope that after reading this report you will also share my belief.

Stephen J. Gage
Assistant Administrator
Research and Development

RESEARCH OUTLOOK 1979

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INTRODUCTION

This *Research Outlook 1979* describes the research plan for 8 separate but interrelated EPA programs. It also includes a number of sections, such as "Global Pollution" and "Research Options" which discuss non programmatic aspects of EPA research. The intent of this document is to elucidate, in an informative and interesting manner, the goals, priorities, and expected results of our key research programs. By focusing on the specifics of our programs, this document is a continuation of the information contained in *Research Outlook 1978*. Last year we described in detail the environmental problems to be investigated and presented the pertinent philosophy that guides our research and helps establish our research goals. In contrast, this year we briefly summarize the environmental problems and associated research needs addressed by each program and then discuss in some detail our plans to fulfill those needs.

In the interest of brevity, research milestones and expected dates of significant research results were tabulated in each program chapter. Where warranted, the text discusses some of the major points about each milestone although a clear picture of our plans can be obtained from the tables. The nonprogrammatic chapters have tables of a different sort but these too are to consolidate the essence of each chapter's information. We mention the summarizing tables for those readers who have an interest in, but not the time for, a complete reading of this report.

Many of our previous planning documents have been criticized for a lack of specificity and for leaving readers wondering just what research will take place. We have attempted to respond to that criticism although the challenge was formidable. That is, we want the document to be concise and easily read but, at the same time, to be specific enough to give an adequate picture of our research plans. To this end, *Research Outlook 1979* occupies a middle ground; you'll get an overview of what we are attempting to accomplish, why we are attempting it, who the results are for, and who will do the actual work. However, we do not delve into separate projects of each research program. We hope we have found the right level of detail.

The combined budgets committed to the programs discussed in this report represent approximately 90 percent ($283 million) of the total EPA research budget for fiscal 1979. All of our research laboratories play some part in one or another of these programs, hence, personnel from each laboratory helped contribute to this report.

We invite comments about this report and about the research plans and programs that are discussed. If the report stimulates dialogues about our research we will have achieved much; if it leaves you with a clear statement of future EPA research we will have achieved all we set out to do.

TOXIC SUBSTANCES

Toxic substances have spread throughout the environment and are now being found in humans. EPA's research is working to gain the understanding necessary for control.

We open *Research Outlook 1979* with this toxic substances chapter in order to emphasize the pervasive nature of toxics research in EPA. With a few notable exceptions, such as hazards from nonionizing radiation or disease from viruses in drinking water, toxic substances provide much of an overview for our program-specific research plans. Currently, $26.3 million is being spent on research in direct support of the Toxic Substances Control Act of 1976. However, a considerably higher portion of EPA's research budget is dedicated to toxics research albeit under different names and within different programs. Therefore, as a prelude to the research plans, goals, objectives and priorities in the individual chapters that follow, we begin this chapter with some fundamental philosophies that guide our research planning, the social consequences of both the toxics problems and our research programs, and some of the complex issues we deal with daily.

The Problem

Modern industrialization of our society has resulted in a dramatic increase in the production and use of chemicals. Within the past twenty years, the annual production of the most common inorganic chemical commodities such as salt, sulfuric acid, lime, etc., has doubled. In the organic chemical industry, production has doubled in only the past decade, exceeding 110 million tons in 1977. Furthermore, these trends are expected to continue.

In parallel with the increase in chemical production has been an enormous increase in the number of different chemical compounds being produced. The master registry of the American Chemical Society already lists over 4,000,000 known compounds and the list is growing at a rate of 6,000 per week. Most compounds in the master registry are exotic and exist only in small quantities, however an estimated 70,000 different chemical compounds are currently in common use; this number is growing at a rate of about 1000 per year.

Some of these chemicals can be directly toxic to man and the environment. Others have delayed deleterious effects (such as asbestos-caused cancer—effects may not show up for thirty years) or subtle, little-understood consequences. But with this recognition of the long-term, less-than-lethal hazards comes a dilemma that is key to the future role of chemicals in our society. The dilemma is basically how to derive maximum social benefit from modern technology while limiting attendant risk to an acceptable level. Maximum benefit at acceptable risk—it is this issue which lies at the heart of the regulatory dilemma; it is this issue which has formed the basis for the ever-growing body of Congressional regulatory legislation on the environment and public health.

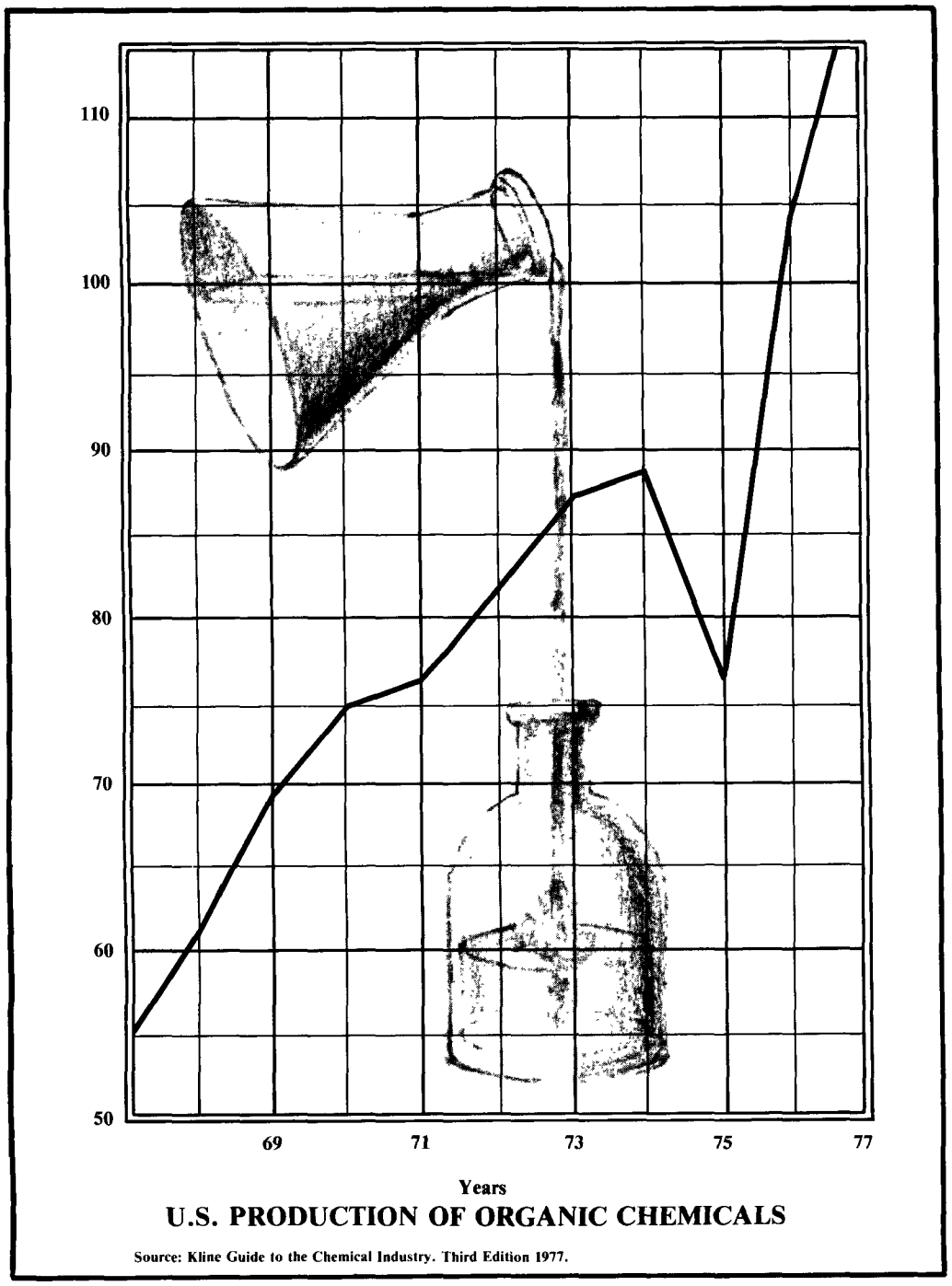
There is no doubt that chemicals have played an important role in our current standard of living.

Benefits

The use of chemicals has resulted in many benefits for our society. The variety, durability, safety and convenience of thousands of consumer products can clearly be attributed to the chemical industry. In agriculture, the increased use of chemical fertilizers correlates with a continual increase in crop production in spite of declining planted acreage during the 1950s and 1960s. Human lifespans have doubled from 40 years in the 1800s to almost 80 years today. Infant mortality has decreased dramatically. Americans, on the average, are larger, healthier, and stronger than past generations. And the epidemics that regularly swept through the population have largely been controlled. While non-chemical factors have also contributed substantially to these benefits, there is no doubt that chemicals have played an important role in our current standard of living.

Risks

The health and environmental risks of continual exposure to chemicals are not well known. A percentage comparison of the leading causes of death in 1900 with those of 1960 shows a striking shift from infectious diseases to a variety of chronic degenerative diseases such as cancer or diseases of the heart, lung and other organs and tissues. Some of this shift can be attributed to chronic diseases "taking the place of" controlled or eradicated infectious diseases. Some can be ascribed to



U.S. PRODUCTION OF ORGANIC CHEMICALS

Source: Kline Guide to the Chemical Industry. Third Edition 1977.

demographic factors such as the increase in the general aging of our population; chronic diseases in older people may occur because the diseases have had greater time in which to manifest themselves or because a latency period between exposure and onset of a disease may have expired. However, such factors alone cannot explain all of the shift which we see. For example, the absolute incidence of cancer in our population shows an increase even after correction for demographic factors; thus the still substantial "residual" increase must be caused by other factors. Although we aren't sure, toxic chemicals may be the cause of this increased incidence of cancer. There is a growing acceptance among the scientific and medical community that 50 to 90 percent of all cancer is related to factors in our environment such as cigarette smoking, exposure to sunlight, occupational exposures to carcinogens, dietary habits (high fat/low roughage), and, possibly, toxic chemicals.

Maximum benefit at acceptable risk—this lies at the heart of the regulatory dilemma.

Non-cancer health risks of chemicals include contributions to virtually all known chronic diseases. These diseases can be caused by direct contact or through influences on modulating body mechanisms such as the neuroendocrine or immunologic systems. Reproductive malfunctions or damage to embryo development are also health risks associated with some chemicals. In fact, it is estimated that chemical induced mutagenesis may be involved in as much as 10 percent of all human disease.

These are only a few of the risks and burdens to society which are posed by increased chemical use. Other chemically-caused effects are property loss in the form of materials damage by corrosive environmental pollutants, nutrient depletion from soils by acid rain, or injury to our natural ecosystems from the discharge of toxic substances.

Research Rationale

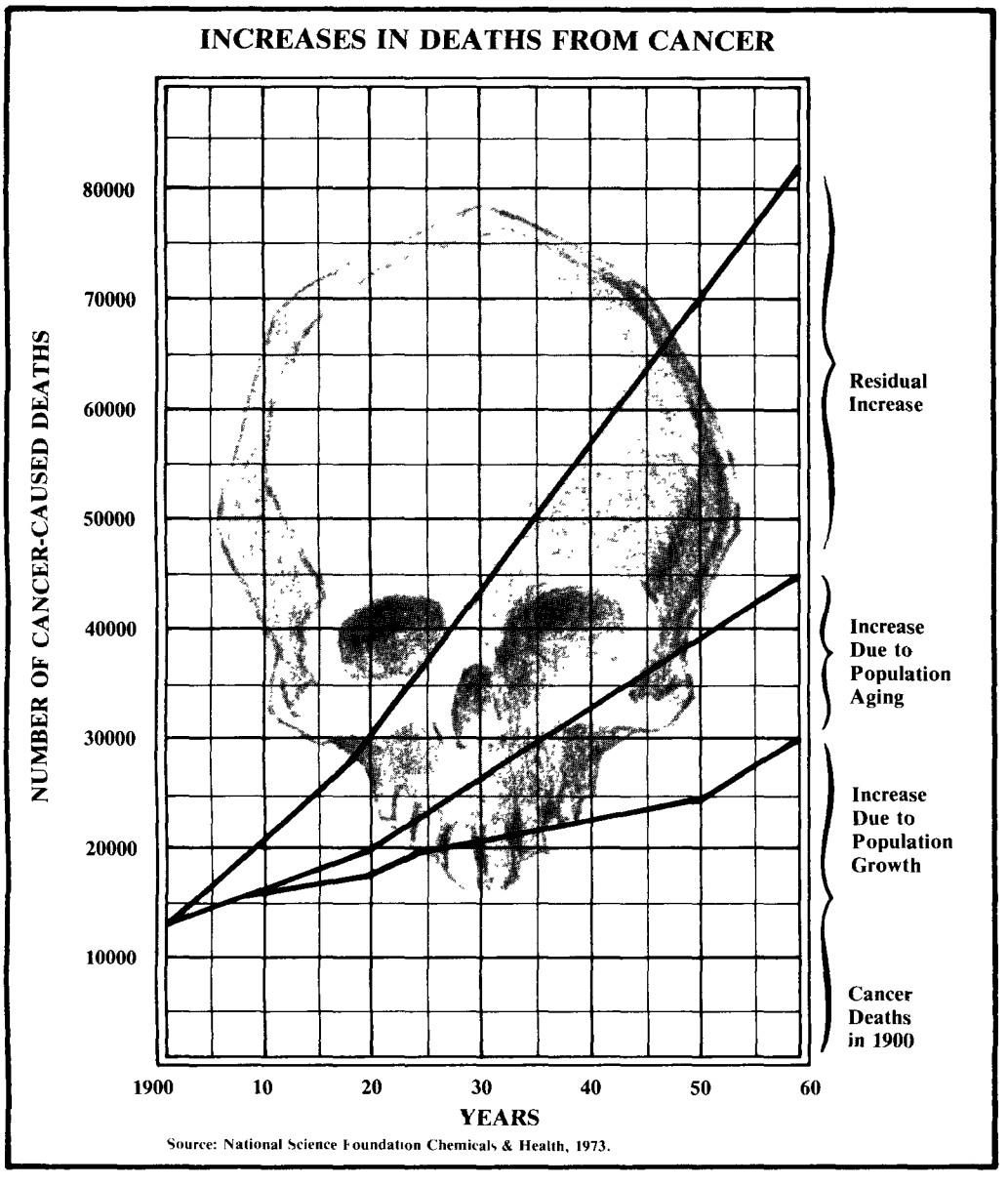
Inherent in the concept of determining acceptable risk are social judgments rendered singly or collectively through our various institutional processes. Scientific research with its empirical and non-judgmental nature, cannot alone determine an acceptable level of risk; non-empirical factors such as socio-economic and political considerations are also involved. However, scientific research does play a significant role in acceptable risk decisions by providing necessary technical information from which to estimate and evaluate risks versus benefits. Then, based upon the decisions that describe the levels of acceptable risk, it is EPA's task to regulate toxics in the environment to insure those levels of risk are not exceeded. It is the generation, evaluation, and continual update of the scientific/technological data base necessary to support that regulation that forms the fundamental mission of the toxic substances research program at EPA.

The Toxics Research Program Plan

To fulfill our support mission in chemical regulation over the next several years, we have established two general research goals, each encompassing a number of subordinate objectives. These goals are:

- to characterize the nature and extent of risks posed by potentially hazardous chemicals; and
- to develop control strategies, technologies, systems and/or management practices which will prevent, interdict or at least minimize exposure to hazardous chemicals.

The first goal involves research in three general areas: toxic substances effects on humans and the environment, assessment



of the magnitude and mechanisms of population exposure to toxicants, and production of integrated risk assessments and criteria documents to support future regulatory decisions. The second goal has two areas for research: characterization of toxic emission sources by developing a data base that describes the chemical industry and development and evaluation of alternate control strategies and/or technological systems to mitigate human exposure to hazardous chemicals.

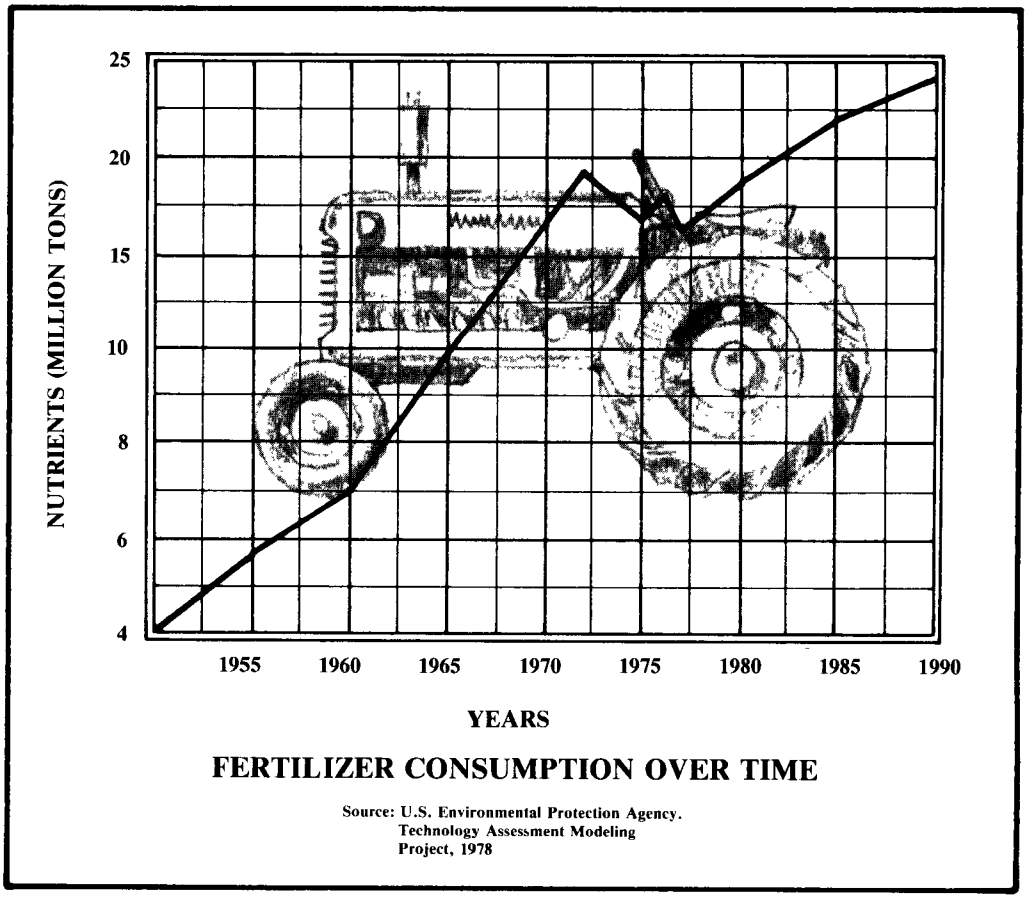
Each of these tasks requires development and application of validated measures and techniques to serve as quality assurance of research results. Documentation of the precision and accuracy of the data base used for risk assessment and regulatory decisions will be achieved through a quality assurance

program that covers personnel, methods, equipment and data handling procedures. Here, the quality assurance program must be applied to each of these components individually and as they function in an integrated research system.

Risk Research

Toxic Effects: Determination of human health and ecological effects of toxic materials requires development, validation, and standardization of toxicity testing and screening methodologies. Inherent in this research plan for toxic effects is the need for a data base for decisions regarding which chemicals to study and in what priority to study them. The sheer size of the problem demands this carefully planned research approach.

At present only a small fraction of the nearly 70,000 chemical compounds in common use have been subjected to health effects testing. But of those tests already made, the majority has been limited to determining acute or sub-acute toxicity and to ascertaining the potential for compounds to cause cancer. Little testing has been done to measure the potential for other biological effects such as mutagenicity, reproductive disorders, neurotoxicity or the contribution of chemical exposure to heart and lung disease. The test methodologies which do exist are frequently not standardized and as a result do not allow comparisons to be made. Furthermore, they tend to be time consuming, laborious, and extremely expensive to perform.



FERTILIZER CONSUMPTION OVER TIME

Source: U.S. Environmental Protection Agency. Technology Assessment Modeling Project, 1978

The large numbers of chemicals involved require the development of test methods that can quickly determine the most harmful compounds. Although some short-term tests and screening procedures exist (such as the Ames Test for mutagenicity), no one short-term test can identify all the different toxic effects a substance can have. Each test is limited by its inability to detect all classes of effects and by its vulnerability to spurious results. For these reasons, groups of short-term tests must be assembled into coordinated test batteries to form a testing hierarchy for the system.

Only a small fraction of the chemical compounds in use have been subjected to health effects testing.

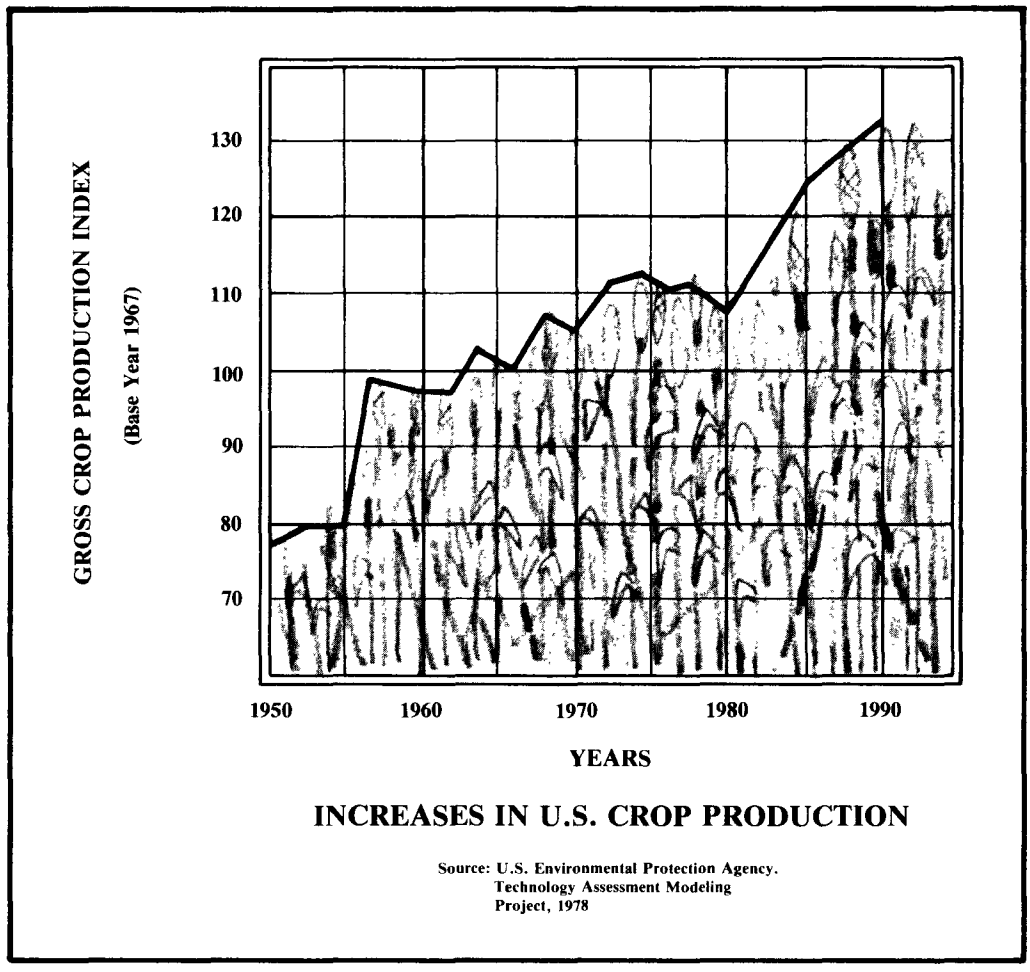
Each test in each tier must be evaluated for overall accuracy, sensitivity and broad spectrum characteristics. Ultimately, this evaluation will lead to a practical group or groups of tests (both short and longer term) to determine human health risks. This development of short-term batteries has the highest priority within the EPA toxic chemical research program. Within this specific area, program emphasis will be primarily on validation of existing test methods; the development of new screening methods will be secondary.

The validation and development of standard testing methodologies is a complex process. The means by which toxic substances act on the human body, nonhuman organism, or ecosystem must be determined before the scientific validity of a test methodology can be assured. Short-term screening tests must be validated by use of longer-term studies that the short-term tests are designed to trigger. Then, whenever possible, the longer-term studies must be validated through controlled or case-specific clinical studies or epidemiology studies that identify dose-response relationships.

Although our toxic effects research projects focus on human health, the overall perspective of our program is that man is a part of an ecosystem and that by better understanding ecology we will take a vital step to providing a healthy environment in which man can live. Ecological work directly supports health effects research: certain aquatic "indicator" organisms are used to detect the presence of carcinogens, mutagens and teratogens in the environment; information on the mechanisms of toxic effects on parts of the ecosystem may be useful in human toxicological research; understanding of the pathway of toxics through the ecosystem, particularly the human food web, will aid in determining likely exposure levels. In short, human health effects research is incomplete without tandem and supporting ecological research.

Exposure Assessment: Effective assessment of the hazards to people posed by a toxic chemical requires not only knowledge of the chemical's effects but also the degree and duration of probable human exposure. Our major research effort in this area will be to improve, to a scientifically acceptable state, methods to predict environmental concentrations of toxic chemicals including chemicals not yet on the open market. More accurate prediction methods will derive from an improved ability to measure and model the transport, transformation, persistence, and fate of a chemical as it moves through the environment from its source to a receptor organism. The results

The large numbers of chemicals involved require the development of test methods that can quickly determine the most harmful compounds.



INCREASES IN U.S. CROP PRODUCTION

Source: U.S. Environmental Protection Agency. Technology Assessment Modeling Project, 1978

of the exposure research will enable us to better measure and predict the total body burden exerted by toxic chemicals. These improvements in exposure assessments will result from:

- Models to predict the degree of absorption and distribution versus the rate of excretion and removal from human tissues.
- Models to predict the transfer of substances from one environmental medium to another (i.e., air to water)
- Methods and models for predicting the likelihood of bioaccumulation/ magnification of toxic materials in the food chain.
- Our ability to design and conduct ambient monitoring studies to validate predictive models.

Finally, we also need to improve, standardize, validate, and assure the quality of our physical, chemical, and biological analytical monitoring and measuring methodologies.

Risk Assessment: Integration of known effects with likely exposures is the fundamental research input to regulatory decisions regarding a specific chemical or class of compounds. From such information it may be possible to determine the degree of potential risk to be weighed against benefits. Progress is being made on methods to accurately determine exposure-effect relationships but much more needs to be learned. We need to refine our methods that extrapolate animal responses to man or otherwise relate exposure to effects; we must also

continue to develop techniques for determining all critical data items required for accurate risk assessments. Until the research into these areas is complete, we must continue to apply existing state-of-the-art techniques to produce risk assessments and criteria documents in support or EPA's regulatory mission.

Control Technology Research

Source Characterization: A description of the sources of toxic chemicals is necessary to estimate potential human exposures and to develop adequate control measures. We will conduct research to determine the magnitude of the problem and to identify potential control points. Information is needed to describe how a chemical moves from a raw material through its various product stages to an end-use product and at what point in this flow the chemical comes into contact with man and the environment. Program emphasis is on characterization, assessment, and prediction of:

- Emissions from industrial processes for chemical production, handling, storage, marketing, and emission control, and
- Discharges and fugitive emissions from hard-to-measure sources such as agricultural and urban runoff or airborne particulates from combustion processes.

Control Measures: Measures to control toxic chemicals once they have been released into the environment are generally difficult to implement, prone to failure, and expensive. For this reason, EPA's strategy for toxics control is based on implementing control measures at, or as near as possible to, the source of the potential toxicant's entry into the environment. Specifically, the strategy has two primary thrusts. The first thrust involves regulating the chemical composition of commercial products before they reach the market place. Registration of pesticides under the authority of the Federal Insecticide, Fungicide, and Rodenticide Act and premarket testing of chemicals as required by the Toxics Substances Control Act are prime examples of the "product control measures" we employ. In support of this effort, our research program will continue to develop or improve methods for toxicity testing and exposure and risk assessment.

The second major thrust of EPA's strategy deals with controlling toxic chemicals which enter the environment through pathways such as industrial wastewater discharges or atmospheric emissions. In the case of industrial wastewater, control is achieved by using mechanisms available under the Federal Water Pollution Control Act such as effluent guidelines; whereas for controlling atmospheric emissions, the Clean Air Act's new source performance standards or ambient air quality criteria might be used. For this type of control, our research program is involved in the development or improvement of specific technologies and management practices which allow the standards to be met. While there is still much to be done, we hope to eventually develop, or foster the development of, the recycle and reuse techniques necessary for "closed-loop" industrial production. Achievement of this long term goal will not only limit the release of potential toxicants into the environment but will also permit better utilization of this country's basic materials and natural resources.

Our approach is oriented toward the development of methods for controlling the causes of pollution.

The concept of internal process modification has already proven feasible in some industrial production cycles (see the "Industrial Wastewater" chapter of

TOXIC CHEMICAL RESEARCH GOALS, MAJOR OBJECTIVES AND EMPHASIS AREAS

To characterize the nature and extent of risk posed by potentially hazardous chemicals.

TOXIC EFFECTS

- Improve toxicity methods for ascertaining chemical dose/effect relationships
  - Short-term testing and screening methods
  - Acute and chronic toxicity test methods
  - Clinical and epidemiological methodology
- Conduct clinical and epidemiological studies to determine causal relationships of priority toxicants, acting singly or in combination, to environmentally induced diseases
- Elucidate toxicological mechanisms of action
- Determine non-human effects of toxic chemicals

EXPOSURE ASSESSMENT

- Elucidate toxicant transport, transformation, persistence and fate phenomena
  - Methods for measuring total body burden
  - Transport, transformation, modeling, etc.
- Improve analytical monitoring methodology
  - Analytical method development, validation and standardization
  - Monitoring network development
  - Data quality assurance programs

RISK ASSESSMENT

- Develop and evaluate risk assessment models
  - Improve basis for extrapolating sub-mammalian and mammalian test results to humans
- Prepare integrated risk assessment and criteria documents for priority compounds and/or chemical classes

To develop control strategies, systems and/or management practices which will prevent, interdict or at least minimize exposure to hazardous chemicals.

SOURCE CHARACTERIZATION

- Ascertain and/or predict potential environmental release of hazardous chemicals
  - Develop and maintain inventory of chemical sources, production processes and chemical handling, storage, use, marketing and disposal practices
  - Identify target points for application of control technologies and/or management practices

CONTROL MEASURES

- Develop "at the source" chemical control strategies and technologies
  - Improve in-stream control through modification of production processes and the development of recycle/closed loop technology
  - Improve necessary end-of-pipe treatment technologies
- Develop alternative strategies and management practices for nonpoint source control of hazardous chemicals
  - Agricultural and urban runoff
  - Mining
  - Alternative methods of pest control
- Develop preventative removal and mitigation practices for hazardous chemical spills

this report). Techniques such as incineration, ozonolysis, adsorption, biological modifications, and chlorolysis offer a spectrum of solutions ranging from complete destruction to conversion to useful saleable products. Although much work is needed to develop knowledge needed to apply these techniques, the potential exists for their integration into manufacturing processes or centralized treatment facilities. Our research program will also continue to support and evaluate "end-of-pipe" treatment techniques for industries in which closed-loop production is not yet achievable or practical.

When dealing with point sources of toxicants from individual production lines or manufacturing plants, specific technological solutions to toxic emission problems are often feasible and attainable. On the other hand more complex or nonpoint sources of toxicants such as agricultural and urban runoff or wastes from mining activities are not so amenable to precise solutions. The research for these sources is planned to emphasize development and evaluation of effective methods for mitigating pollution from toxic chemicals. The primary thrust of our approach here will be to develop methods to control the cause (i.e., the source) of the pollution rather than to control pollutants after they have been discharged into the environment.

Human health effects research is incomplete without tandem and supporting ecological research.

Other EPA chemical research will focus on the development of new, less hazardous uses of beneficial chemicals in society. One example of research in this area relates to chemical control of infectious diseases. Chlorination to disinfect drinking water and organic wastes has been an important component of public health protection for many years. But recent evidence shows that the chlorine combines with other chemicals to generate compounds that have the potential for inducing cancer. As a consequence, EPA will continue to support research to develop and evaluate alternatives to chlorine disinfection.

EPA will also continue to support research to develop new or improved systems and equipment for the prevention, containment, control, treatment, removal, recovery and disposition of spills or other acute releases of hazardous polluting substances.

Assessment of Program Capabilities

The capabilities of EPA research to respond to the problems posed by toxic chemicals are related to recognition of the immensity and pervasiveness of the overall problem. But solution of the toxics problem will require mobilization of vast resources of our society. No one sector of society, let alone a single government agency, commands the resources and expertise necessary to cope with the entire problem. A major challenge to EPA, therefore, is to forge an effective partnership among the various federal and state regulatory and research agencies, the academic community, and private enterprise.

EPA contributes to this partnership in a variety of ways. Of our total monetary research resources, only about one-third are expended in-house by EPA scientists. Approximately 50% is expended through extramural grants and contracts with universities and private organizations. The balance is expended through fund transfers to other federal agencies for work on problems of mutual concern.

Interagency agreements also support the partnership. EPA has always used such agreements to some degree, however, during the past year interagency coordination and cooperation received even further impetus through the formation of the Interagency Regulatory Liaison Group (IRLG) which consists of

EPA, the Food and Drug Administration (FDA), the Occupational Safety and Health Administration (OSHA), and the Consumer Product Safety Commission (CPSC). These federal agencies are the principal ones responsible for regulating toxic and hazardous substances. The IRLG will help to more closely coordinate regulation development, enforcement actions, general information exchange, and the effective planning and use of available research resources.

Solution of the toxics problem will require mobilization of vast resources of our society.

The IRLG is already producing some tangible results in research planning and coordination. Notable among these results has been the development of a joint EPA/FDA neurotoxicology research program. This program addresses the critical information gap in our understanding of the behavioral and other neurotoxicological effects of environmental contaminants. EPA had developed only a modest capability in this area at its Health Effects Research Laboratory in North Carolina, but was unable to devote sufficient resources to mount a serious attack on the problem. At the same time, the FDA was preparing to start a small neurotoxicology program at its National Center for Toxicological Research. However, it was recognized through the IRLG that separate small programs would be less effective than a combined program, thus the EPA and FDA programs have now been merged. The merger will enable a better response to the regulatory needs of all the IRLG agencies. Location of the joint program at EPA's North Carolina facility takes advantage of the close proximity of the National Institute for Environmental Health Sciences which is also involved in neurotoxicology research.

Another example of the improved coordination brought about by the IRLG has been the joint participation in the Zero Base Budgeting process with the National Institute of Environmental Health Sciences, the National Cancer Institute, and the National Institute of Occupational Safety and Health. Here, an analysis was performed of their collective research programs in order to develop a better integrated toxic chemical research budget for the fiscal 1980 submission to Congress. This kind of integrated action will continue to provide cost effective response to the hazards of toxic chemical exposure.

AIR POLLUTION

We have no choice but to breathe the air around us. EPA's research is working to insure that it is clean.

Significant progress has been made in cleaning the air of the United States. Efforts by federal, state, and local air pollution control agencies have resulted in reductions of particulate and sulfur dioxide concentrations, but concerns remain about the quality of air throughout the nation. The more that is learned about the complex mixture of fine particulates and other pollutants that are in the air, the deeper the concerns regarding their potential adverse effects on health and welfare.

Concerns remain about the quality of air throughout the nation.

Our atmospheric research program will concentrate on three particularly troublesome pollution problems: (1) interregional transport and transformation of air pollutants; (2) the fate and effects of air pollutants; and (3) their diffuse sources. As we investigate these areas we will address the major concern that aerosols formed from various gaseous and particulate air pollutants can have adverse health and environmental effects. We will also address the possibility that strategies designed to deal with long-term regional and interregional air quality degradation may be ineffective because of projected pollution emissions increases from the number, type and distribution of future sources. The atmospheric research program is specifically designed to provide information to directly support EPA regulations for establishment and revision of standards and development of control abatement strategies.

In addition to a thorough investigation of the pollution-related problems, our research response will include an attempt to resolve questions of accuracy of past air pollution data that have resulted from a lack of detailed standards methods. We feel a completely standardized collection and analysis system is a prerequisite to successful research in pollution abatement control.

Air Pollution Research

Interregional Transport and Transformation of Inhalable Particles, Ozone/Oxidants, and Secondary Organics

Particles. The interregional transport and transformation of particles is a primary health and environmental concern. When these particles and their precursors are inadequately controlled, visibility problems and the formation of acid rain can result. Some of these particles, when breathed, can penetrate deeply into the respiratory system and cause potentially serious adverse health effects. Most of these "inhalable" particles are formed by reactions of pollution gases after the gases have been released into the atmosphere. Such reaction products include sulfate and nitrate particles that can be transported long distances. Epidemiology studies have indicated that low atmospheric sulfate levels may produce a variety of respiratory health problems such as aggravated asthma and bronchitis. In addition to sulfates, atmospheric nitrates are suspected of causing adverse human health effects. However, very little is known to date on this issue and clearly more experimentation is needed.

In EPA's research program, we will evaluate the adverse chronic health effects risks associated with particles that are subject to interregional transport. This evaluation will be achieved through animal toxicology studies on chronic effects of exposure to particles of varying chemical composition including sulfates and nitrates. Subsequent studies will assess the effects of exposure to mixtures of particles of known chemical composition. Concurrently, long-term epidemiological studies are being designed and conducted. Our particle research will deal with inhalable particles (defined as having an aerodynamic diameter of 15 micro-

REGIONAL ATMOSPHERIC EMISSIONS OF SO_2 FROM UTILITY AND INDUSTRIAL COMBUSTION

FEDERAL REGION	1975		1990	
	10^3 TONS	%	10^3 TONS	%
I	331.1	1.1	259.6	1.3
II	877.4	3.0	889.7	4.3
III	4,279.8	14.5	3,205.8	15.4
IV	6,164.3	20.8	6,162.2	29.6
V	10,985.7	37.2	5,814.4	28.0
VI	4,048.5	13.7	2,282.3	11.0
VII	1,951.8	6.6	665.6	3.2
VIII	552.2	1.9	813.1	3.9
IX	272.1	0.9	498.7	2.4
X	102.5	0.3	192.7	0.9
TOTALS:	29,565.4	100.0	20,784.1	100.0

Source: United States Environmental Protection Agency. Technology Assessment Modeling Project, 1978.

meters or less). This perspective is consistent with an Inhalable Particles Standard which is an option EPA is considering in the review of the existing Total Suspended Particle Standard. (The research plan to deal with this contemplated change has been jointly developed by research personnel and representatives from the air regulatory and enforcement offices.)

Research into the improvement of air quality simulation models (AQSM) to predict the long-range transport of particles is also necessary. To improve these models we will conduct:

- laboratory and chamber studies to identify transformation processes and important removal mechanisms;
- direct field measurements of interactions between chemical-physical and meteorological parameters and particle variables such as rates of formation, dispersion, transport and deposition; and
- development and validation studies of quantitative relationships among those parameters and variables to allow prediction of long-range transport.

Our research plan also includes studies to provide standardized monitoring systems that will assure comparable data throughout the system. This will be achieved by developing reference methods, standard reference materials traceable to a common source, laboratory and monitoring station certification and data handling systems for all generated data. A network for monitoring inhalable particles will be established at approximately 300 sites. Associated studies using supplemental mobile monitors in selected cities will provide a precise description of population exposure at these locations.

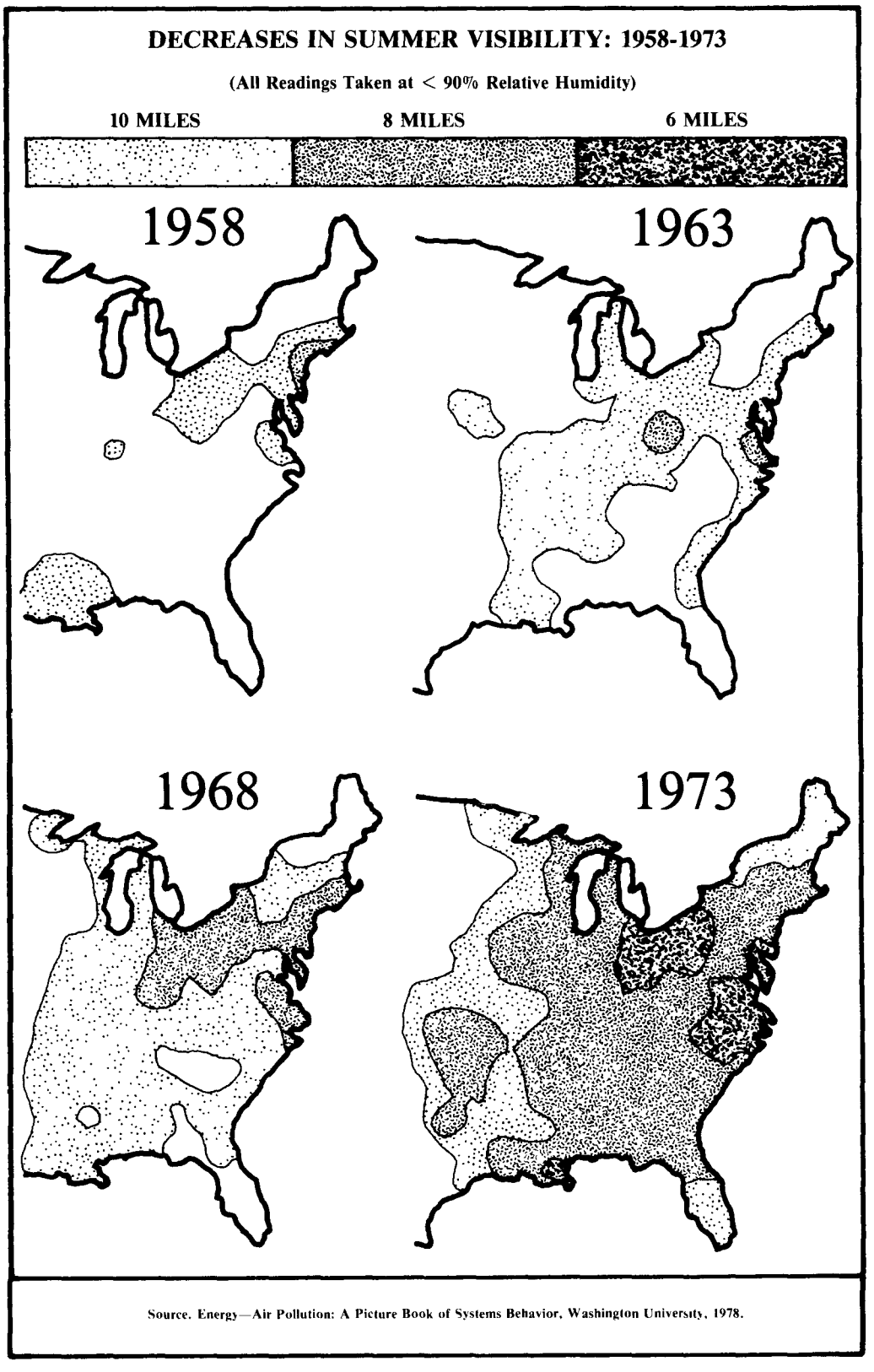
Ozone/oxidants and precursors. The transport and transformation of ozone/oxidants and precursors also need thorough investigation. At present we do not possess an assured capability to predict their interregional transport because most currently available models are limited to urban scale pollution. However, we are beginning to develop and validate models that can address ozone/oxidants interregional transport processes. The first step in the development of these models is to quantify multi-day, rather than multi-hour, dispersion and transport. This necessitates the ability to predict movement of air masses at the regional scale. Studies will concentrate on field collection of meteorological and air quality data sufficient to develop the transport component of an interregional model.

Trace elements can cause biological damage to organisms, ecosystems and humans.

The second step is to identify and quantify removal processes for ozone and its precursors. In particular we need to know deposition velocities for soil, vegetation and water surfaces. A combination of laboratory and field studies will be carried out to measure the rates of these processes.

The third step in the development of a model is to define and quantify multi-day chemical mechanisms associated with transport. These mechanisms will be studied in smog chambers designed to simulate atmospheric chemistry. Field studies will provide validation of the laboratory results and will support development of the interregional oxidant model.

Secondary organics. The transport and transformation of secondary organics is the final problem in this category to be addressed. Secondary organics, however, is not recognized as a serious and present problem, as are inhalable particles and ozone, and thus must be considered as only a potential problem. We therefore need to develop an understanding about the prevalence, concentrations, formation, and transport of primary and second-



Source. Energy—Air Pollution: A Picture Book of Systems Behavior, Washington University, 1978.

ary organic particles and vapors in urban air. We do know that the atmosphere is a fertile medium for a variety of oxidation processes and products and that ambient air in metropolitan areas contains large amounts of hydrocarbons. We need to determine, however, if this combination creates organic air pollution. Potential adverse health effects of secondary organic products have not been evaluated, although it is possible that toxic concentrations now exist in some polluted air. This general lack of knowledge about organics prevalence and concentrations in urban atmospheres dictates that our initial research concentrate on characterizing the problem.

Our research will develop practical methods capable of identifying and measuring specific organics in ambient air. Reliable methods are lacking for direct *in situ* chemical characterization of ambient organic aerosols. Major problems that must be overcome to develop such methods are artifact formation and the unreliability of capture methods to collect quantities large enough for analysis.

Included in our research will be field studies to determine the presence of secondary organics in urban ambient air. These field studies are necessary to predict potential population exposures to secondary organics of known or suspected toxicity. The results of the studies will indicate the need for further study of health effects, source controls, and transport and transformation.

Fate and Effects of Trace Elements and Visibility Degrading Pollutants

Trace elements and organic compounds. Trace elements are of concern to our research program because they can cause biological damage to organisms, ecosystems, and humans. Some trace elements are transition metals that perform valuable roles in the regulation of cellular activity but may be toxic in high concentrations. Other heavy metals may be required by cells in trace amounts but may be toxic to those same cells at relatively low concentrations. Many trace elements may be fairly prevalent in the air since most are emitted by combustion sources and industrial processes. Although controls will reduce the amount of emissions of trace elements from individual sources, the increase in the number of sources will in many cases cause trace element air pollution levels to increase. The trace metals problem is more potential than actual because we generally do not find them in significant concentrations except in localized situations. However, until more definitive information becomes available on their health effects, emissions, and fate, trace metals will continue to be a concern.

Our trace elements research will quantify emissions of trace elements from stationary and mobile sources and will evaluate control technologies. The emissions characterization studies will provide the requisite data base for integrated risk assessments of specific trace elements. The control technology evaluations will concentrate on studying and possibly testing a series of new collection approaches including charged droplet scrubbers, ceramic membrane filters, magnetic filter beds, and a number of new types of fiber filters. The purpose of the evaluations will be to identify potential cost-effective means to reduce trace element emissions.

The chemical form in which the element is found may be as important as the quantity.

We will also develop methods to identify the chemical form of trace elements in emissions and the ambient environment. Present methods of analysis typically do not note chemical speciation or particle size. But the chemical form in which the element is bound may be as important as the quantity because toxicity is related to

MAJOR MILESTONES

Research on Interregional Transport and Transformation Problems

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
FIRST PRIORITY	
Health Effects of chronic exposures to particles	Data from animal toxicology studies on effects of particles of selected chemical composition. (FY 82)
	Data from animal toxicology studies on effects of selected sulfates and nitrates. (FY 80)
	Data from animal toxicology studies on effects of mixtures of particles of known chemical composition—post. (FY 82)
	Data from long-term air pollution epidemiology studies on inhaled particulate matter, metals, sulfates, nitrates, energy-related emissions, and airborne carcinogens. (FY 82)
	Data from controlled human clinical studies of particles, NO_2, and O_3 both alone and in combination. (FY 83)
Improve air quality models to predict long range transport of particles and ozone oxidants	Data on chemical mechanism, rates of formation, dispersion, transport and deposition of particles and ozone/oxidants. (FY 79)
	Improved models to predict long range transport. (FY 80)
Control technology for particles control	Evaluation of precharger for electrostatic augmentation of precipitators. (FY 80.)
Standardized monitoring system	Implementation of inhalable particulate networks in 100 stations by FY 79, 160 stations by FY 80 and a goal of 300 stations by (FY 83).
SECOND PRIORITY	
Multi-day transport of oxidants	Development of transport component of interregional model. (FY 80).
Quantify ozone and precursor sink processes	Deposition rates for soils, vegetation, and water surfaces. (FY 80)
Define and quantify chemical mechanisms	Interregional ozone air quality model. (FY 81)

MAJOR MILESTONES

(CONT.)

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
THIRD PRIORITY	
Methods to identify and measure organics	Improved measurement method for specific organics. (FY 80)
Determine prevalance of organics in ambient air	Data from urban field characterization studies. (FY 81)

the chemical composition, concentration and particle size. To address this measurement methods problem we will examine the use of molecular emission (fluorescence and Raman scattering) for identification of specific compounds.

Our trace elements research will also provide the scientific basis needed to assess potential health and environmental risks from trace element emissions. Effects research is especially important for those metals that form metalalkyls, because such compounds accumulate in cells and are poisonous to the central nervous system of higher organisms. General health and ecological toxicity test methods must be developed for better prediction of potential effects from trace metals in different chemical forms. Transport and transformation studies will be carried out to provide better methods for predicting the ultimate form and distribution of trace metals, including the potential for uptake into the food chain.

Visibility. Degradation of visibility has the potential for producing human and material costs in the form of automobile accidents, transportation delays, and mental depression caused by hazy weather. Over the past 25 years, significant visibility degradation has occurred in the eastern third of the United States. Research into this situation has noted the existence of a large (regional) hazy air mass concentrated over a multi-state area. Trend analyses have indicated a high correlation between the appearance of the air mass and elevated ambient sulfate levels. In the western portion of the United States where increased development and use of energy resources is anticipated, major concerns have been raised about the potential for increased visibility degradation. As a result, our research program is currently funding several programs in the West (e.g. VISTTA which stands for Visibility Impairment due to Sulfur Transport and Transformation in the Atmosphere).

The naturally occurring pollutants of primary concern are hydrocarbons.

To date, the specific causes and effects of visibility degradation have not been quantified. Some qualitative information includes studies of expanding urban

development along coastal areas associated with local visibility problems brought about by local microclimatological changes; reduced visibility in particular areas attributed to transport of fine particulate emissions from other regions; and local emissions as the primary cause of visibility reduction. Our research on visibility degradation is designed to help us better understand the extremely complex and inadequately researched fundamental aspects of the problem.

In our research we intend to determine the chemical composition of the fine particulate size fraction primarily responsible for visibility degradation. Several analytical techniques have evolved over the past few years that should greatly assist in these characterization studies. Among them are carbon analysis (for measuring total organic carbon, total inorganic carbon, and elemental carbon), ion chromatography (for increased accuracy and quicker analyses of sulfates, nitrates, ammonium, chloride, bromide) and improved techniques and instruments for measuring visibility-related parameters (telephotometer, nephelometer, absorbtion coefficient measurement). measurement).

MAJOR MILESTONES

Research on Trace Elements and Visibility Problems

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
FIRST PRIORITY	
Quantify emissions of trace elements and evaluate control technologies	Emissions data from source characterization studies. (FY 79)
	Evaluation of filters technologies. (FY 80—FY 83)
Measurement methods for chemical forms of trace elements	Performance data on instruments. (FY 81)
Health and environmental effects	Test methods for predicting health effects. (FY 80)
	Test methods for predicting ultimate form and distribution. (FY 80)
SECOND PRIORITY	
Chemical composition of aerosol causing visibility degradation	Chemical composition from characterization studies. (FY 79—FY 81)
Relate aerosols to sources	Air quality models relating emissions to meterology to visibility. (FY 83)
Methods to assess human and economic costs	Reports on selected case studies. (FY 80—FY 81)

We will also provide the data base required to evaluate possible control strategies. Development of this data base will require field studies during periods of low visibility. We plan to measure the composition, concentration, and size distribution of the visibility-degrading fine particulates and then determine the polluting sources through meteorology, atmospheric chemical mechanisms, and aerosol dynamics.

Additionally our research will provide methods to evaluate the human and economic cost of visibility degradation. Because substantial resources may be required to improve visibility, decisions on alternative control strategies will have to balance the costs against the benefits of visibility improvement. Research is required to provide the methods and the data appropriate for estimating the benefits of improved visibility.

Diffuse Sources

Fugitive sources. The fugitive sources of particular concern to our study are fugitive emissions including fugitive dust. These pollutants are the principal cause of failure by 400 of the 3200 U.S. counties to meet the primary ambient air quality standard for Total Suspended Particles. These same fugitive sources may make it difficult to attain potential fine particulate ambient air quality standards in many regions.

Fugitive emissions complicate the problem of revising present ambient particulate standards

Fugitive emissions including fugitive dust complicate the problem of revising present ambient air quality total particulate standards. We do not have the data to assess the relative contribution nor the health risks associated with particulates from fugitive sources. We have therefore established a research plan to better address this problem. We will develop instrumentation to provide size spectrum and chemical composition data for ambient air particulates. These measurement methods are required to discriminate among the various kinds of particulates, their sources and their potential adverse health effects. Our source sampling, modeling, and field studies will relate the various chemical and size fractions of particulate matter to specific sources. The emphasis will be on the design and evaluation of alternative control strategies.

The research will include fate and effects studies to determine risks associated with fugitive materials. The nature of these studies will be determined largely by the results of the chemical composition and particle size distribution research. The purpose will be to fill fate and effects data gaps created by study conditions specific to fugitive emissions and dust.

Our plans also include the development of industrial fugitive process particulate (IFPP) controls to reduce emissions. The sources of IFPP emissions are numerous, vary among industries, and even differ among sources within a particular plant. The emissions are typically difficult to collect and control and often require tailor-made solutions; for example, hoods used to collect fugitive emissions from pushing coke are entirely different from hoods used to collect offgases from a copper converter.

Naturally occurring air pollutants. The naturally occurring pollutants of primary

MAJOR MILESTONES

Research on Diffuse Source Problems

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
FIRST PRIORITY	
Characterize fugitive particulates by size and chemical composition	Instrumentation to provide size spectra and chemical composition. (FY 80)
Relate ambient particulates to sources	Data from selected field characterization studies. (FY81)
Fate and effects studies	Data from laboratory studies. (FY 80)
Role of natural sulfur compounds in sulfate and aerosol problems	Ambient data from field and simulated chamber studies. (FY 82)
Industrial fugitive process particulate controls	Evaluated new and modified control technologies. (FY 79—FY 81)
Role of natural hydrocarbons in O_3 and aerosol problems	Evaluation data from laboratory and field studies. (FY 80)
SECOND PRIORITY	
Natural versus anthropogenic allergenic materials	Data from laboratory and field baseline studies on ambient concentrations and allergenic effects. (FY 83)

concern are hydrocarbons. Some hydrocarbon compounds are known to be precursors of photochemical oxidants and aerosols, and preliminary investigations have shown measurable emissions of vegetation-related hydrocarbons. In the past, natural emissions of hydrocarbons have not been part of the design of ozone control strategies, but future control strategies to meet primary ambient air quality standards for ozone concentrations may have to consider natural hydrocarbon emissions.

We hope to provide emissions data to assess contributions of natural sources of hydrocarbons to ambient concentrations of ozone/oxidants in metropolitan areas. Laboratory and field studies will focus on the determination of hydrocarbon emission factors from plant and tree growth and from natural decomposition. In order to relate these emissions to ozone/oxidant concentrations, field studies of the transport and transformation of natural hydrocarbons will be necessary.

Finally, we hope to provide characterization and effects data to determine the relative importance of natural versus anthropogenic air pollutants in causing allergenic discomfort. This is a long-term project. As the pollutants that are the greatest concern to health come under control, interest may shift to pollutants that cause less severe health effects, for example, allergenic materials. Baseline laboratory and field studies relating natural and anthropogenic materials to allergenic response will precede any additional research or regulatory decisions in this area.

Research Capabilities

EPA has assembled a highly qualified team of researchers in the air pollution area. These investigators have at their disposal superb laboratory facilities for carrying out animal and human exposure studies, an excellent computer and data management capability, and sophisticated analytical chemistry support. The clinical studies facility located in Chapel Hill, N.C., is the only one of its kind in the world for studying, under carefully controlled conditions, the effects of gaseous and particulate air pollutants, alone and in combination, on human subjects under a variety of temperature, humidity, and stress conditions. Long-term population studies are supported extramurally under the guidance of EPA epidemiologists. To complement EPA's health scientists, EPA has formed a highly qualified team of chemists, meteorologists, and engineers who are responsible for the development of standardized analytical methods for monitoring air pollution, development of cost effective control technologies, and development of quality assurance protocols to be applied to a broad spectrum of environmental data.

EPA has assembled a highly qualified staff for air pollution research.

EPA's laboratories and those of EPA-funded contractors and grantees comprise the predominant expertise in long-range interregional transport of air pollutants. Practically all of the major advances toward the understanding of interregional transport have been wholly or partially carried out by EPA-funded activities. EPA is cooperating with the Electric Power Research Institute in the design of future studies for joint benefits. Similarly, EPA is cooperating with the Department of Energy (DOE) on a research program emphasizing interregional transport of power plant emissions. Finally, EPA has been closely involved with European scientists in addressing the transport problem. One result of that interaction is the possible application to the U.S. of EUROMAP, a

model for predicting sulfate formation and transport in Western Europe.

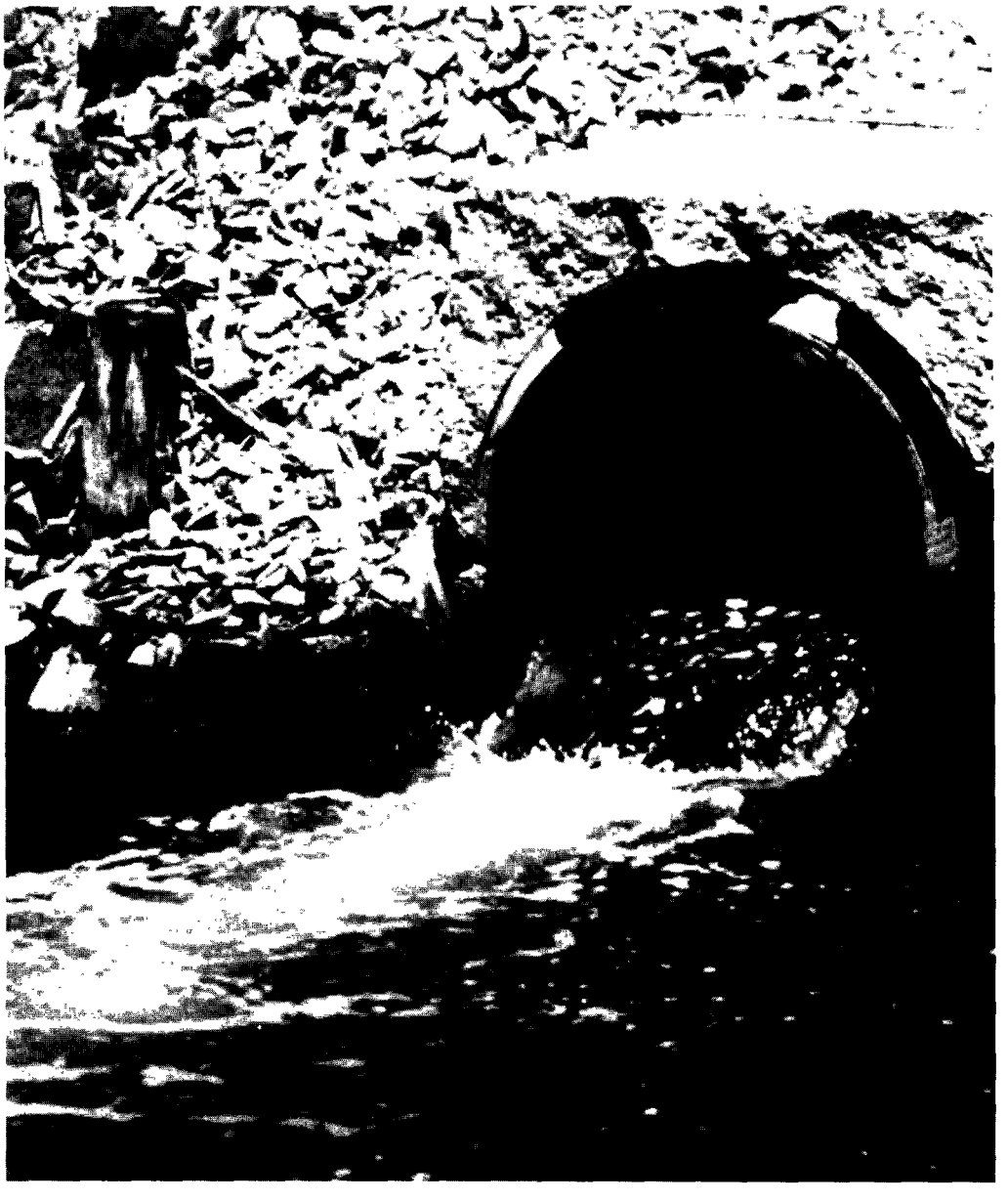
EPA's research in secondary organics is also recognized. Our atmospheric chemistry and physics program has carried out or supported extramurally most of the major advances in this area. The fugitive emissions research at EPA is also a leading effort supported within EPA or extramurally through EPA support.

EPA and DOE have carried out or sponsored the majority of research for trace elements, and European interest in this area of study is increasing. Our mercury exposure assessment work is at the frontier of the subject; we expect to continue to lead in this area with able assistance from the university and commercial research community. However, our capabilities to study movement and transformation of trace elements through the atmosphere is relatively undeveloped and will have to be substantially supplemented by research carried out in other federal agencies and academia.

EPA is a leader in research on visibility degradation. We have carried out or have supported major research studies for visibility measurements, trends, causes, and predictive methods. This research has relied heavily on academic expertise and will continue to in the future.

EPA has internal expertise for addressing the problem of hydrocarbons emitted from natural sources. The major questions in this area have been raised primarily as a result of EPA's activities. However, EPA has practically no present capability to investigate the role of natural sources in the creation of allergenic discomfort. Research has purposely focused on anthropogenic substances with known potential for adverse health effects. In order to carry out proposed research on allergenic discomfort, EPA would have to rely heavily on extramural expertise.

INDUSTRIAL WASTEWATER



A prime pathway for the release of toxic substances into the environment is through industrial wastewater. EPA is researching treatment and recycle techniques to reduce this pollution.

According to 1975 estimates by the Department of Commerce, major industrial water users daily discharged approximately 62 billion gallons of wastewater into rivers and streams. Depending on the industry, this wastewater can contain any of a variety of toxic and conventional pollutants such as phenols, benzene, chlorinated hydrocarbons, metals, suspended solids, and oxygen-demanding compounds. All of these contribute to degraded water quality.

The industries of prime concern to EPA's industrial wastewater research program are the organic chemical, pulp and paper, iron and steel and petroleum refining industries. The organic chemical industry produces wastewater with the highest concentration of toxic pollutants and is the major source of toxics in industrial wastewater; the other industries produce less polluted wastewater but at higher discharge volumes. Another concern of EPA is that many small industrial plants discharge wastewaters to public sewers that lead to publicly owned treatment works (POTW's). These discharges to POTW's create two problems: normal treatment is interfered with or inhibited, and toxics untreated by the POTW are released to the sewage treatment sludge or liquid effluent.

Congress made the elimination of pollutant discharges to U.S. waters a national goal.

PROJECTED USE OF WATER BY MAJOR INDUSTRIAL USERS

	Gross Use	Intake	Consumption	Total Discharge	Product Volume in 1972 Dollars (Billions)
1975					
Pulp and Paper	29,000	10,000	1,000	9,000	18,552
Petroleum	25,000	5,000	1,000	4,000	28,756
Chemical and Allied Products	44,000	21,000	1,000	20,000	61,401
Total Manufacturing	153,000	69,000	7,000	62,000	758,751
1985					
Pulp and Paper	43,000	7,000	2,000	6,000	32,428
Petroleum	29,000	2,000	1,000	1,000	38,241
Chemical and Allied Products	82,000	6,000	2,000	4,000	107,119
Total Manufacturing	227,000	27,000	10,000	17,000	1,166,057
2000					
Pulp and Paper	69,000	6,000	5,000	1000	35,515
Petroleum	41,000	1,000	1,000	500	41,987
Chemical and Allied Products	159,000	6,000	4,000	1,000	125,282
Total Manufacturing	371,000	23,000	17,000	6,000	2,380,627

Data are Rounded to the Nearest 1,000 Million gal/d. Source: U.S. Department of Commerce

THE SIX CATEGORIES OF CHEMICAL PRODUCING AND CONSUMING INDUSTRIES

INDUSTRY	ACTIVITIES	PRODUCTS
Industrial Organic Chemical	Production of "Building Block" Organic Chemicals	400 Basic Organic Chemicals Used as Intermediates, Solvents
Principal Organic Products	Chemical Processing of Industrial Organic Chemicals to Produce Synthetic Chemical Materials	Plastics, Synthetic Rubber, Drugs, Organic Dyes, Pesticides
Primary Non-Chemical	Mining, Smelting, Agriculture, Petroleum and Natural Gas Production, Petroleum Refining, Forestry (Primary Extraction and Processing Industries Other than Organic Chemicals)	Metals, Minerals, Petroleum Products, Agricultural Products, Wood and Lumber
Compounded Chemical Products	Mixing of Chemical Materials to Produce Formulated and Packaged Products	Soap and Detergents, Cosmetics, Food and Beverage, Surface Coatings, Pharmaceuticals, Adhesives
Fabricated Products	Molding, Shaping or Manufacturing of Parts or Products, Metal Working, Painting	Auto Parts, Textiles, Molded Plastics, Metal Parts
Trade and Service	Drycleaning, Restaurants, Hospitals, Transportation, Auto Repair	Industrial and Consumer Services

In 1977 there were two particularly severe cases of industrial wastewater pollution. In Ohio, release of carbon tetrachloride into a tributary of the Ohio River almost contaminated drinking water supplies from Cincinnati to New Orleans. In New York, industrial discharges of PCBs into the Hudson River have meant an indefinite suspension of commercial fishing.

Recognizing the major threat industrial wastewater poses to the maintenance of water quality, Congress made the elimination of pollutant discharges to U.S. waters a national goal by passing the 1972 amendments to the Federal Water Pollution Control Act (FWPCA). As a result, industries must adopt successively more stringent control measures aimed at the removal of 65 toxic substances from their effluent.

Because it is either not feasible or prohibitively expensive to treat their wastewater, many industries have responded to these strict effluent limitations by trying to recycle as much wastewater as possible. Recycle and reuse programs have also been stimulated by the increasing cost of water resulting from decreasing supplies. An important side benefit of wastewater recycle and reuse has been that as products are recovered from the effluent stream less solid waste is produced.

A U.S. Department of Commerce forecast for 1975-2000 indicates that by

2000 industry will have reduced its daily water intake from 62 billion gallons to 23 billion gallons while at the same time doubling its gross water use. During this same period, U.S. industrial capacities are expected to expand by 60% and the structure of some specific industries, particularly the petrochemical and organic chemical industries, are expected to undergo significant shifts. Adoption of recycle/reuse processes in the near term will avoid costly retrofits to the new industries while concurrently reducing future industrial wastewater discharges. But to achieve these reductions in discharge major control technology prob-

MAJOR MILESTONES

Technology to Treat Toxic Pollutants

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
FIRST PRIORITY	
Chemical analytical methods	Program in progress: Analytical procedures for 65 priority pollutants identified in the 1977 Amendments to the FWPCA. (FY 80)
Generic surrogate analytical methods for chemical pollutants	Correlation studies and identification of at least one surrogate parameter. (FY 81)
Bioassay analytical methods for wastewater streams	Correlation studies of pollutants and bioassay results for textile, petroleum refining and iron and steel industries. (FY 80)
	Bioassay screening of wastewater streams for organic chemicals, timber, pulp and paper, plastics, and pharmaceuticals industries. (FY 81)
SECOND PRIORITY	
Application of existing technologies not widely practiced to industrial wastewaters	Bench and pilot plant data for activated carbon (or other technology) treatment in the plastics, pharmaceuticals, pesticides and organic chemicals industries. (FY82)
Investigations of fundamental science and technology for the development and application of exotic treatment technologies to industrial wastewaters	Findings on the applicability and chemistry of advanced treatment (e.g., reverse osmosis, electrodialysis, ion exchange, etc.) in the plastics, pharmaceuticals, pesticides, and organic chemicals industries. (FY 84)
THIRD PRIORITY	
Evaluations of existing, management, operating and housekeeping practices to reduce pollutant origination.	Manuals of practice for the inorganic chemicals, electroplating and mining industries. (FY 83)

SELECTED INDUSTRIAL SOURCES OF WATER POLLUTION: 1975

(Thousand Tons)

Source/Pollutant*	BOD	%Total	COD	% Total	TSS	% Total	TDS	% Total
Textiles	700.7	19.2	7,126.5	73.4	992.6	13.6	16.3	.1
Pulp and Paper	730.9	20.1	—	—	1,105.3	15.2	0.0	0.0
Petroleum Refining	22.5	0.6	100.2	1.0	9.8	0.1	—	—
Electroplating	—	—	—	—	—	—	138.1	.7
Other	2,187.3	60.1	2,476.1	25.6	5,187.5	71.1	20,848.8	99.2
Total	3,641.4	100.0	9,702.8	100.0	7,295.2	100.0	21,003.2	100.0

*BOD—Biochemical Oxygen Demand
COD—Chemical Oxygen Demand
TSS—Total Suspended Solids
TDS—Total Dissolved Solids

Source: U.S. Environmental Protection Agency. Technology Assessment Modeling Project. 1978.

lems must be resolved. The diverse composition of industrial effluents demands technology that sufficiently renovates water for reuse in many sensitive industrial processes. Designs are needed for centralized treatment plants that will be fed by small industrial concerns unable to afford their own water recycle plants. And economic viability and operational feasibility must be demonstrated to ensure commercial acceptance.

Major industrial water users daily discharge approximately 62 billion gallons of wastewater into rivers and streams.

To provide the control technology base for water treatment and recycle and reuse, research will therefore have to proceed on a number of fronts. Our research perspective can be defined as developing control concepts and prototype technology, demonstrating the commercial viability of the technology and finally, making the technology information available so that industry can install the technology and meet wastewater discharge laws. Research must also have the continued participation of industry in order to pay part of the enormous cost of developing effective control technologies.

Industrial Wastewater Research

EPA industrial wastewater research is aimed at aiding the development of technologies for advanced treatment and recycle systems. Because the technology required is highly industry specific and very expensive, our research is oriented toward the development of information which, in turn, will help with the development of technology. The program has three prime goals:

- Technology for Treatment of Toxic Pollutants
- Technology for Reuse and Recycling of Industrial Wastewater
- Information for Environmental Assessments.

Technology to Treat Toxic Pollutants

EPA needs to rapidly refine its list of 65 toxic substances identified under the 1977 Amendments to the FWPCA. Many potentially toxic compounds not on the list are being identified in industrial wastewater samples analyzed by EPA's Effluent Guidelines Division (EGD) and, conversely, several of the 65 substances have yet to be found by the EGD survey. By 1980, development will be completed for analytical methods to identify and measure contaminants in wastewater. The first chemical analysis methods developed will be appropriate for the 65 toxic substances. Because the repeated application of any analytical methods is expected to involve major costs, we also intend to develop sets of generic or surrogate parameters representative of groups of individual pollutants. Already existing cost-effective analytical methods such as non-specific detector analysis will be complemented by the surrogates. Development of those sets of parameters must await completion of the analytical methods, but we still expect to complete this cost saving portion of research in 1980.

Following the development of the methods to analyze water contamination, we will then be able to test the adequacy of conventional (i.e., biological) technologies for treating wastewater effluent. Testing will be done here on the plastics, pharmaceuticals, pesticide, and organic chemical industries. If conventional technology proves inadequate, we

MAJOR MILESTONES

Reuse and Recycle of Industrial Wastewater

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
FIRST PRIORITY	
Fifty percent water use reduction through reuse and recycle for industrial wastewaters	Demonstration of the reduction of water use for the electroplating, textile, petroleum refining, pulp and paper industries. (FY 83)
SECOND PRIORITY	
Closed loop operation for two major production processes for toxic chemicals	Demonstration of closed loop operation for two process operations, e.g., pulp and paper, and electroplating industries. (FY 84)
THIRD PRIORITY	
Low pollution production process modifications including raw materials	Identification and documentation of alternative processes and/or raw materials to eliminate toxic contamination of wastewaters for the textile and organic chemical industries. (FY 84)

MAJOR MILESTONES

Environmental Assessments in Decision Making

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
FIRST PRIORITY	
Centralize and insure integrity of data for toxic pollutant discharges	Data base available for use. (FY 84)
SECOND PRIORITY	
Environmental assessments	Priority listing of discharges from the textile, iron and steel and other industries. (FY 84)

will then investigate the chemistry and technology necessary to apply more advanced treatment technologies such as reverse osmosis, electrodialysis, and ion exchange.

We also plan to document effective practices currently in use for pollution abatement associated with industrial operation, maintenance, and housekeeping functions. Such practices are viewed as the "first line of defense" against pollution.

Reuse and Recycling of Industrial Wastewaters

Although it is used primarily as a coolant, water also serves as a process chemical and solvent and thereby becomes a major contributor to industrial water pollution. Therefore, our research will be oriented toward the development and demonstration of water use reduction and closed loop operation for process and solvent application. First, we will develop recycle/reuse methods for water use reduction in those industries that are high water consumers. These recycle/reuse methods will simultaneously prevent pollution and conserve water. Our aim is for a 50% reduction in water use as a first step toward closed-loop operations in the electroplating, textile, petroleum refining, and pulp and paper industries. This closed-loop concept will then be demonstrated on an operational basis in two of these industries. Demonstrations are not planned for each type of industry due to the high costs necessary to deal with the many industry-specific concentrations and types of wastewater pollutants. We have tentatively identified the pulp and paper and electroplating industries for the demonstrations.

But it may be impossible to reduce water use significantly or to achieve closed-loop operation for some industries. So, we plan to examine alternative low pollution processes as well as process modifications (such as changes in raw input materials) in an effort to limit sources of toxic contamination of wastewater. This research will focus primarily on continuation of our examination of the textile industry and on the organic chemical industries.

Information for Environmental Assessment

Federal agencies, state governments, universities, and industry are spending considerable funds, not to mention time, to collect data on toxic pollutants in industrial effluents. Information is slowly becoming available from these sources that, if properly integrated, could form the basis for rational environmental assessments. As the list of pollutants in air, land, and water grows, and the health and ecological effects data suggest more stringent regulations, environmental and economic trade-offs gain increasing importance in EPA policy making. For this reason, research will focus on developing the capability to make accurate assessments. Under this research program we will develop and implement research to estimate the quality of environmental measurements important to regulation and pollution control. We will also consolidate, or develop, linkages between the important data sources on industrial effluents. These linkages will permit effluent characterizations, exposure potential and geographic "hotspot" evaluation. We will then develop a list of the most severe discharges for the textile, iron and steel, and other industries. This list will be used to direct future industrial wastewater research.

Research Capabilities

EPA is the primary source of federal industrial pollution control technology research in this country. Our industrial wastewater research component is currently funded at an annual level of $7.4 million. Renewed concern to accelerate the development of water reuse and recycle options has resulted in a projected increase of $4.3 million in fiscal 1980. Two EPA research laboratories are dedicated to the solution of industrial problems. Our research laboratory in Cincinnati, Ohio, focuses primarily on industries such as chemical, pulp and paper. and smelting. The Research Triangle Park (North Carolina) laboratory deals mostly with industries such as iron and steel, petroleum refining and textile. Both deal with all environmental aspects of their specialty industries.

EPA is the primary source of federal industrial pollution control technology research in this country.

Most of our in-house research will be devoted to the most pressing and immediate short term projects. Longer term research or programs requiring heavy manpower commitments will be performed extramurally through grants and contracts. We have existing contracts with major consulting firms in the areas of process technology, environmental controls, and energy recovery systems. Expertise available through these contractors deals with special surveys, unique problems, environmental impact description, and sampling and analysis activities.

One difficulty we expect in the near future is the inability of our research to keep pace with the production of organic chemicals. For this reason, we expect problems will arise from insufficient sampling and analysis techniques and protocols. Another possible problem concerns our projected work on environmental assessments. At this point, the research hinges on the availability of the health effects information to permit the development of trade-off factors. If such data are not available, the assessments research plan will be modified.

WATERSHED MANAGEMENT

Water is vulnerable to pollution from many sources. EPA's research of watershed management is an effort to develop preventive controls at the lowest cost.

Water can be polluted directly by point source discharges of contaminants, particularly toxic chemicals, or indirectly by diffuse, or nonpoint, sources of contaminating materials. This indirect pollution of water occurs as a result of rainfall and snowmelt and consists primarily of runoff from city streets, construction and forestry activities, and agriculture and animal production. Recently, it has been found that acid precipitation, produced as a result of chemical reactions between raindrops and pollutants in the air, is also a major source of water pollution. Altogether, these "nonpoint sources" contribute sediment, pesticide residues, nutrients, toxics, metals, organic compounds, and pathogens to U.S. waters in quantities which are responsible for over half of our water pollution problems.

Nonpoint source pollutants can cause public health problems, adversely affect aquatic life, and involve great expense in cleanup. For instance, nonpoint sources were clearly linked to the formation of suspected carcinogens in the water supply of Fairfax County, Virginia. This 1976 study concluded that approximately 90% of the nitrates, phosphates, and suspended solids found could be attributed to nonpoint sources. Improper logging practices in Washington State were responsible for a washout into the Chehalis River during a severe rainstorm which has heavily damaged salmon spawning areas eight miles downstream. The pesticides DDE, DDT, and dieldrin from agricultural runoff have been found in algae and fish from the Iowa River. As a result, commercial fishing on the river has been banned indefinitely. And, a forty-five year study of fish populations in the lakes of the Adirondack mountains has shown a correlation between decreasing fish population and decreasing pH caused as a result of acid precipitation.

Watershed management is the assurance that desired water uses can be achieved at the minimum cost to society.

Furthermore, expected increases in agriculture, construction, and forestry required to support a growing population and the expanded development of domestic energy resources indicate that pollution from nonpoint sources will be even more of a problem in the future. For example, projections for agricultural runoff in eight major crop categories show that by 1990 sediment will increase by 50%, pesticide residues will increase by 93%, and fertilizers will increase by 178% over 1975 levels.

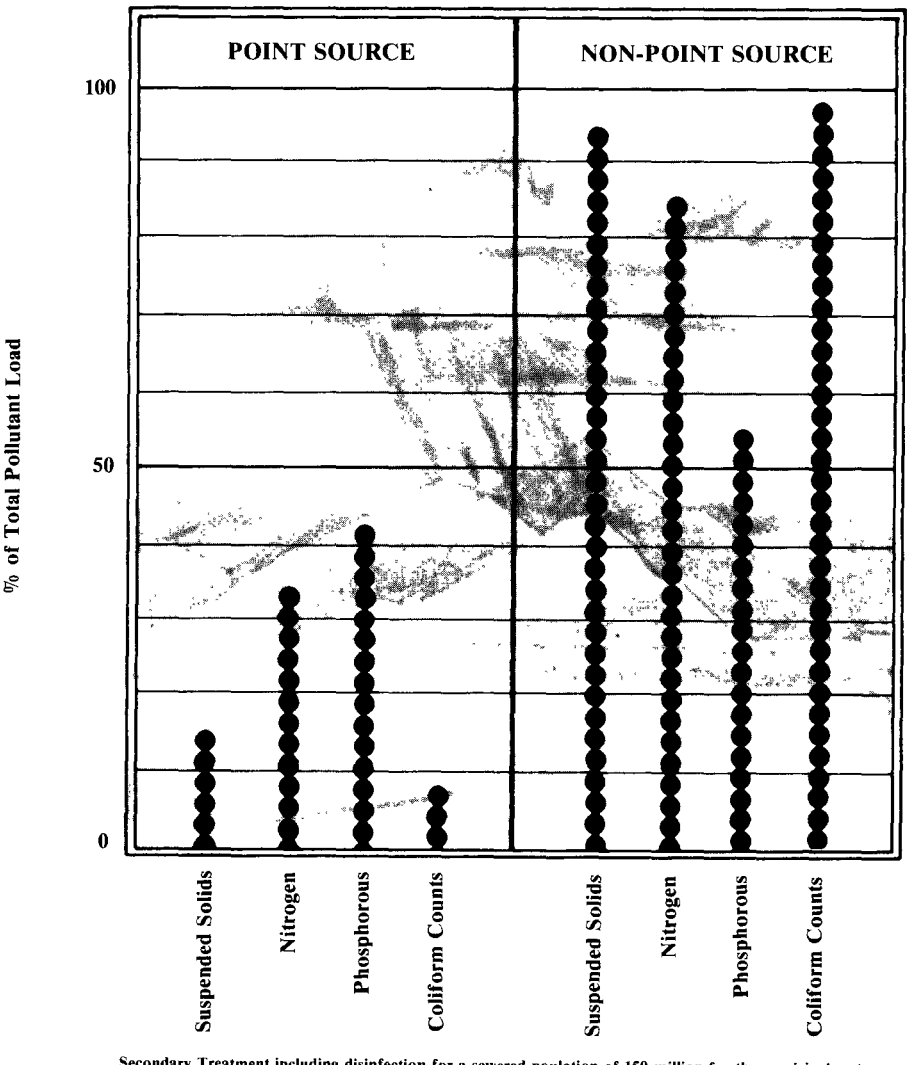
The Concept of Watershed Management

In order to minimize the detrimental effects of point and nonpoint sources on an ecosystem, comprehensive management of the watershed is required. This is not a straight forward process, however. First, we must develop a fundamental understanding regarding the dynamics of the physical, chemical, and biological interactions within the watershed. With such an understanding, we can then devise the predictive capability required to estimate the extent of ecosystem modification induced by point and nonpoint source pollution discharges. (These modifications may occur within the watershed ecosystem where the discharge originates or within an adjacent ecosystem which receives air or water transported material from the "source" watershed). Next, through monitoring and analysis, the pollution discharged into a watershed and the relationship between pollutant loading and water quality can be established. And, finally, using this information and taking into consideration socioeconomic and energy factors, the appropriate pollution control measures can be specified.

Research Needs

The watershed management research program will concentrate primarily on nonpoint sources because point sources have received so much attention in the past. We project that as point source pollution loads continue to decrease due to adequate controls, nonpoint source pollution loads will increasingly predominate. EPA plans to meet this pollution problem through voluntary controls for agriculture and silviculture and through regulatory programs for construction and mining. To stimulate acceptance of voluntary controls (i.e., Best Management Practices or BMPs) we feel

NATIONAL SUMMARY OF RELATIVE POLLUTANT LOADS AFTER THE 1977 REQUIREMENTS FOR POINT SOURCES ARE ACHIEVED



Secondary Treatment including disinfection for a sewered poulation of 150 million for the municipal sector and uniform application for Best Practicable Treatment for six SIC industrial categories.

Source: Projections by the National Commission on Water Quality, Hydroscience, Inc., August 1975; "An Overview of Waste Loads and Urban Suburban Stream Quality Response."

it is essential to demonstrate that the benefits of controlling or minimizing nonpoint source pollution exceed the costs of control.

The limited resources devoted to total watershed ecosystem studies have resulted in a scientific data base which is currently inadequate for local decision-makers to select and implement cost-effective control systems. New or improved methods are needed to develop a sound capability to predict the ecological consequences of environmental perturbations such as those caused by pesticides, heavy metals, and other toxicants. We need to know how nutrient and pesticide loading from nonpoint sources, toxic discharges and spills, and industrial wastes interact with chemical and physical ecosystem structures. We also need to know how the populations of living organisms within the watershed ecosystem are affected and modified.

Particular emphasis will be placed on the effects of toxic pollutants.

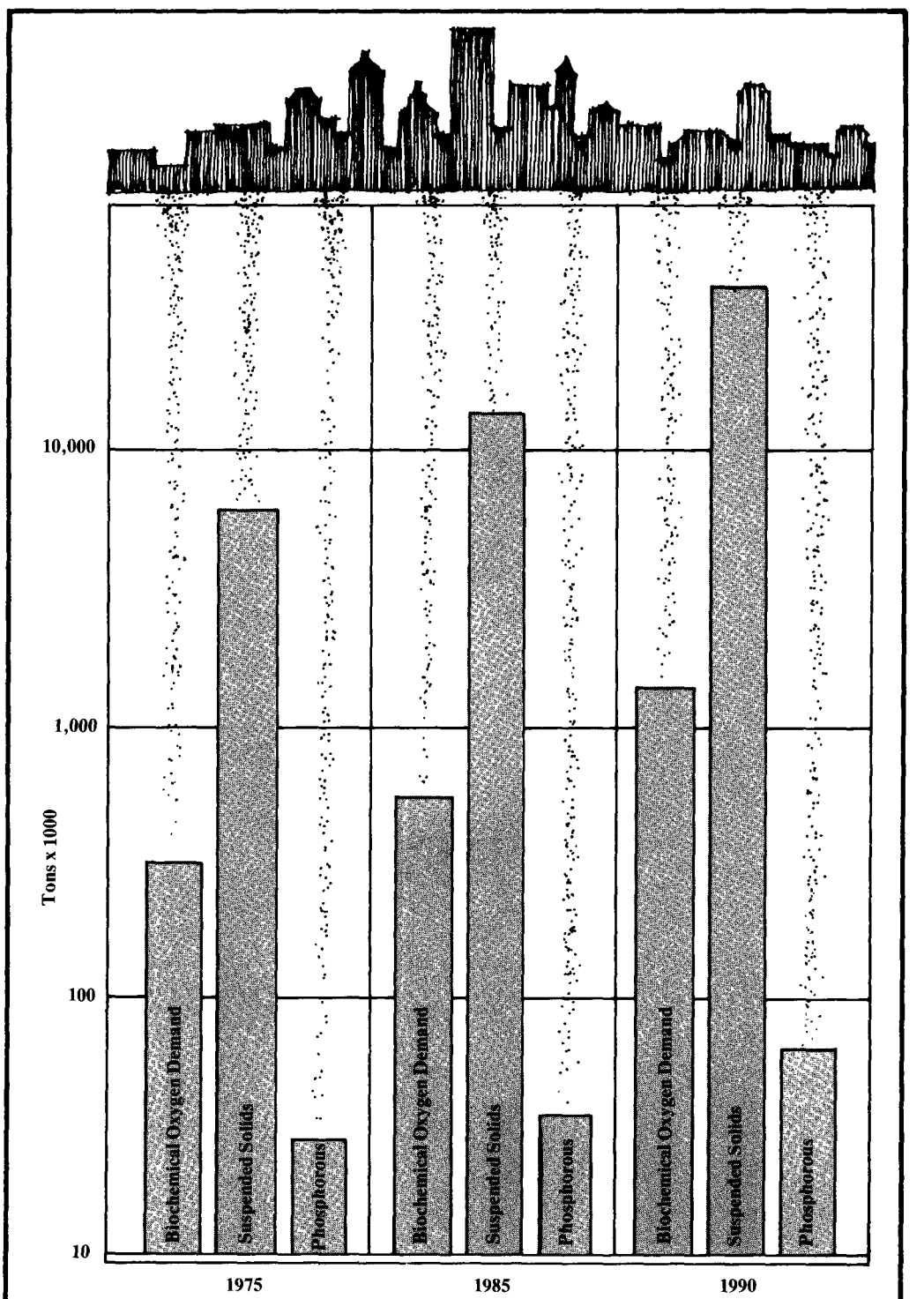
Since the effectiveness of current approaches remains open to question, better methods should be devised for the control of nonpoint source pollution. Additionally, ways should be found to encourage the proper use of these control methods. For example, BMPs should be designed to concurrently maximize water quality and conserve soil and water. We also need to develop and demonstrate monitoring techniques that can identify nonpoint source problems as well as detect and record indicators of BMP effectiveness. Some techniques now under study include aircraft and satellite imagery (i.e., photography, infrared and multispectral scanning), helicopter-borne water probes and samplers, and automated *in situ* sensors.

Nonpoint Source Research

EPA's goals for nonpoint source research encompass most of the research needs identified above. Our first goal will be to understand further the complex relationship between nonpoint source pollutant discharges and the quality of the affected waterways. Here, particular emphasis will be placed on the effects of toxic pollutants. Our second goal will involve the development and evaluation of cost-effective management methods to limit pollution from nonpoint sources. This goal will address structural as well as nonstructural approaches to the control of these pollution sources. An example of a structural approach is land terracing to control runoff; nonstructural approaches include improved timing of pesticide or fertilizer application, development of easily degradable pesticides and integrating biological pest controls with chemical pesticides. Finally, our third goal for research will focus on the development and demonstration of effective implementation strategies for nonpoint source control methods. This research goal is needed for the development of improved voluntary acceptance approaches to the use of control methods for nonpoint sources.

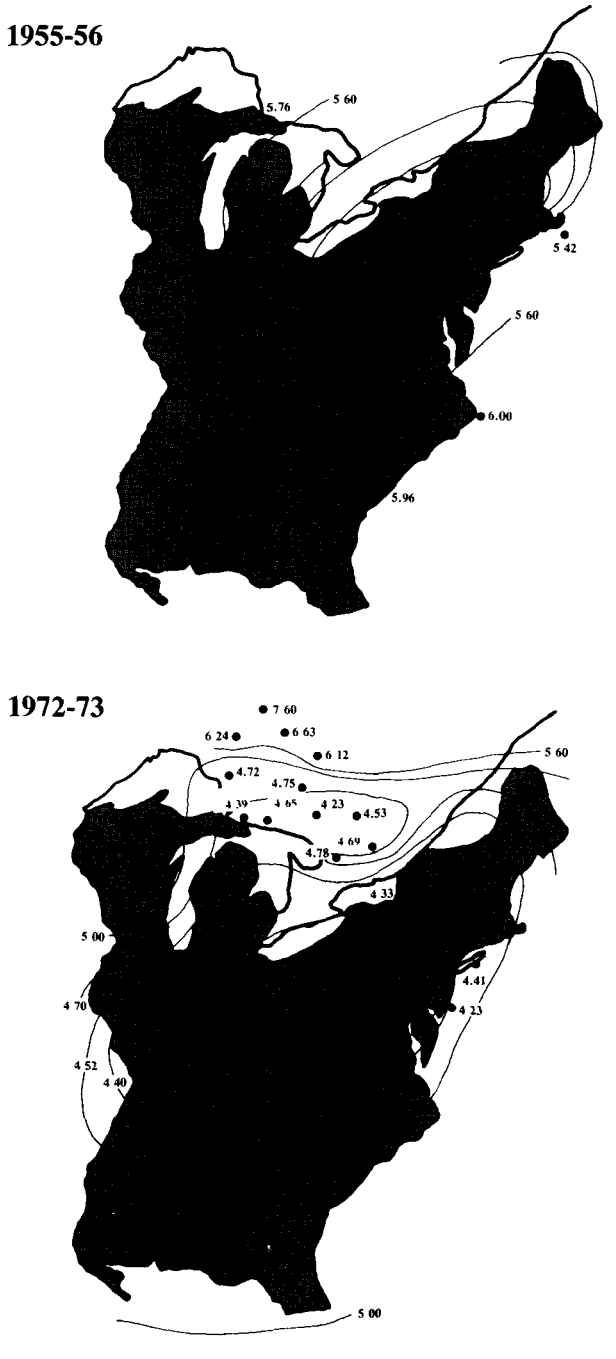
Understanding How Nonpoint Sources Impact Water Quality

Our first task will be the development of methods to evaluate the physical, chemical, and biological water quality impacts from the discharge of nonpoint source pollutants from urban runoff and agricultural production. Here techniques will be developed which relate climate conditions and urban and rural land use activities to enable the prediction of the total amount of pollutants discharged to a receiving stream. (Other nonpoint sources such as forestry activities will receive attention in the future.) This information will then be used to obtain criteria for the level of nonpoint pollutant discharges allowable for specified water uses.



PROJECTED GROWTH IN GROSS POLLUTANT LOADS FROM URBAN RUNOFF

Source: U.S. Environmental Protection Agency Technology Assessment Modeling Project. 1978.



THE WEIGHTED ANNUAL AVERAGE OF pH OF PRECIPITATION IN THE EASTERN UNITED STATES IN 1955-56 AND 1972-73

Source: National Academy of Sciences, Nitrates: An Environmental Assessment, 1978.

In addition, monitoring techniques will be developed to measure the amount of nonpoint source pollutant discharge. As part of this work, special emphasis will be placed on continuing our aircraft and satellite remote sensing techniques to assess the impact of nonpoint source pollution, to devise appropriate control strategies, and to determine the water quality improvements resulting from nonpoint source control.

Research will aid in determining the most cost-effective method of meeting established water quality standards.

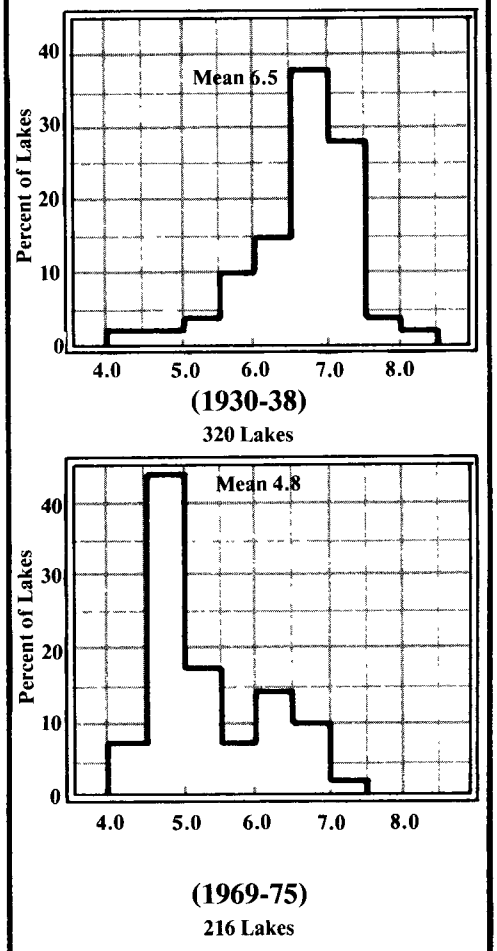
Some of this research will improve our capability to monitor and predict both the quantity and quality of precipitation and should therefore assist in the evaluation of watershed impacts caused by acid rain. Here, we plan to focus on impacts in the following general areas: aquatic environments, soils, agriculture, forestry, natural ecosystems, and long term trends. In addition to assessing the impact of acid precipitation on water quality, we will also examine its impact on other natural resources such as soil productivity.

Finally, we will address the relationships between point and nonpoint source pollutants on an individual watershed basis. This research will aid in determining the most cost-effective method of meeting established water quality standards. As part of this work, methodologies will be developed for determining allowable discharges for both conventional pollutants (such as organic matter, suspended solids, and fecal coliform) and toxic materials based on land use, climate, soil types, and pollutants for an entire watershed.

Methods of Controlling Nonpoint Source Pollution

The first step here will be to evaluate the effectiveness of existing methods to control coventional as well as toxic nonpoint source pollutant discharges in a watershed. Since local conditions may be such that more than one nonpoint source control method is required, various combinations of methods will be evaluated. Methodologies will be developed to match the most appropriate control method or combination of methods to a given set of

FREQUENCY DISTRIBUTION OF pH IN LAKES IN THE ADIRONDACK MOUNTAINS, NEW YORK



Source: Schofield, C.L. Acid Precipitation: Effects on Fish, AMBIO. 1976

local problems. In line with this approach, we will publish guidelines for planning, conducting, and evaluating field demonstrations of nonpoint source control methods to assist state and local water quality management agencies in developing effective nonpoint source control programs.

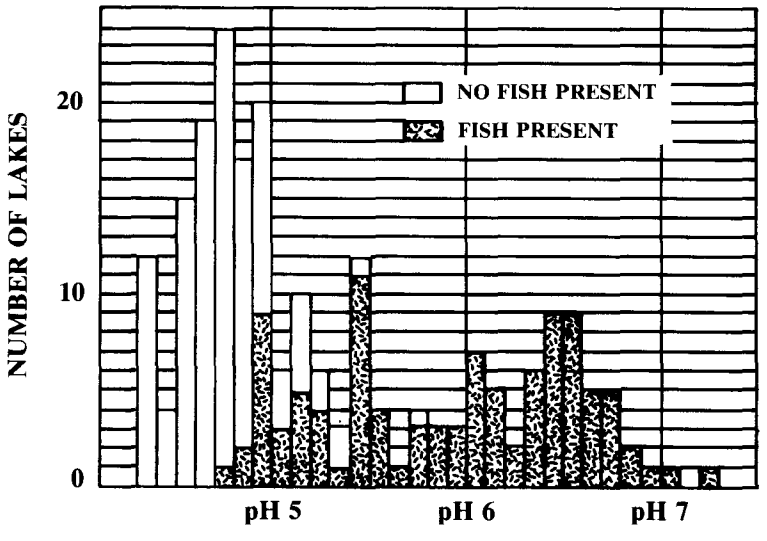
Because nonpoint source control for agriculture and silviculture is a voluntary program, it will be crucial that users in the field be aware of the latest developments. To this end, we will evaluate information transfer mechanisms currently available for nonpoint sources to determine their effectiveness in reaching the user community. In the years ahead, these mechanisms will play a major role in the transfer of nonpoint source assessment and prediction capabilities, results from demonstration studies, and improved or new management concepts to the field.

As a final task, we will demonstrate and evaluate new or improved control methods which have been developed by other federal and state agencies. Particular emphasis will be placed on those methods which are appropriate for multiple uses. Since accurate and timely information will be needed by state and local management agencies during the implementation phase of nonpoint source control programs, we will also develop an information system to retrieve water quality monitoring data on the effectiveness of nonpoint source controls.

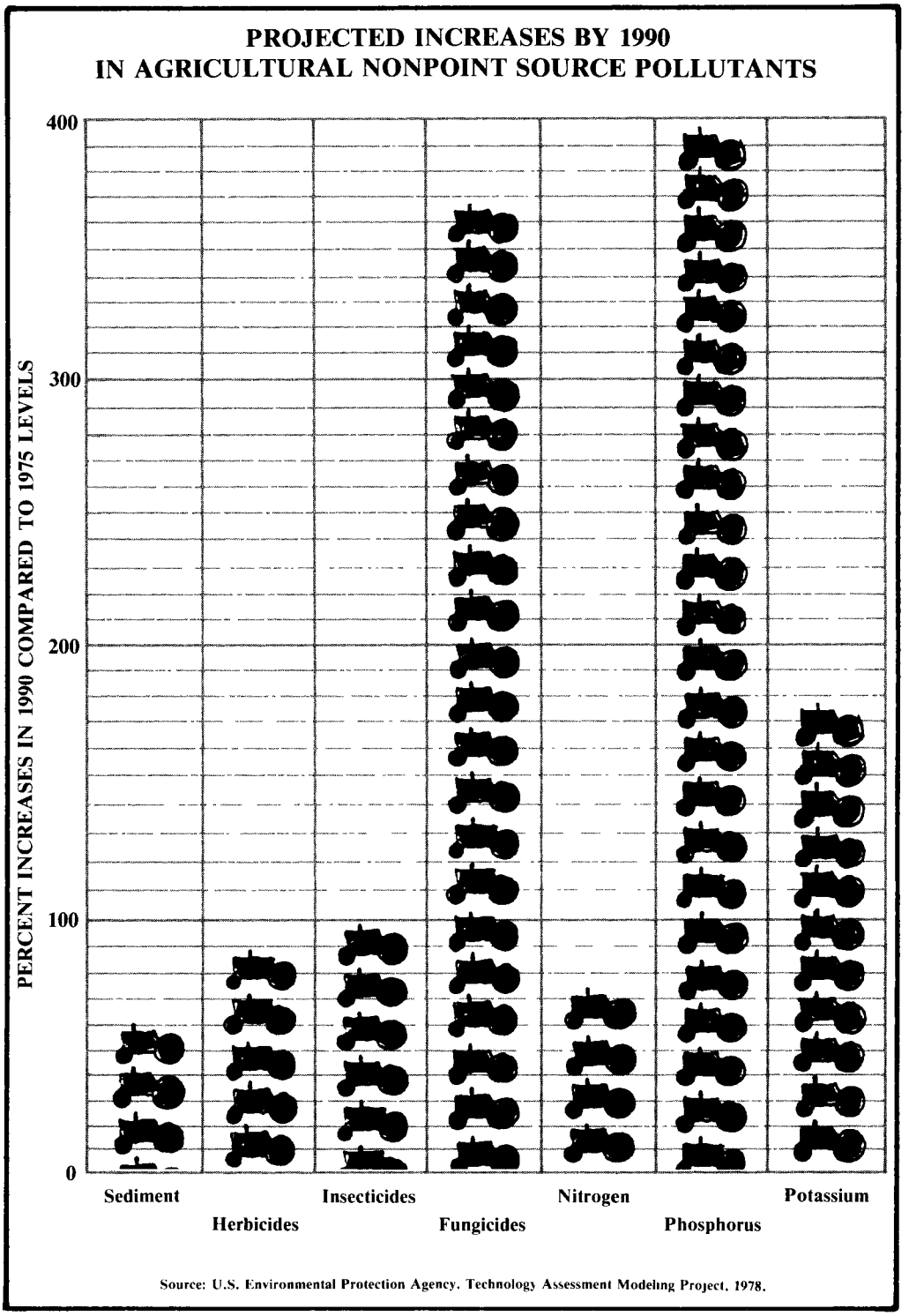
Implementing Nonpoint Source Controls

In order to improve our capability to implement a voluntary nonpoint source control program, EPA's research will focus on the development of relevant

DISTRIBUTION OF pH AND FISH POPULATION STATUS IN ADIRONDACK MOUNTAIN LAKES DURING THE SUMMER OF 1975



Source: Schofield, C.L. "Acid Precipitation: Effects on Fish," AMBIO. 1976.


PROJECTED INCREASES BY 1990
IN AGRICULTURAL NONPOINT SOURCE POLLUTANTS
PERCENT INCREASES IN 1990 COMPARED TO 1975 LEVELS
400
300
200
100
0
Sediment
Herbicides
Insecticides
Fungicides
Nitrogen
Phosphorus
Potassium
Source: U.S. Environmental Protection Agency. Technology Assessment Modeling Project. 1978.

MAJOR MILESTONES

Understanding How Nonpoint Sources Impact Water Quality

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATES
FIRST PRIORITY	
Methods to evaluate and assess the physical, chemical, biological, and ecological water quality impacts	Manual on methods to assess water quality degradation in fresh water streams and impoundments. (FY 80)
"Wet weather" water quality criteria appropriate for 1983 water quality goals and uses	Guidelines for allowable types and amounts of nonpoint source pollution as a function of water use and runoff magnitude. (FY 81)
Monitoring techniques for identifying water quality impacts	Report on remote sensing techniques appropriate for monitoring nonpoint source pollution. (FY 82)
	Report of workshops on remote automated *in situ* water quality sensors. (FY 79)
SECOND PRIORITY	
Methodology to assess the loading and impact on water quality from acid rain	Manual on methods for assessing acid rain loading and impact on water quality resulting from: 1) discharges directly into the receiving waters and 2) discharges from runoff. (FY 81)
	Nationwide assessment of water quality impacts from airborne pollutants. (FY 82)
Methodology to determine the relative impact on water quality of point sources and nonpoint sources	Report on techniques to identify, measure, and distinguish between the water quality degradation caused by point and nonpoint source discharges. (FY 80)
Methodology for determining allowable conventional pollutant discharges into flowing streams and impoundments with different water uses	Methods for determining allowable stream and impoundment loadings of conventional nonpoint source pollutants. (FY 81)
Methodology for determining allowable toxic discharges into flowing streams and impoundments	Methods for determining allowable loadings for toxic pollutants in nonpoint source runoff. (FY 81)
	Assessment of toxic material loadings from animal waste. (FY 82)
THIRD PRIORITY	
Identification of water quality impacts and problems resulting from variations in land use, climate, and soil types	Reports on available models to predict water quality impacts as a function of nonpoint source type. (FY 81)

MAJOR MILESTONES

Better Methods to Control Nonpoint Source Pollution

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATES
FIRST PRIORITY	
Individual structural and nonstructural control methods and combinations of methods to control nonpoint source pollutants	Report on evaluation of irrigated agricultural management systems in Rio Grande River Basin (FY 81)
	Demonstration results on combination of integrated pest management techniques with structural agricultural nonpoint source controls (FY 82)
	Report on field demonstrated cost-effectiveness of agricultural nonpoint source controls in Corn Belt (FY 81)
Methodologies for selecting cost-effective control methods that meet watershed water quality standards	Manual for selection of agricultural nonpoint source control methods in the Corn Belt (FY 82)
	Evaluation of the effectiveness of nonpoint source control methods at Model Implementation Program Sites on the Delaware River and Indiana Heartlands (FY 82)
Guidelines for planning, conducting, and evaluating field demonstrations of nonpoint source controls	Guidelines for evaluating the effectiveness of agricultural nonpoint source controls (FY 80)
SECOND PRIORITY	
Assessments of current and new technology information transfer mechanisms	Recommendations on how to use existing organizations to educate potential users of agricultural nonpoint source control methods (FY 80)
Transfer of results from field evaluation studies on water quality improvement from utilization of nonpoint source control methods	Case study reports on successfully implemented nonpoint source control methods (FY 81)
	Workshops on water quality improvement from implementation of nonpoint source controls in potential Rural Clean Water Program watersheds (FY 80 and FY 81)
THIRD PRIORITY	
Demonstrations and evaluations of new or improved control methods developed by other federal and state research groups	Evaluation of available new agricultural control methods for nonpoint sources (FY 82, FY 84)

MAJOR MILESTONES

(CONT.)

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATES
Cost-effective urban systems incorporating runoff rate and volume controls, storage and treatment, and innovative methods of combining stormwater runoff with wastewater treatment	Guidelines for selecting optimum combinations of cost/performance methods for abating urban wet weather pollution (FY 83)
Data management systems to provide appropriate water quality and resource data for use by state and local agencies	Manual describing data management system developed for agricultural nonpoint sources (FY 80)

economic impact data, the analysis of existing institutional mechanisms, and opportunities to integrate nonpoint source control programs with other pollution control programs. Special attention will be paid to economic impacts at the local, regional, and national levels for agricultural and silviculture nonpoint source control methods. Here, various incentives also will be investigated to determine those that are the most feasible and appropriate for local problems and conditions. Coordination of existing cost sharing programs, such as the Rural Clean Water Program for agricultural nonpoint sources and the Municipal Construction Grants Program for urban runoff, will also be included.

Second, we will evaluate the effectiveness of existing institutional mechanisms in encouraging the use of nonpoint source control methods. Current laws and regulations will be reviewed to identify impediments to effective nonpoint source control. Educational programs will be assessed and successful examples of voluntary implementation of nonpoint source controls will be evaluated and documented.

Finally, we will investigate opportunities to integrate nonpoint source control efforts with other pollution control efforts. This area shows particular promise. For example, air pollution controls to reduce the potential for acid rain as well as the fallout of nutrients and toxic substances could have a significant impact on the need for nonpoint source controls on the ground. Other programs, especially those involving water supply (including protection of groundwater), land application of municipal effluents and sludges, and industrial nonpoint source control will be investigated to determine where program integration would be desirable.

Special attention will be paid to economic impacts for agricultural and silvicultural nonpoint source control methods.

MAJOR MILESTONES

Effective Implementation Strategies for Nonpoint Source Control

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATES
FIRST PRIORITY	
Economic impact at the local, regional, and national levels of implementing methods to control nonpoint source pollution	Report on the economic impacts on individual farmers who install nonpoint source controls and on the entire watershed. (FY 81)
	Report on the economic impacts on individual communities who install urban runoff controls. (FY 81)
Impact of existing and proposed incentive systems to encourage use of nonpoint source control methods	Effectiveness evaluation of agriculture cost-sharing grants under the Rural Clean Water Program for encouraging the implementation of nonpoint source controls. (FY 82)
SECOND PRIORITY	
Effectiveness of institutional arrangements and mechanisms for implementation of nonpoint source control measures	Evaluation of agricultural project sites under the Rural Clean Water Program and Model Implementation Program to determine effectiveness of these institutional arrangements in achieving water quality improvements. (FY 81)
Documentation of successful voluntary implementation programs	Report on effectiveness of voluntary agricultural programs to implement nonpoint source controls, including social acceptance and impacts on farmers. (FY 80)
Review of current laws and regulations and recommendations for appropriate legislative changes (federal, state, local) to encourage implementation of nonpoint source control	Report on nonirrigated agricultural legislation (federal, state, local) which impedes the implementation of nonpoint source controls. (FY 80)
THIRD PRIORITY	
Integration strategies for implementation of nonpoint source control programs with other media pollution control programs	Guidelines for multi-media pollution control programs. (FY 81)

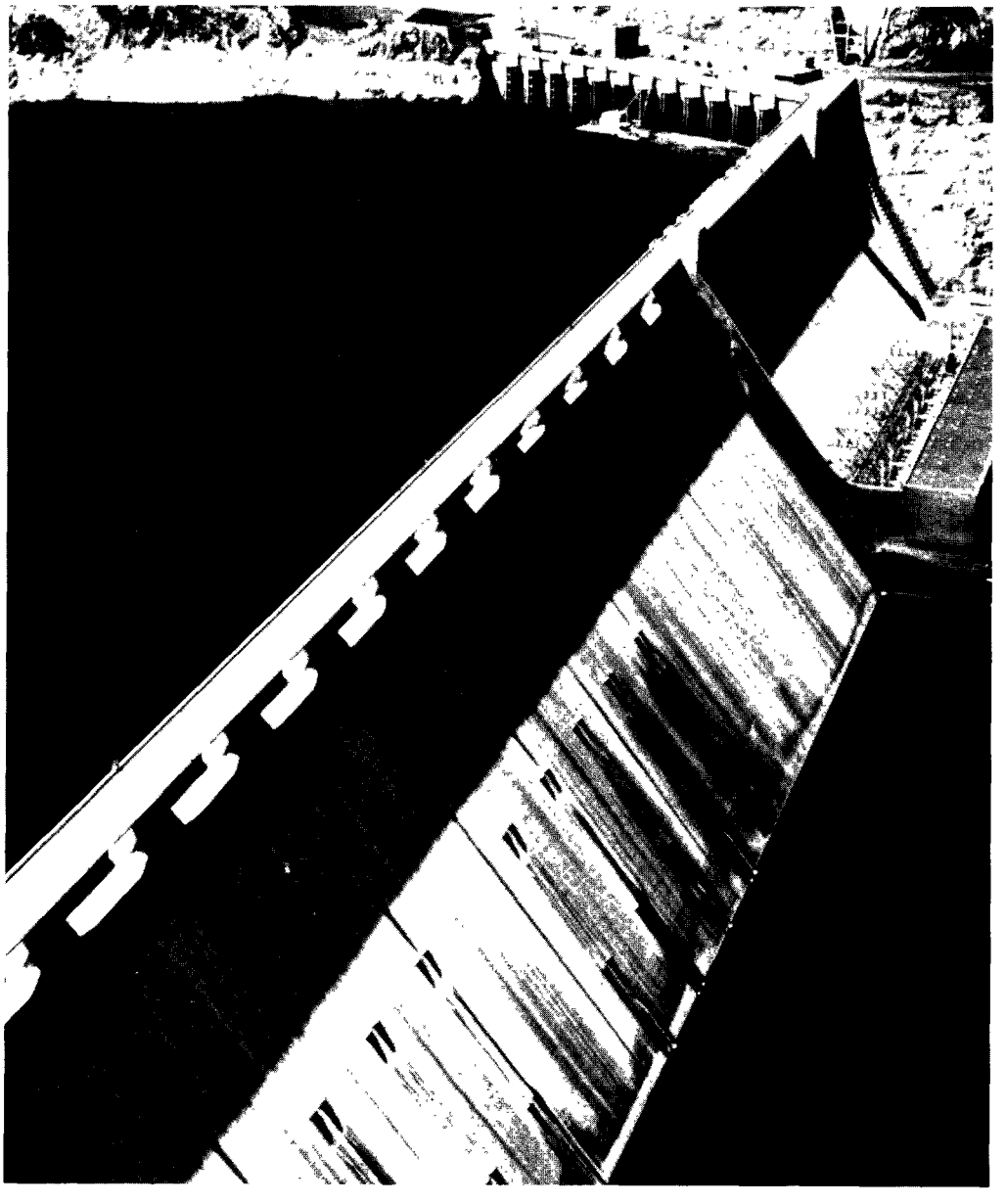
RESEARCH CAPABILITIES

EPA's watershed management research program currently is funded at an annual level of $41.7 million. This multidisciplinary research program embodies necessary skills in the key areas of hydrology, engineering, agronomy, biology, economics, and limnology. This program is conducted through eleven EPA components:

Laboratory	Research Areas
Athens—Environmental Research Laboratory	Agricultural Runoff—(dry land) Transport and Fate Forestry Runoff Watershed Management
Ada—Robert S. Kerr Environmental Research Laboratory	Agricultural Runoff—(Irrigation) Animal Production
Cincinnati—Municipal Environmental Research Laboratory	Urban Runoff Land Application of Sludges
Corvallis—Environmental Research Laboratory	Ecosystem Modelling Clean Lakes Acid Precipitation
Duluth—Environmental Research Laboratory	Freshwater Ecosystem Processes Pesticides/Toxics Fate and Effects
Gulf Breeze—Environmental Research Laboratory	Chesapeake Bay Marine and Estuarine Processes
Cincinnati—Health Effects Research Laboratory	Municipal Effluents and Sludges Pollutants in Shellfish and Recreational Waters
Cincinnati—Environmental Monitoring and Support Laboratory	Water Quality Monitoring and Analytical Techniques Quality Assurance
Las Vegas—Environmental Monitoring and Support Laboratory	Quality Assurance Remote Sensing Monitoring Systems
Cincinnati—Environmental Research Information Center	Technology Transfer
Headquarters	Integrated Pest Management

During the next five years, priority will be given to coordinating EPA's research activities with other watershed related projects being conducted elsewhere in EPA and in other federal agencies. It is our intention to integrate the research aspects of several existing implementation programs for nonpoint source control." These include: (1) EPA-USDA Model Implementation Projects; (2) Rural Clean Water Projects (proposed); (3) EPA & USDA Controlled Watershed Research Projects; (4) USDA's PL-566 Small Watersheds Program; (5) EPA-208 Urban Runoff Demonstration Projects; (6) Regional/State 208 studies; (7) Clean Lakes Projects; 8) Great Lakes projects; and (9) Chesapeake Bay Programs.

DRINKING WATER



Often our drinking water comes to us from a contaminated source. EPA is researching the health effects of specific contaminants and potential control methods.

In recent years, modern techniques and equipment have become available to detect and measure very small quantities of contaminants in drinking water. The applications of these sensitive methods have identified potentially hazardous organic contaminants in drinking water already treated by filtration and chlorination. With the explosive growth in the use of chemical compounds in industry, homes, and farming, chemicals are also finding their way into our drinking water sources. Some of these chemical contaminants may cause cancer, genetic mutations, or birth deformities. Protection of our drinking water from chemical as well as microbiological contaminants is, therefore, an important preventive public health measure.

Conventional treatment plants may not be effective in removing chemical contaminants and trace metals.

Treatment plants originally built to produce drinking water from less polluted sources may not be effective in removing the increasing amounts and varieties of chemical contaminants and trace metals existing today. For example, a 1972 study on pollution in the lower Mississippi River indicated a link between compounds present in the wastes of industrial discharges and those chemicals detected in the raw and treated water supplies in that area. In 1974, a study of the water supplies of 80 cities revealed the presence of numerous organic compounds. An EPA survey covering 113 locations in 1976 and 1977 clearly indicated the presence of trace organics in all the drinking water supplies, chiefly the trihalomethanes (chloroform, bromoform, dibromochloromethane, bromodichloromethane). Asbestos has also been of concern in several drinking water supply systems. Even the chlorination process, our primary means of water disinfection, has been found to produce organic compounds which may threaten human health.

The task then in preserving the quality of our drinking water is to reduce the risk of chemical contamination and, at the same time, not increase the risk of waterborne infection.

Drinking Water Research

Specifically, EPA drinking water research goals are to:

(1) develop detection, measurement and monitoring methods to identify and quantify drinking water contaminants
(2) develop treatment technology to reduce contaminant levels to acceptable concentrations
(3) assess the health effects of contaminants
(4) establish scientific and technical bases for action to protect ground water quality.

This last goal is especially important because approximately 50% of the U.S. population depends on underground sources for their drinking water. This constitutes a reliance on ground water by 80% of all public water supply systems and over 95% of all rural domestic supplies.

In the short term, our highest priority will be technology development and assurance of the quality of analytical methods. In the long term, emphasis will be placed on health effects, development of analytical methods, and ground-water research.

These research projects have been designed to develop information from which EPA can determine if there is a need to regulate drinking water contaminants. Furthermore, if regulations are deemed appropriate our research information can help establish the levels at which regulations should be set. Our drinking water research data will also be used by EPA's Office of Drinking Water to evaluate institutional solutions to some drinking water problems. Some of the

pertinent areas are regionalized water supply systems to serve the small scale user, aid to states regarding economics of water supply, and management of water supply systems.

Better Methods to Identify and Quantify Contaminants

In the absence of reliable contaminant measurement and monitoring methods, it will be impossible to provide scientifically valid and legally defensible data to support and enforce the regulations of the Safe Drinking Water Act. Consequently, primary emphasis will be placed on continuing our quality assurance program in EPA, state, local, and contract laboratories. Specifically, our research will support these laboratories by providing validated measurement systems, reference standards and samples, interlaboratory performance tests, procedures and criteria for certification of laboratories, and other quality control materials and services re-

MAJOR MILESTONES

Better Methods to Identify and Quantify Contaminants

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
FIRST PRIORITY	
Continuing quality assurance functions	Quality assurance program to support monitoring requirements of Safe Drinking Water Act—performance evaluation samples, performance evaluations, etc. (continuing)
Analytical methods for organics	Analytical methods for nonpurgable organics. (FY 83)
Surrogate methods for measurement of classes of organics	Surrogate methods for measurement of volatile organic compounds. (FY 80)
SECOND PRIORITY	
Microbiological determination methods	Methods to determine presence of cysts and viruses. (FY 82)
	Radiometric method for detection of sanitary indicator microorganisms in treated water. (FY 80) Analysis of ATP (adenosine triphosphate) method to monitor bacterial levels. (FY 82)
THIRD PRIORITY	
Multielement analysis capabilities	Comparison of several methods of mutlielement analysis, i.e., optical emission spectrometry with an inductively coupled plasma source and x-ray fluorescence. (FY 82)

quired to document the precision, accuracy, and intercomparability of monitoring data. A companion objective will be to develop analytical methods for organics. In almost all cases only those organic compounds that are volatile enough to pass through a gas chromatograph can be identified and measured in water. Because of this restriction, only 10 to 20% of the total mass of organics in most waters is analyzed. However, since time and resources will not permit determination of health effects of the thousands of organic compounds on an individual basis, research will be concentrated on the development of surrogate methods to measure *classes* of organic compounds.

The task is to reduce the risk of chemical contamination and not increase the risk of waterborne infection.

In the area of contaminant quantification, our research will be directed toward development of methods for determining the microbiological quality of drinking water. Here, we will focus on methods to detect cysts such as giardia and the virus that causes hepatitis.

Methods are currently available for measuring the inorganic constituents in drinking water, but many of these methods are costly and difficult to use. We will therefore focus on ways to facilitate their use and reduce their cost. Here, special attention will be given to multi-element analysis techniques because they allow laboratories to handle many more samples simultaneously than would be possible using element-by-element analysis. We will also refine newer measurement techniques including spark source mass spectrometry, inductively coupled plasma emission spectrometry, and neutron activation analysis.

Better Treatment Technology for Drinking Water

The lack of unequivocal health effects data related to organic contaminants in drinking water does not relieve EPA's responsibility to define treatment methods when reasonable doubt about health effects exists and monitoring is not practical. The development of treatment processes to control organic compounds will be the first task in our treatment technology research. Organic contaminants selected for study will be identified in surveys that quantify the occurrence of the compounds and identify any health effects data. Treatment processes will then be developed through bench-and pilot-scale studies and will be applied in field evaluations. We will attempt to convert some processes now in use in larger treatment systems for use in the smaller systems. One aspect of this conversion will be to keep the technology simple enough so that the training required for operators is minimal.

The two immediate needs in the inorganics area are: to develop treatment processes that will enable small systems to meet regulations economically, and to evaluate treatment processes for removal of asbestiforms. The development of treatment processes to control other inorganic compounds in these small systems will be the second task. Primary emphasis will be placed on the more troublesome inorganics such as nitrates, arsenic, fluorides, and selenium.

The major thrust in treatment to reduce microbiological contaminants will be the evaluation of alternate disinfection methods with emphasis on small systems and prevention of deterioration of water quality in distribution systems.

Health Effects Data on Contaminants

As of April 1978, 698 organic compounds had been identified in U.S. drinking water. While important information

MAJOR MILESTONES

Better Treatment Technology

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
FIRST PRIORITY	
Processes for organics control	Field studies involving carbon absorption for organics control methods. (FY 82)
SECOND PRIORITY	
Processes for inorganics control	Bench scale studies for fluoride, arsenic, nitrates, and selenium control. (FY 80)
	Field studies to evaluate full scale operations of promising inorganics control methods successful at bench scale. (FY 81)
	Field studies to evaluate processes to remove asbestiforms. (FY 80)
	Special studies to provide treatment methods for small systems, e.g., reverse osmosis, ion exchange, activated alumina. (FY 82)
THIRD PRIORITY	
Microbiological control	Viral and parasite removal. (FY 82)
	Determine factors affecting growth of microorganisms in distribution systems. (FY 82)
	Develop and evaluate alternate indicators of disinfection efficiency. (FY 83)

on concentrations, occurrences, and health effects need to be developed, a number of these compounds are suspected to be detrimental to health. Therefore we will first attempt to assess the health effects of certain of these organic compounds. The focus of this health effects research will be on carcinogenicity potential. Because there is such a large number of compounds, our research will pursue two avenues. First, we will examine those compounds which have already been identified as potential human health hazards. And second, our investigations will focus on various groupings of compounds selected on the basis of observed concentrations, frequency of occurrence and preliminary hazard evaluations from either available data or short-term bioassays.

Considerable attention has been given to the relationship between the presence of inorganic compounds in drinking water and cardiovascular disease. The National Academy of Sciences predicted a possible 15% reduction in heart disease mortality

by manipulation of the nation's water supplies but stressed that the specific alterations have yet to be determined. The Council on Environmental Quality has also published information that suggests a correlation between water softness and heart disease. As with organics, we will

Many available methods for measuring the inorganic constituents in drinking water are costly and difficult to use.

therefore develop health effects information on inorganic compounds. Here, we will perform a comprehensive review of a number of inorganic Maximum Contaminant Levels including those for fluorides, nitrates, selenium, lead, cadmium, and arsenic. We will also specifically assess the health effects of asbestiforms. Additionally, we will attempt to determine if the water softness/heart disease correlation is caused by benefits from "hard" water or detriments from "soft" water.

The fact that some chemical compounds, suspected to be carcinogenic, are formed during chlorination of drinking water creates a dilemma. It is important to limit human contact with suspected cancer-causing agents, but it is also essential to keep waterborne infections at their current low levels. Consequently, we will continue to monitor outbreaks of waterborne disease and to characterize the causative agents to develop data necessary to maintain desired levels of contaminant-free drinking water.

Scientific Basis for Protecting Ground Water Quality

A primary objective of the program is to identify major problems in protection of ground water and to provide the appropriate assessment methods to states and local communities. A corollary objective is to develop scientific and engineering guidelines on which source control criteria can be based. (see the Solid Waste chapter of this report.) Work on assessment methods will include development of biological and chemical indicators of ground-water pollution, methods to detect pressure increases resulting from well injections, and protocol for determining pollution potential of activities in a specific area.

Research to produce the scientific information upon which to base guidelines for source control criteria will focus on petroleum exploration and development, application of waste to the land, artificial recharge of ground-water aquifers, and agricultural practices. In addition, we intend to complete our assessment of the severity of ground-water pollution nationwide, by adding 16 states to the 34 already studied.

Research Capabilities

EPA research on drinking water involves over 100 people and a current budget of approximately $18 million. Most of the growth over the past few years has come from extramural funds for grants and contracts rather than increases in EPA staff. During this time, our laboratory research has been maintained to produce timely results for the regulatory programs, to chart the course of future research, and, at the same time, to manage the extramural program. As a result, the primary strength of our drinking water research program lies in a highly skilled staff able to deal with changing conditions.

The National Institutes of Health, particularly the National Cancer Institute and the National Institute of Environmental Health Sciences, make major contributions of interest to the drinking water research program. The Food and Drug Administration produces information of value on contaminants in food and water. The Occupational Safety and Health Administration and the National Institute of Occupational Health deal with con-

taminants in the workplace. In some instances, this information can be translated into exposures through drinking water. Finally, the U.S. Geological Survey has a long history of collecting basic ground-water data and continues to contribute to the information base on ground-water quality and quantity.

Water treatment practices in other countries are similar to those used in the United States with the important exception that greater use is made of granulated activated carbon and disinfectants other than chlorine in these countries. New developments in the drinking water area are transmitted through contacts among

MAJOR MILESTONES

Health Effects Data on Contaminants

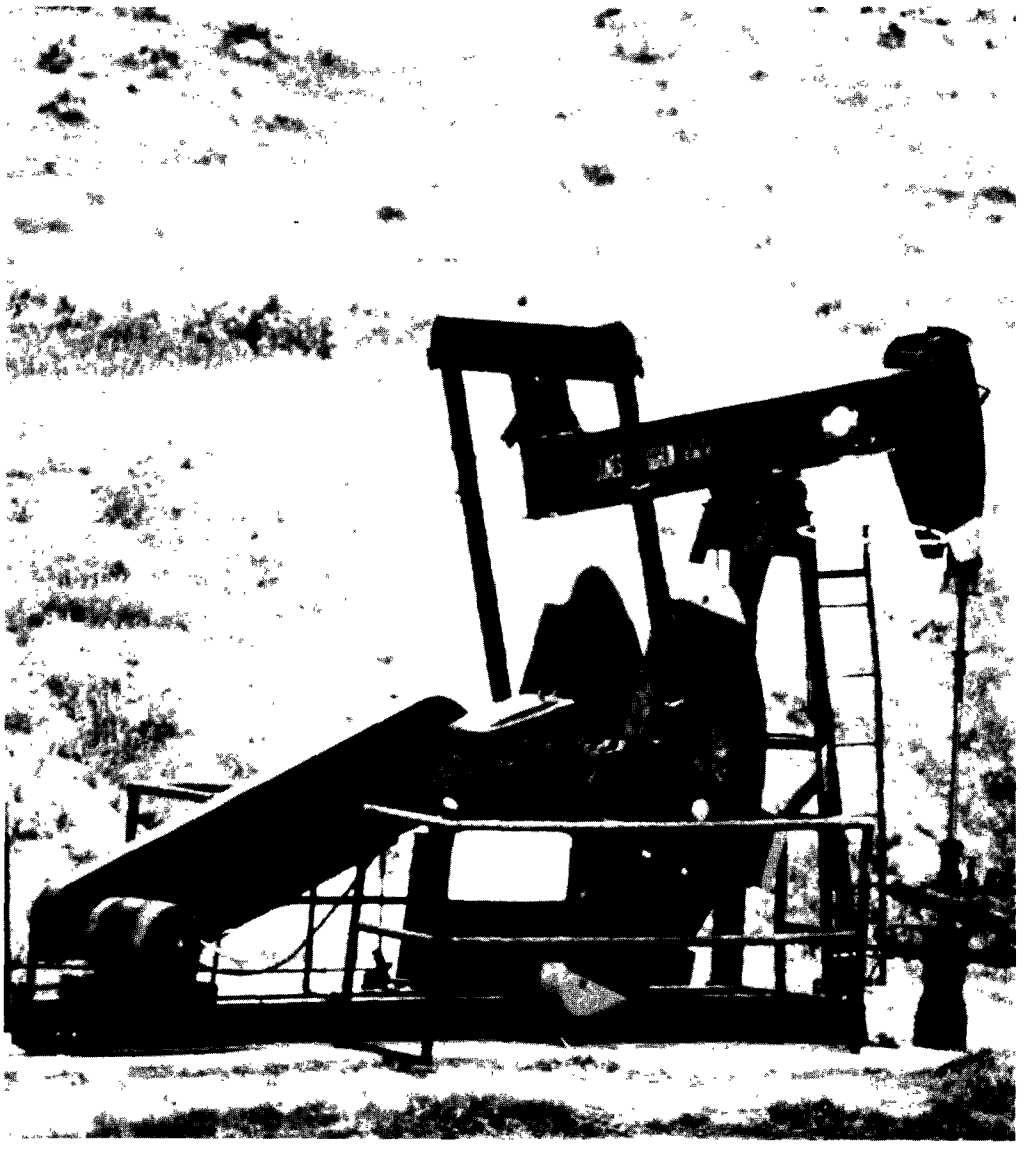
OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
FIRST PRIORITY	
Health effects of organic compounds	Concentration and chemical characterization of organic compounds from 5 cities' tap water. (FY 80)
	Selection and evaluation of indices of health significant organics. (FY 81)
	Association between cancer and exposure to drinking water contaminants. (FY 82)
	Selection of organic parameters which can be used for standards setting. (FY 83)
	Toxicological and epidemiological studies to validate health significance of organic parameters. (FY 84)
SECOND PRIORITY	
Health effects of inorganic compounds	Health effects of arsenic. (FY 80)
	Neurochemical effects of lead. (FY 81)
	Carcinogenic potential of nitrate. (FY 81)
	Health effects of asbestiforms. (FY 81)
	Inorganics and cardiovascular disease. (FY 82)
	Toxicity of inorganics in advanced waste treatment effluents. (FY 82)
THIRD PRIORITY	
Protect microbiological quality of drinking water	Annual review of waterborne disease outbreaks continuing
	Characterization of the etiologic agents of viral gastroenteritis and giardiasis. (continuing)

individual scientists, the NATO Committee on Challenges to Modern Society, the World Health Organization, and professional organizations.

MAJOR MILESTONES

Scientific Basis for Protecting Ground Water Quality

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
FIRST PRIORITY	
Assessment methods for ground-water compounds	Biological and chemical indicators of ground-water pollution. (FY 80)
	Pressure increases resulting from well injections. (FY 80)
	Transport and transformation of hazardous materials. (FY 81)
	Protocol for determining pollution potential of activities in a specific area. (FY 84)
SECOND PRIORITY	
Guidelines for controlling pollutant source categories	Petroleum exploration and development. (FY 82)
	Land application of waste. (FY 80)
	Artificial recharge. (FY 80)
	Agricultural practices. (FY 83)
THIRD PRIORITY	
Identification of major ground-water pollution problems	Extension of studies from 34 states to 50 states. (FY 84)



Energy supply and development can be compatible with environmental protection. EPA is researching controls to minimize the health and environmental impact of expanding energy development.

The profile of U.S. energy development and use will undergo major changes in the years ahead. Although only slowly evolving, it appears that our national energy policy will call for a widespread conversion of utility and industrial power facilities from scarce oil and gas to plentiful coal, decreased fuel consumption, particularly for the transportation sector, and, in the longer term, the use of technologies that are only now beginning to emerge for the production of liquid and gaseous fuels from coal and oil shale.

Shifts in energy development and use pose potential threats to human health.

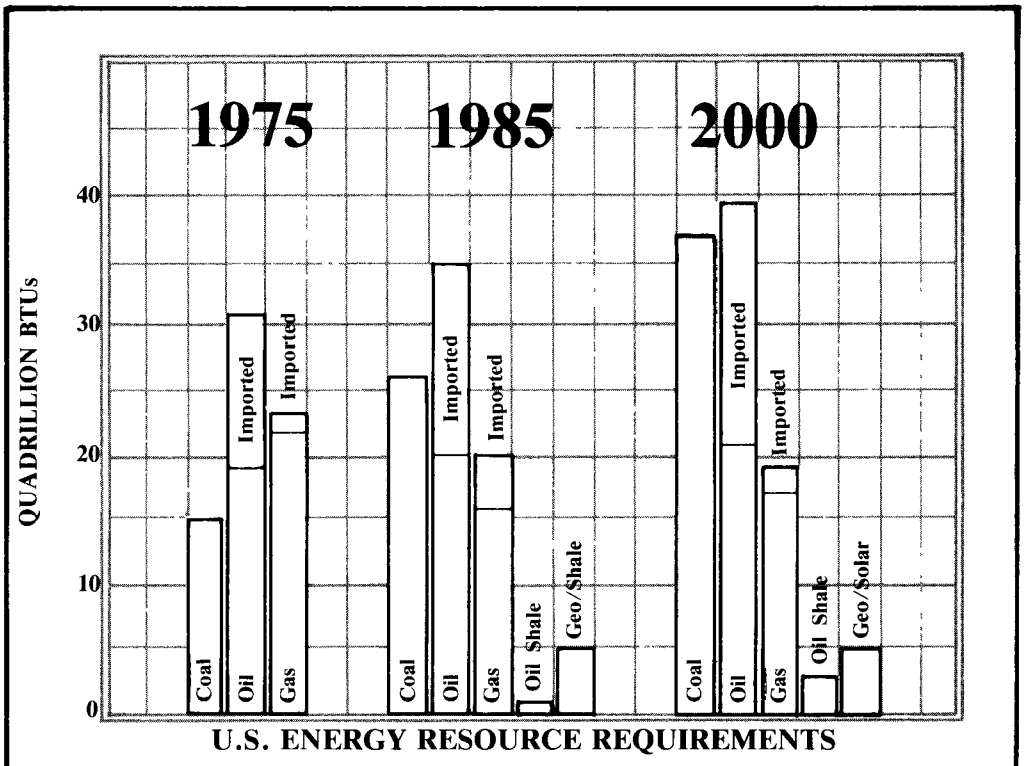
Projections indicate that total U.S. coal mining activities will increase from today's annual production of 700 million tons to nearly 1 billion tons by 1985 and will more than double by the year 2000. In 2000, conversion of existing utility and industrial facilities from oil and gas to coal coupled with construction of new conventional and advanced coal utilization facilities will consume approximately 1.4 billion tons of coal annually. Although conventional combustion of coal will predominate, by the year 2000 emerging coal-based technologies are projected to consume 300 million tons of coal per year. Furthermore, the National Highway Traffic Safety Administration predicts that diesel powered cars, which offer 20 to 30% gains in fuel efficiency, will account for 25% of all new car sales in 1985.

These shifts in energy development and use pose potential significant threats to human health in the next two decades. Massive increases in coal and oil shale mining, off-shore oil and gas production, and uranium extraction are all projected by the year 2000. Intensified mining activity will create erosion problems and generate runoff which can contaminate surface waters. Aquifers may also be polluted as a result of leachate or drainage from the mines themselves, or from the improper disposal of mining wastes. Increased use of coal by utilities, industries, and new technologies will produce more air pollution and solid waste residue than are currently produced. The pollutants expected to increase are nitrogen and sulfur oxides, ashes, and sludges. Because of the way they are formed, pollutants emitted from new technologies can be varied and complex and may prove to be even more harmful to human health than those emitted from current technologies. And the use of diesel engines as an alternative to gasoline spark-ignition engines will generate large quantities of particulate matter, which may be carcinogenic to humans and which EPA research has already shown to be mutagenic in test animals.

Research Needs

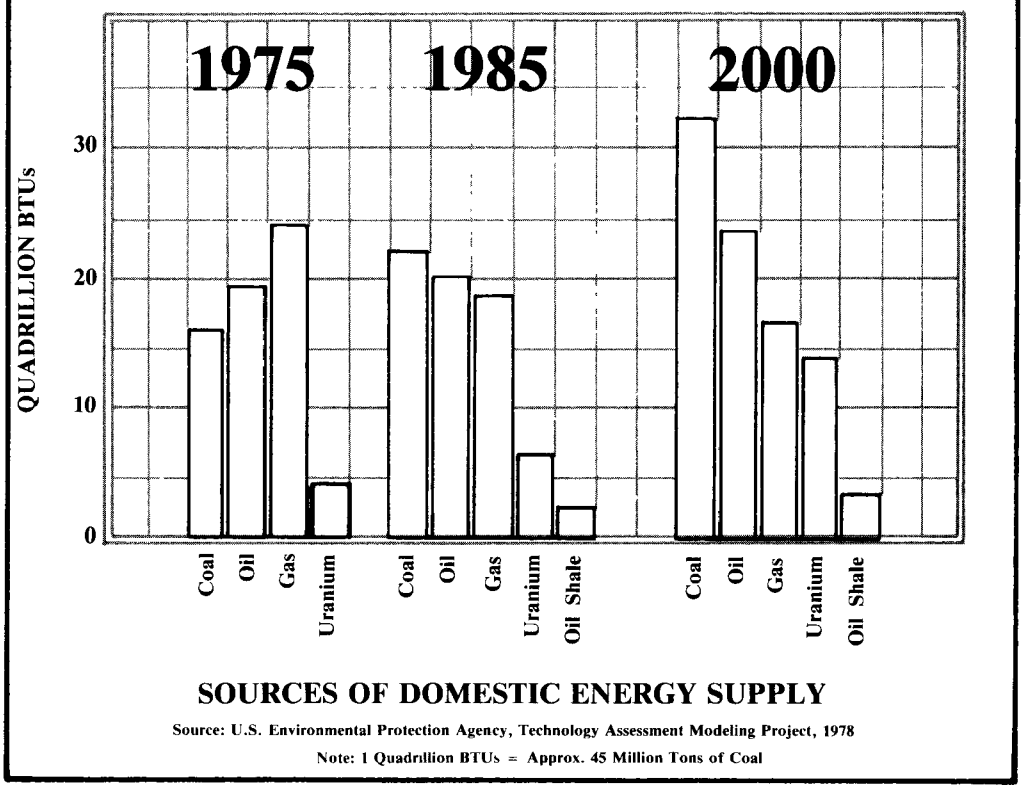
A multitude of information is needed to avert massive future environmental impacts.

For mining activities, particularly those associated with coal, oil shale, and uranium production, the impact of runoff on receiving streams and of mine drainage of toxic pollutants on groundwater needs to be quantified and the appropriate control methods developed. Techniques to combat water and wind erosion of reclaimed land are sorely needed. Improved methods are also required to mitigate radiation problems resulting from mining and milling uranium ores. Expanded use of existing coal burning technologies demands that technologies for sulfur oxide and particulate control be improved. Since they are in such an early stage of development, control technologies for nitrogen oxides must undergo vast improvement in the years ahead. Additionally, research must strive to address major information gaps regarding the magnitude of the health and environmental problems associated with trace elements, radioactive material, and polycyclic organic emissions produced during conventional combustion of coal.



U.S. ENERGY RESOURCE REQUIREMENTS

Source: U.S. Environmental Protection Agency, Technology Assessment Modeling Project, 1978



SOURCES OF DOMESTIC ENERGY SUPPLY

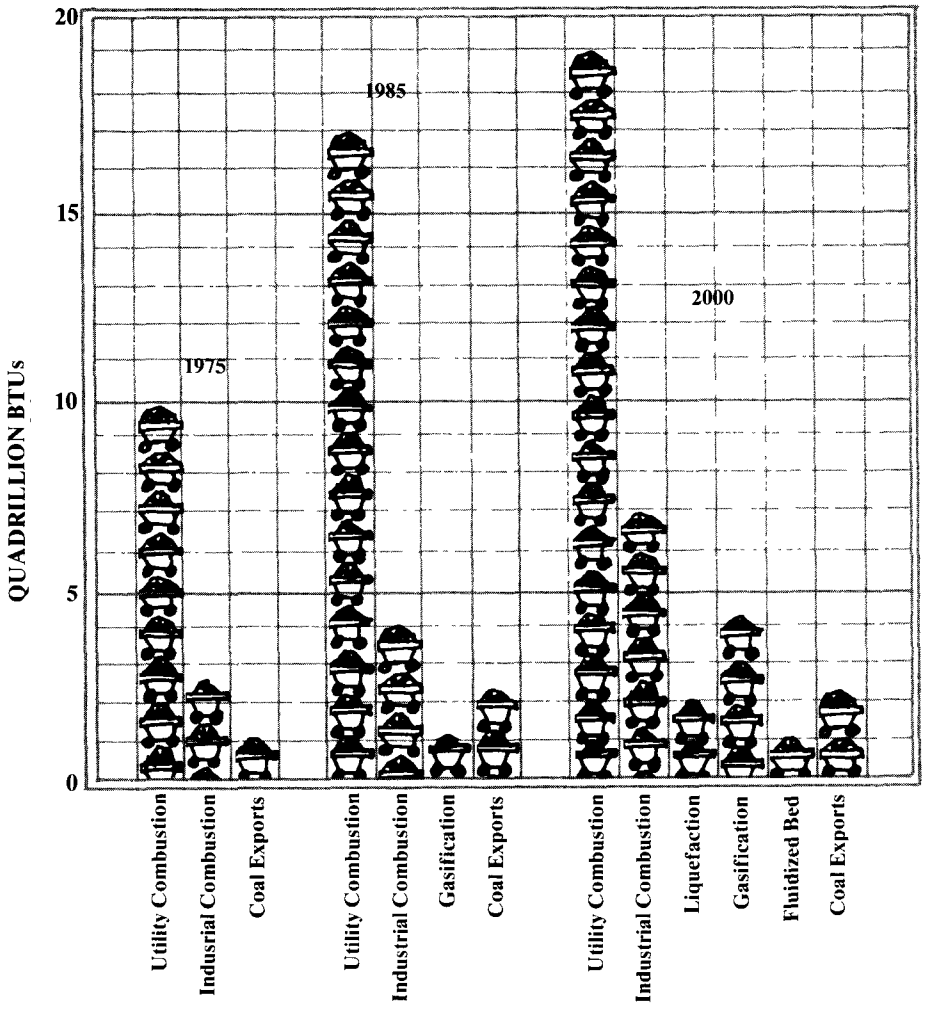
Source: U.S. Environmental Protection Agency, Technology Assessment Modeling Project, 1978

Note: 1 Quadrillion BTUs = Approx. 45 Million Tons of Coal

Emerging energy technologies must also undergo careful scrutiny for environmental impacts. Particularly, the level of sulfur and nitrogen oxides, particulates, heavy metals, and toxic and carcinogenic organic compounds, produced by the coal-based technologies of gasification, liquefaction, and fluidized bed combustion need to be assessed. Geothermal energy production methods should be examined from the perspective of hydrogen sulfide gases released, waste heat and steam plumes produced, and land-use implications. Solar energy systems should also be evaluated in terms of land and water use, sludge and residual production, and the possible leakage of toxic working fluids.

Finally, research needs to determine the cancer-causing potential of diesel soot and, if positive results are found, to establish the link between ambient concentrations and the incidence of cancers in humans.

COMPONENTS OF COAL UTILIZATION



Note: 1 Quadrillion BTUs ≈ Approx. 45 Million Tons of Cost

Source: U.S. Environmental Protection Agency, Technology Assessment Modeling Project, 1978.

MAJOR MILESTONES

Minimizing Impacts of Increased Conventional Combustion

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATES
FIRST PRIORITY	
Environmental assessments of conventional utility, industrial, commercial, and residential combustion sources with emphasis on currently unregulated pollutants.	Environmental assessment report on conventional combustion. (FY 80)
Low NOx burner capable of controlling emissions for new and existing utility and industrial coal-fired facilities.	Evaluation results on low NOx coal burner design on two industrial boilers. (FY 82)*
	Evaluation results on low NOx coal burner design on a 100-300 MW utility boiler. (FY 82)
Resolution of remaining operational problems associated with current generation of flue gas desulfurization (FGD) processes.	Completion of testing at the Shawnee prototype facility to improve reliability and operability of lime and limestone processes. (FY 80)
	Pilot scale tests of MgO process for coal fired utility boiler applications. (FY 81)
SECOND PRIORITY	
Effects of combustion pollutant emission on terrestrial organisms and ecosystems.	Determination of ecological effects of coal power plant emissions (SOx, NOx) on terrestrial ecosystems. (FY 81)
	Documentation of environmental impact of pollutants from coal-fired power plants located in the mid-west. (FY 80)
	Evaluation of deposition and accumulation of pollutants from mechanical draft cooling tower drift on plants and soils. (FY 79)
Improved efficiency, applicability, and cost effectiveness of current generation particulate control technology.	Evaluation of the applicability of fly ash conditioning agents to various coals and to precipitation problems. (FY 84)
	Full scale evaluation of a bag house on a low sulfur coal application to quantify its costs and reliability. (FY 80)
Economical control technology for the disposal of flue gas desulfurization (FGD) sludges and fly ash.	Demonstration of forced oxidation on a full scale FGD module at TVA's Widows Creek Power Plant. (FY 81)
	Long term study of the environmental impacts of FGD sludge disposal methods at the Shawnee prototype test facility and Louisville gas and Electric Co.'s Cane Run Steam Station.

MAJOR MILESTONES

(CONT.)

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATES
THIRD PRIORITY	
Effective physical coal cleaning processes for sulfur control.	Assessment of advanced coal cleaning processes at demonstration scale for high removal level of pyritic sulfur. (FY 82)
Flue gas denitrification technology capable of high levels of NOx control for utility and large industrial applications.	Evaluation of dry NOx control technology for large stationary sources. (FY 83)

*Note: One boiler probably complete in FY 81 + preliminary data on one boiler in FY 80 Both will be completed with documentation at end of FY 82

Energy and Environment Research

Our energy and environment research, development and demonstration program has the concurrent goals of assessing the magnitude of health and environmental problems to establish a data base for the formulation and refinement of meaningful standards and developing effective, commercially acceptable control technology. The major energy-related environmental areas requiring intensive research are, in their order of priority:

- Minimize impacts of increased conventional combustion
- Minimize impacts of increased energy extraction
- Quantify the cancer-causing potential of diesel soot
- Minimize impacts of emerging energy technologies

Minimizing Impacts of Increased Conventional Combustion

The Power Plant and Industrial Fuel Use Act of 1978 mandates the conversion of many existing utility and industrial power facilities from oil and gas to coal, prohibits practically all new oil or gas industrial and utility boilers, and for the most part limits new utility applications to coal and nuclear systems. Accordingly, conventional combustion of coal is a top priority EPA research area.

Research will focus primarily on control technology to reduce the impact of increased coal combustion.

Our research in conventional combustion will focus primarily on the development of control technology to reduce the environmental impact from expanded coal combustion. Here, we will concentrate on developing and demonstrating a low NOx burner capable of controlling emissions from new and existing utility and industrial coal-fired facilities. We will also attempt to resolve the remaining operational problems associated with cur-

rent flue gas desulfurization processes. Since relatively few air pollutants are controlled by the current regulations, it is important to know which *other* pollutants produced as a result of conventional combustion may pose a threat to human health and the environment. Therefore, we will perform environmental assessments of conventional utility, industrial, commercial, and residential combustion sources with emphasis on currently unregulated pollutants such as heavy metals and organic compounds.

Since operational and cost considerations are crucial to the success of environmental control technology, a second research objective will be to improve the efficiency and cost effectiveness of current particulate control technology. As part of this work, we will evaluate the applicability of fly ash conditioning agents to various types of coals. We also will develop and demonstrate economical control technology for disposal of large amounts of fly ash and sludge and will evaluate the impacts of these combustion products on terrestrial organisms and ecosystems.

Finally, our research in this area will aim toward the development of more advanced control technology for coal combustion. Specifically, we will develop effective physical and chemical coal cleaning processes for sulfur control and flue gas denitrification technology capable of high levels of NOx control for utility and large industrial applications.

Minimizing Impacts of Increased Energy Extraction

Since mining activities must be stepped up considerably in response to the increased demand for coal and other energy resources, priority research also will deal with the environmental problems associated with energy resource extraction.

One particular area of concentrated research will be the identification of specific health damages resulting from coal mining in general and the quantification of the effects of western coal and oil shale extraction on surface and ground waters. Research on environmental damage caused by coal extraction will focus on methods of limiting pollution through improved sediment and mine drainage control techniques and on a better definition of Best Management Practices (BMPs) for use by the regulatory programs of EPA and the Office of Surface Mining in the Department of the Interior. Water quality effects in the west will be treated by quantifying the relationships between pollution from strip mining and oil shale mining and the damage to aquatic organisms and their habitat. As part of this research, existing water monitoring networks in western energy extraction areas will be augmented to collect data on annual water quality trends.

EPA is currently conducting one of the largest energy-related environmental research programs in the country.

Another research avenue we will pursue is the assessment of the potential environmental damages from oil and gas extraction and handling. Much of this research will be devoted to developing methods of preventing, controlling, and cleaning up oil spills on land and water. Furthermore, for the purpose of recovering damage costs, we will develop a method of quantifying ecological damage resulting from oil spills. In addition, we will assess the impact of uranium extraction on surface and groundwaters and will develop appropriate control technology. We will also demonstrate revegetation and reclamation techniques for western surface mined areas. This work will include assessment of the impact of mining and reclamation practices on western surface water hydrology, forests, and range lands. Methods will be developed for the ecological recovery of toxic spoils

MAJOR MILESTONES

Minimizing Impacts of Increased Energy Extraction

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATES
FIRST PRIORITY	
Effects of Western coal and oil shale extraction on surface and ground-water quality.	Evaluation of the acute and chronic effects of pollutants from oil-shale mining and processing on freshwater organisms. (FY 80)
	Assessment of environmental impact of coal extraction and definition of Best Management Practice and treatability of effluents. (FY 81)
	Pollution Control Guidance Document for Oil Shale Development. (FY 80)
	Mathematical model relating quality of water and state of streams biota to mining, reclamation, and watershed characteristics. (FY 81)
	Water quality assessment in Northern Great Plains strip mined areas focusing on habitat impacts for aquatic organisms and wildlife species.
Water quality monitoring network in western energy development areas.	Augmented regional water monitoring network in key energy areas for energy related water pollutants. (FY 79)
	Regional water pollution baseline data for coal development. (FY 81)
	Development of regional ground-water monitoring methodology. (FY 79)
Development of Best Management Practices for Eastern coal mines.	Assessment and determination of Best Management Practices for Surface Mine Sediment Control. (FY 79)
	Manual of Practice for Eastern Coal Mines. (FY 79)
SECOND PRIORITY	
Environment damage assessments for oil and gas extraction and handling.	Assessments for on-shore oil and gas production facilities. (FY 83)
	Assessments for off-shore oil and gas production facilities. (FY 81)
	Methods to prevent, control and clean up oil spills on land and water. (FY 80)

MAJOR MILESTONES

(CONT.)

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATES
Revegetation/reclamation techniques for western surface mined areas.	Report on ecological recovery after reclamation of toxic spoils left by coal surface mining. (FY 81)
	Impact assessment of mining and reclamation practices on surface hydrology, forest, and rangelands in the West. (FY 80)
Environmental damage assessments for uranium extraction and development of control technology.	First generation assessment of *in situ* leaching. (FY 79)
	Best Management Practices for uranium solid waste disposal. (FY 81)
	Impact assessment of uranium extraction. (FY 81)
THIRD PRIORITY	
Energy related water quality baseline data in major eastern coal areas projected for major development in late 1980's.	Annual trend reports for coal areas in Southwestern Ohio, Pennsylvania, Tennessee, Kentucky, Virginia, Indiana. (FY 81-89)

generated by surface coal mining.

Finally, we will establish energy-related water quality baseline data in major eastern coal areas that have been identified for new development in the late 1980s.

Quantifying the Cancer-Causing Potential of Diesel Soot

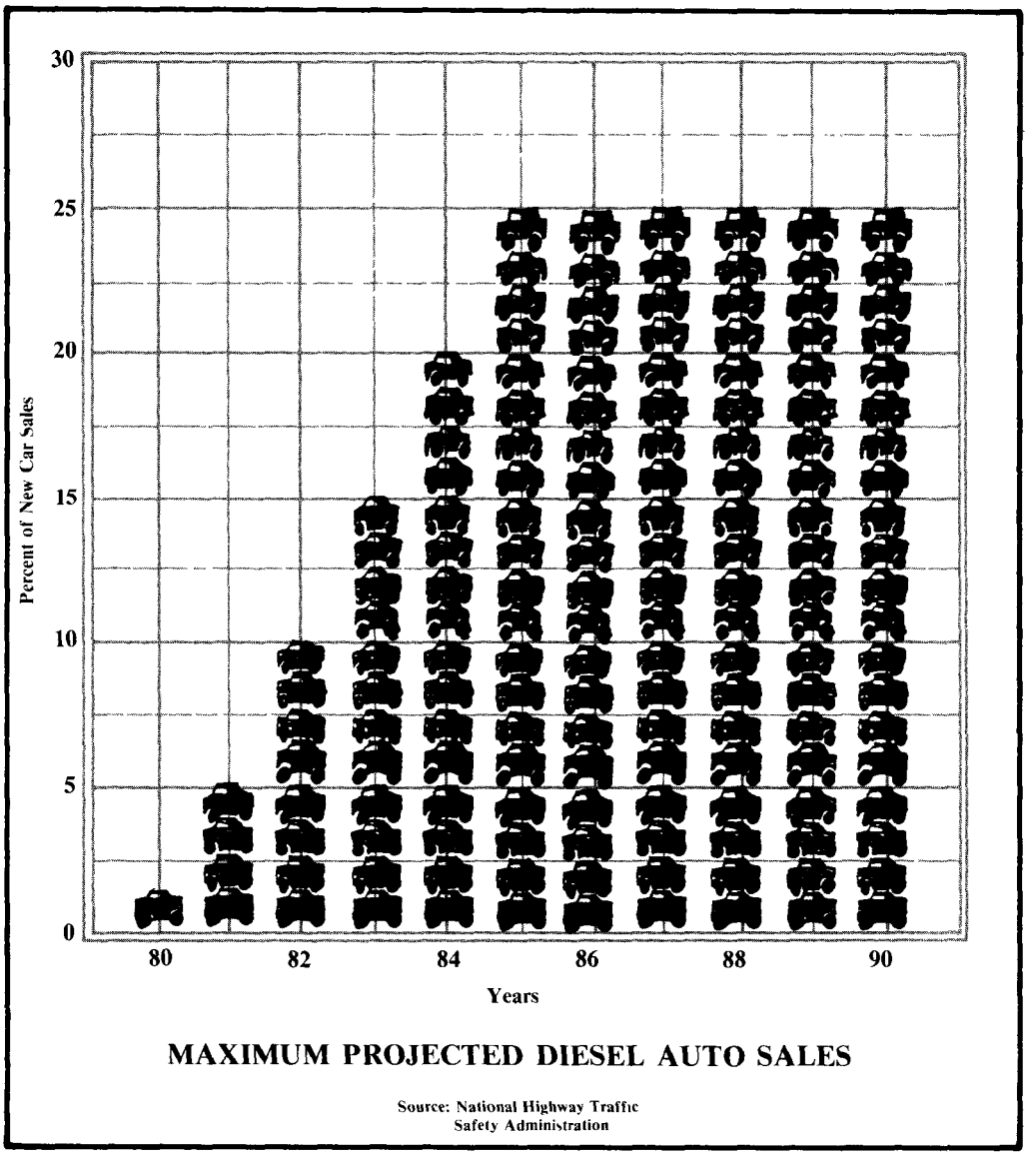
Anticipated market penetration of diesel cars will make the potential health problems associated with the use of diesel engines a major issue in the near future. For this reason, diesel health effects research will be a priority research area. In order to obtain a health effects assessment for diesel soot, we have initiated whole animal exposure studies using intratracheal instillation, inhalation and skin painting. Simultaneously, we plan to continue our research dealing with evaluations of the carcinogenic potential of diesel particulate emissions from different fuels and engines. Here, we will attempt to determine if these parameters can be altered to lessen or eliminate the possible cancer threat posed by diesel combustion.

We will also make ambient measurements to estimate the background levels of "soot" (i.e., prediesel levels) in population centers throughout the United States. Additional work in this area will be aimed at predicting the exposure of various population segments to diesel soot as a function of market penetration. Information generated from this work, coupled with available health effects data on diesel soot, will allow risk assessments to be made.

Research relating to the effectiveness of various control devices will concentrate on identifying ways to reduce substantially the quantity and potency of particulate emissions while still retaining the superior economy characteristics of diesel fuel. Here, we will evaluate current catalytic converter technology as well as advanced control techniques with the aim of identifying cost-effective control methods.

Minimizing Impacts of Emerging Energy Technologies

The multi-billion dollar energy technology development program now underway in the Department of Energy and in the private sector will present environmental problems as these tech-



MAXIMUM PROJECTED DIESEL AUTO SALES

Source: National Highway Traffic Safety Administration

MAJOR MILESTONES

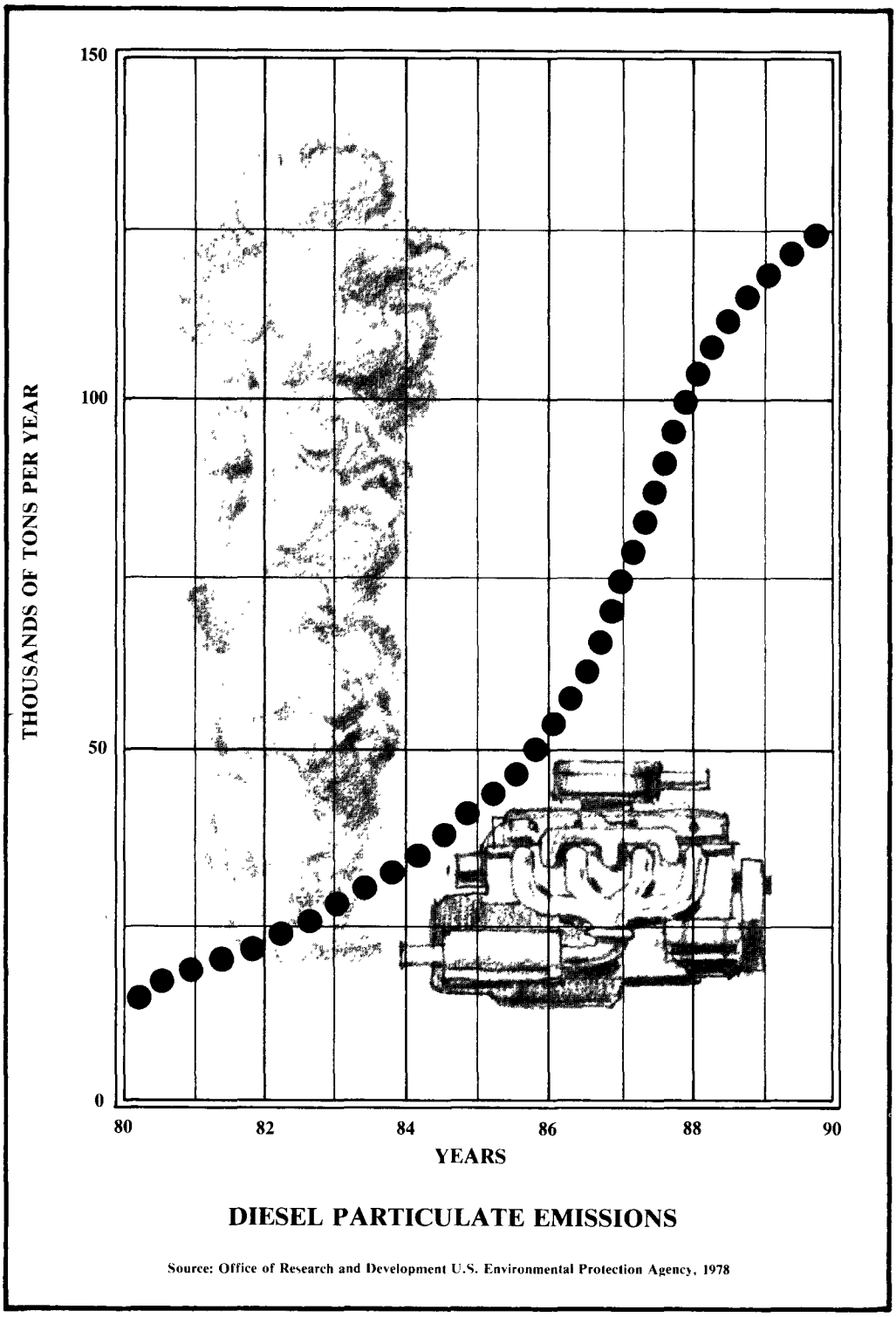
Quantifying the Cancer Causing Potential of Diesel Soot

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATES
FIRST PRIORITY	
Compare carcinogenic potency of diesel soot with cigarette condensate, roofing tar and coke oven soot through whole animal testing.	Results from mouse painting tests. (FY 81) Findings for intratracheal instillation testing on hamsters. (FY 82)
SECOND PRIORITY	
Assessment of carcinogenic potential of diesel soot through whole animal inhalation tests.	Inhalation testing on cancer susceptible mice. (FY 80) Inhalation testing on cancer susceptible hamsters. (FY 80)
Assessment of mutagenic and carcinogenic potential of diesel soot using in-vitro techniques.	Upgrading Ames mutagenicity test as an analytical tool for control evaluation. (FY 80) Results on comparative testing of diesel soot, cigarette condensate, roofing tar and coke oven soot via in-vitro bioassay testing. (FY 80)
Exposure assessment of diesel soot on general population.	Complete exposure assessment study. (FY 80)
THIRD PRIORITY	
Technology for diesel soot control.	Evaluation of state-of-the-art catalytic converters. (FY 79) Development of second generation control technology. (FY 82)

nologies become commercialized. EPA will continue to apply research to the broad spectrum of evolving energy-related processes, but will change the research direction and emphasis as necessary when specific new technologies approach commercialization. Currently, for example, it appears that innovations in oil shale extraction methods pose a significant potential threat to the environment. So we see as our first task the environmental assessment of the major first generation in-situ and surface oil shale processes such as the promising Paraho process. Our assessments will characterize input materials, products and waste streams, identify potential environmental impacts, describe performance and costs

of control alternatives, and suggest appropriate discharge limits and control technology.

Similar assessments will be performed for major coal gasification, coal liquefaction, and fluidized bed combustion processes. Some of the processes we will examine include the Wellman Galusha,



DIESEL PARTICULATE EMISSIONS

Source: Office of Research and Development U.S. Environmental Protection Agency, 1978

MAJOR MILESTONES

Minimizing Impacts of Emerging Energy Technology

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATES
FIRST PRIORITY	
Environmental assessments of important first generation oil shale processes.	Pollution Control Guidance Document for Oil Shale Development. (FY 80) Oil Shale Environmental Assessment Report (EAR)*. (FY 83)
SECOND PRIORITY	
Environmental assessments of low/high Btu coal gasification, coal liquefaction and fluidized bed combustion processes.	EARs for low and medium Btu coal gasification: Wellman Galusha (FY 79); Willputte Chapman (FY 79); Lurgi or Stoic (FY 80); and In situ process (FY 84) EARs for high Btu coal gasification: Lurgi (FY 79); Hygas (FY 80); and Slagging Lurgi (FY 80) EARs for fluidized bed combustion: atmospheric (FY 79) and pressurized. (FY 84) EARs for coal liquefaction: Solvent Refined Coal (SRC I/II) (FY 79); H-coal (FY 80); and Fisher Tropsch. (FY 81)
THIRD PRIORITY	
Environmentally assess other emerging energy technologies.	EARs for solar energy (FY 83); geothermal (FY 82); advanced power cycles (FY 85); waste-as-fuel (FY 83); and selected processes for biomass conversion or energy conservation (by FY 82).

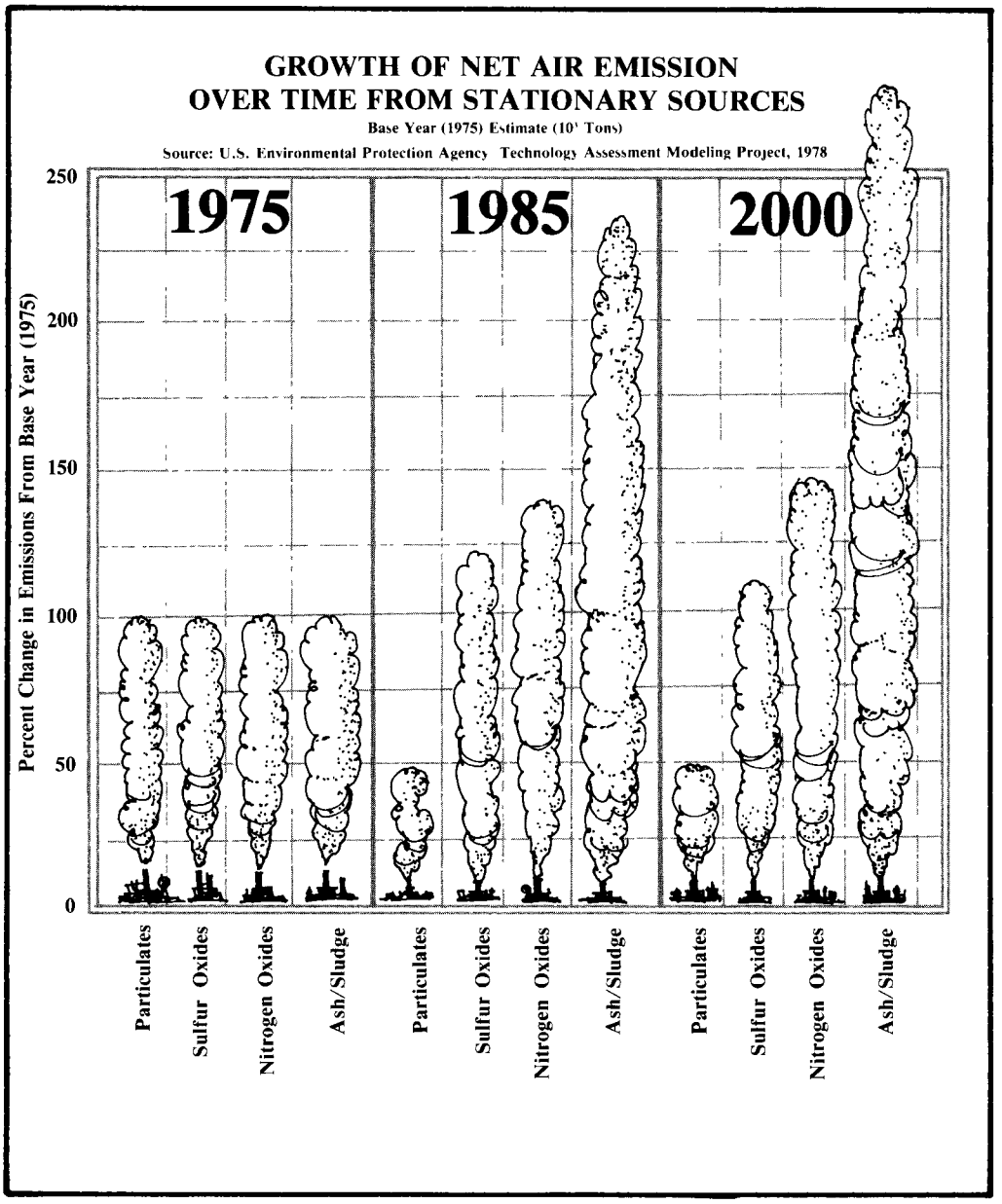
*Environmental Assessment Reports include a characterization of input materials, products and waste streams, performance and cost of control alternatives, analysis of regulatory requirements and environmental impacts, summary of additional data needs, and suggested discharge limits and associated control technology.

Willputte Chapman, Lurgi, and in-situ processes for coal gasification; the Solvent Refined Coal, H-coal, and Fischer Tropsch processes for coal liquefaction; and the atmospheric and pressurized methods of fluidized bed combustion.

In addition, we will produce environmental assessments of other important new energy technologies including geothermal, waste-as-fuel, solar, advanced power cycle, biomass conversion and energy conservation techniques.

Research Capabilities

Energy-related environmental research programs are conducted throughout the federal sector with a total annual budget of nearly one-half of a billion dollars. EPA with $115.9 million and 185 positions devoted to energy-related environmental research is currently conducting one of the largest energy-related environmental research programs in the country. The program, which involves seventeen other federal departments and agencies under EPA coordination, is planned so that all ongoing or future projects can be quickly analyzed in terms of the energy source involved (coal, nuclear, etc.), the energy cycle component (extraction, processing, use, etc.) and the functional area (health effects, control technology, etc.). Formal interagency agreements with all participating agencies permit annual reevaluation of R&D goals and objectives and afford a mechanism for transfer of funding. Of the more than 600 projects funded, one-fourth are implemented by agencies other than the



SUMMARY OF R&D CONTROL TECHNOLOGY NEEDS FOR CONVENTIONAL COMBUSTION

Source Princiotta, F T., 1977, Utility and Industrial Power, Energy/Environment II
U S Environmental Protection Agency EPA-600/9-77-012 (Updated for Research Outlook, Aug 1978)

Description of Pollutant	Standard Presently Established	Type of Control Technology	Present Status	Secondary Residuals	Needed Control Technology R&D
Sulfur Dioxide (SO_x)	Yes NSPS & AAQS*	Coal Cleaning	1st Generation Demo Planned	High S-Refuse	— Eliminate Secondary Pollution — Demonstrate Practicability in Conjunction with FGD — Develop Chemical Processes Capable of High Efficiencies
		Flue Gas Desulf. (FGD)	1st Generation in Full Scale Demo 2nd Generation in Bench and/or Pilot Scale	Sludge, Purge Streams	— Improve Removal Efficiency — Eliminate Secondary Pollution — Improve Reliability — Improve Energy Efficiency
Nitrogen Oxides (NO_x)	Yes NSPS & AAQS*	Combustion Modification (CM)	Commercial for Some New Units	Purge Streams for Certain Processes	— Lower Costs — Demonstrate Low NO_x Burner Capable of 80% Control — Broaden Applicability of Combustion Modification Technology — Evaluate Flue Gas Cleaning Process at Pilot Scale
		Flue Gas Treatment	Pilot Scale and Demo in Japan on Oil; Pilot Scale on Coal in U.S.		
Particulate Matter	Yes NSPS & AAQS*	Electrostatic Precipitators	Commercial-1st Generation Demo	Fly Ash	— Improve Conventional Fine Particulate Control Technology — Broaden Applicability — Develop Novel Devices with Improved Capability and Cost Effectiveness
		Bag Houses	1st Gen. Commercial		
		Wet Scrubbers	2nd Gen. Full Scale Demo		
		Novel Devices	Bench or Pilot Scale		
Potentially Hazardous Materials	No	Undefined	Undefined	Undefined	— Assess the Magnitude of Problems Associated with Unregulated Pollutants Via Chemical and Biological Characterization

* Ambient Air Quality Standard (Health-Related)

SUMMARY OF EMERGING ENERGY TECHNOLOGIES

Emerging Energy Technologies	Status	Major Environmental Concerns
FOSSIL FUEL		
Coal Gasification	Lurgi low BTU gasification is commercial in Europe for certain non-coking coals. Various low BTU processes are and will be demonstrated in the United States under Department of Energy funding. Low BTU gasification for on-site heating will be available in mid-1980's. Methanated Lurgi and second generation high BTU process will be available in 1990's.	Sulfur and Nitrogen compounds Particulate emissions Water contamination Heavy metals and organic compounds Acidic gases Subsidence (*in-situ* gasification) Aquifer disruption (*in-situ* gasification)
Coal Liquefaction	Major processes near commercialization are Solvent Refined Coal (SRC) and H-coal processes. Currently at pilot scale; demonstration of two processes planned by the Department of Energy.	Sulfur and nitrogen compounds Particulate emissions Water contamination Heavy metals and organic compounds Acidic gases
Coal Fluidized Bed	30MW pilot FBC (atmospheric) being studied at Rivesville, West Virginia by the Department of Energy. Availability expected in 1990. Small pressurized EPA unit has been operated for several years (0.63MW); DOE plans a 14MW pilot unit in the early 1980's. Availability expected in 1990's.	Sulfur and nitrogen oxides and particulates Toxic heavy metals and organic compounds Thermal pollution Spent sorbent disposal problems
Oil Shale	Both above ground and underground (in situ) retorting processes under development. Major on-going efforts include the Navy's Program, using the Paraho above ground process, nearing completion of its goal to produce 100,000 barrels of shale oil and Occidental *in situ* process which has produced in excess of 50,000 barrels to date.	Sulfur and nitrogen compound emissions Particulate emissions Water contamination and availability Overburden and spent shale Toxic and combustible gases Subsidence and aquifer disruption *(in situ)*
OTHER		
Geothermal	Three principal types: Convective hydrothermal; geopressurized hydrothermal and hot dry rock. Present generating capacity of convective hydrothermal is 500MV. Hot dry rock is the largest resource but because of the difficulty in fracturing the rock, it has generated no commercial interest. Increased geothermal application is expected in the 1990's.	Hydrogen sulfide release Waste heat and steam plumes Seismic effects Subsidence Minerals precipitation Noise and blowout Land use
Solar	Three major areas: Heating and cooling of buildings, production of electricity (photovoltaic) and production of clean fuels from biomass. Clean fuels at commercial scale from biomass (gasohol) are currently being produced; and space heating currently state of the art.	Toxic working fluid leakage (photovoltaic) Sludge and residuals from silicon distillation (photovoltaic)

EPA; most of the remainder are conducted by EPA-monitored extramural grants and contracts. Since these interagency programs supplement existing capabilities in other agencies, it tends to improve communication and coordination of the entire spectrum of these agencies' energy-related activities.

EPA will continue researching the broad spectrum of evolving energy-related processes.

Projects under this interagency agreement cover a vast range of topics. For example, we are working with DOE to monitor and assess pollutants from prototype and demonstration synthetic fuel plants. EPA is involved in several TVA research projects aimed at improving the economics and applicability of various techniques for disposal of flue gas desulfurization sludges and in tests of alternative flue gas desulfurization systems under different operating conditions. We are participating in a coal cleaning development program with the Bureau of Mines and other organizations. This particular effort involves major studies of the potential economic benefits of combining coal cleaning with partial scrubbing of flue gas to achieve levels of pollution control comparable to total scrubbing systems. Also, a joint study by EPA, DOE, TVA, the National Bureau of Standards, and the National Oceanic and Atmospheric Administration is being conducted to determine the fate of energy-related pollutants in the atmosphere.

As the Interagency Program continues to successfully link efforts to various agencies involved in energy-related environmental research, it continues to expand its list of participants. For example, a formal memorandum of understanding has been signed with the Electric Power Research Institute, a utility-funded energy research organization. In addition, both the Nuclear Regulatory Commission and the U.S. Coast Guard have indicated an interest in becoming formal participants.

With fourteen environmental research laboratories actively involved in energy-related research, EPA's own multidisciplinary capabilities include: pollutant identification, measurement and monitoring; pollutant transport, transformation and fate; pollutant effects on human health; pollutant effects on organisms and ecosystems; control technology development; and integrated technology assessment. In addition to our own capabilities, the interagency program structure allows us to focus the unique expertise and capabilities of virtually any federal department or agency involved in energy-related research on specific environmental problems and specific environmental goals.

SOLID WASTE

Improper handling and disposal of solid wastes can have dramatically adverse effects. EPA is researching better methods with emphasis on waste reduction, recovery and reuse.

Solid waste is produced in this country at a rate of 487 million tons per year. This amount includes 344 million tons of industrial waste, 130 million tons of municipal refuse, 5 million tons (dry weight) of municipal wastewater treatment sludges, and 8 million tons (dry weight) of scrubber sludges from air pollution control devices. Moreover, this yearly total does not reflect the annual production of 2.5 billion tons of mining waste and 2.2 billion tons of agricultural refuse. Projections indicate large increases in the amount of solid waste from each of these sources in the years ahead. In fact, even if industrial production were to remain constant in future years, amounts of industrial wastes would continue to increase because raw material quality is declining.

'Cradle to Grave' control and disposal is planned for hazardous waste materials.

This enormous amount of solid waste creates a number of environmental problems. The primary problem is protection of public health. For example, EPA's Office of Solid Waste estimates that 10-15% (35-50 million tons) of all industrial waste is particularly hazardous due to toxicity, flammability, corrosiveness or risk of explosion, and must therefore receive special handling and disposal to protect public health and safety. EPA is planning a "cradle to grave" system of controls and disposal for these very dangerous materials.

EPA sees a solution to the overall health problem through development of safe disposal methods. But past disposal practices such as open air incineration or water dumping have been sharply curtailed due to environmental control measures taken to prevent air and water pollution. Landfill therefore has become the primary means of disposing of solid waste. Improper disposal of solid waste on the land, however, can also pose major environmental threats of ground-water contamination from leaching, surface water contamination from runoff, and air pollution from open burning, evaporation, sublimation and wind erosion.

A recent EPA news release identified 32,254 waste disposal sites that may contain hazardous materials. Of those sites, 638 may contain significant quantities of hazardous wastes and 103, for which information is available, show high potential for adverse public health effects.

An example of the dangers posed by improperly managed hazardous waste materials comes from the Love Canal incident in New York State. A General Accounting Office report states:

Chemical odors from the site are evident at all times, but are particularly obnoxious on hot humid days. Children use the site as a short cut and as an unofficial playground. The part of the site near the grammar school has been graded and is used as an official playground by school children. Highly contaminated leachate is seeping into basements of the homes surrounding the site from where it is pumped into storm sewers. Chemical fumes are present in the basements.

Evidence exists that Mirex and other pollutants have been discharged to the Niagara River.

Leachate containing halogenated and unhalogenated organic compounds is definitely migrating in the top soil horizon. Though not identified or quantified, organic chemicals are definitely vaporizing directly from the site.

This situation has received wide news media coverage in which it was reported that the State's Health Department noted a high incidence of miscarriage and birth defects in the area abutting the canal and that EPA reported at least 82 industrial chemicals were found of which 11 are suspected carcinogens. Arrangements have reportedly been made to relocate 122 families and the area has been declared a National emergency.

Another less-publicized example of the hazards of improper waste management comes from a 1977 EPA study of 50 hazardous waste land disposal sites. Of the 50 sites, 43 had contaminated nearby ground-water sources with heavy metals or inorganic compounds. Since half of the nation's population depends on ground water for drinking water, proper control of waste disposal is essential.

43 of 50 disposal sites had contaminated nearby groundwater sources.

Economics, convenience, or politics at the expense of environmental considerations have typically governed the manner in which solid waste is disposed. For instance, EPA estimates that less than 10% of municipal refuse sites meet acceptable environmental standards, while the standards used in industrial waste disposal can only be surmised since 70% to 80% of the disposal takes place on private property. In a study of the annual practices of 14 key industries during 1973-1975, it was estimated that only 9.6% of the hazardous waste was disposed in an environmentally adequate manner.

The EPA research response to the solid waste problem has grown out of the recognition of the enormity of the problem, the severity of public health risks, and a congressional mandate provided by the 1976 Resource Conservation and Recovery Act (RCRA). In addition to charging EPA with protecting public health, the Act also calls for EPA to develop means to conserve natural

	1975	1980	1985	1990
MUNICIPAL	128	156	166	167
*INDUSTRIAL	329	365	408	443
*HAZARDOUS	33	36	40	44
FLUE GAS DESULFURIZATION	1	11	13	NA
MINING				
METALS	1637	2153	2982	3423
NON METALS	579	753	983	1072
COAL	132	160	199	242
AGRICULTURE		NA	NA	NA
ANIMAL MANURES	1805			
CROP RESIDUES	450			
LOGGING RESIDUES	25			

* Includes hazardous wastes NA—Projections not available

ESTIMATES AND PROJECTIONS OF SOLID WASTE GENERATION (MILLIONS OF TONS)

Source: Office of Solid Waste, U.S. Environmental Protection Agency 1978

Industry	Hazardous Substances										
	As	Cd	Chlorinated hydrocarbons*	Cr	Cu	Cyanides	Pb	Hg	Miscellaneous organics†	Se	Zn
Mining and metallurgy	•	•		•	•	•	•	•		•	•
Paint and dye		•		•	•	•	•	•	•	•	
Pesticide	•		•			•	•	•	•		•
Electrical and electronic			•		•	•	•	•		•	
Printing and duplicating	•			•	•		•		•	•	
Electroplating and metal finishing		•		•	•	•					•
Chemical manufacturing			•	•	•			•	•		
Explosives	•				•		•	•	•		
Rubber and plastics			•			•		•	•		•
Battery		•					•	•			•
Pharmaceutical	•							•	•		
Textile				•	•				•		
Petroleum and coal	•		•				•				
Pulp and paper								•	•		
Leather				•					•		

* Including polychlorinated biphenals.

† For example acrolein, chloropicerin, dimethyl sulfate, dinitrobenzene, dinitrophenol, nitroaniline, and pentachlorophenol.

REPRESENTATIVE HAZARDOUS SUBSTANCES WITHIN INDUSTRIAL WASTE STREAM

Source: Solid Waste Facts, U.S. Environmental Protection Agency, 1978

resources through waste reduction, recovery, and reuse of materials now discarded. Thus, the EPA solid waste research program is characterized by two parallel directions of investigation:

- development of safe disposal management practices
- development of resource recovery methods.

Among the technical questions to be answered are finding out what mechanisms are at work to produce leachates and gases and how these substances migrate through soil, the characteristics of such leachates and gases, and the resultant impact on ground-water quality for hazardous and other solid waste. Research information is also required to support RCRA in the areas of thermal decomposition, detoxification, chemical stablization, encapsulation, concentration, and fixation of hazardous wastes.

These technical issues also pose socioeconomic questions such as how to minimize land use impacts by developing better methods to monitor and increase the efficiency of waste disposal on land. Ways need to be found to accelerate the decomposition of organic materials in landfills so that the area can quickly be returned to constructive use. Remedies to limit pollution from active and inactive landfills also need to be developed and demonstrated. Resource recovery systems must be shown to be commercially viable including dependability of markets for recycled products, methods to upgrade the quality of marketable products, and the development of new markets that adequately recognize the inherent value of materials that can be recovered from solid waste.

MAJOR MILESTONES

Better Methods for Solid and Hazardous Waste Management

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATES
FIRST PRIORITY	
Methods for landfill site selection, design, operation, and maintenance	Prediction models for gas and leachate generation and movement at municipal and hazardous waste sites (FY 83)
	Criteria and design manuals for landfill siting, design, and contaminant control (FY 83)
	Performance data on improved concentration, immobilization, treatment, and destruction methods (FY 82)
Perform risk, environmental and economic assessments of methods currently available for large scale processing and treatment of hazardous wastes. Develop new processing and treatment methods.	Design and operating criteria for thermal destruction, pesticide decomposition and disposal, encapsulation, and microwave detoxification (FY 82)
Development of management practices to handle large volumes of solid waste produced by utility industry and mining.	Practices for utility industries and mining industries (phosphate, metallic and uranium) (FY 83)
Development and implementation of a total quality assurance program.	Sampling and analytical methods (FY 81)
SECOND PRIORITY	
Remedial actions for minimizing impact of environmentally unacceptable land disposal sites	Manual of practice for remedial actions for municipal landfills (FY 81), hazardous waste disposal sites and surface impoundments (FY 83)
Alternatives to landfilling	Field evaluation of engineering, economic, and environmental quality characteristics of land cultivation with solid wastes. (FY 83)
Determination of quantity and quality of industrial wastes and development of industrial process modifications to change waste characteristics to enhance disposal	Assessment of key industrial solid waste generators (FY 83)
	Develop industrial process modifications (FY 84)
THIRD PRIORITY	
Better methods for collection and transportation of municipal waste	Develop base on collection storage, and transportation alternatives which reflect recent advancements in private solid waste processing. (FY 85)

The Research Plan for Solid Waste

Better management of solid and hazardous wastes is our top priority because of the increasing magnitude of the current problem, its attendant costs in dollars and in land use, and its environmental consequences when improperly managed. Research necessary to develop methods of waste reduction through recovery and reuse, while ultimately the preferred method for handling the solid waste problem, will be a longer term activity. Here, recommendations of the Resource Conservation Committee established under RCRA will have a strong influence on the research and development activities over the next several years.

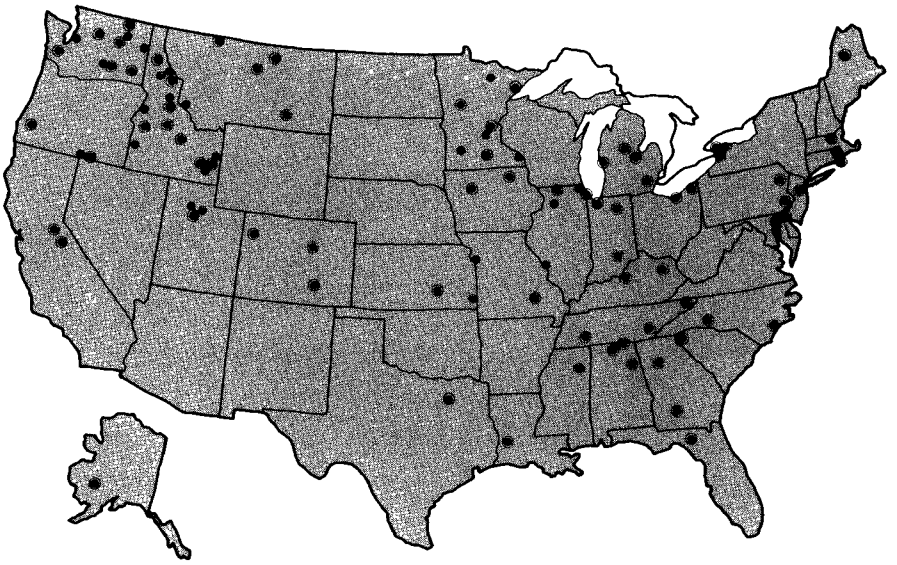
The Strategy

EPA's research strategy for hazardous wastes will in the near term focus on minimizing adverse impacts to health and the environment particularly with respect to ground-water contamination. Much of this near-term research is a continuation of experiments conducted on a laboratory scale under simulated field conditions. Specific research projects will therefore be directed toward validating, under actual field conditions, the information obtained by this small scale research. Nearly all of this research will be conducted by grant or contract since we have a limited in-house research capability in this area.

Our intermediate term research attempts to accelerate the ability to respond to hazardous material spills and to develop technologies to reduce waste volumes. Research efforts to reduce waste volume will be aimed primarily at resource recovery, more efficient handling and packing of solid waste and optimizing waste processing systems.

In the long range, we will develop advanced waste treatment and destruction techniques. We also plan to attack the

SITES CONTAINING HAZARDOUS WASTES ON WHICH EPA HAS INFORMATION



Source: Office of Solid Waste, U.S. Environmental Protection Agency, 1978

cause of the waste problem: that waste is created at all. Research projects will look into ways of reducing the amounts of wastes generated, will pursue promising by-product recovery and reuse options and will, ultimately, develop low waste technology.

Thus our research strategy is to first treat the immediate and dangerous symptoms of the solid waste problem and then, as public health risks are adequately lowered, to develop the means to treat and eventually eradicate the causes of the problem.

Research on Better Methods for Solid and Hazardous Waste Management

There are four high priority objectives as steps toward better methods for waste management:

(1) The development of new or improved methods for landfill site selection, design, operation and maintenance. We plan to develop methods to control and accelerate the decomposition of landfill wastes, to estimate potential impacts of gas and leachate migration, and to control such migration. The influence of mixed wastes (industrial and municipal) on the decomposition processes and on gas and leachate production at co-disposal landfills will also be determined. Further, our research will determine changes in municipal solid waste management practices required to deal with anticipated increases of industrial waste and sewage sludge that are to be disposed of in municipal landfills.

(2) Evaluation of the technical, environmental, and economic strengths and weaknesses of methods currently available for large-scale processing and treatment of hazardous and municipal wastes. Where deficiencies are found, we will develop new processing and treatment methods. Emphasis will be placed on developing methods which involve cost-effective biological, chemical, and physical treatment processes applicable to both homogenous and heterogenous hazardous waste streams.

ESTIMATED ENVIRONMENTAL ADEQUACY OF DISPOSAL PRACTICES FOR POTENTIALLY HAZARDOUS WASTES*

Source: Office of Solid Waste, U.S. Environmental Protection Agency, 1975

Disposal Practice	Percent of Total Wet Weight of Potentially Hazardous Wastes
ENVIRONMENTALLY INADEQUATE	
Unlined Surface Impoundments	48.3
Non-Secure Landfills	30.3
Uncontrolled Incineration	9.7
Deep-Well Injection	1.7
Landspreading	.3
Use on Roads	< .1
Sewered	< .1
Total	90.4
ENVIRONMENTALLY ADEQUATE	
Controlled Incineration	5.6
Secure Landfills	2.3
Recovery	1.7
Lined Surface Impoundments	< .1
Wastewater Treatment	< .1
Autoclaving	< .1
Total	9.6

*Based on annual generation in 14 key industries during the period 1973-1975.

(3) Development of management practices to handle the large volumes of solid waste produced by the utility industry and the mining industry. Utility solid wastes include ash residues from combustion of fossil fuels and flue-gas desulfurization sludges as by-products of sulfur control. Mine wastes include tailings, waste rock, low-grade ore and overburden.

(4) Development and implementation of a total quality assurance program for all aspects of waste reduction, recovery, reuse and disposal.

A second priority will be to develop remedies for adverse land disposal impacts at existing landfills. The results of this research will provide local communities, industry, and private landfill operators with the data necessary to select the most appropriate methods of upgrading disposal sites. These results will also permit compliance with RCRA, which requires all unacceptable landfills to be upgraded or closed.

Beginning in fiscal 1980, our research will also determine the quantity and quality of industrial wastes and will subsequently seek to develop industrial process modifications to change the waste characteristics sufficiently to permit environmentally acceptable disposal.

We also plan to examine alternatives to landfill for solid and hazardous waste. Methods to be investigated include deep well injection of wastes, placement of waste in underground mine cavities, and land spreading of hazardous or municipal waste. The engineering feasibility, economic attractiveness, and environmental stress of these techniques have yet to be determined adequately.

EPA estimates that less than 10% of municipal refuse sites meet acceptable environmental standards.

The lowest priority research for better waste management will focus on two problems: improved methods of collection and transportation of municipal waste and determination of detrimental effects of materials released into the environment because of poor mining disposal practices. Approximately 80% of the $5 billion annual expenditures for municipal waste is associated with collection and transportation, so even minor improvements could have major economic impacts.

Research on Better Methods for Waste Reduction, Recovery, and Reuse

In recent years, the combined need for new energy resources and waste disposal techniques that would conserve land and reduce costs in metropolitan areas has stimulated interest in systems that can recover resources from municipal solid waste. Use of waste as fuel has been successful on a small scale. However, much of the equipment presently available has not been specifically designed for use on municipal solid waste and, thus far, operating experience has been insufficient to provide for the design and selection of optimum equipment configurations. Our research program will attempt to supply the needed data. We will evaluate existing techniques of recovery to see where technology is lacking and we will develop technology to fill the needs. Our research projects will examine municipal refuse resource recovery operations including shredding, magnetic separation, air classification, screening, drying and densification. We will also evaluate the efficiency and economic viability of materials handling systems such as conveyors, dust collectors, cyclone separators, electrical controls, storage, and fuel retrieval bins as well as systems with provisions for energy recovery.

In conjunction with the equipment and process evaluations we will study the potential for development of new and marketable products and chemicals that could be produced economically from municipal and industrial solid wastes. The focus will be on development of methods for the biological and chemical conversion of wastes to such things as chemical feed stocks, protein, alcohols, and ammonia.

A second priority emphasis will be research into product and industrial process modifications that can reduce waste generation or enhance recovery and reuse. Basically, we intend to determine if prod-

MAJOR MILESTONES

Better Methods for Waste Reduction, Recovery, and Reuse

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATES
FIRST PRIORITY	
Evaluation of existing resource recovery techniques for municipal solid waste	Performance data on air classifiers, dry recovered materials handling systems, trammels, shredders, and emerging resource recovery processing equipment (FY 82)
Methods for conversion of wastes to products which can be economically produced and marketed.	Assessment of marketability of solid waste products. Those tentatively identified include solid waste as a chemical feedstock, protein, and ammonia (FY 82)
Improved methods for conversion of municipal solid waste and related industrial wastes to energy.	Advanced technology for producing energy from solid wastes via pyrolysis, and gasification (FY 84).
SECOND PRIORITY	
Product and process modifications to reduce waste or enhance recovery and reuse	Report on feedstock changes and process modifications for waste reduction in the dye and pigment, petrochemical, pesticide, plastics and synthetic chemicals and metal finishing industries (FY 83)
	Technology demonstration for recovery and reuse of heavy metals in waste streams in the metal finishing industry (FY 83)
THIRD PRIORITY	
Recovery methods for mining wastes	Assessments data on recovery techniques for benefication concentrates in copper and lead/zinc mining and ore processing (FY 85)

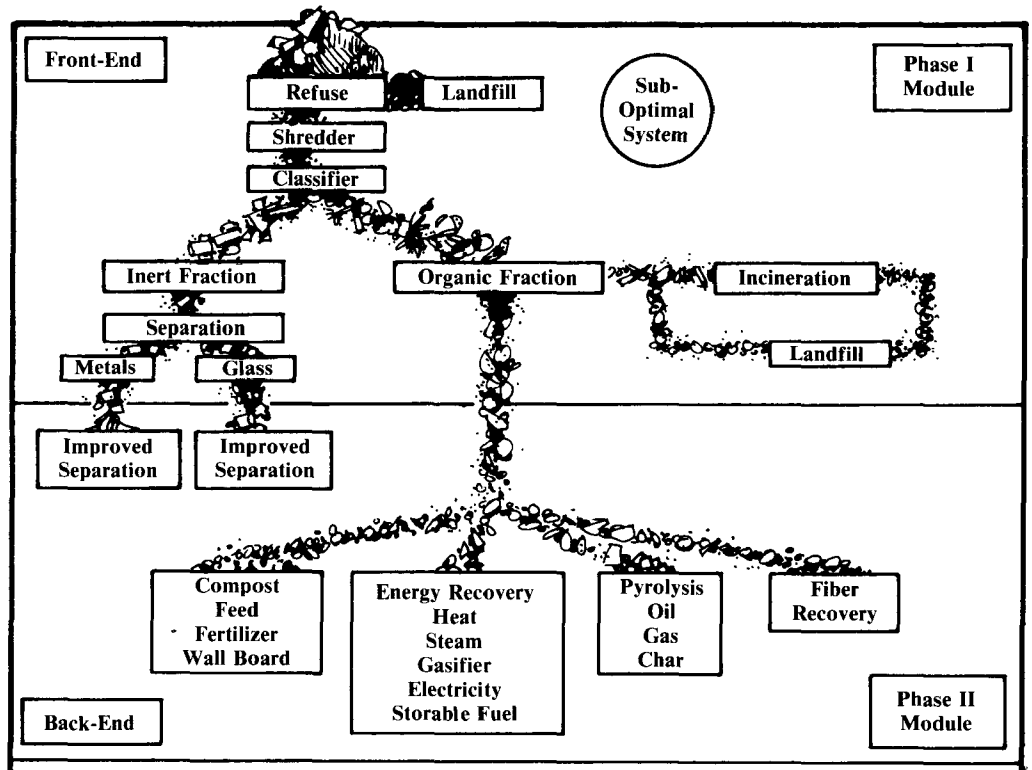
uct designs can include provisions for waste reduction by making it easy to separate potentially valuable materials such as certain metals, glass, and paper from other solid wastes. At present, the difficulty of separating the reusable commodities is a major shortcoming of resource recovery.

The study of mining wastes is our third priority resource recovery research. We will evaluate available methods for extracting resources from mine waste disposal sites. Our work will focus primarily on mining wastes generated in the early 1900s that are still relatively rich in minerals.

EPA and Other Federal Research Capabilities in Solid Waste

EPA is the only federal agency dealing with the entire solid waste management problem. The combined staffs of EPA's research laboratories involved in solid and hazardous waste management provide expertise in the technology areas of resource recovery, composting, sanitary landfill design and operation, pollutant transport and ground-water management, industrial and hazardous waste processing and disposal, mining waste control, and sludge management. This expertise requires talents of chemical engineers, economists, chemists, soil scientists, sanitary engineers, mining engineers, and geologists. However, even though many of the research programs are staffed with individuals with the required backgrounds, staff reductions coupled with increased budgets have dictated that solid and hazardous waste research be conducted entirely by contracts and grants. In fiscal 1979, EPA will provide $8.1 million and 20 positions for solid waste research.

Two other federal agencies make major contributions to solutions of solid waste problems. The Department of Energy is currently examining the potential for energy recovery from landfills and from combustible municipal and industrial wastes. These activities are coordinated by EPA and DOE staffs in Washington D.C. and at the field laboratories. The EPA Office of Solid Waste serves as the primary interagency contact and with the participation of the EPA Office of Research and Development, formulates



MODULAR APPROACHES TO RESOURCE RECOVERY

Source: Water Pollution Caused by Inactive Ore and Mineral Mines, EPA-600/2-76-298, 1976

coordinated interagency activities. EPA and DOE exchange information on a formal workshop basis, jointly fund projects of mutual interest, and provide staff support as needed. Similar working arrangements and exchange of information exists with the Department of Defense

EPA is the only federal agency dealing with the entire solid waste problem.

which is developing processing and technology to deal with its unique hazardous waste disposal problems. Other federal agencies with research in areas pertinent to solid waste management are:

- Department of Interior, Bureau of Mines—reuse of mining wastes, and metals recovery from municipal waste streams
- Department of Agriculture—utilization of crop residuals and wastes from food processing industries, beneficial utilization of animal wastes, composting of municipal sludges
- Department of Transportation—containerization and transportation of hazardous materials
- National Science Foundation—basic research studies (e.g., use of soil invertebrates in decomposition and conversion of land spreaded sludges)
- Department of Commerce, National Bureau of Standards—specifications for recovered materials, development of markets for secondary materials
- Department of Interior, U.S. Geologic Survey—hydrologic information fundamental to disposal site selection.

NONIONIZING RADIATION

We are faced with increasing low and moderate exposures to radio and microwave frequencies, and EPA is researching the possible effects on human health.

Proliferating communication and radio-navigation systems and electronic devices for home and industry have steadily increased the intensity of public exposure to nonionizing radiation at microwave frequencies. Futhermore, forecasts indicate that this upward trend will continue. Projected increases in satellite communications, an expanding U.S. weather and news network, and the potential use of microwaves for transmitting power to earth from satellite-based solar collectors are only a few examples of major new sources of public exposure to nonionizing radiation.

Little is known about the possible non-thermal human health risks posed by lower levels of exposure.

While it is well known that intense levels of exposure to nonionizing radiation can produce thermal effects in the form of severe heating within body tissues, little is known about the possible nonthermal human health risks posed by lower levels of exposure. The Soviet Union, Poland, and Czechoslovakia report cases of reactions in the central nervous systems of humans as a result of low level exposures. Data from ongoing EPA and other U.S. research are beginning to indicate that chronic, low level exposures of laboratory animals can produce adverse biological effects. Some of the observed effects are: increased mitotic activity of chemically stimulated lymphocytes, increased release of calcium from the brain and altered behavior and blood chemistry. As yet, however, there is disagreement among scientific authorities about what effects actually take place at low exposure levels or which biological mechanisms may be affected. This lack of agreement has resulted in the establishment of widely different exposure standards. East European countries have standards set at a level which recognizes their findings that they attribute to the *non-thermal* effects of nonionizing radiation. The United States, on the other hand, bases its occupational exposure standard solely on the *thermal* effects of nonionizing radiation. As a result, allowable exposures in the U.S. are 1000 times greater than those in the Soviet Union. To place this difference in standards in perspective, the present Soviet standard makes the operation of microwave ovens virtually impossible in that country. But an equally important perspective is that currently 99% of the American populace is exposed to levels lower than the Soviet standard.

Research is needed to develop scientifically sound information that can be used to resolve the differences in exposure standards. Further, information is required to assess potential health effects of continuous low level exposures as well as moderate level exposures at frequencies used extensively in our society.

Nonionizing Radiation Research

The nonionizing radiation research strategy has both a near term and a long term plan. In the near term, our research will contribute to making decisions on the need to establish environmental guidelines applicable to the general population. Research projects will be devoted to expansion of the current health effects data base to determine whether a standard developed solely from thermal effects data provides adequate protection of public health.

In the long term, the research plan is to develop a better understanding of human vulnerabilities to nonionizing radiation. Our projects will investigate how low and moderate level exposures interact with biological systems. While the mechanism through which intense levels of exposure to nonionizing radiation induce heating in biological systems is known, the mechanisms of action for lower levels of exposure is not. Knowledge of these interaction mechanisms will allow prediction of potentially hazardous exposure condi-

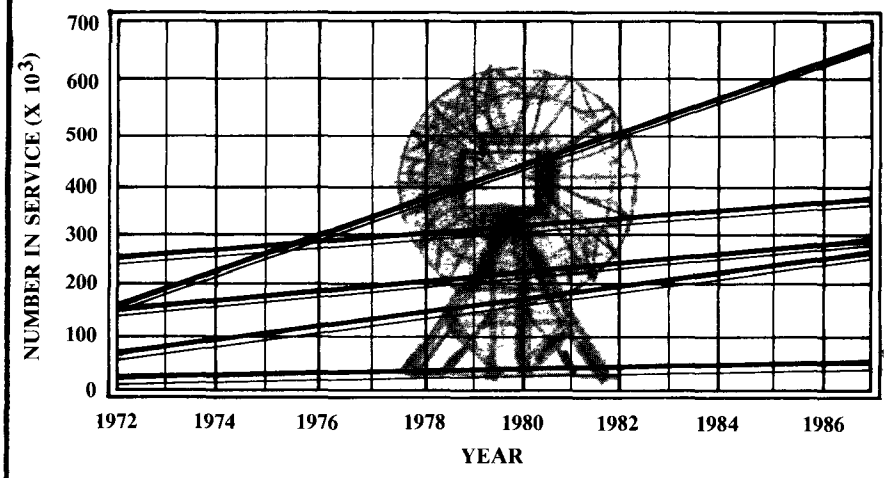
tions as well as guide us in periodic re-evaluations of existing exposure situations.

Near-Term Research--Expanding the Data Base

Expansion of the health effects data base will come from two sources: projects that determine the impact of low level exposures on selected biological processes in animals, and studies of retrospective and prospective epidemiologic data. Activities here will focus on determining health parameters associated with types of non-ionizing radiation exposures known or suspected to cause adverse effects. We will continue to conduct experiments on animals using both continuous low and moderate level exposures at FM (100 megahertz), near UHF-TV (425 megahertz), and microwave (2450 megahertz) frequencies as well as other prevalent frequencies. These experiments will focus on teratologic, hematologic, immunologic, and behavioral effects. To supplement the data from animal experiments, we will attempt to correlate exposure data to adverse human health effects by examining historical epidemiological data on persons who have been occupationally exposed.

We also plan to expand our research work into the areas of reproduction, genetics, and epidemiology. As part of this overall effort, we will conduct prospective clinical and epidemiologic studies of people who have just entered a non-ionizing radiation exposure situation and, within limits, will attempt to identify the specific frequencies that have a high potential for causing biological problems.

Other research activities will include studies of the more complex and subtle aspects of potential problems from non-ionizing radiation. For example, ex-



PROJECTED INCREASES IN SAFETY AND SPECIAL RADIO SERVICES

(Primarily Medium Power Base Stations But Includes Ships and Aircraft: Low Power Mobile Transmitters Generally Not Included)

Source: Electronic Industries Association, Electronic Market Data Book, 1977

MAJOR MILESTONES

Expanding the Health Effects Data Base on Nonionizing Radiation

OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
FIRST PRIORITY	
Teratologic hematologic, immunologic, and behavioral effects of continuous, low level exposure in animals.	Health effects findings on rats chronically exposed to a microwave (915MHz) frequency. (FY 80)
Health effects in animals of moderate level exposure to commonly used frequencies (e.g., FM and UHF).	Health effects findings on rats chronically exposed to FM (100 MHz) and UHF-TV (425 MHz) frequencies (FY 80)
Retrospective epidemiologic studies of occupationally exposed personnel and selected urban populations.	Findings on the frequency with which tumors occurred for high and low ratio emission densities in the Portland, Oregon area. (FY 81)
SECOND PRIORITY	
Frequencies with the potential for interaction with biological structures.	Determination of the biological absorption potential of frequencies in the 25 to 8000 MHz range. (FY 81)
Reproductive and genetic effects on animals of continuous, low level exposures.	Identification of the dominant lethal/mutagenic effects in rats of continuous prolonged exposure to a microwave frequency (915 MHz). (FY 81).
Prospective epidemiologic studies of people exposed in their work.	Clinical investigations of persons prior to and during occupational exposure. (FY 83)
THIRD PRIORITY	
Effects on lifespan and cancer causing potential of continuous, moderate level exposures in rodents.	Pathology results from lifetime exposures of mice to 2450 MHz. (FY 84)
Interactive effects of ambient environmental factors and exposures on selected health parameters (e.g. behavioral).	Findings on the influence of temperature and humidity of operant and spontaneous behavior of rodents and primates. (FY 81)
Potential for synergistic effects resulting from simultaneous exposure to multiple frequencies.	Results from simultaneous FM and UHF-TV frequency exposures of rodents. (FY 84)

periments on rodents will be used to determine the effect that continuous, moderate level exposures have on lifespan and on potential carcinogenicity. We will also attempt to identify the interactions between nonionizing radiation and ambient environmental factors such as temperature and humidity. Finally, we plan to investigate the potential for synergistic effects resulting from simultaneous exposure to multiple frequencies.

Long-Term Research--Identifying Interaction Mechanisms

EPA's long-term research will be to develop an understanding of the functions of biological trigger mechanisms that result from low and moderate level exposures to nonionizing radiation. The work in this area is still in an evolutionary stage, thus our first priority will be to conduct research aimed at refining existing theories on the interaction of nonionizing radiation and biological systems. Here, we will be examining theories which describe how damage occurs to cell membranes and to cell biopolymers (e.g., enzymes and protein) as a result of exposure.

We will also examine newly observed phenomena that have the potential to contribute to the development of new theories. Work in this area will be aimed at explaining what "types" of nonionizing radiation can cause cellular damage.

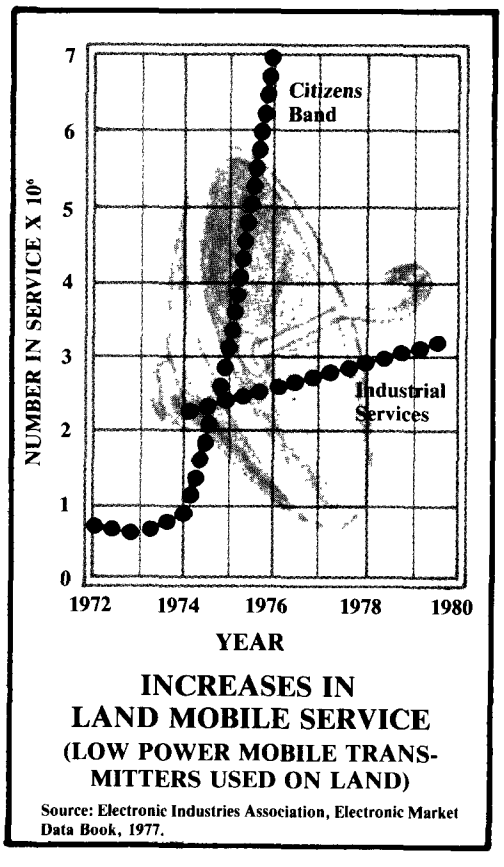
The research plan is to develop a better understanding of the human vulnerabilities to nonionizing radiation.

Specifically, we will perform studies to determine if frequency and power density combinations known to possess a high interaction potential with one biological system might also have similar high interaction potentials with other biological systems. Additionally, we will examine the interaction of extremely low AM frequency exposures with the central nervous system and will identify those frequency bands having a high biological resonant absorption.

Finally, our research will attempt to identify exposure effects phenomena in laboratory animals. These research activities will deal primarily with identification of "hot spots" within tissues and organs that are particularly sensitive to nonionizing radiation exposures. We will then develop indices for evaluating the degree of stress induced by such exposures.

EPA Program Capabilities and Other Federal Research

EPA's health effects research program for nonionizing radiation, funded at a level of $1.9 million in fiscal 1979, is the largest program of its type in the federal government. Our Health Effects Research Laboratory in Research Triangle Park, North Carolina, embodies skills in the key areas of biology, microwave engineering, and physics necessary to achieve most of the outlined research objectives. With our



INCREASES IN LAND MOBILE SERVICE
(LOW POWER MOBILE TRANSMITTERS USED ON LAND)

Source: Electronic Industries Association, Electronic Market Data Book, 1977.

MAJOR MILESTONES

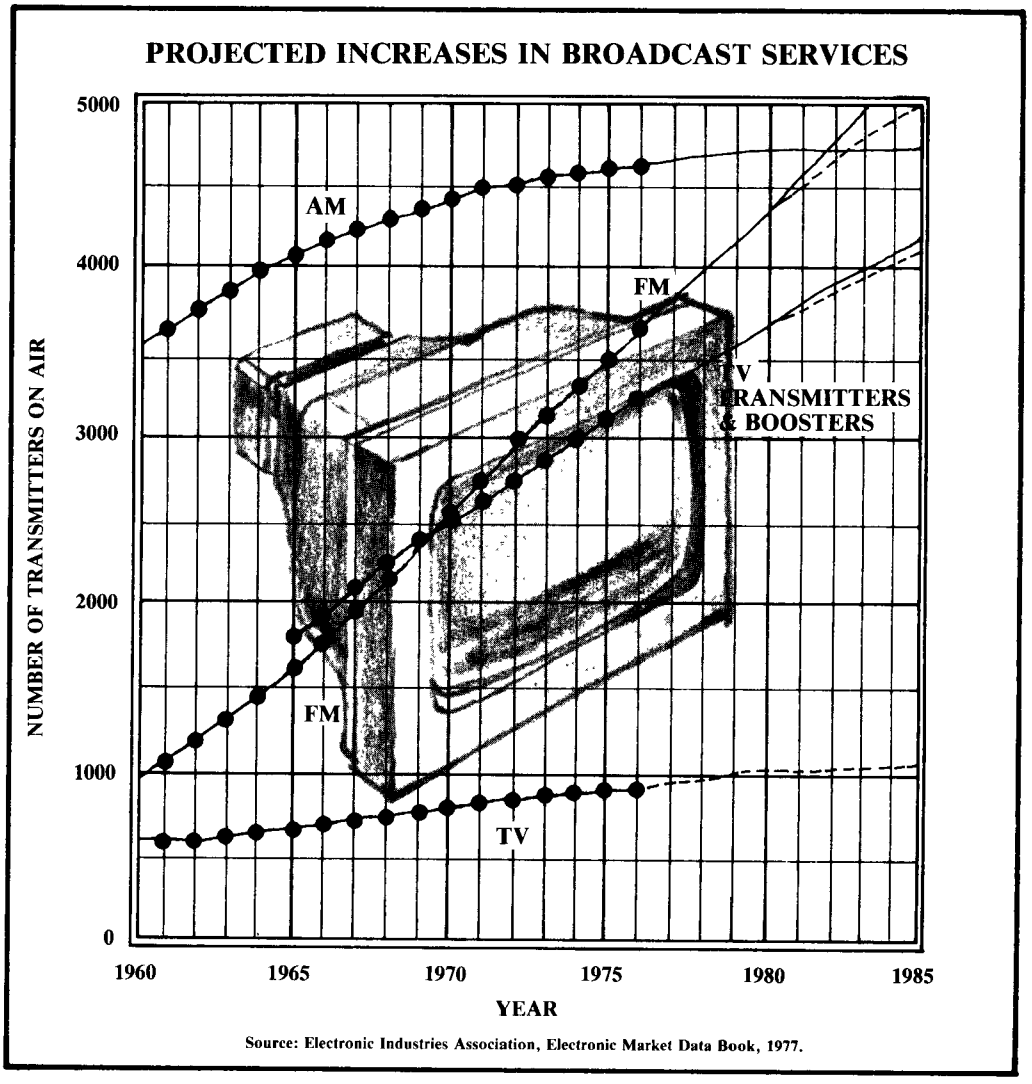
Identifying Interaction Mechanisms Between Nonionizing Radiation and Biological Systems

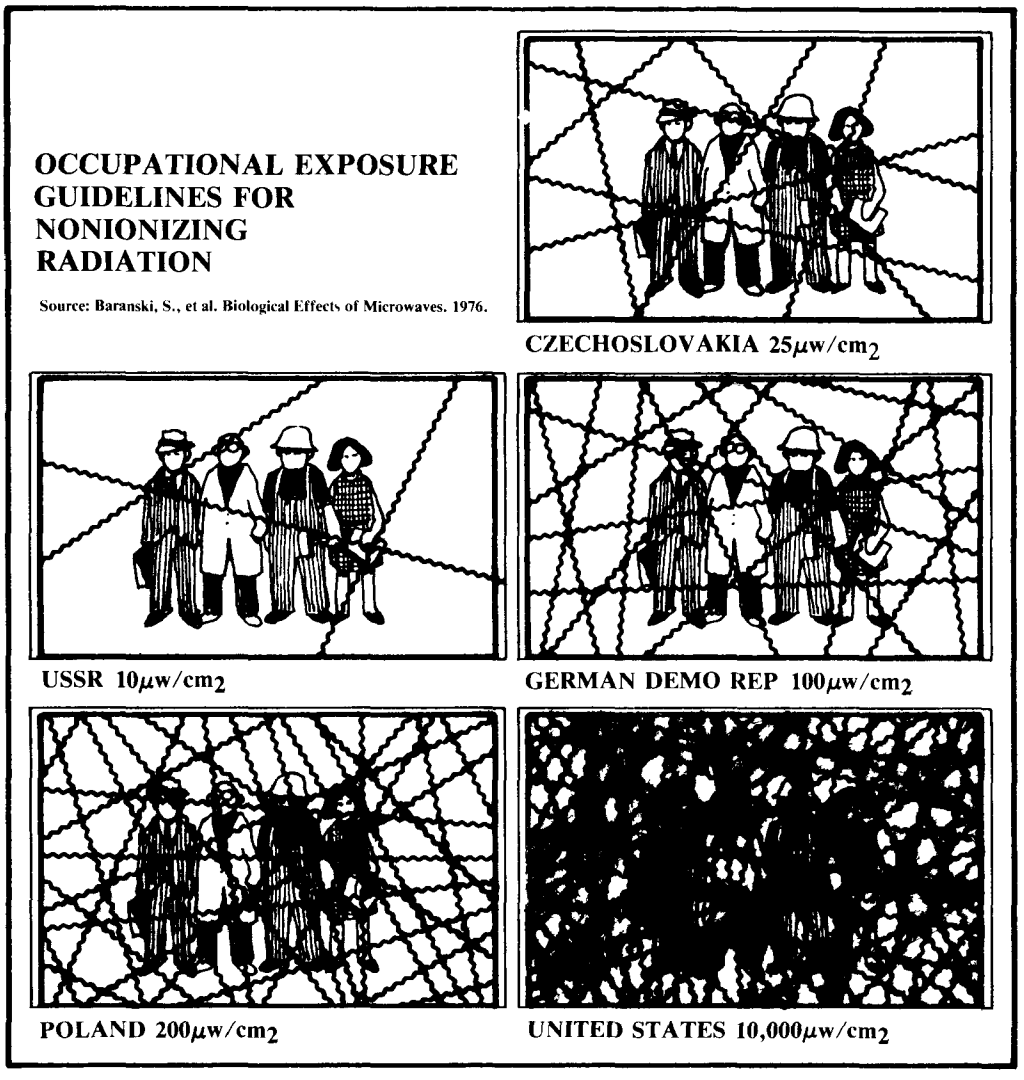
OBJECTIVES	MAJOR MILESTONES/EXPECTED DELIVERY DATE
FIRST PRIORITY	
Interactions of nonionizing radiation with cell membranes.	Determination of the effects of radio/radar frequencies on membranes using the fluorometric technique. (FY 81)
Interactions of nonionizing radiation with cell biopolymers.	Determination of the effects of radio/radar frequencies on biopolymers using the spectrophotometric technique. (FY 80)
SECOND PRIORITY	
Universality of the power density "window" for various biological systems.	Identification of the range of power levels at which biological effects occur. (FY 82)
Interactions of extremely low frequency AM exposures with the central nervous system.	Determination of the range of AM frequencies at which biological effects occur. (FY 82)
Frequency bands with high resonant absorption in biological structures.	Determination of absorption spectra of molecular, subcellular, cellular and tissue samples exposed to frequencies ranging from 250 to 8000 MHz. (FY 81)
THIRD PRIORITY	
Internal energy distribution (i.e., "hot spots") in biological systems exposed to nonionizing radiation.	Internal temperature profile in exposed animals. (FY 80)
Indices for evaluating the degree of stress induced by nonionizing radiation.	Evaluation of the Selye Syndrome aspects of exposure (FY 81)

current staff, however, tradeoffs between timeliness of results and depth of analysis will have to be made. At present, we do not have adequate in-house expertise to support fully our planned epidemiological research. Furthermore, because work on the determination of potentially hazardous frequency ranges requires highly accurate instruments not currently available to us, additional extramural funding will be necessary. We also expect to fund outside sources for our proposed long-term, low level exposure studies and most of the research requiring physiological expertise.

Three agencies have primary responsibilities related to the health effects of nonionizing radiation: the Department of Defense (Air Force, Army and Navy), the

Department of Health, Education and Welfare (Bureau of Radiological Health, National Institute of Environmental Health Sciences, and the National Institute of Occupational Safety and Health), and EPA. The military services emphasize research related to specific frequency ranges, emission devices, and operational environments applicable to their personnel, e.g., field, airport, and shipboard radars. Under Public Law 90-602, "The Radiation Control for Health and Safety Act of 1968," DHEW is responsible for establishing and conducting a radiation control program designed to protect the public health and safety from electronic product radiation including radio frequency and microwave radiation—microwave ovens and medical diathermy units, for example. Under authority transferred by the Reorganization Plan No. 3 of 1970, EPA is responsible for determining the health effects of continuous low and moderate level radiation from sources such as radio and TV broadcast generators, civilian radars, and other radio communication systems and, if indicated, promulgating environmental exposure standards. DOD, DHEW, and EPA account for 90% of the U.S. nonionizing





radiation research program (based on FY 76 funding) with funds disbributed as follows: DOD (55%), DHEW (20%), and EPA (15%).

Other agencies peripherally involved in nonionizing radiation research include the National Bureau of Standards, the Veterans Administration, the National Cancer Institute and the National Science Foundation. The Department of Energy may eventually become a major factor in the field of nonionizing radiation research if it decides to implement its proposed Satellite Power System.

The recently formed (May 1978) National Telecommunications and Information Administration (NTIA), Department of Commerce, is responsible for coordinating the entire federal program for nonionizing radiation research. In this role, NTIA functions as did its predecessor, the Office of Telecommunications Policy (OTP), within the Executive Office of the President, to ensure that the research programs for each participating agency are complementary and avoid unnecessary duplication.

GLOBAL POLLUTION

The earth is a closed system with a finite tolerance for pollution. Research must address global implications and solutions, as well as local ones.

The increasing awareness of the transport of pollutants across political and geographical boundaries and observable harmful effects from the deposition of pollutants in distant regions has led to the recognition of pollution as a global problem.

Close cooperation between many nations will continue to be necessary to resolve the specific problems associated with the spread of pollutants throughout the air and waters of our planet. Some efforts aimed at understanding the problems, seeking viable solutions, and encouraging worldwide mitigating actions have already been initiated by the United Nations Environment Program (UNEP), the Organization for Economic Cooperation and Development (OECD), the World Meteorological Organization (WMO), the World Health Organization, the International Committee of Scientific Unions, the Economic Commission for Europe (ECE), and the Committee on Challenges to Modern Society (CCMS). For example, the U.S., Canada and Sweden have begun regulating the manufacture and use of chlorofluorocarbons; thirteen other nations agreed to take similar actions at an international conference held in West Germany in December, 1978.

Effects of long range transport of air pollution is our highest global pollution research priority.

EPA recognizes the implications of our nation's activities on the environment of our neighbors and realizes the value of research and development in understanding and controlling the effects of global pollution. Although EPA has not formalized an R&D program in global pollution per se, many of its ongoing and planned research efforts will assist in resolving international pollution problems.

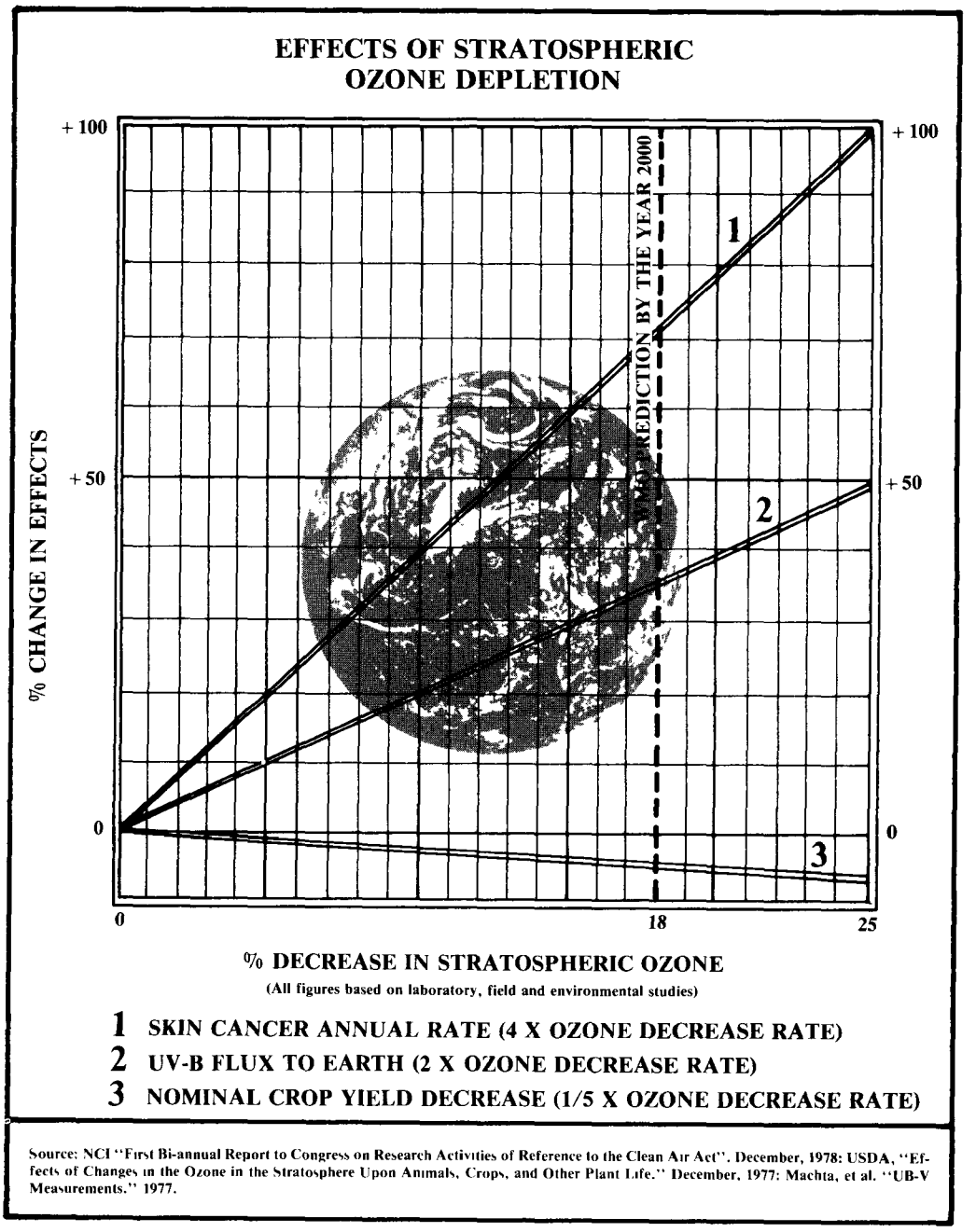
Presently recognized worldwide environmental problems which are truly global in nature include: acid precipitation and other effects of intercontinental transport of power plant emissions; ozone depletion in the stratosphere; carbon dioxide and other aerosol increases in the atmosphere, and related climatic changes; and marine pollution.

Research on Long-range Transport of Power Plant Emissions

The ongoing conversion throughout the world to greater capacity power plants, increased fossil fuel use, taller stacks and other strategies which result in less pollution in the vicinity of sources has increased pollution thousands of miles downwind. The "tall stack" strategy which was implemented to improve air quality in the vicinity of the source has succeeded. However, it was believed that pollutants injected at greater heights into the atmosphere would be widely dispersed and diluted before they could do harm. This, in fact, has not occurred as predicted. Often the integrity of plumes carrying pollutants is maintained over thousands of miles resulting in pollution problems far removed from the source. Frequently, geographical and political regions unassociated with the locations of the emitting sources suffer severe pollution effects. For example, Sweden believes that acid precipitation from United Kingdom fossil fuel power plant emissions is responsible for fish kills in Swedish lakes. Canada and the U.S. are jointly concerned about transboundary atmospheric contamination affecting each other's air and water quality. Within our own country, it is plausible that if New York were to shut down all its fossil fuel power plants, its air pollution concentrations would still remain above permissible levels under certain meteorological conditions because of incoming high concentrations of pollutants from the west.

Contaminants in the Atmosphere

The steadily increasing concentrations and persistence of atmospheric contaminants such as carbon dioxide, chlorofluoromethanes (CFM's) and other aerosols are expected to be responsible for climate changes and ozone depletion in the stratosphere in the near future. Natural cleansing processes, especially in the stratosphere, are slow in removing significant amounts of contaminants. Mankind has no alternative to the natural cleansing processes for removing atmospheric pollutants.



Source: NCI "First Bi-annual Report to Congress on Research Activities of Reference to the Clean Air Act", December, 1978; USDA, "Effects of Changes in the Ozone in the Stratosphere Upon Animals, Crops, and Other Plant Life," December, 1977; Machta, et al. "UB-V Measurements." 1977.

Unfortunately, some widely used halocarbons, particularly CFM's and methyl chloroform, have long atmospheric lifetimes and when transported to the stratosphere are transformed to compounds capable of reacting with and destroying ozone molecules.

The integrity of pollutant-carrying plumes is often maintained over thousands of kilometers.

The continuing emission of chlorofluorocarbons into the atmosphere at current (1977) rates has recently been predicted by WMO to lead to about an 18% decrease in stratospheric ozone in a few decades. The 1-2% ozone reduction expected to date by predictive models is not yet measurable by existing techniques. We do know that stratospheric ozone depletion is expected to result in an increased flux of harmful solar UV-B radiation to the earth's surface, an increase in UV-B radiation flux of about 2% for each 1% decrease in stratospheric ozone. Scientific field data and laboratory studies forecast undesirable and possibly intolerable effects as a result of the increased flux of UV-B radiation. WHO has estimated from epidemiological studies that for each 1% decrease in stratospheric ozone, skin cancer incidence will increase about 4%.

The deleterious effects of UV-B radiation on the growth rates and yields of plants and agricultural crops have already been observed. Though water is a good absorber of UV-B radiation, studies indicate that embryonic fish residing close to the surface of marine or estuarine waters can also be seriously affected by increased UV-B radiation. Lesions and other serious physiological changes have been observed in important food fish such as mackerel, anchovy and shrimp.

A National Academy of Sciences study in 1978 concluded that the ever-increasing worldwide use of nitrogen based fertilizers, including that used by third world nations struggling to produce more food for their increasing and underfed populations, can be projected in the future to result in sufficient quantities of nitrous oxide, which after diffusion to the stratosphere, will also contribute to stratospheric ozone depletion.

Carbon dioxide emissions to the atmosphere caused by increasing fossil fuel combustion will, scientists believe, result in future global temperature increases and rising sea levels from melting polar icecaps, thereby significantly changing global and regional climate patterns. Thus climate changes can be expected to have major impacts on food production, energy requirements, water supply and quality, and other human needs. Other aerosols in the atmosphere will similarly impact the global and environmental climate.

Marine Pollution

The oceans provide a substantial and essential amount of food for the world's population. This vital food source must be kept free from toxic contaminants. Although direct dumping of wastes into the ocean is common and has been considered a regional and even national problem in the past, the slow and sustained

Increased UV-B radiation can be expected to be responsible for increased skin cancer cases.

dispersion of pollutants including toxic substances into and through the waters of the world has increased the magnitude of the problem. We do not adequately know the pathways nor time constants for the disperson of long-lived contaminants in

the marine environment. But we know, by the existence of DDT and PCB's in the polar regions for example, that long-lived contaminants probably will eventually pervade waterways throughout the world. Kepone, which has contaminated the James River in Virginia and is encroaching on the Chesapeake Bay, can be expected to reach the Atlantic Ocean in a few years.

Research Needs

A research program to provide creditable scientific and technological information for use in the regulatory policy and decision-making process is essential.

Research on Long-range Transport of Air Emissions

Additional research is needed to provide new knowledge and higher quality data on the exact cause and effect relationships which will enable us to relate and assess an effect back to the source(s) that caused the damage. Every aspect of the problem from emission transport, transformation, and deposition characteristics to effects on human health, water quality, soil quality, and plant growth needs to be studied more thoroughly. Control technologies and strategies which will lead to decreased damage to life and property are also needed. (Specific research programs associated with long-range air pollution research needs are detailed in the "Air Pollution" and "Energy and Environment" chapters of this report.)

Research on Effects of Contaminants in the Atmosphere

Our knowledge of the effects of stratospheric ozone depletion on the earth is relatively meager except for understanding that increased UV-B radiation in the range anticipated from expected stratospheric ozone depletion levels can be expected to be responsible for increased skin cancer cases and may be detrimental to fish, phytoplankton, plants and other biological organisms and ecosystems. Much more UV-B radiation research at the organism and ecosystem level needs to be undertaken since UV-B radiation effects on living species are quantitatively unknown. The role of UV-B in photosynthesis, including the effect of UV-B radiation on phytoplankton, the keystone in aquatic food chains, must be studied to insure continued production of world food supplies.

Natural cleansing is slow in removing significant amounts of contaminants.

Though CFM's have been detected in the stratosphere and their reactions studied extensively, EPA-supported studies have found CFM's and other halocarbons (man-made and naturally occurring) to be distributed in the troposphere in quantities and with lifetimes that corroborate diffusions to the stratosphere from gound level emissions. These studies will continue, especially to better identify and understand the dynamics of man-induced atmospheric contaminants capable of reaching and significantly reacting with stratospheric ozone.

Our studies will also identify acceptable substitute materials for those halocarbons whose use must be restricted because of potential stratospheric modification. EPA's Environmental Sciences Research Laboratory will hold a workshop early in 1979 on this subject.

Climate changes due to increasing amounts of CO_2 in the atmosphere caused primarily by fossil fuel combustion are being studied by a multitude of national and international scientific and socioeconomic organizations. The dominant thrust of the U.S. climate research program as now planned is to improve our understanding of climatic processes. A better knowledge of expected changes in climate and the resultant impacts should

improve our capability to adapt to those changes. However, future research must also be directed at identifying and characterizing the causes, so that we can learn to control and abate them. Therefore, control strategies, including the development of control technologies for reducing emissions of CO_2 and other harmful substances, should be a high priority study area. In order to determine the optimum degree of control necessary, via either technology or regulation, we must substantially increase our quantitative understanding of the effects of this pollution on health and other living things.

Research on Marine Pollution

Because the transport and fate of pollutants in the oceans are not understood as well as they are in the atmosphere, monitoring is needed to establish historic baselines for environmental contaminants and to detect deviations from these baselines. However, the deployment of pollutant monitoring instruments throughout the seas appears to be economically prohibitive and the sampling of marine waters by oceanographic research vessels provides discontinuous information. So the scientific community is seeking and evaluating biological indicators in the ocean. EPA is studying mussels as a means of measuring marine pollution because mussels ingest and concentrate ocean pollutants. The U.S. is also supporting the implementation of a worldwide "mussel watch" to systematically and uniformly monitor marine pollution throughout the world.

The scientific community is seeking biological indicators in the ocean.

More knowledge must also be gained on oceanic transport processes, the fate of toxic substances, the biological accumulation processes for pollutants, and the chain of effects through the entire food web from the smallest organism to man. Specific research projects applicable to the global aspects of marine pollution are incorporated in EPA's marine research program. EPA is cooperating with NOAA which has the responsibility for developing a marine research plan under the Ocean Pollution Research, Development and Monitoring Planning Act of 1978.

Research Program Goals

The goals of the global pollution research efforts are to understand processes by which pollutant emissions give rise to global impacts, to develop the capability to predict the movement and concentrations of pollutants in the global biosphere and to identify and assess resulting effects on human health and on other living organisms and ecosystems, and the effects of climate change on human health and welfare.

The effects of long range transport of air pollution is our highest priority global pollution research area because of the national policy of increased coal consumption, coupled with the development of large power plants and the trend to utilize tall stacks. Energy and environment relationships make this a subject of increasing importance. Understanding how to protect ozone levels in the stratosphere is a secondary research area because, to evaluate the need for and impact of regulatory options concerning essential uses of fluorocarbons much more definitive knowledge is needed on the tropospheric and stratospheric behavior of other halocarbons intended as substitutes for the fluorocarbons, and on the effects of increased UV-B radiation.

The effects of climate changes and variability will be given less emphasis because such changes are so little understood that meaningful socio-economic assessments cannot yet be undertaken. Climatologists need to provide quantitative information on the characteristics of expected regional and

global climate changes (wind pattern, temperature, precipitation, seasonal and annual weather patterns, etc.)

Marine pollution will also be researched at a relatively moderate level because severe marine pollution episodes are local in character and the time for localized pollution to affect the global marine environment is relatively long compared with atmospheric transport times. Furthermore, marine pollution problems are not as readily identified nor given as serious an urgency as air pollution.

Capabilities

EPA scientists have particular expertise concerning the chemical and physical processes of pollution transport, transformation and fate. Our scientists are also experts in air pollution photochemistry. For example, the fact that under certain meteorological conditions aerosol plumes retain their integrity over several hundred miles was first observed in airborne sensing studies conducted as part of EPA's Regional Air Pollution Studies in St. Louis.

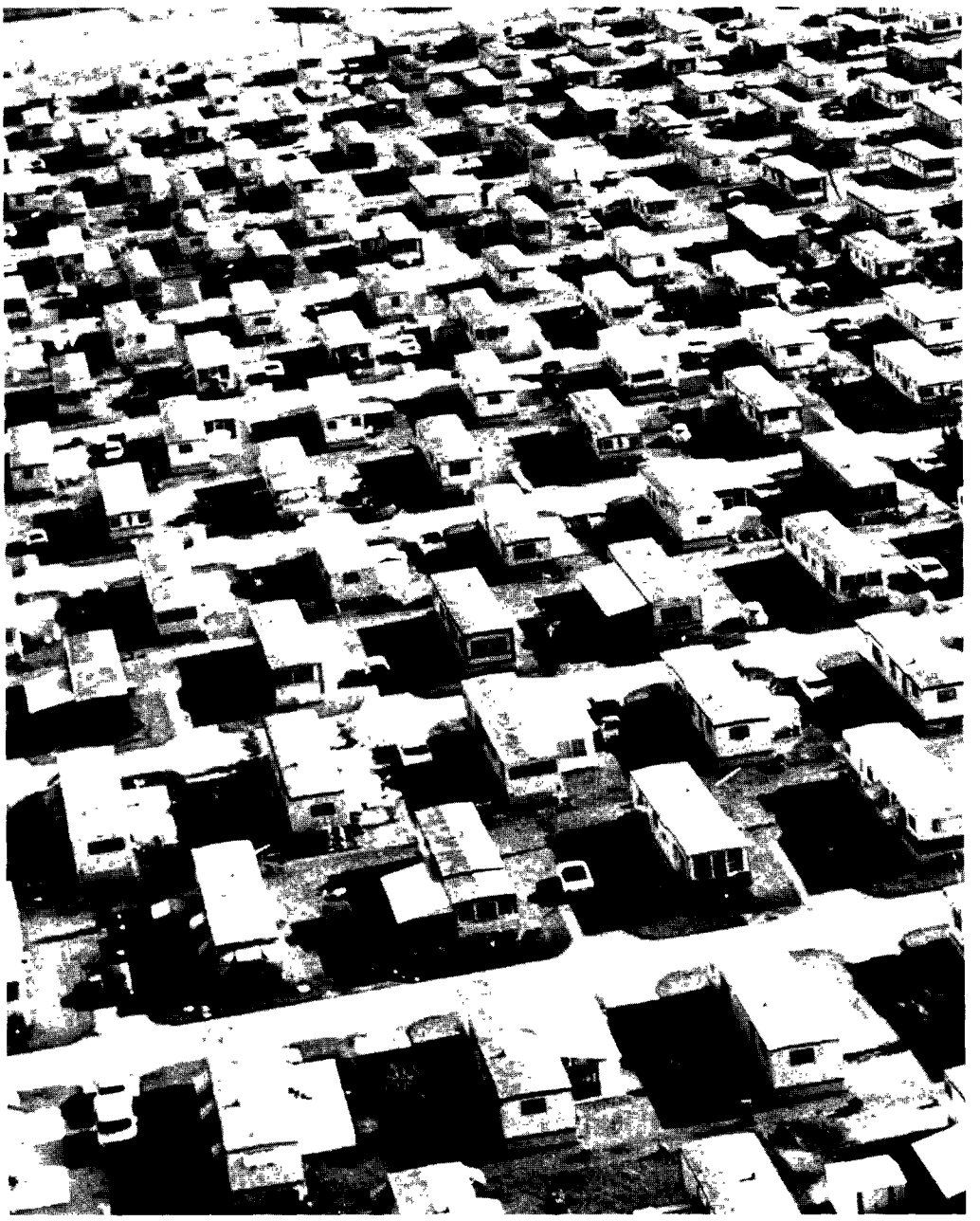
EPA recognizes the value of research and development in understanding and controlling the effects of global pollution.

In the area of stratospheric ozone protection research, EPA scientists will assist expertise outside EPA to produce most of the scientific information needed as a basis for regulatory decision-making. EPA's major function will be to integrate and evaluate research findings and assess the impact of continued and controlled emissions. We will perform this function with the assistance of the Interagency Committee on Stratospheric Ozone Protection (ICSOP) and its several subcommittees which also participate in the development and review of the overall federal research program.

At present, EPA produces climate data for the U.S. climate program (specifically, meteorological and microscale data obtained in the conduct of field studies on air pollution). EPA has the expertise to conduct pollution climatology research and to continue its research on improving technological processes for controlling emissions from power plants and other industrial enterprises. EPA also has the capability to assess the impacts of climate change on air quality, water quality and supply, and on health and other environmental matters.

Finally, EPA has several marine laboratories staffed with experts who are studying transport, fate and effects of a variety of pollutants on marine quality and marine life, including the quality of recreational waters as affected by pathogens.

ANTICIPATING ENVIRONMENTAL RESEARCH NEEDS



We must learn to identify environmental problems before they become critical. EPA is applying anticipatory research toward this end.

The previous chapters in this report have dealt with specific programs to investigate reasonably well-defined environmental problems and concerns. This chapter steps away from that perspective and looks instead at a set of problems which are just now evolving. Some of these problems can only begin to be identified, some will not become evident until the emergence of the technologies, politics, economics or social patterns that spawn them. Our research to anticipate future problems has shown progress in the last few years, but it is still just a tentative step.

We want our approach to be strategic, that is, to decide what should be studied, not necessarily how to carry out the studies. Then, by understanding the nature of future environmental concerns, EPA can develop data and plan actions before a problem situation becomes critical. In short, we will be able to anticipate rather than merely react to environmental concerns. EPA believes that results of exploratory research conducted in this vein will enable others, particularly other government agencies, to be sensitive to significant future environmental dangers. Through interagency agreements, informal working arrangements and other coordination, we hope to profoundly influence the consideration given to the long range environmental consequences of government mandated actions.

By understanding future environmental concerns, EPA can develop data and plan action before a problem becomes critical.

The prime factors that will dictate future problems are population, affluence and new technology. Many of the difficulties we experience today, particularly energy, have their roots in these causative factors; however, we do not yet understand the very complex cause and effect relationships. We identify below examples of research goals that may be needed for understanding these factors. However, because solutions to future problems often are intimately linked to improved technological or management approaches, EPA will not have the sole responsibility for implementing specific research. Rather, continuing national commitment by government and industry will be needed; thus, the goals we present should be viewed as representative, not absolute.

Population and Affluence

Population changes affect demands for products of all types. Population size influences the size of the labor force, material usage and disposable income. In the four decades between 1930 and 1970, the population of the United States increased by about 80 million people, rising at an annual average rate of 1.3 percent. The most recent projections of the Bureau of the Census indicate that the U.S. population will be between 245-282 million by the year 2000 and population growth rates will not level off until 2020 or 2030. Expected trends from this increase in population include increased numbers of immigrants, particularly from Mexico, large numbers of women entering the labor force, and shifts in population from the industrialized north to the sun belt and western coal states. Each of these forces will have important regional effects on resource development and the demand for goods and services.

World population, however, is projected to increase until the end of the next century. United Nations' projections show world levels ranging from 6.0 to 7.1 billion. With these increases will come the serious burden of many new workers in the job market. The International Labour Organization (ILO) estimates that in 1975, in some less developed countries, close to 40 percent of the labor force was either out of work or underemployed. Projections for the end of the century indicate

that the work force in the developing world will expand by 86 percent, the equivalent of 880 million jobs.

The need to employ more people will require significant amounts of capital, natural resources and energy (see the "Energy and Environment" chapter of this report for just the projected U.S. energy needs). These population increases, coupled with rising expectations for affluence, will result in important challenges to the world's economic and social systems, particularly with respect to food supplies, housing, and mineral production.

Research goals to anticipate problems caused by population and affluence are to develop an improved understanding of (l) the dynamic forces that influence the U.S. and world population and (2) the expectations of the U.S. population and its drive for affluence.

The forces that influence the size, movement and composition of the U.S. and world population are topics beyond the research capabilities of EPA. However, it is expected that EPA will focus on understanding the impacts of its regulatory decisions on the U.S. population. Thus, an important task is for EPA to monitor population trends within the U.S. as they are affected by government actions and population trends of other countries with possible indirect effects on the U.S. Special attention may have to be given to approaches that predict overloads of environmental carrying capacities of selected U.S. regions. Ultimately, many national and international government

ESTIMATES AND PROJECTIONS OF TOTAL POPULATION: 1980 TO 2025

(IN THOUSANDS, AS OF JULY 1. INCLUDES ARMED FORCES OVERSEAS)

YEAR	SERIES I	SERIES II	SERIES III
ESTIMATES			
1930[1]	123,188		
1935[1]	127,362		
1940[1]	132,594		
1945	140,468		
1950	152,271		
1955	165,931		
1960	180,671		
1965	194,303		
1970	204,878		
1975	213,640		
1976	215,118		
PROJECTIONS			
1980	224,066	222,159	220.732
1985	238,878	232,800	226,879
1990	254,715	243,513	236,264
1995	269,384	252,750	241,973
2000	282,837	260,378	245,876
2005	297,600	267,603	248,631
2010	315,248	275,335	250,892

[1]Excludes Alaska and Hawaii.
[2]The figure excluding Alaska and Hawaii is 132,122.

Source: Current Population Reports, Series P-25, No. 632, Tables 5 and 6

STATE POPULATION PROJECTIONS

Sunbelt/Western Coal States

State	1975	1985	2000	Percent Increase 75-2000
Arizona	2224	2908	3989	42
Florida	8346	9899	14461	72
Georgia	4926	5536	6742	37
Louisiana	3791	4050	4562	22
Texas	12237	14233	17405	43
Wyoming	374	454	483	29
Utah	1206	1365	1639	33

Northeast/North-Central States

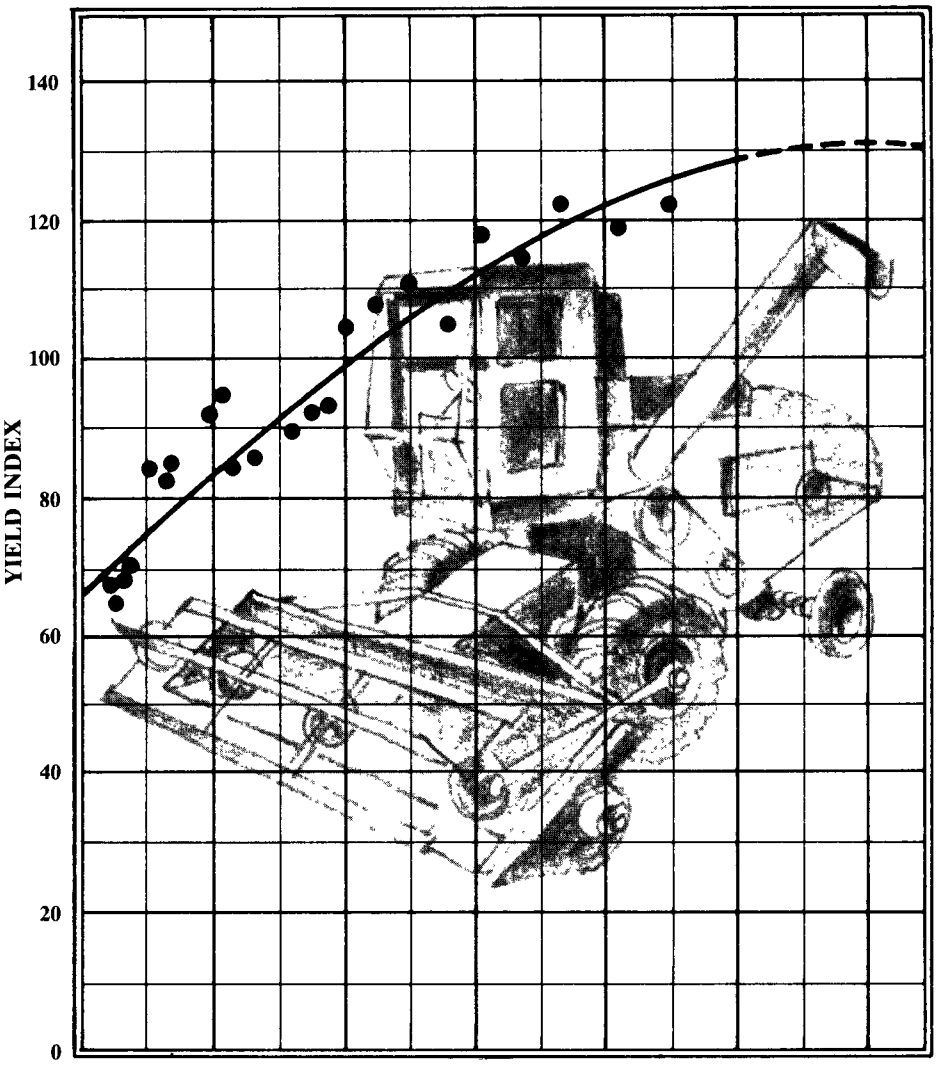
Maine	1059	1112	1190	13
Massachusetts	5818	6131	6612	14
Pennsylvania	11829	11999	12300	4
Ohio	10759	11216	11956	11
Illinois	11145	11646	12245	10
New York	18122	18256	18692	3

Source: U.S. Environmental Protection Agency. Technology Assessment Modeling Project. 1978.

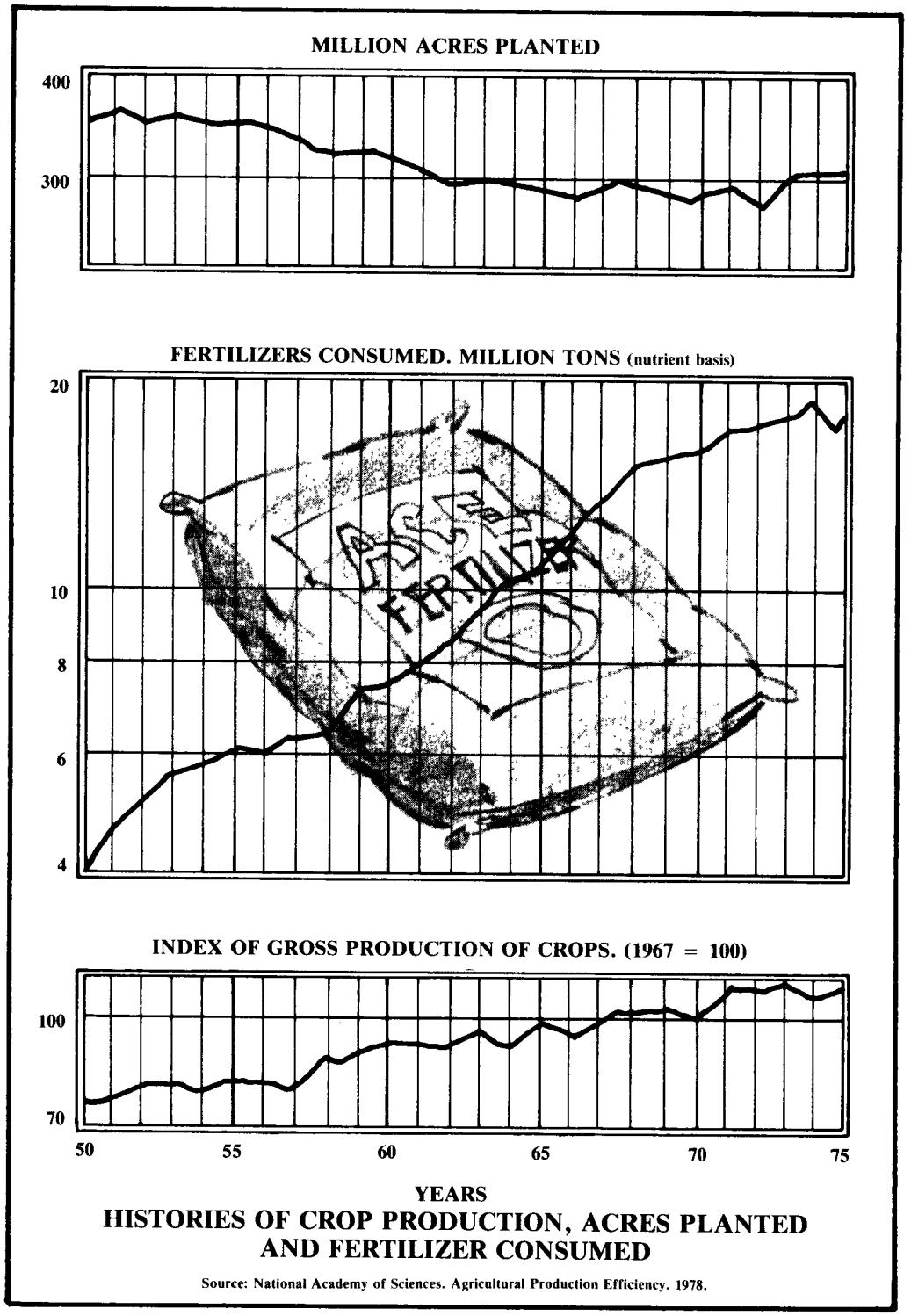
policies may have to be analyzed to ascertain effects on the U.S. population and environmental quality.

Consumer expectations for affluence will influence environmental quality. EPA needs to understand how these expectations and subsequent increases in affluence affect the environment and also needs to develop an appreciation of the impacts of greater affluence on the U.S. Many public policy groups will eventually realize the necessity for this information, thus EPA's role should be aimed at developing an understanding of the problems sufficient to support federal regulatory decisions.

FERTILIZER USED AND CROP YIELDS. 1910-1969.



Source: National Academy of Sciences. Agricultural Production Efficiency. 1975.

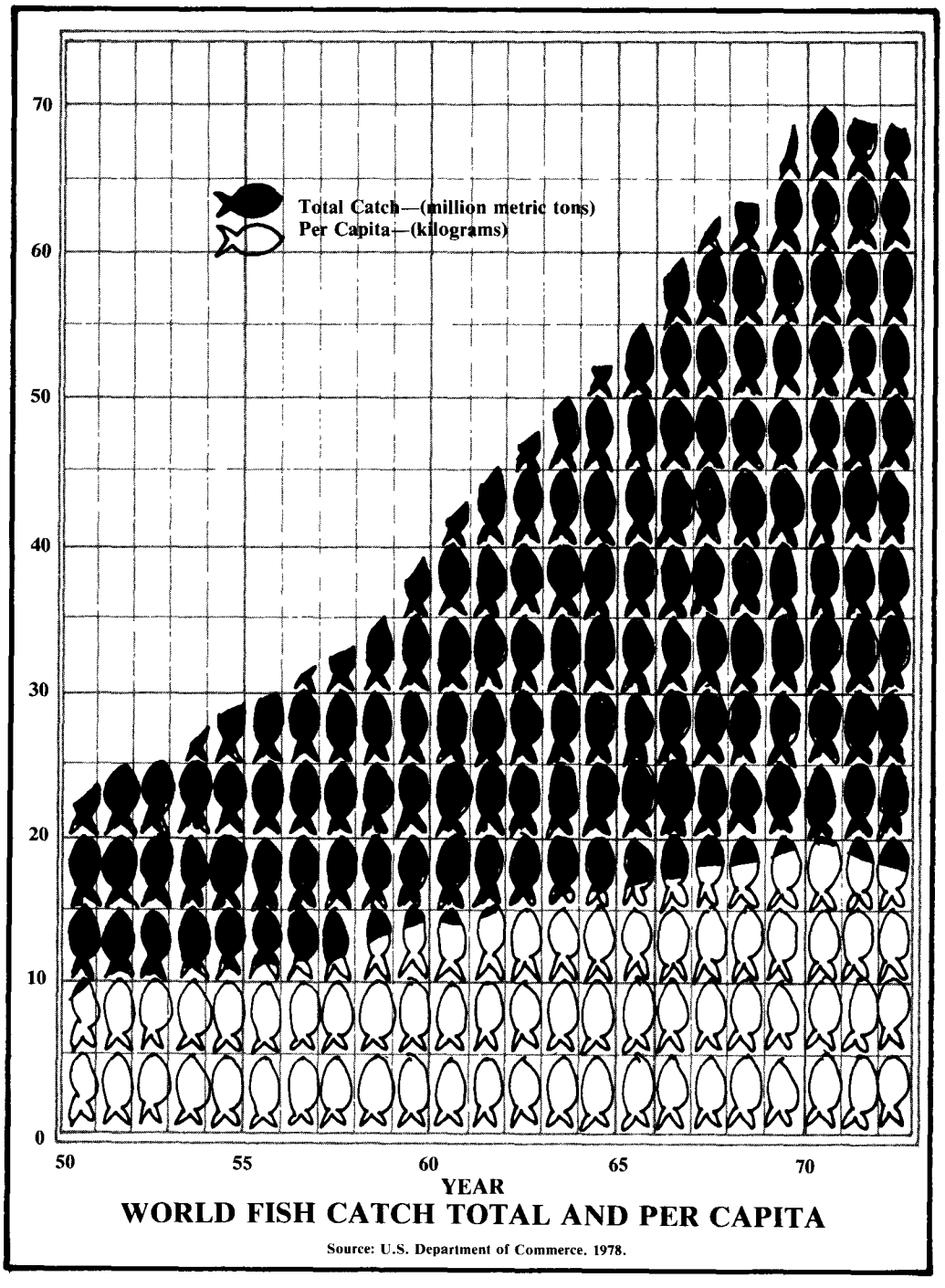


HISTORIES OF CROP PRODUCTION, ACRES PLANTED AND FERTILIZER CONSUMED

Source: National Academy of Sciences. Agricultural Production Efficiency. 1978.

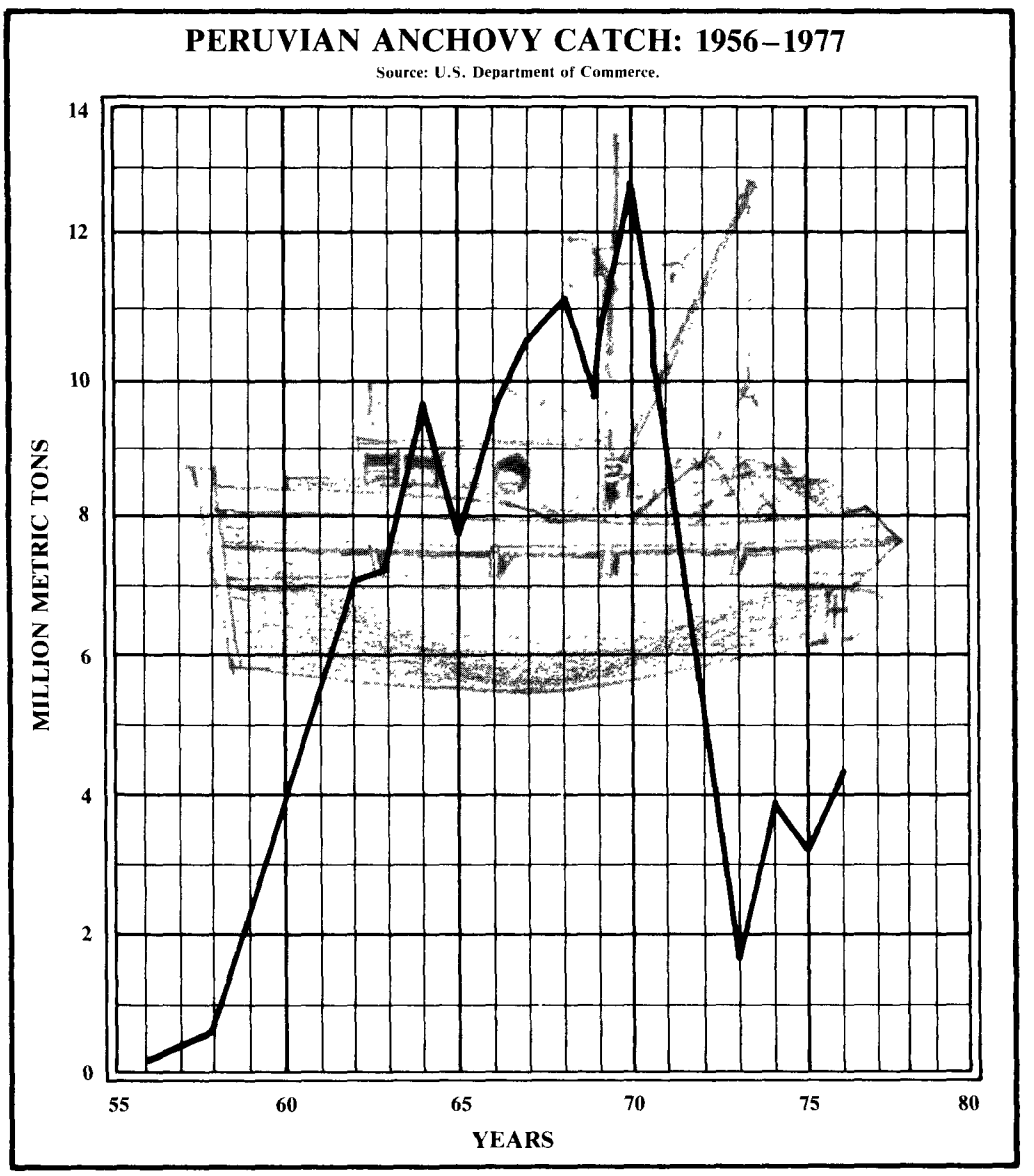
Food Supplies

Much of America's food surplus is annually exported to a hungry world. However, in recent years, we have begun to recognize a leveling of the long-term rise in grain yields per acre. Chemical fertilizer applications are no longer producing increased yields in those areas where fertilizers have been used extensively in the past. Doubling of world grain output over the last thirty years has been due to the expanded use of commercial fertilizer more than any other factor, thus, this



WORLD FISH CATCH TOTAL AND PER CAPITA

Source: U.S. Department of Commerce, 1978.



productivity change is to be closely watched. Good cropland lost to erosion, urbanization and transportation networks further contracts production. Present U.S. Department of Agriculture projections indicate that wheat production increases from approximately two billion bushels in 1974-76 to approximately three billion bushels in the year 2000, will require genetic improvements, advances in pest control, adequate energy, fertilizer and capital.

Stress to marine biological resources will also increase over the next decade. The total world fish catch, which increased during the 1920-70 period from 20 to 70 million tons per year, leveled off during the seventies. The Pacific mackerel and Peruvian anchovy are examples of species which have had rapid declines. However, in 1976, a relatively affluent U.S. population established a record of 13.0 pounds per capita fish consumption. The decreased supply/increasing con-

sumption trend will require careful monitoring as the world population and the demand for protein increase.

Research will be needed to assure that environmentally sound approaches are developed and used to produce food. Attempts to increase food supplies are likely to utilize a combined approach of traditional methods as well as new approaches. One potential environmental problem stemming from future food production using conventional approaches will be the increase in nonpoint source pollution from agricultural runoff. If inadequately managed, such runoffs are likely to include increased loads of pesticides, herbicides, and fertilizers. Research will continue to be aimed at developing and evaluating methods to assure that these impacts on the food production process are minimized. New approaches to food production will create new environmental challenges. For example, single cell protein rich organics derived from agricultural waste may be used as a major source of protein in the future, especially for livestock. The potential for pesticides, heavy metals and toxicants in the wastes to accumulate in the human food chain will have to be carefully evaluated. Another new problem is the vulnerability to pollution and disease of new species or cultivated specialized crops introduced for economic reasons. Environmental controls will be needed to assure that the benefits from such crops are fully realized. In these cases, EPA's role is to assure that information, methods and ap-

AREA OF COMMERCIAL TIMBERLAND, BY REGION, 1952, 1962 AND 1970

(THOUSAND ACRES)

REGION	1952	1962	1970	Change 1962-1970
New England	30,935	31,878	32,367	+ 488
Middle Atlantic	42,098	46,737	49,685	+2,947
Lake States	52,604	51,530	50,841	− 690
Central	44,559	44,942	45,008	+ 65
Total North	170,198	175,089	177,901	+2,812
South Atlantic	46,962	47,911	48,463	+ 551
East Gulf	42,104	43,128	41,334	−1,794
Central Gulf	49,497	53,361	51,454	−1,907
West Gulf	53,518	55,504	51,291	−4,214
Total South	192,082	199,905	192,542	−7,364
Pacific Northwest	50,589	50,407	49,713	− 694
Pacific Southwest	18,216	18,132	17,909	− 223
Northern Rocky Mountain	38,337	38,792	36,669	−2,124
Southern Rocky Mountain	25,554	25,810	24,963	− 848
Total West	132,696	133,141	129,254	−3,888
All Regions	494,978	508,137	499,697	−8,440

Source: U.S. Department of Agriculture. The Outlook for Timber in the U.S. 1973.

PROJECTED GROWTH RATES FOR FOREST PRODUCT INDUSTRIES

New Construction	3.6%
Maintenance Construction	4.7
Lumber and Wood Products	4.4
Veneer and Plywood	3.5
Household Furniture	3.9
Other Furniture	5.3
Pulp Mills	4.9
Paper Mills	4.5
Overall GNP	3.8

Source: U.S. Environmental Protection Agency. Technology Assessment Modeling Project. 1978.

Fiber

For the last fifty years the U.S. has relied on imports of timber products to fill approximately 10% of its needs. Many factors point to the likelihood of increased imports. There has been a continual shift of about one million acres of timberland to cropland, pastureland, urban areas and other uses, yet the environmental impacts in terms of air quality (increased CO_2), water quality (erosion), and wildlife habitat destruction associated with this shift remain to be quantified. (See, for example, the "Watershed Management" chapter.)

proaches are developed to assess the impact of new production technologies and to be certain that they can be introduced into the environment under circumstances that will favor their success.

EPA will focus on understanding the impacts of its regulatory decisions on the U.S. population.

Elimination of losses in the chain of food storage, packaging and distribution could represent an important step toward an adequate world food supply. For research in this area, private enterprise and other agencies clearly have a major role; EPA will encourage development of techniques to reduce losses, since eliminating losses will effectively increase supplies, thereby reducing the amounts of fertilizers and pesticides released into the environment.

AVERAGE ANNUAL DEMAND FOR HOUSING IN THE UNITED STATES, BY SOURCE OF DEMAND, 1920-1970, WITH PROJECTIONS TO 2020 (THOUSAND UNITS)

Period	Total Demand	Household Formations
1920-29	803.4	556.6
1930-39	365.1	496.2
1940-49	809.0	800.5
1950-59	1,522.4	1,005.2
1960-69	1,648.7	1,039.3
1970-79	2,340.0	1,490.0
1980-89	2,370.0	1,240.0
1990-99	2,070.0	850.0
2000-09	2,160.0	810.0
2010-19	2,120.0	670.0

Source: U.S. Department of Agriculture. The Nation's Renewable Resources—An Assessment 1975. 1977.

U.S. AND WORLD MINERAL RESERVES

Source: U.S. Department of Interior, Mineral Facts and Problems. 1977.

COMMODITY	UNITS	U.S.	WORLD TOTAL
ANTIMONY	THOUSAND ST	100	4,565
BERYLLIUM	THOUSAND ST	28	419
CHROMIUM	MILLION ST	—	577
COBALT	MILLION LB.	—	5,404
COPPER	MILLION ST	90	450
IRON	BILLION ST	4	100
MANGANESE	MILLION ST	—	2,013
MOLYBDENUM	BILLION LB.	6	13
NICKEL	MILLION ST	—	60
TIN	THOUSAND LT	42	10,120

—No Reserves

There is a generally low productivity of forest resources despite opportunities for higher productivity due to differences in climate, soils, and elevation (e.g., only 10 percent of commerical timber areas are classed as high-productivity—capable of producing at least 120 cubic feet of timber per acre). Finally, based on population and economic growth, the projected demand for timber products is expected to remain strong. Softwood timber products of prime importance for lumber and plywood used in housing are projected at current prices to suffer a 15 billion board foot gap between supply and demand by the year 2000, which must be filled by imports.

EPA's research role in the near term must be to continue to focus on development and evaluation of management and technical approaches which minimize environmental degradation during harvesting and processing of forest products. Close cooperation with the Department of Agriculture is required to develop approaches which increase productivity and, at the same time, protect the environment. Practices that must be encouraged by both agencies include better management of timberland, more complete utilization of logging residues, and greater use of recycled fibers. In addition, EPA must assure development of information on impacts of air and water pollution on forests and other ecosystems. As large areas of land are harvested, vegetation emissions sources will change and natural sinks for many elements will no longer be

available. The long term implications of these intermedia transport phenomena will become increasingly important as EPA attempts to control man-made emission sources and as it assesses the interregional long term effectiveness of its programs.

Minerals

The natural distribution of minerals throughout the world results in a substantial interdependence among nations and places the industries in the developed countries, including the U.S., in potentially vulnerable positions. One strategy for decreasing vulnerability is to increase available supplies either through stockpiling or through development of lower grade ores. However, enhancement of reserves through the development of lower grade ores requires excavating large land areas and results in high residual tailings levels that could pose substantial new environmental problems in the future. Substitution of alternative materials for critical minerals will only put new stresses on other material reserves. Hence, minerals problems are likely to be characterized by occasional spot shortages of certain key minerals, a continuing decline of a broad spectrum of higher grade ores and slow development of lower grade ores.

EPA research to examine the minerals problem must shift from a focus on existing mineral processing industries to evaluations of new technologies and the corresponding development of environ-

COMPARISON OF PREVAILING U.S. PRIMARY MINERAL SUPPLY-DEMAND WITH PROJECTED HISTORICAL TRENDS

Commodity	Units	1974 U.S. Primary Production from Domestic Sources	1974 U.S. Primary Demand	1985 U.S. Primary Demand	2000 U.S. Primary Demand
Antimony	ST	1,319	20,323	30,600	49,500
Beryllium	ST	N.A.	209	430	1,150
Chromium	Thousand ST	——	560	700	1,100
Cobalt	Thousand lb	——	28,183	27,100	43,000
Copper	Thousand ST	1,597	1,953	2,700	4,200
Iron	Million ST	58	91	107	129
Manganese	Thousand ST	35	1,492	1,680	2,130
Molybdenum	Thousand lb	112,011	76,400	102,000	193,000
Nickel	Thousand ST	14	219	260	385
Tin	LT	N.A.	45,900	58,000	64,000

——No Reserves
N.A.—Not Available

Source: U.S. Department of Interior, Mineral Facts and Problems. 1977.

mentally sound control approaches. In the long term, environmental criteria must become an inherent part of the design of new methods and technology for minerals production.

New Technologies

New energy technologies represent perhaps the greatest area of very real potential environmental problems. EPA devotes a good share of its research budget to new energy technologies (see the "Energy and Environment" chapter of this report). Other new technologies are now emerging which also may have significant future impacts. The impacts of technologies such as weather control, deep ocean mining, satellite power systems, or advanced energy systems push our predictive capabilities to their limits. For example, two rapidly advancing technologies are genetic engineering and consumer electronics. In the genetic engineering area, agricultural researchers have been successfully modifying and improving different crops for years. This type of research will undoubtedly continue to make major contributions toward easing the world's food problems. Research on recombinant DNA and basic life processes may eventually lead to dramatic advances in man's health and to fundamental industrial changes. For example, manufacturing techniques for synthetic insulin are only a few years away; other new industries for the biological processing and production of food, fiber, and materials may emerge by the end of this century. The far-reaching environmental implications associated with genetic engineering could range from the accidental release of exotic new genotypes, to the need for effluent controls for production facilities employing genetically engineered pollution control technologies.

Expanded applications of electronics have resulted in products such as microwave ovens, hand calculators, CB radios, digital watches, large computers for data handling and storage and satellites for telephone and television transmissions. In the near future, we expect the introduction of home computers and robotics. This latter development may have significant impacts on the labor force at a time when increasing numbers of women and young workers are entering the job market and others are extending retirement dates. Increased communications will tend to raise aspirations and homogenize goals of all the world's people. In the near future, effects from electronic products may be less significant in changing the quality of the environment than the long term forces generated by these technologies.

The goal of research for this new technologies problem would be to identify new technologies and emerging social trends and assess the environmental implications. The identification of new technology problems can neither be done haphazardly nor through the use of a single mechanism or approach. The process must rely on the ingenuity of individual scientists, the creativity of research teams and the disciplined analyses of many societal and technological trends. EPA will examine longer term problems by supporting the unique ideas of individual researchers and establishing long term programs in institutional centers. EPA will also systematically analyze the long term impacts of regulation and other government actions and policies that might ultimately affect environmental quality in the U.S. Our program will not prevent accidents or predict emergencies in local areas, however, it will provide EPA with the first substantial effort to identify long term problems and predict environmental implications in advance.

EPILOGUE

Environmental research is a continuing process. As immediate problems are solved, less serious concerns can be studied; as new materials are discovered and produced, new pollution threats will emerge for research and regulation. Our research plans today are devoted to current and foreseeable problems as defined by our best technological judgments and scientific insights, but we expect these plans to be dynamic, to change as the dangers of environmental pollution become better known. Our methods for planning research will also be dynamic; we will learn from our successes as well as from our failures how to better study the exceedingly complex sets of environmental problems. Moreover, as we see how our research results are used to support regulations or to develop control technologies, our planning processes can better tailor research programs to fit specific time requirements and data needs. But optimal use of our research can only come through continuing dialogues with those individuals, agencies, industries and institutions that use or are affected by our results.

It is the establishment and improvement of such dialogues that will be the key to effective, economical applications of our current and future research program results. Similarly, continuing dialogues will make our research process more cost-effective. A full appreciation of the uses of our results will translate into more finely tuned, better focused programs.

This *Research Outlook* series of publications is part of our attempt to stimulate this dialogue. Other methods to communicate our research will also be used. We expect to publish more documents keyed to our research projects, we will hold workshops, meetings, and seminars to delve into some of the details of our programs, and our management will give talks about our research programs. In all of these methods, however, as with this report, we want and need to hear and read your comments, concerns, criticisms and discussions about our research plans. If this occurs, EPA's research will benefit immeasurably.

APPENDIX A

Research Options

In the *Research Outlook 1979,* we have described our plans for environmental research and development which encompass approximately 90 percent of the funding for the fiscal year 1979 program. In the coming years, EPA's ability to address the research objectives in each of the program areas will depend upon the level of funding that we receive. With this in mind, this appendix presents an analysis of our research plan for three budget growth options.

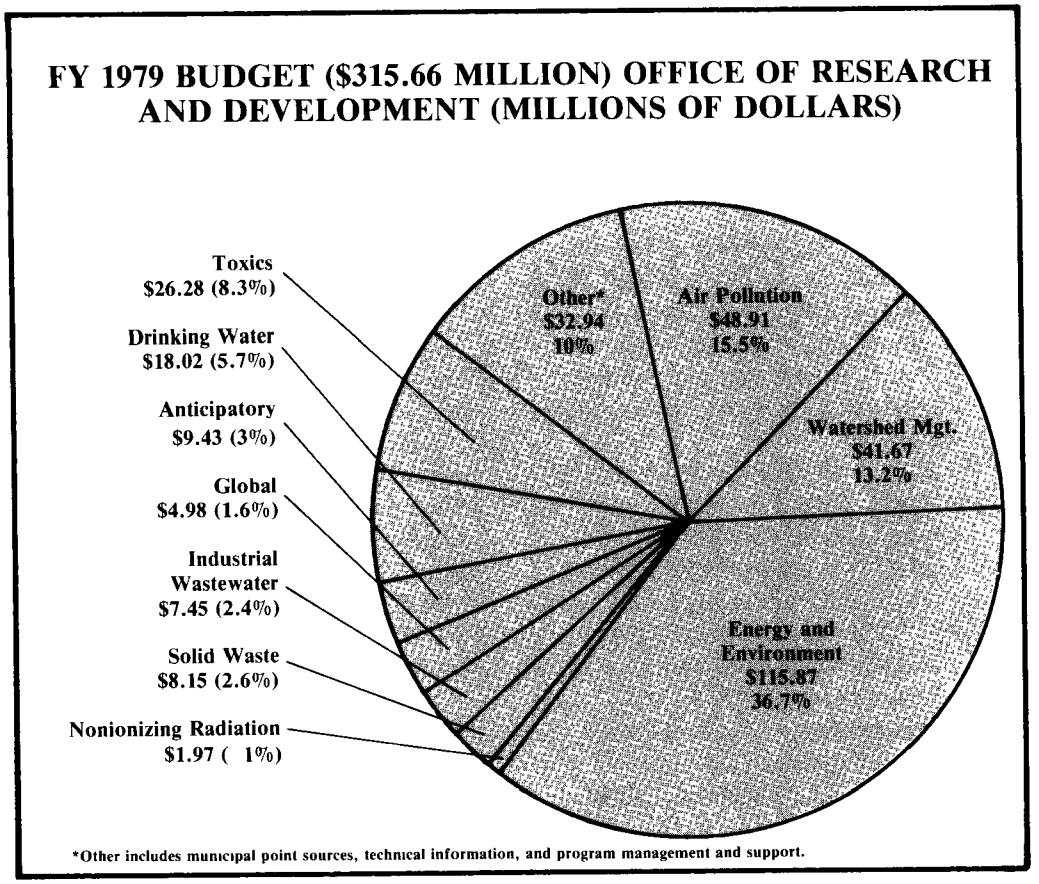
We have not attempted to analyze our plan from the "bottom up" by associating a cost with each objective, developing an overall priority ranking of objectives, and allocating the funds available under each growth option. This type of analysis is performed on a year to year basis during EPA's zero based budgeting process. Instead, we have approached this analysis from a more "top-down" strategic perspective. We have coupled our best scientific judgments with forecasts of environmental futures and estimates of available funding in order to identify where the research program should go over the next five years.

The funding data for this analysis was drawn from two sources, the fiscal 1979 research budget and the President's budget proposal for fiscal 1980. This proposal includes a significant Public Health Initiative to expand health research on toxic substances, air pollution, drinking water, and nonionizing radiation. We have defined the three research budget growth options as follows: *no growth* assumes that the total EPA research budget remains at the fiscal 1980 level throughout the four year period to fiscal 1983; *moderate growth* assumes a five percent growth in the total budget compounded annually through to fiscal 1983; and *high growth* assumes a ten percent growth rate compounded annually through to fiscal 1983. All options are analyzed under the assumption of constant dollars with fiscal 1979 as the base year. Based upon these assumptions there will be $354 million, $409 million, and $471 million available for research under the respective budget growth scenarios in 1983. The results of our analysis for each of the topic areas in the *Research Outlook 1979* are described below.

Toxic Substances

In fiscal 1979, $26.3 million (8.3 percent of the research budget) was specifically earmarked for toxics research. The President's budget for fiscal 1980 which includes a large portion of the Public Health Initiative, proposes funding toxics research at a level of $42.7 million (12.1 percent of the research budget). The work contained in the Public Health Initiative will focus primarily in the areas of short-term tests, screening tests, mammalian tests, human exposure assessment, and epidemiology. These are areas which were identified by the Interagency Regulatory Liaison Group (consisting of EPA, the Consumer Product Safety Commission, the Food and Drug Administration and the Occupational Safety and Health Administration) as having major deficiencies in the information base. Furthermore, these areas were accorded highest priority by a seven-agency zero base budget ranking committee convened this past summer to integrate the federal toxic substances research program. That committee included the National Institutes for Cancer, Occupational Safety and Health, and Environmental Health Sciences as well as the four IRLG agencies listed above.

Because of the growing awareness of the serious and complex problems toxic substances pose, this area will continue to experience higher growth rates than any of EPA's other research programs in the years ahead. By 1983, we estimate that $49.8 million, $57.9 million, and $66.4 million will be channeled into toxics research under the respective budget growth options. The main thrust of the program for the next three to five years will be on the development of tools for



performing assessments emphasizing the development and refinement of effects, exposure, and epidemiological protocols in conjunction with the integration of predictive and evaluative approaches and results and extrapolations of effects tests to humans. While significant control work will proceed in parallel with this effort, we see the development of methods for toxics control coming to the forefront toward the latter part of the five year planning period.

Air Pollution

EPA currently spends a significant percentage of it research resources on air pollution. In fiscal 1979, $48.9 million is being devoted to air pollution research and $66.8 million is proposed for fiscal 1980. By 1983, we envision spending $68.3 million, $79.0 million, and $91.3 million under each of the respective budget growth options. Over the next three to five years, several of our major research efforts will be nearing completion. The bulk of our work on inhalable particulates, sulfates, and the ozone-oxidant problem will be completed toward the latter part of the five year planning period. As these areas are completed, air pollution research will focus more on inter-regional pollutant transport, the aerosol complexes, and secondary organics. In addition, the Clean Air Act (as amended in 1977) requires a review every five years of the data base which supports EPA's ambient standards. At present, there exists a major need to refine the health data which support current standards and develop more rapid and conclusive techniques for evaluating the health effects of those pollutants

suspected of representing a threat to human health. These areas are addressed as part of the fiscal 1980 Public Health Initiative. Our proposal here calls for accelerating the efforts to correlate exposure and dose relationships with observed health effects, to determine specific health effects on populations in high risk areas, and to improve ways of determining health effects from pollutant measurement data.

Industrial Wastewater

Although the resources currently devoted to industrial wastewater research are relatively small, $7.5 million for fiscal 1979, we anticipate that this area will grow over the next five years in rough proportion to the actual growth of the total R&D budget. Two considerations that played a role in reaching this conclusion are: first, a significant proportion of the growth in toxics research will be in areas such as health effects that are applicable to industrial wastewater probems; and second, toward the end of the five year planning period, emphasis of the program will shift from effluent characterization and treatability assessment to development of technology required to meet higher removal requirements (dictated by health effects data) and permit the recycle and reuse of wastewater. An increase of $4.3 million is proposed.in fiscal 1980 for this purpose. EPA will continue to act as an evaluator and information clearinghouse for new technology.

Watershed Management

Over the next five years, we expect to fund research in watershed management at $38.2 million, $44.2 million, and $50.8 million for no, moderate, and high growth budget options respectively. The emphasis of the program will shift from quantification of nonpoint source cause-effect relationships and development of control methods to understanding a watershed as a control volume for environmental contaminants. As we continue to develop a better understanding of conventional pollutants, toxics-related problems will play an ever increasing role especially for our modeling efforts in watershed management research. Work will also accelerate during the five year period in understanding how pollutants move through a watershed. These efforts will focus on the "sinks" or endpoints for toxic contaminants.

Drinking Water

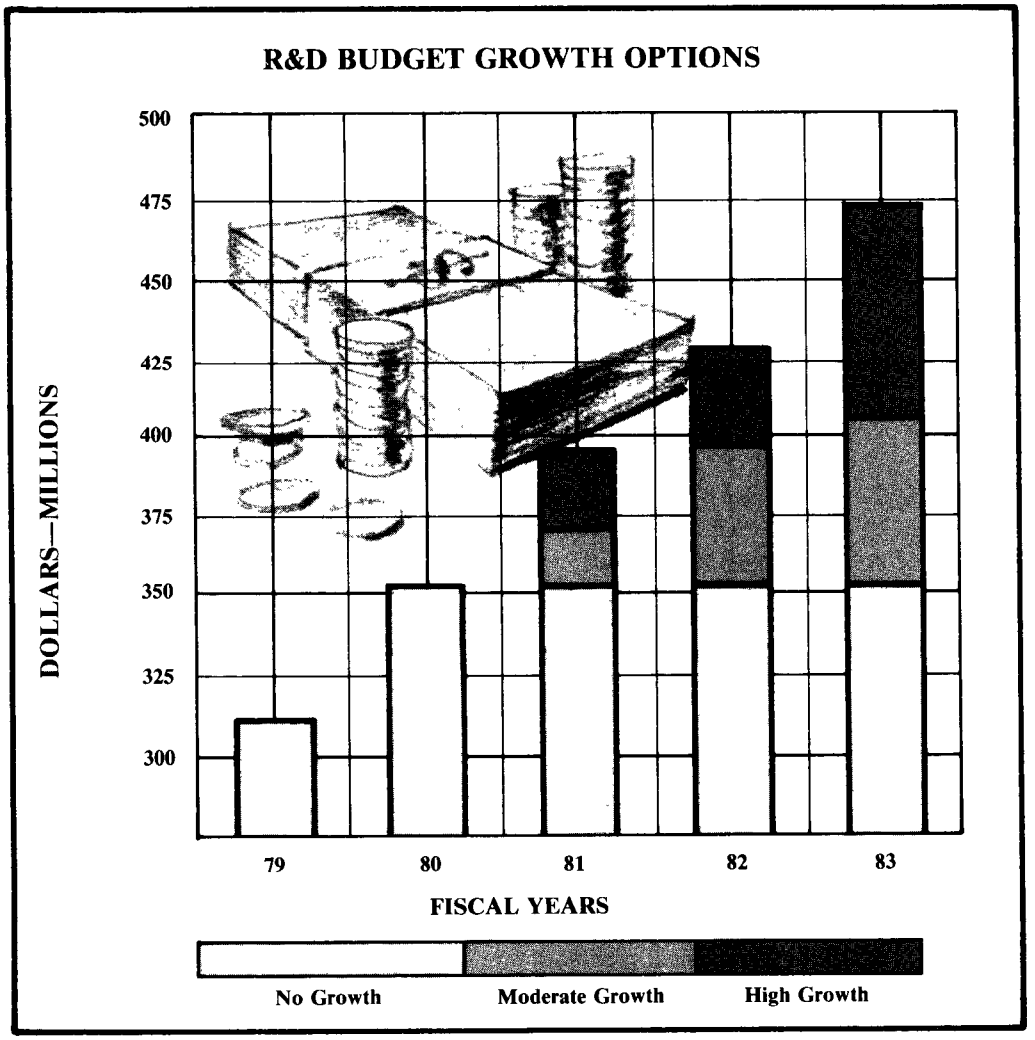
Drinking water research is also an area which we expect to grow at least in rough proportion to the overall R&D budget. Our attention will concentrate on providing control technology for small water supply systems (including technology for either the removal of organics or prevention of organics formation) and on ground-water research. Development of control technologies for small systems could possibly require a major funding effort. However, our current plan calls for a systematic evaluation and possible adaptation of existing technologies. If we are successful, we will be able to provide control technology which is economical for small systems. Our current knowledge about ground-water contamination is so limited that our research must initially be confined to information gathering and analysis. We can then move quickly to establish the scientific basis for methods to prevent ground-water contamination.

Both the control technology program and the groundwater program must be founded on a firm health effects information base. In the long term, the health effects part of the program will, therefore, constitute a top priority. The fiscal 1980 Public Health Initiative proposes to expand health research by $5 million. This expansion will be directed mainly toward research on organic compounds. The ultimate objective of this effort will be to identify those compounds or classes of compounds posing potential health risks and to assess the extent of those risks. While the carcinogenicity of organics will

be emphasized, other effects will be investigated as well. For example, epidemiological studies will examine the relationship between organic and inorganic water quality and the occurrence of birth defects or diseases such as multiple sclerosis. These studies will complement controlled laboratory studies.

Energy and Environment

Our work on energy and environment has been so intense in the past that we now envision a relatively stable growth in this research area during the next five years. We anticipate spending $98.8 million, $110.0 million, and $122.8 million under the no, moderate, and high growth scenarios. Research related to energy and the environment, however, will still consume approximately 28 percent of the total EPA R&D budget in fiscal 1983 (under the moderate growth option). The current emphasis on health and ecological



effects and control technology for energy extraction and conventional combustion will decrease considerably over the next three to five years. The primary focus of the research program will shift to evaluation of potential health and environmental impacts of emerging energy technologies.

Solid Waste

In the past, the solid waste research program has focused on the development of technologies and techniques for disposal of hazardous and other forms of solid waste. Since much of this work has been at bench scale, our efforts over the next five years will be directed toward testing the disposal methods developed in our laboratory work under actual field-scale conditions. We will also place more emphasis on recovery and reuse of wastes. Toward the latter part of the period, we hope to move more actively into research on industrial process modifications aimed at minimizing waste production than is now possible. We anticipate spending $11.7 million, $13.5 million, and $15.5 million respectively under the three budget growth scenarios. These increases over the fiscal 80 budget of $8.1 million recognize the increasing attention hazardous waste problems will be receiving in the years ahead.

Nonionizing Radiation

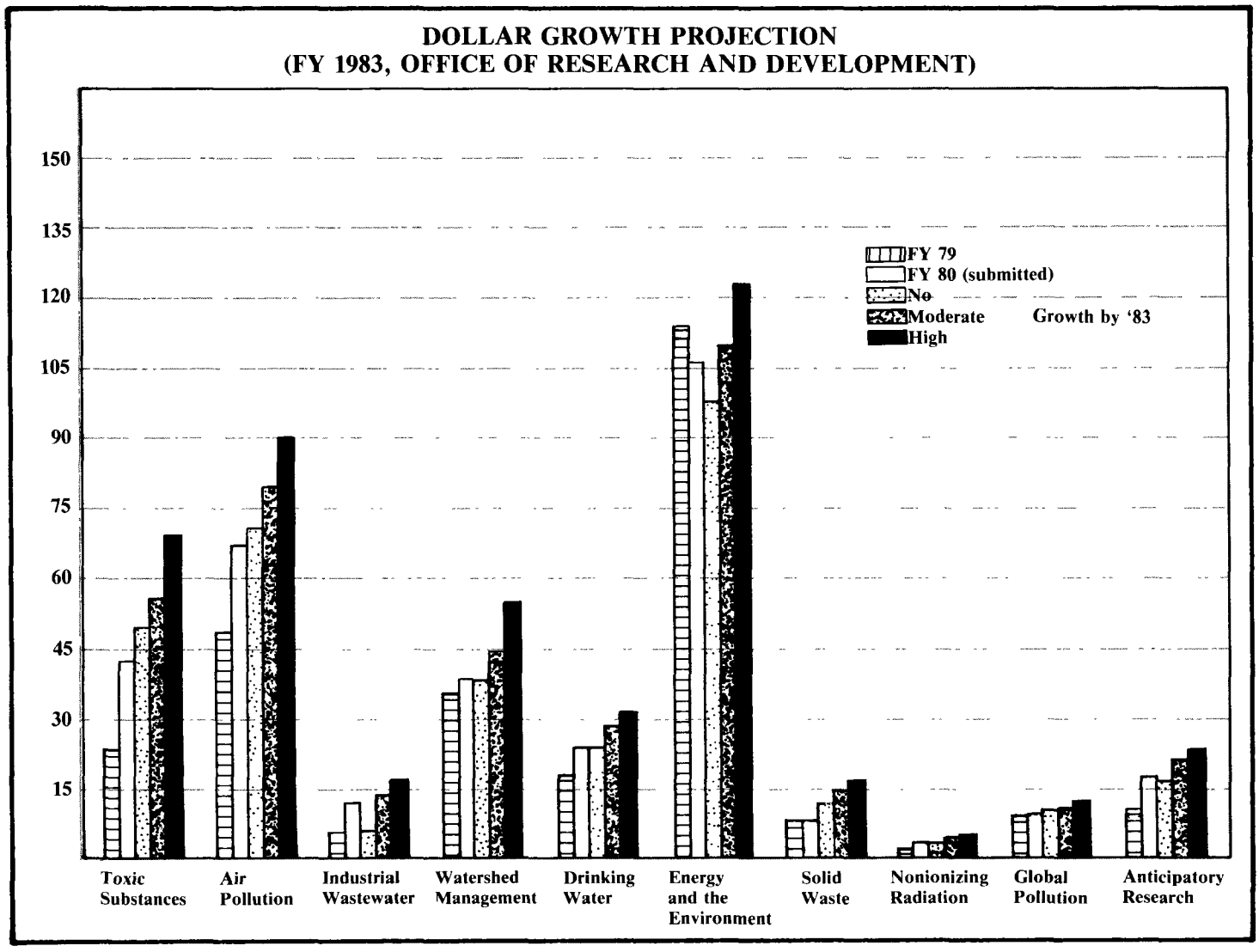
EPA's health effects program for nonionizing radiation is the largest intramural program of its type in the federal government. Because of recent expanded interest in this area, our nonionizing radiation research program, funded at a level of $0.9 million in fiscal 1978, has received funding of nearly $2.0 million in fiscal 1979. Moreover, the Public Health Initiative calls for an increase of nearly $1 million in fiscal 1980.

The program currently concentrates on providing information relevant to the interim guidelines EPA is considering establishing. In the future, the program will focus on obtaining the information which will be needed to revise the interim guidelines and on likely exposures which may have health implications. The Public Health Initiative proposes to expand and refine the information on the biological effects of chronic, low level exposures. This will be accomplished primarily through studies of mutagenic, teratogenic, immunological, and neurobehavioral effects. Here, long-term animal studies will be undertaken to help identify the most sensitive biological systems. Epidemiological investigations having parallel objectives will also be conducted. And, projects to reveal the mechanisms by which nonionizing radiation interacts with biological systems will receive increasing attention and support in the years ahead.

We do not anticipate that the rapid rate of growth experienced in this program over the past two years will persist through 1983. Instead, we project a more modest growth to levels of $2.9 million, $3.4 million and $3.9 million in each of the respective budget options.

Global Pollution

About 1.6 percent of EPA's fiscal 1979 research budget is dedicated to global problems. This research addresses primarily coastal and estuarine problems which have possible implications for oceans research and, to a much lesser extent, depletion of the ozone layer. Our interests will be on global processes, the consequences of anthropogenic contamination of the atmosphere and hydrosphere, and the resulting effect on the biosphere. Given the current orientation of our global research, we foresee small increases under the no growth and moderate growth budget options. We will, however, be looking to the efforts of other federal agencies such as the National Oceanic and Atmospheric Administration and the Department of Energy to provide much of the needed information on global problems. Under a high growth scenario, global research is projected to increase to a level of $8.0 million by 1983. These additional funds would be used primarily to augment the research efforts of other agencies.



Anticipatory Research

Our research has been oriented largely toward providing support for EPA's regulatory mission. Recently, the National Academy of Sciences pointed out that EPA also needs an anticipatory program to identify potential environmental problems before they reach crisis proportions and to further our understanding of fundamental environmental processes. We have consequently taken major steps toward the establishment of an anticipatory research program in EPA. This program was initiated in fiscal 1978 at a funding level of approximately $9 million.

In fiscal 1979, we are funding the program at $9.4 million and anticipate that the funding level will grow at a rate roughly equivalent to the growth of the overall research budget. The anticipatory program is presently focusing on better delineation of problems of current interest such as acid rain, environmental carcinogens, assessment of benefits derived from environmental control, and environmental forecasting techniques. In the long term we expect this program to be used primarily to identify areas for possible regulation development.

APPENDIX B

Interagency Coordination

Approximately three-fourths of the environmental research funded by the federal government is performed by agencies other than EPA. At present, our Office of Research and Development maintains formal coordination with 39 of these federal agencies. Because of shared interests, we are also currently co-funding more than 200 research projects. In each chapter of this report we have attempted to identify the major agencies with which EPA deals in the conduct of its research. However, some of our interagency work cuts across the programmatic descriptions given in this report and is therefore difficult to discuss under a separate program chapter. Thus, we have included this appendix on interagency coordination to highlight some of our *other* important working relationships.

Health Effects

EPA has major involvement with a number of agencies involved in environmental health effects research. The Assistant Administrator for Research and Development is a member of the National Advisory Environmental Health Council which provides guidance to the National Institute of Environmental Health Sciences (NIEHS) on extramural research related to cancer and other environmentally-caused health effects. EPA also works with an interagency task force to examine the long term needs, goals, and resources for NIEHS research programs and participates in various working groups created to implement task force recommendations. In response to Section 402 of the Clean Air Act Amendments, the Administrator of EPA chairs a task force which is specifically charged with recommending and coordinating a comprehensive research effort to assess the relationship between environmental pollution and human cancer and heart and lung disease. Task force members include the National Cancer Institute (NCI), the National Heart, Lung, and Blood Institute (NHLBI), the National Institute of Occupational Safety and Health (NIOSH), and the NIEHS.

EPA maintains an interagency agreement with the Center for Disease Control (CDC) for support on epidemiological studies and health emergencies. We are also contributing to epidemiological studies conducted by the Food and Drug Administration and the National Cancer Institute. These agencies are studying water supply and tap water samples to determine whether carcinogens that may contribute to bladder cancer exist in drinking water.

Finally, EPA participates in several other health-related task forces and advisory panels such as the Army Science Advisory Panel and the Steering Committee on Primate Use.

Marine Pollution

EPA participates in several interagency cooperative research efforts aimed at improving our understanding of the impact of human activities on the ocean. EPA and the Bureau of Sports Fisheries and Wildlife jointly conduct research into ocean-borne pesticides. We coordinate shellfish pollution studies with the Food and Drug Administration and assist the Department of Interior's Bureau of Outdoor Recreation in the selection of appropriate study sites. Our work with the National Science Foundation includes evaluation of water quality indicators; we are also engaged in modeling the transport and fate of pollutants in the marine environment with the National Oceanic and Atmospheric Administration, U.S. Geological Survey, and the Bureau of Land Management.

Other interagency research addresses impacts and cleanup of oil spills. EPA, the Department of the Interior, the National Oceanic and Atmospheric Administration, and the U.S. Coast Guard are developing an oil spill damage assessment program. Some EPA efforts under this program include a cooperative study with the National Oceanic and Atmospheric Administration on the Argo

INTERAGENCY COORDINATION

Source: Research Outlook 1978.

Department or Agency	Air Pollution	Water Pollution	Energy	Pesticides & Toxics	Radiation	Health Effects	Other[a]
Agriculture		o,x	x	o,x			
Federal Research Science and Education Administration	o,x	o,x	x				
Food Safety Quality Service				o,x			
Commerce					o		
National Bureau of Standards	o,x	o,x	o,x		o,x	o,x	
National Oceanic and Atmospheric Administration	o,x	o,x	o,x				
Defense	o,x	o,x		o	o,x	o,x	
Corps of Engineers		o					
Energy	o,x	o,x	o,x		o,x		o,x
Health, Education and Welfare, Public Health Service				o	o	o	
Food and Drug Administration	o	o,x		o	o	o,x	
Bureau of Radiological Health						o	
National Center for Toxicological Research				o,x		o,x	
National Center for Health Statistics	x	x				o,x	
Disease Control Center				o,x		o,x	
National Institute of Occupational Safety and Health			o,x	o,x		o,x	
National Cancer Institute	o,x			o,x		o,x	
National Heart, Lung, and Blood Institute						o,x	
National Institute of Environmental Health Sciences	o	o	o,x	o,x		o,x	
Housing and Urban Development	o,x	o,x	x	o,x		o,x	
Interior	o	o	x				
Fish and Wildlife Service		o,x	x				
Bureau of Land Management		o,x					
National Marine Fisheries Service		o,x	o,x		o,x		
United States Geological Survey		o,x	x				
Heritage Conservation and Recreation Service		o					
Bureau of Sport Fisheries and Wildlife		o,x					
Bureau of Outdoor Recreation		o,x					
Labor				o		o	
State	o	o					o
Transportation	o						o
Federal Aviation Administration	o						o
United States Coast Guard		o			o,x		
OTHER AGENCIES							
Council on Environmental Quality	o,x	o,x		o,x		o,x	
National Aeronautics and Space Administration	o,x	o,x	x		o		
Consumer Product Safety Commission	o			o		o	
Tennessee Valley Authority	o	o,x	o,x				
National Science Foundation	o	o,x		o,x			
National Academy of Sciences/National Academy of Engineering	o	o					
Nuclear Regulatory Commission	o	o,x	o			x	
Great Lakes Basin Commission		o					

[a]Including noise, solid waste, and policy research.

o—Coordination through committees.
x—Coordination through joint research.

Merchant oil spill; cooperation with the Bureau of Land Management to review outer continental shelf documents; and co-sponsorship of an oil spill conference with the U.S. Coast Guard, Bureau of Land Management, National Oceanic and Atmospheric Administration, Department of Energy, and the Office of Naval Research. EPA also uses U.S. Navy facilities to do research on the characteristics and effects of drilling mud, and through a joint EPA-Army Corps of Engineers technical committee, we coordinate research on the regulatory aspects of dredging.

Monitoring

A fundamental environmental management problem has been the fragmentation of the many on-going environmental monitoring efforts. For example, data are collected by the Food and Drug Administration on pollutant levels in food, by the U.S. Department of Agriculture on pollutant levels in soil, and by the U.S. Geological Survey on pollutant levels in water. However, these related data sets cannot be synthesized due to gaps in collection, incompatibility of data storage techniques, and differences in methods of analysis. Monitoring coordination necessary to resolve these problems is needed in three primary areas: linkage of environmental monitoring data with health effects data, ecological (or biological) monitoring programs, and state monitoring programs for air and water quality.

EPA has taken major steps to promote monitoring coordination. With respect to health and environmental data, EPA and the National Center for Health Statistics are working to correlate the Center's mortality and morbidity data with EPA's environmental data. Our recent contributions to the Interagency Regulatory Liaison Group also promise to improve environmental and health data collection analysis. In the biological monitoring area EPA has developed a computerized system that provides centralized storage and retrieval for aquatic data. This system is currently being operated on a pilot basis.

Another biological monitoring coordination program deals with the lack of standardization of sample collection, sample preservation, and analysis techniques. In this program EPA will help produce guidelines for standardized biological laboratory procedures. State monitoring programs will be upgraded by guidance in establishing and operating air and water monitoring systems that can meet the requirements of EPA regulations and standards. This guidance will be provided to states through EPA's ten regional offices. It will assure quality of data collection through the use of approved measurement methods, quality control techniques and materials, and audits of data and system performance. Furthermore, efforts are underway to prevent duplication of state monitoring activities and to provide uniform guidance to state monitoring programs for analysis of ambient air, stationary pollution sources, and drinking water.

APPENDIX C

International Coordination

Many countries throughout the world are actively involved in environmental research of interest to the U.S. Government in general and EPA in particular. This appendix briefly describes some of EPA's more important international relationships. For a more complete discussion of our international activities, the reader is referred to *Research Outlook 1978.*

EPA expands its reach by seeking information from many nations

EPA's involvement with other nations is oriented toward the solution of environmental problems of current U.S. concern. The focus of research is primarily in the areas of toxic substances, atmospheric pollution, water pollution, hazardous wastes, energy, and environmental monitoring. Our specialists work on joint projects under bilateral agreements with Canada, the Federal Republic of Germany, Japan, Mexico, the USSR, Egypt, Poland, Yugoslavia, Pakistan, and India. We participate in working groups within multilateral organizations such as the Organization of Economic Cooperation and Development (OECD), NATO's Committee on the Challenges of Modern Society, United Nations Environmental Program, World Health Organization, Pan American Health Organization, Commission of European Communities, and the Economic Commission for Europe. EPA also participates in factfinding missions, attends international symposia, and provides advice to countries requesting our assistance in solving their environmental problems.

Toxic Substances

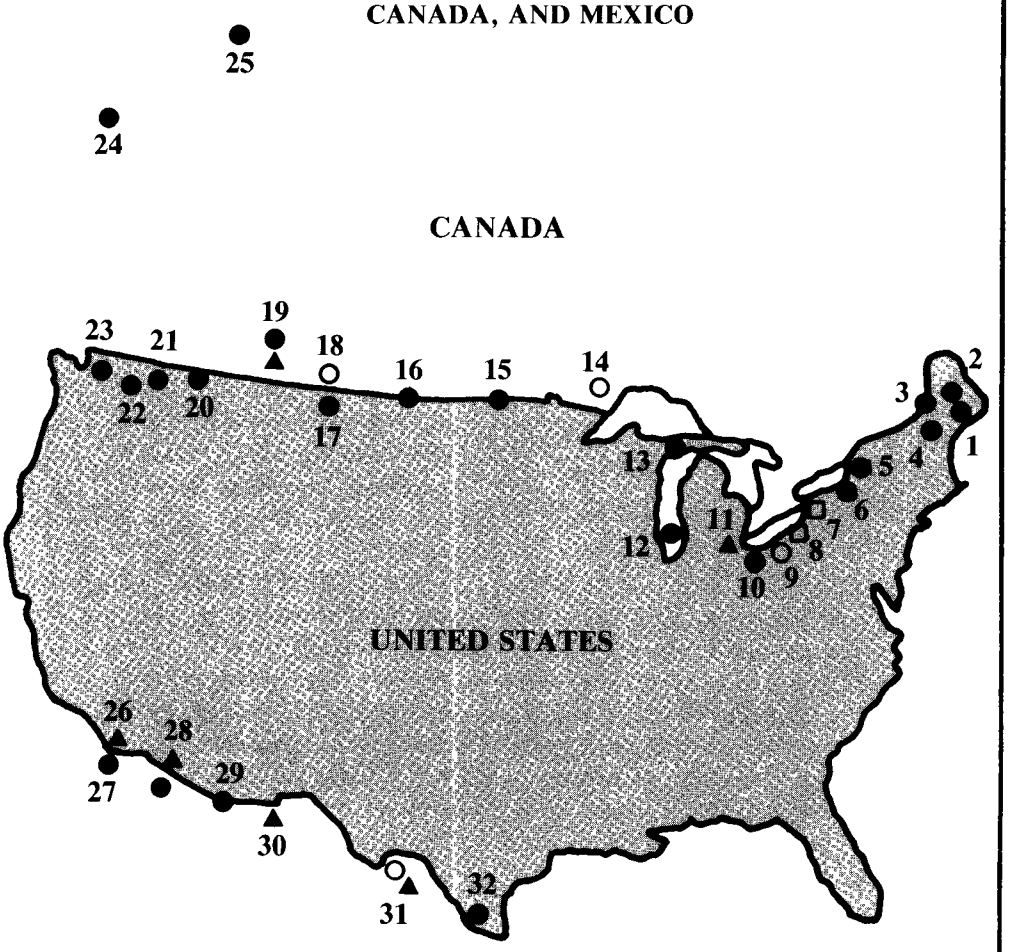
Through major international organizations such as the Chemicals Group of OECD we are actively involved in a chemical testing program to harmonize test methods and develop the capability to predict long-term human health effects of a chemical before that chemical enters the environment. We are discussing with the Commission on European Communities the standardization of premanufacturing procedures and the evaluation of toxicity testing methods. In cooperation with the World Health Organization, EPA is developing an international plan of action to improve the evaluation of chemical exposure health risks.

EPA is also working with individual nations on toxic substances issues. Particularly noteworthy is our involvement with Japan and the Federal Republic of Germany. Under a U.S.-Japan bilateral agreement, we have exchanged information on mercury removal from contaminated wastewater and sludges, DDT and PCBs in accumulated sediments, the fate and effects of toxic substances in sediments, and dredging technology. EPA is cooperating with the Federal Republic of Germany in a study of methods for, and the feasibility of, an environmental specimen bank. The objective here will be to develop a capability for long-term storage of biological specimens for future trends analyses of pollutant burdens.

Atmospheric Pollution

EPA's international program on atmospheric pollution has a primary focus on transport and transformation and the biological and health effects of air pollutants. Because the United States and Canada have an increasing number of cross-boundary air pollution problems, EPA has assisted the Department of State and the International Joint Commission to assess both countries' potential public health impacts of air pollution sources. Furthermore, EPA and Environment

ENVIRONMENTAL ISSUES AND PROJECTS—UNITED STATES, CANADA, AND MEXICO



Legend:

1. Eastport
2. St. Croix River Basin
3. St. John River
4. Dickey-Lincoln Dam
5. Richelieu-Champlain
6. Reynolds Metals
7. Prescott-Brockville
8. Darlington
9. Nanticoke
10. Lake Erie
11. Detroit-Windsor
12. Great Lakes
13. Lake Michigan
14. Atikokan
15. Rainy River
16. Red River
17. Garrison Diversion
18. Boundary Dam
19. Poplar River Plant
20. Flathead River/Cabin Creek Mining
21. Okonagon River
22. Skagit River
23. Puget Sound
24. Yukon River Basin
25. Beaufort Sea
26. San Diego-Tijuana
27. San Diego-Tijuana
28. Calexico-Mexicali
29. Nogales-Nogales
30. El Paso-Ciudad Juarez
31. Eagle Pass-Piedras Negras
32. Laredo-Nuevo Laredo

● Water ■ Nuclear Power Plants ○ Coal-Fired Plants □ Air Pollution

Source: Washington University. Energy—Air Pollution: A Picture Book of Systems Behavior. 1978.

Canada are working closely on mobile source air pollution problems.

The United States also has cross-boundary air pollution problems with Mexico. EPA and Mexico's Subsecretariat for Environmental Improvement are formulating a Memorandum of Understanding to establish a formal exchange of information, training, and surveillance methods. It is expected that this joint U.S.-Mexico program will assist the Mexican government in the design and implementation of standardized air monitoring systems so that data collected in Mexico are comparable to United States data. We hope future activities will include joint studies that determine the transport of air pollutants across the border in both directions and that can assist in developing mutually agreeable control programs.

EPA is also involved in air pollution research activities on problems not directly affecting our borders. We currently assist the Economic Commission for Europe's Steering Body on Long Range Transport of Air Pollutants in the study of sources, transport, and fate of sulfur oxides. Researchers from Japan and EPA exchange information on meteorology and photochemical air pollution with particular emphasis on conditions that create smog. EPA and the USSR are jointly working on air pollution modeling and measurement and stationary source control technology. Two specific projects under this joint research will be: a wind tunnel experiment to simulate distribution of air pollutants over a specified complex terrain, and a field experiment in the USSR to study formation and transformation of natural aerosols. EPA has participated in activities under the Tripartite Agreement on Stratospheric Monitoring that has accelerated coordinated research within the member countries of France, the United Kingdom, and the United States. Finally, EPA represents the U.S. position on stratospheric ozone to the United Nations Coordinating Committee on the Ozone Layer.

Water Pollution

Clean up and restoration of the Great Lakes and development of improved information on wastewater treatment and disposal methods are the two major areas of EPA's water pollution research cooperation with other countries. Under the 1972 U.S.-Canadian Great Lakes Water Quality Agreement, EPA research is producing management models for control of phytoplankton, pathway studies for hazardous substances, sediment-water interaction models, and studies of nonpoint source and thermal discharge effects on Great Lakes biota. Both countries are exchanging information on the methodology for setting water pollution standards and are comparing information on toxicology methods including biochemical, microbial, and analytical chemical methods.

Participation by EPA in international wastewater research includes source characterization of pollution, advanced wastewater treatment technology, process modification, and analyses of sludges and their environmental behavior. The study of advanced wastewater treatment being conducted under the auspices of NATO's Committee on the Challenges of Modern Society (CCMS) is one of the most important of the research efforts. The United States, United Kingdom, Canada, Italy, France, and Germany are studying such topics as format standardization for international information exchange, use of oxygen-enriched air to treat contaminated effluent, land spreading of sludge, nutrient removal, reverse osmosis, electrodialysis, and ion exchange. The US-USSR Working Group on Prevention of Water Pollution from Industrial and Municipal Sources is focusing on various phases of new Soviet technologies to process wastewater including electrolytic coagulation, high energy magnetic separation, freezing, ozonization, dissolved air flotation, and air stripping.

SUMMARY OF EPA'S ENVIRONMENTAL INTERNATIONAL ACTIVITIES

Organization/Activity	Research, Development, and Demonstration Programs							
	Air Pollution[a]	Water Pollution[b]	Radiation	Pesticides	Noise	Waste Management[c]	Toxic Substances	Energy
INTERNATIONAL ORGANIZATIONS								
Commission of European Communities (CEC)	●	●			●	●	●	
Committee on Challenges to Modern Society (CCMS)	●	●				●		●
International Organizaton for Legal Metrology (OIML)	●	●	●	●	●	●	●	●
International Standards Organizations (ISO)	●	●	●	●	●	●	●	●
Organization for Economic Cooperation and Development (OECD)	●	●	●	●	●	●	●	●
United Nations Economic Commission for Europe (ECE)	●	●				●	●	●
Food and Agriculture Organization (FAO)				●				
Intergovernmental Maritime Consultative Organization (IMCO)		●				●		
International Atomic Energy Agency (IAEA)			●			●		●
International Civil Aviation Organization (ICAO)	●				●			
World Health Organization (WHO)	●	●	●	●	●	●	●	●
World Meteorological Organization (WMO)	●	●						
United Nations Educational, Scientific, and Cultural Organization (UNESCO)	●	●						
United Nations Environment Program (UNEP)	●	●	●	●	●	●	●	●
BILATERAL COOPERATION								
Brazil	●	●						
Canada	●	●				●	●	●
Federal Republic of Germany	●	●				●	●	●
France		●					●	
France and United Kingdom[d]	●				●			
Iran	●	●				●		
Israel	●	●						●
Japan	●	●		●		●	●	●
Mexico	●	●	●			●		
Saudi Arabia	●	●				●		
Soviet Union	●	●		●		●		●
United Kingdom	●	●					●	●
SCIENTIFIC ACTIVITES OVERSEAS PROGRAM								
Egypt	●	●		●			●	
India	●	●		●			●	●
Pakistan	●	●						
Poland	●	●	●			●	●	●
Yugoslavia	●	●		●			●	●

[a]Includes troposphere and stratosphere.

[b]Includes marine, estuarine, and freshwater environments

[c]Includes hazardous, solid, and radioactive wastes.

[d]Tripartite agreement.

Source: Research Outlook 1978.

Hazardous Wastes

EPA is working with various countries to assess risks and benefits of hazardous waste disposal methods. Through NATO's CCMS, we are participating in a study on alternative disposal methods for hazardous wastes from electroplating and steel hardening processes. Areas of potential future cooperation between EPA and Japan include pyrolysis of solid waste, environmental effects of vinyl and polyvinyl chlorides, improved collection systems management and technology, hazardous waste treatment and disposal technology, recovery of past consumer waste, and industrial waste management information systems. Finally, as part of the revised U.S.-Canada Great Lakes Agreement, a supplementary hazardous substances report is being developed.

Energy

Our international energy research efforts deal primarily with coal. In 1977 the United States and the Federal Republic of West Germany initiated a cooperative program to examine control of emissions from coal-fired facilities. EPA and the German Ministry of Research and Technology have agreed to exchange information and, in certain cases, to work together to assure efficient development of technologies that permit coal to be burned in an environmentally acceptable manner. Included in this cooperative effort are the control technologies for sulfur oxides, nitrogen oxides, and particulates.

EPA is also working on four projects under a U.S.-USSR Environmental Agreement. The projects concern gaseous emissions, particulate abatement technology, process improvement and modification, ferrous metallurgy, and "a new United States initiative"—protection of the environment from coal preparation plant operations. Both countries are examining a variety of energy issues including abatement of sulfur dioxide emissions through various control techniques using lime/limestone, magnesia, and ammonia scrubbing; dust collection technology; characterization of aerosols; demetalization pretreatment for the hydrodesulfurization of petroleum residuals; preliminary coal cleaning; and fuel utilization methods in power generating systems to eliminate harmful emissions.

The Great Lakes

EPA serves as a resource base and focal point for interagency research on the unique problems of the Great Lakes. In addition to our cooperative efforts with the International Joint Commission on the Great Lakes, we also share information and closely coordinate research with the National Oceanic and Atmospheric Administration, the Great Lakes Basin Commission, and the Great Lakes Fisheries Commission. One current joint research effort between EPA and the Great Lakes Environmental Research Laboratory of the National Oceanic and Atmospheric Administration is the modeling of nearshore processes and hydrodynamic transport mechanisms. Additionally, EPA's Large Lakes Research station maintains the data base for the Great Lakes Research community, including federal and state agencies, academic institutions, and the Canadian government.

Monitoring

In addition to its activities in the Stratospheric Ozone Monitoring Program, EPA has the lead responsibility to fulfill the international monitoring program on the Great Lakes under the 1972 U.S.-Canadian Water Quality Agreement. International coordination of monitoring activities is achieved through the surveillance subcommittee of the Water Quality Board. This subcommittee devises the most cost-effective plans and assures collection of appropriate measurements for use in nutrient management models. The resulting data are shared by the two countries. Currently, intensive monitoring efforts on each lake occur only every 5 years. The Research Advisory Board, however, feels that more intensive biological monitoring will improve our

understanding of trends in the Great Lakes.

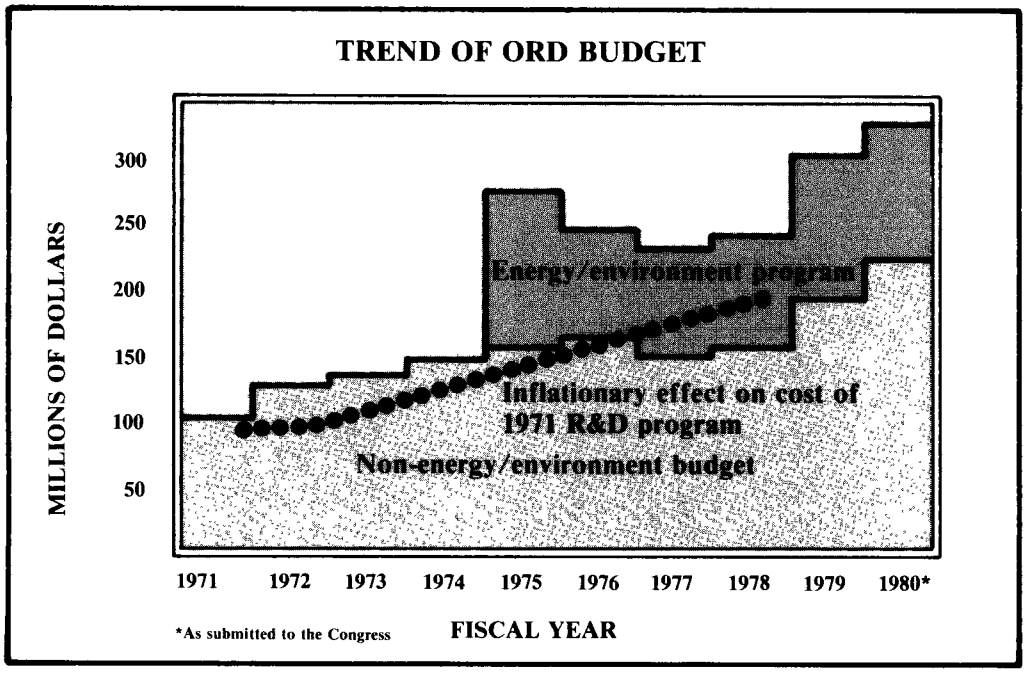
EPA is also active in the United Nations Environmental Program's Global Environmental Monitoring System. This system will link existing national air monitoring activities. United States cooperation in the global water quality monitoring network is expected to increase as a result of EPA's role as a World Health Organization Collaborating Center for Environmental Pollution Control. The data from joint surveillance and monitoring of the Great Lakes will be incorporated into the Global Environmental Monitoring System.

APPENDIX D

Office of Research and Development

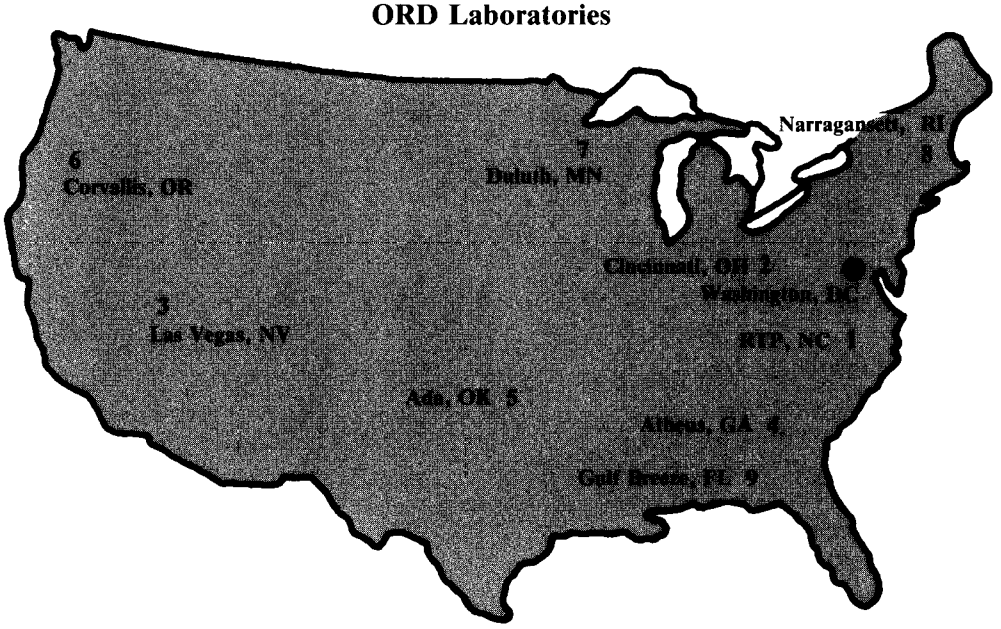
The Office of Research and Development (ORD) is responsible for planning, managing, and implementing EPA's comprehensive environmental research, development, and demonstration program. Under the direction of an assistant administrator, ORD produces scientific data and technical tools upon which EPA can base national policy for effective pollution control strategies and reasonable environmental standards. The Assistant Administrator for Research and Development also serves as principal science advisor to the EPA Administrator and coordinator for EPA policies and programs concerning carcinogenesis and related problems.

ORD's current resource base is approximately $316 million and 1800 staff members. The scientific capabilities of ORD are in the functional areas of health, ecology, pollutant transport and fate, control technology, and environmental monitoring.



ORD LABORATORIES AND ORGANIZATION

ORD Laboratories



Office of Research and Development

Office of Research Program Management Environmental Research Information Center, Cincinnati, Ohio Environmental Criteria Assessment Office (RTP, North Carolina)	● Assistant Administrator for Research and Development	Office of the Principal Science Advisor Carcinogen Assessment Group

Office of Monitoring and Technical Support

Headquarters Technical Divisions:
- Monitoring Technology
- Technical Support

Laboratories
- 1 Environmental Monitoring and Support, RTP
- 2 Environmental Monitoring and Support, Cincinnati
- 3 Environmental Monitoring and Suport, Las Vegas

Office of Energy, Minerals and Industry

Headquarters Technical Divisions:
- Energy Processes
- Industrial Extractive Processes

Laboratories
- 1 Industrial Environmental Research, RTP
- 2 Industrial Environmental Research, Cincinnati

Office of Air, Land And Water Use

Straospheric Modification Research Staff

Headquarters Technical Divisions:
- Media Quality Management
- Waste Management
- Agriculture and Non-Point Sources Management

Laboratories:
- 1 Environmental Sciences Research, RTP
- 2 Municipal Environmental Research, Cincinnati
- 4 Environmental Research, Athens
- 5 Robert S. Kerr Environmental Research, Ada

Office of Health and Ecological Effects

Headquarters Technical Divisions:
- Health Effects
- Ecological Effects

Criteria Development and Special Studies

Laboratories:
- 1 Health Effects Research, RTP
- 2 Health Effects Research Cincinnati
- 6 Environmental Research, Corvallis
- 7 Environmental Research, Duluth
- 8 Environmental Research, Narragansett
- 9 Environmental Research, Gulf Breeze

The EPA research, development, and demonstration program is planned and managed by EPA's Washington, D.C. headquarters and is implemented through four major ORD offices:

- The Office of Monitoring and Technical Support (OMTS) is responsible for the development and demonstration of monitoring systems, quality control of pollutant measurement and monitoring techniques, dissemination of technical information, and technical support services. Three laboratories report to OMTS.
- The Office of Energy, Minerals, and Industry (OEMI) is responsible for assessment and development of methods to control environmental and socioeconomic impacts from energy and mineral resource extraction, processing, conversion, and utilization and from other industrial operations. Three research laboratories report to OEMI.
- The Office of Air, Land, and Water Use (OALWU) is responsible for the development and demonstration of cost-effective methods to prevent or manage pollutant discharges or waste disposal (except the disposal or discharges related to energy, minerals, or industrial processes). Four research laboratories report to OALWU.
- The Office of Health and Ecological Effects (OHEE) is responsible for health and ecological data to support establishment of standards and criteria or guidelines for those components of the environment that may need to be protected from specific pollutants or activities. Six research laboratories report to OHEE.

APPENDIX E

CHESS--The Community Health and Environmental Surveillance System--Congressional Recommendations--Status Report II

Background: A controversy about the scientific credibility of results from the CHESS study prompted a series of congressional hearings in 1976. Subsequently, 17 major recommendations were made by Congress to EPA regarding methods and means to upgrade its environmental research. These recommendations covered a wide spectrum of subjects. Public Law 95-155, the Environmental Research, Development and Demonstration Authorization Act of 1978 specified that EPA annually report on the implementation status of each recommended action. This report is the second status report; the first was in *Research Outlook 1978.*

Because last year's report was the first status report, it included descriptions of all the recommendations and subsequent EPA actions. The reader is referred to that report and documents in the bibliography for detailed information about the recommendations. Given below is a status update of only those EPA actions taken last year.

Recommendation 3--CHESS Monograph

This recommendation concerns the public access to and understanding of the limitations of the CHESS monograph. To comply, we have sent an appropriate cover letter and copies of the *Research Outlook 1978* (which contains the first status report on the CHESS recommendations) to locatable holders of the CHESS monograph. Any additional copies of the CHESS monograph that are distributed will be accompanied by copies of the cover letter and the *Research Outlook 1978.* Finally, a notice is planned for the *Federal Register* informing the public of the availability of further information on the CHESS monograph. These actions, we believe, satisfy the intent of recommendation 3.

Recommendations 10(a), 10(c) and 12(a)

These recommendations concern peer review of EPA's scientific research. The subject has received increased attention in various quarters of EPA in the past year.

To improve the quality of research throughout ORD, the EPA Assistant Administrator for Research and Development has directed establishment of peer review mechanisms at the laboratory level. He has also directed the headquarters line managers, to whom the laboratories report, to structure a headquarters level peer review. Submission of ORD research results to referred scientific journals is also being stressed.

The EPA Science Advisory Board (SAB) is a prime source for peer review of research and research program planning advice. Its various components regularly examine elements of ORD's research program.

Recommendation 10(a) specifically concerns establishment of an interdisciplinary task force to draw up a plan for EPA to develop "a solid base of knowledge and procedures in aerometric instrumentation and measurements, meteorology, field data gathering, quality control, epidemiology project design, and testing and panel planning." Last year's status report indicated that this recommendation would be discussed with the EPA's Science Advisory Board. The Board's Health Effects Research Committee was directed by Public Law 95-155, the Research, Development and Demonstration Act of 1978, to review EPA's health effects research, including the recommendations of the CHESS Investigative Report. The Committee is in the process of completing its report. We await that report, and the recommenda-

RESOLUTION OF INVESTIGATIVE REPORT RECOMMENDATIONS

Number	Summary of Recommendations	Action
3(a)	EPA should publish an announcement regarding the limitations of the CHESS Monograph	Implemented
3(b)	EPA should not use the CHESS Monograph without explicit qualification	Implemented
3(c)	EPA should publish an addendum to the CHESS Monograph including most of the Investigative Report	Implemented
4(a)	Legislation should be reexamined regarding unrealistic procedures and schedules	Implemented
4(b)	EPA should design research to gain information and not support positions	Implemented
4(c)	OMB should allow all necessary resources if public policy requires expeditious research	Implemented
4(d)	EPA should advise Congress if budgetary restrictions will impact completion of major projects	Implemented
5	OMB should be asked to develop procedures for prompt review of questionnaire	Implemented
6(a)	CHESS date analyses should be carried out only on data with high validity potential	Implemented
6(b)	EPA should publish research in referred journals in a timely fashion	Implemented
6(c)	EPA should not publish large projects solely in monograph form	Implemented
6(d)	EPA should not initiate projects for policy consideration unless they can be completed in a realistic time frame	Implemented
7(a)	EPA should strengthen the CHAMP aerometric and quality control programs	Implemented
7(b)	EPA should shorten the time between data acquisition and quality assurance analysis of data	Implemented
7(c)	EPA should stop employing development stage instruments before qualification testing	Implemented
7(d)	EPA should not use laboratory models of instruments in the field until they have been field checked and operating personnel trained	Implemented
7(e)	EPA should reevaluate the opening of the CHAMP operations contract to competition	Implemented
7(f)	EPA research and monitoring personnel should closely coordinate regarding chemical species	Implemented
8	EPA should have additional meteorological support for air pollution health effects research studies	Implemented
9	EPA should examine accelerating research in pollutant characterization	Implemented
10(a)	An interdisciplinary task force should draw up an integrated air epidemiology-exposure assessment program plan for EPA	Implemented
10(b)	CHAMP should verify instruments and protocols so that reliable data can be achieved	Implemented
10(c)	EPA should have epidemiological questionnaires and panel selection criteria approved by peer groups	Implemented
10(d)	EPA should review research concepts obtained from team interviews	Implemented
11	The Environmental Resarch Center at Research Triangle Park (RTP) should not be reorganized until the end of FY 77	Implemented
12(a)	EPA should establish authoritative peer review panels to assist in improving research coordination	Implemented
12(b)	EPA should have a stronger focus on management at the Environmental Resarch Center, RTP	Implemented
12(c)	EPA should create a systems analysis-operations research program review group	Implemented
12(d)	The Science Advisory Board's charter should be expanded	Implemented
13(a)	EPA should seek cooperative research programs with universities and other laboratories and agencies	Implemented
13(b)	EPA should promote the exchange of scientists within and outside the Agency	Implemented
13(c)	EPA should fund individual Ph.D. thesis research	Under consideration

(CONT.)

Number	Summary of Recommendations	Action
13(d)	The Science Advisory Board should develop outreach programs	Under consideration
14	The Administrator should clarify the role of the Office of Research and Development and its laboratories	Shall be implemented
15	EPA should resolve the separation of facilities at RTP	Under consideration
16	EPA should develop a professional career development program for each professional employee	Implemented
17	The Administration should determine if EPA should conduct research under its present organizational configuration	Implemented

Source: Research Outlook 1978

tions of the Committee's Subcommittee on Epidemiologic Studies. We will take appropriate action based on the recommendations.

Recommendation 10(c) concerns peer review and approval of epidemiological questionnaires and panel selection criteria. Appropriate review and approval are part of the review of epidemiology studies in EPA's research program, conducted by the SAB's Health Effects Research Review Committee. It should be noted that the Interagency Regulatory Liaison Group (IRLG), composed of EPA, OSHA, CPSC, and FDA has a working group on epidemiology. A subgroup addresses standards which would apply to epidemiological studies in order to assure scientific validity for use as court evidence.

Recommendation 12(a) refers to peer review panels for increased coordination of research. The review responsibilities of the Committees mentioned in recommendations 10(a) and 10(c) fulfill this recommendation. In addition, improved peer review of EPA research was incorporated within a new research planning system established within the past year to improve the responsiveness of ORD to EPA program offices. This subject is discussed in two reports to Congress: "The Planning and Management of Research and Development Activities Within EPA," June 1978, and a follow-up status report in December 1978.

These reports describe research planning via specially formed research committees. Each committee will consist of representatives from ORD and EPA Program Offices, and will plan research specific to those offices. The new research planning system calls for incorporation of peer review mechanisms throughout the planning and management process in order to improve research quality. Several research committees have been operating successfully on a pilot basis, and more are planned. While systematic peer review has not yet been implemented in the pilot committees, EPA hopes to do so within the coming months.

Recommendations 13(a), 13(c) and 13(d)

These recommendations address a perceived isolation of EPA research. They concern technical information exchange and interaction of EPA scientists with peers outside EPA, particularly with the university community.

Last year's status report described EPA's ties with the university community, mentioning, most notably, EPA extramural research which involves grants

with universities. In FY 1977, EPA awarded 618 grants to 355 academic institutions. Each grant is monitored by an EPA project officer, an arrangement enabling our people to work closely with researchers outside EPA.

Additionally, the Intergovernmental Personnel Act has allowed an exchange of researchers between EPA and state and local governments and universities. A report to Congress, "Laboratories Needed to Support Long-Term Research in EPA," April 1978, further explores possible ties between ORD and universities. The report recommends a selectively expanded program of long-range research with both intramural and extramural components. An important means of assuring coordination of these components is scientist-to-scientist contact between EPA and the academic community. The extramural portion of the program would initially be a series of small centers for long-range research at universities and other institutions dedicated to specific research problems. In FY 1979, ORD will propose three such centers, one each for advanced control technology, epidemiology, and groundwater research. These centers would serve as bridges to the academic community and should provide ORD with a reservoir of talented scientists.

ORD's Minority Institutions Research Support (MIRS) program also serves the spirit of recommendation 13. MIRS was established in 1972 to help minority institutions develop the potential for conducting environmental research and thus become more competitive for federal funds. The EPA's MIRS staff maintains continual liaison between university researchers and the ORD scientific staff to develop relevant research proposals. Some expansion of the program is being considered.

Recommendation 13(c) refers specifically to EPA programs to fund individual PhD theses. EPA's workforce training program, recently placed under ORD's aegis, includes both academic training grants given to various institutions and fellowships to individuals. EPA's role in this type of program is unique since many whose work is crucial to achieve environmental goals are not directly employed by EPA. This nonfederal workforce includes wastewater treatment operators, state environmental employees, and other professionals. EPA currently is working with the Department of Labor and the Office of Education to address various options for further workforce development.

Recommendation 13(d) concerns Science Advisory Board assistance to EPA to develop an outreach program. We have actively sought SAB counsel for many activities related to our connections with the academic community. For example, the SAB helped prepare the report cited above, "Laboratories Needed to Support Long-Term Research in EPA." Additionally, the EPA Assistant Administrator for Research and Development made a formal presentation to SAB concerning ORD's university relations. As a result of this presentation and previous discussion, the SAB will develop outreach program suggestions for further consideration.

Recommendations 14 and 17

These recommendations state that the EPA Administrator should clarify the role of the EPA Office of Research and Development and determine if research should be conducted in its present organizational configuration.

The Environmental Research, Development and Demonstration Act of 1978 (Public Law 95-155) directed the EPA Administrator to report to the President and Congress the most appropriate means of assuring that EPA's research efforts reflect the needs and priorities of the EPA regulatory program offices. The EPA Administrator fulfilled that mandate with the distribution of the report "The Planning and Management of Research and Development Activities within EPA" (June 1978). The information in this

report satisfies both recommendations.

Concerning Recommendation 14—the clarification of the role of ORD and its laboratories—the report provided a mechanism for improved coordination between ORD and program offices for planning research. This mechanism, described above in connection with peer review, is a series of research committees, established for each research planning unit. Five pilot committees have already been established for key research areas and more are planned. Each research committee is chaired by a research manager (designated by ORD) and has representatives from relevant program offices and EPA Regions. At a hearing before the House Science and Technology Committee, Subcommittee on the Environment and the Atmosphere, the EPA Administrator and Assistant Administrators attested to the success of this approach. A formal status report on the pilot activities was provided to ORD's authorizing committees in December, 1978.

Further exploration of ORD's role in the Agency was provided by the report mentioned under Recommendation 13. This report, "Laboratories Needed to Support Long-Term Research in EPA" (April 1978) examines alternative approaches for conducting long-term environmental research and presents findings and recommendations. The report also reviews the history of ORD laboratories, describes representative research areas that could benefit from enhanced long-term support, describes mechanisms used by other federal agencies for carrying out this kind of research, and presents options for long-term research within EPA.

Concerning Recommendation 17—that EPA determine whether it should conduct research under its present organizational configuration—a study group found that "the Agency's R&D problems have not resulted from the way the R&D program is organized." To reach this conclusion, the group reviewed a number of similar organizational structures in various federal agencies. Possible use of some of those organizational structures was rejected and, instead, the study group proposed for ORD the management system changes described above.

Recommendation 15

This recommendation directs EPA to resolve the separation of facilities at Research Triangle Park (RTP), North Carolina. EPA's Office of Research and Development (ORD) is presently preparing a program of requirements for a new research and development facility at Research Triangle Park. Additionally, the Agency has set up an EPA long-range plan for special purpose facilities. This long-range plan would be agency-wide and would include the EPA regional offices' facilities as well as the Office of Research and Development laboratories.

BIBLIOGRAPHIES

Toxic Substances

Chemicals and Health. National Science Foundation. Report of the Panel on Chemicals and Health of the President's Science Advisory Committee, Washington, D.C., 1973.

Historical Statistics of the United States, Colonial Times to 1957, United States Bureau of the Census, Government Printing Office, Washington, D.C., 1960.

Human Health and the Environment-Some Research Needs. National Institute of Environmental Health Sciences. Report of the Second Task Force for Research Planning in Environmental Health Science, Government Printing Office, Washington, D.C., 1977.

Maugh, T.M., Chemicals: How Many Are There? Science 199 #4325, p. 162, 1978.

Meegan, Mark K. (Editor), Kline Guide to the Chemical Industry, Third Edition, Charles H. Kline & Co., Inc. Fairfield, N.J., 1977.

Technology Assessment Modeling Project, United States Environmental Protection Agency, 1978.

Air Pollution

Air Quality and Stationary Source Emission Control, National Academy of Sciences. Prepared for the Committee on Public Works, United States Senate, March 1975.

Air Quality Criteria for Ozone and Other Photochemical Oxidants. Vol I and II. United States Environmental Protection Agency, Prepared by the Office of Research and Development, April 1978.

Annual Environmental Analysis Report, Vol. I, Environmental Challenges of the President's Energy Plan: Implications for Research and Development. United States Energy Research and Development Administration. Report prepared for the Committee on Science and Technology, United States House of Representatives by the Congressional Research Service, Library of Congress. Washington, D.C., 1977.

Energy-Air Pollution: A Picture Book of Systems Behavior. Washington University, St. Louis, Missouri, 1978.

Health Effects Considerations for Establishing a Standard for Inhalable Particulates. United States Environmental Protection Agency. Prepared by the Office of Research and Development, July 1978.

Inhalable Particles Research Plan. Prepared by the Inhalable Particles Research Committee. United States Environmental Protection Agency. Washington, D.C., 1978.

Miller, S.S., Inhaled Particulates, Environmental Science and Technology. Vol. 12, No. 12 (p 1353-1355), December 1978.

Ogren, J.A., D.L. Blumenthal, W.H. White, and W.E. Wilson, Pollutant Measurements on Plumes from Power Plants and Cities: Summer 1975, February 1976, and February 1977. EPA Report number 600/7-78-041, March 1978.

Research and Development Relating to Sulfates in the Atmosphere. United States Environmental Protection Agency. Prepared for the Subcommittee on the Environment and the Atmosphere, Committee on Science and Technology, United States House of Representatives, June 1975.

Stern, A.C., Air Pollution, New York, Academic Press. Vol. I-V, 1976.

Technology Assessment Modeling Project. United States Environmental Protection Agency, 1978.

Industrial Wastewater

Census of Manufacturers-Water Use in Manufacturing, 1972, United States Department of Commerce, Bureau of Census, 1975.

Environmental Quality 1977, Council on Environmental Quality, December 1977.

Forecasts of Manufacturing Water Use, United States Department of Commerce, Bureau of Census.

National Water Quality Inventory 1975 Report to Congress, United States Environmental Protection Agency, EPA 440/9-75-014 September 1975.

Proceedings of the Third National Conference on Complete Water Reuse Sponsored by American Institute of Chemical Engineers and the United States Environmental Protection Agency, June 1976.

Proposed Program: Environmental Impact from the Production and Use of 400 Major

Industrial Organic Chemicals, internal memorandum Dr. E.E. Berkau, United States Environmental Protection Agency, February 1978.

Second National Water Assessment, United States Department of Commerce, Bureau of Census.

Technology Assessment Modeling Project. United States Environmental Protection Agency, 1978.

Water Reuse Highlights, The American Water Works Research Foundation, January 1978.

Water Reuse Studies, American Petroleum Institute, API Publication 949, August 1977.

Watershed Management

Consad Research Corporation, A Compendium of Relevant Materials Regarding the Design, Programming and Testing of the SEAS/III Landuse Mobile, EPA Contract No. 68-01-1700, March 22, 1976.

Dredging America's Waterways and Harbors—More Information Needed on Environmental and Economic Issues, Comptroller General of the United States, CED 77-74, June 28, 1977.

Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et. seq.), Section 101.

McPherson, M.B., and Zurdema, F.C., Urban Hydrological Modeling and Catchment Research: International Summary, ASCE, UWRR Program Technical Memorandum No. 1HP-13, November 1977.

Memorandum of Working Relationship Between the Environmental Protection Agency and the Department of Agriculture for Development and Implementation of a Model Implementation Program for Water Quality Improvement, September 1977.

National Water Quality Goals Cannot Be Attained Without More Attention to Pollution from Diffused or "Nonpoint Sources," Report to the Congress, Comptroller General of the United States, CED 78-6, December 20, 1977.

National Water Quality Inventory—Report to Congress, Office of Water Planning and Standards, Environmental Protection Agency, EPA 440/9-76-024, 1976.

National Water Quality Inventory, Report to the Congress, Office of Water Planning and Standards, United States Environmental Protection Agency, Vol. 1, EPA-44-19-74-001, 1974.

Nitrates: An Environmental Assessment. National Academy of Sciences, Washington, D.C., 1978.

Sweeten, John M. and Reddell, Donald L., Nonpoint Sources: State-of-the-Art Overview, Transactions of the ASAE, 1978.

Schofield, C.L., Acid Precipitation: Effects on Fish, AMBIO, Vol. V, No. 5-6 p 228-230, 1976.

Soil Water Air Sciences Research—Annual Report, Federal Research, Science and Education Administration, United States Department of Agriculture, 1978.

Technology Assessment Modeling Project, United States Environmental Protection Agency, 1978.

Water Quality Strategy (Draft), United States Environmental Protection Agency, July 5, 1978.

Drinking Water

Benenson, A.S. editor, Control of Communicable Diseases in Man, 11th edition, 1970.

Donaldson, W.T., Trace Organics in Water, Environmental Science and Technology, Vol. II, page 348, April, 1977.

Drinking Water and Health, National Academy of Sciences, 1977.

Eighth Annual Report of the Council on Environmental Quality, pages 256-267. December, 1977.

National Organics Monitoring Survey, United States Environmental Protection Agency, 1977.

New Orleans Area Water Supply Study, Analytical Report, Region VI, United States Environmental Protection Agency, 1974.

Rook, J.J., Formation of Haloforms During Chlorination of National Waters, 1976.

Symons, J.M., et al., National Organics

Reconnaissance Survey for Halogenated Organics, Junior American Water Works Association 67:634, 1975.

Water Chlorination: Environmental Impact and Health Effects, Ann Arbor Science, Vol. 2, 1978.

Energy and Environment

Inventory of Federal Energy-Related Environment and Safety Research for FY-1977; United States Department of Energy, July, 1978.

Ketcham, Brian and Pinkwas, Stan. Diesels and Man, New Engineer, MRC Communications, Inc. April, 1978.

National Energy Research and Development Plan, Energy Research and Development Administration, June, 1977.

Report to Congress Requirements for Environmental Monitoring, Assessment and Controls for Nonnuclear Energy Demonstration Projects, United States Department of Energy, DOE/EV-0014, May, 1978.

Rulemaking Support Paper for 1981-1984 Passenger Auto Average Fuel Economy Standards, United States Department of Transportation, July, 1977.

Technology Assessment Modeling Project. United States Environmental Protection Agency, 1978.

Solid Waste

Annual Report to the President and the Congress, fiscal year 1977; Environmental Protection Agency Activities under the Resource Conservation and Recovery Act in 1976; United States Environmental Protection Agency, 1978.

Campbell, William J., Metals in the Wastes We Burn, Environmental Science and Technology, May, 1976.

Edward Grobert III, Increasing The Harvest, Environment vol. 17, No. I, Jan/Feb 1975.

Environmental Quality, The First Annual Report of the Council on Environmental Quality. Council on Environmental Quality, August 1970.

How to Dispose of Hazardous Waste—A Serious Question that Needs to be Resolved. General Accounting Office, Report to Congress. CED 79-13, December, 1978.

Lazar, Emery C. Damage Incidents from Improper Land Disposal. Journal of Hazardous Materials, 1: 157-164, 1975.

Martin, Harry W., et al.; Water Pollution Caused by Inactive Ore and Mineral Mines, A National Assessment; EPA-600/2-76-298, December, 1976.

Materials Relating to the Resource Conservation and Recovery Act of 1976. Subcommittee on Transportation and Commerce of the Committee on Interstate and Foreign Commerce, United States House of Representatives. Committee Print No. 20, April, 1976.

NCRR Bulletin, National Center for Resource Recovery, Inc., Volume 11, No. 3, Fall 1972.

Report to Congress, Disposal of Hazardous Wastes, United States Environmental Protection Agency, Office of Solid Wastes, Report No. SW-115, 1974.

Resource Recovery and Waste Reduction, Fourth Report to Congress, United States Environmental Protection Agency, Office of Solid Waste, Report No. SW-600, August, 1977.

Solid Waste Facts, Environmental Protection Agency, (SW-694), May, 1978.

State Decision Makers Guide for Hazardous Waste Management. Environmental Protection Agency, 1977.

Study of Adverse Effects of Solid Wastes from All Mining Activities, PEDCO Environmental, Inc., unpublished report, prepared for United States Environmental Protection Agency, June 8, 1978.

Waste Disposal Practices and Their Effects on Groundwater, Report to Congress, United States Environmental Protection Agency, Office of Water Supply, Office of Solid Waste Management Programs, January, 1977.

Waste Disposal Practices—A Threat to Health and the Nation's Water Supply. Report to Congress by the Comptroller General of the United States. CED-78120, June 16, 1978.

Wastes in Relation to Agriculture and

Forestry. United States Department of Agriculture, Mise, Pub. No. 1065, March, 1968.

Weaver, Dallas E., et al., Data Base for Standards/Regulations Development for Land Disposal of Flue Gas Cleaning Sludges; EPA-6—/7-77-118, December, 1977.

Nonionizing Radiation

Athey, T. W., Tell, R.A., Hankin, N.N., Lambdin, D.L., Mantiply, E.D. and Janes, D.E., Radiofrequency Radiation Levels and Population Exposure in the Urban Areas of the Eastern United States, EPA-520/2-77-008, 1978.

Baranski, S. and Czerski P., Biological Effects of Microwaves, Dowden, Hutchinson and Ross, Stroudsburg, PA, 1976.

Berman, E. and Carter H., Mutagenic and Reproductive Tests in Male Rats Exposed to 425 MHz and 2450 MHz-CW Radiation, Presented at 19th General Assembly of the Union of Radio Sciences International, Helsinki, Finland, 1978.

Blackman, C.F., Elder, J.A., Weil, C.M., Benane S.G., and Eichinger, D.C., Two Factors Affecting the Radiation-Induced Calcium Efflux from Brain Tissue, Presented at the International Symposium on Biological Effects of Electromagnetic Waves, Airlie, Virginia, 1977.

Electronic Market Data Book, Electronic Industries Association, 1977 Edition, Washington, D.C., 1977.

Fourth Report on the Program for Control of Electromagnetic Pollution of the Environment, Office of Telecommunications Policy, Executive Office of the President, Washington, D.C., 1976.

Gage, M.I., and Guyer, W.M., Interaction of Ambient Temperature and Microwave Power Density on Schedule Controlled Behavior in Rats, Presented at 19th General Assembly of the Union of Radio Sciences International, Helsinki, Finland, 1978.

Kaplan, J., Polson, P., Rebert, C., and Lunan, Y., Biological and Behavioral Effects of Pre- and Postnatal Exposure to 2450 MHz Electromagnetic Radiation in the Squirrel Monkey, Presented at the 19th General Assembly of the Union of Radio Sciences International, Helsinki, Finland, 1978.

Lovely, R.H., Guy, A.W., Johnson, R.B., and Mathews, M., Alteration of Behavioral and Biochemical Parameters During and Consequent to 500 pW/cm^2 chronic 2450 MHz Microwave Exposure. Presented at International Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, 1978.

Smialowicz, R.J., Kinn, J.B., Weil, C.M., and Ward, T.R., Chronic Exposure of Rats to 425- or 2450 MHz Microwave Radiation. Effects on Lymphocytes, Presented at International Symposium on Biological Effects of Electromagnetic Waves, Airlie, Virginia, 1977.

Solar Power Satellite, System Definition Study, Boeing Aerospace Company, Part I and Part II, Volume I, 1977.

U.S. News and World Report. Vol. LXXXV, p. 78, July 17, 1978.

Global Pollution

Climate Research Board Workshop, National Academy of Sciences (NAS)—to be published.

Effects of Changes in the Ozone in the Stratosphere Upon Animals, Crops, and Other Plant Life, United States Department of Agriculture (USDA), December 1, 1977.

First Bi-Annual Report to the Congress on Research Activities of Relevance to the Clean Air Act, National Institute of Health (NIH)-National Cancer Institute (NCI), December, 1977.

Initial Report of Findings 1975-1977 of the National Oceanic and Atmospheric Administration as required by section 126, on "Ozone protection", of TL-95-95, the Clean Air Act Amendments of 1977", National Oceanic and Atmospheric Administration (NOAA).

Machta, L., Hass, W., UV-B Measurements, paper presented at BACER Review Workshop, 1977.

National Aeronautics and Space Administration (NASA) "Reports to the Congress and to the Administration of the United States Environmental Protection Agency on the National Aeronautics and Space Administration Upper Atmospheric Research Program", January 1, 1978.

Nitrates: An Environmental Assessment, National Academy of Sciences, Washington, D.C., 1978.

NOAA Climate Program Research Plan, 1978.

Results of Studies and Research to Protect the Ozone, Environmental Protection Agency Report to the Congress, January, 1978.

WMO Symposium on the Stratosphere, World Meteorological Organization (WMO) Report #511, Toronto, June, 1978.

Anticipating Environmental Research Needs

Agricultural Production Efficiency, National Academy of Sciences, Committee on Agricultural Production Efficiency, Washington, D.C., 1975.

Brown, Lester R., The Global Economic Prospect: New Sources of Economic Stress, Worldwatch Institute, May 1978.

Current Population Reports, United States Department of Commerce, Bureau of the Census, No. 632. Series p-25.

Fisheries of the United States, 1977, Department of Commerce, National Oceanic and Atmospheric Administration, Washington, D.C., April, 1978.

Mineral Facts and Problems, United States Department of Interior, Bureau of Mines, 1977.

Technology Assessment Modeling Project. United States Environmental Protection Agency, 1978.

The Nation's Renewable Resources—An Assessment 1975, United States Department of Agriculture, United States Forest Service, Report No. 21,·1977.

The Outlook for Timber in the United States, United States Department of Agriculture, United States Forest Service, Report No. 20, 1973.

Yearbook of Fishery Statistics, Food and Agriculture Organization of the United Nations (FAO), Vol. 42, 1976.

CHESS

Health Consequences of Sulfur Oxides: A Report from CHESS, 1970-1971. United States Environmental Protection Agency. EPA 650/1-74-004. May, 1974.

Laboratories Needed to Support Long-Term Research in EPA: A Report to the President and the Congress. United States Environmental Protection Agency. EPA 600/8-78-003. April, 1978.

Pilot Study of the Revised Planning and Management System for Research and Development in the Environmental Protection Agency: A Status Report to the Congress. United States Environmental Protection Agency. November, 1978.

Report of the Task Force to Review CHESS. United States Environmental Protection Agency. April 7, 1976.

Report on Joint Hearings on the Conduct of the Environmental Protection Agency's Community Health and Environmental Surveillance System' (CHESS) Studies. United States Congress. House Interstate and Foreign Commerce and House Science and Technology Committee. 94th Congress, 2nd Session. Washington, United States Government Printing Office, April, 1976.

Report on the Environmental Protection Agency's Research Program with Primary Emphasis on the Community Health and Environmental Surveillance System (CHESS). United States Congress. House Committee on Science and Technology Committee. 94th Congress, 2nd Session. Washington, United States Government Printing Office, November, 1976.

Research Outlook 1978. United States Environmental Protection Agency. EPA 600/9 78-001, June 1978.

Rood, W.B. EPA Study—The Findings Got Changed. Los Angeles Times, February 29, 1976.

The Planning and Management of Research and Development Within EPA: A Report to the President and the Congress. United States Environmental Protection Agency. June 30, 1978.

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